CONFIDENTIAL

THE SECOND WORLD WAR
1939–1945
ROYAL AIR FORCE

SIGNALS

VOLUME IV

RADAR IN RAID REPORTING

Promulgated for the information and guidance of all concerned.

By Command of the Air Council,

ISSUED BY THE AIR MINISTRY (A.H.B.)
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Preface

THE 1939–45 War was the first in which a scientific and co-ordinated raid reporting and fighter control organisation was employed in air battles. The essential requirements of this air defence scheme were the provision of some method of detection whereby early warning of hostile raids could be obtained, a communications system over which the early warning reports were passed to suitable centres from which intercepting aircraft could be controlled, a means of distinguishing friendly from enemy aircraft, and the use of suitable devices carried in the aircraft whereby interception was aided. The foundations of this Royal Air Force system were based on Signals facilities, being dependent on radar devices and on ground and air telecommunications. A comprehensive narrative of Signals in air defence during the Second World War is too extensive to be included within the confines of one book. This Volume is therefore concerned only with the first of the essential air defence requirements, namely, the method of detection by means of which efficient raid reporting was possible.

The method of detection employed was known as "Radar"[1], a system which was to revolutionise the art of raid reporting during the War. The secret research in radar before hostilities broke out made a most important contribution to the preparedness of this country to face aggression—thanks to the foresight of scientists and Royal Air Force officers who had developed this radiolocation system. This narrative, therefore, begins at a time (1935) when the whole question of air defence was being reviewed and the first proposal for radio detection was made. After describing the scientific background, the introductory chapters continue the story to the point where a practical radio warning system was emerging and Royal Air Force Signals personnel were beginning to take over radar duties from research scientists. From that point onwards, the field of application of raid reporting radar in the Service expanded rapidly and became world-wide as the War progressed.

The story has been written in some detail, since radio detection was a novel principle in the military field and played a great and ever-increasing role throughout the War. From the original demonstration of the radar principle in the United Kingdom on 26 February 1935, a lead was established so that Britain, and later her Allies, maintained a supremacy over the enemy in the radar field. The importance of this cannot be emphasised too fully, as radar, more than any other single development since the aeroplane, changed the face of warfare by blunting the edge of one of the greatest weapons in war, namely, surprise.

Although radar was developed originally as the basis for defence against air attack and it is that aspect which is discussed in this volume, ultimately defending fighter aircraft were controlled directly from special radar stations.

[1] The detection system was originally known as "R.D.F." It was renamed "Radar" in September 1943 to conform with United States terminology and thus avoid technical and administrative difficulties between the Allies. Throughout the Royal Air Force Signals War ~~Historical~~ Monographs the name current at the time under consideration has been adhered to as far as possible. A further term introduced for general use was "Radiolocation" —when the existence of R.D.F. was disclosed to the public on 18 June 1941 by a statement in the House of Commons.

The growth of fighter control radar stations is dealt with elsewhere.[1] Nevertheless, eventually many radar stations, particularly in overseas theatres of war, had a dual function, being responsible for both early warning and fighter control. As a consequence, the fighter control aspect of these stations after 1942 is discussed in this volume as well as their raid reporting functions.

Finally, the metamorphosis of ground search radar operational technique, from a network of dispersed ground stations (reporting to an operational control centre) to a master control radar station which combined all the functions of early warning and fighter control in a centralised form, is dealt with in the closing chapters of this volume. Perhaps it is at this stage that the most valuable lessons are to be learned for the future employment of the radar " eyes " of our land, sea and air forces.

[1] Volume V, " Fighter Control and Interception."

RADAR IN RAID REPORTING

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CHAPTER 1

THE CONCEPTION OF R.D.F. RAID REPORTING, 1935

In 1934, before experiments into radio detection of aircraft were authorised by the Air Staff, little work was being done on technical devices to assist in air defence. The only development in hand was Sound Location (Acoustic Mirrors), which seemed to have reached a stage where further improvement in operation was problematical. Judged by modern standards, sources of air raid warning, communications, and Operations Rooms were all of a primitive nature. The period of warning from the Observer Corps and the accuracy of prediction of the movements of hostile aircraft were inadequate. The time-lag in raid reporting and the increasing speed of aircraft made it imperative that some means should be devised for providing earlier warning.

Formation of Committee for Scientific Survey of Air Defence (C.S.S.A.D.)

On 12 November 1934, the Director of Scientific Research (D.S.R.), Air Ministry (Mr. H. E. Wimperis), drew attention to the difficulties of defence against hostile aircraft in view of the higher speed of aircraft, higher ceilings, less noisy engines, and the ability to fly with automatic pilot in cloud and fog.[1] He suggested that a committee under the chairmanship of Mr. H. T. Tizard, the Chairman of the Aeronautical Research Committee, might be set up in order to intensify research into new defence measures, such as the development of a ray of energy capable of nullifying engine ignition or capable of detonating bombs ; also to determine the effect of this radiation on the human body, or on the metal fuselage or wings of aircraft. He advocated that scientific surveys in these and other means of defence at that time untried might open up some such visionary channels for exploration. Mr. Wimperis suggested that members of the committee should include Professor A. V. Hill, Professor of Biology at University College, London, and Professor P. M. S. Blackett.

The suggestion was made to the Air Member for Research and Development, (Air Marshal Sir Hugh Dowding), the Chief of Air Staff (Air Chief Marshal Sir Edward L. Ellington), and the Secretary of State for Air (The Marquess of Londonderry), who all approved the formation of such a committee with the widest terms of reference to cover all possible developments, namely :—

> "To consider how far recent advances in scientific and technical knowledge can be used to strengthen the present methods of defence against hostile aircraft."

The constitution of this Committee for Scientific Survey of Air Defence was as follows :—

Chairman	Mr. H. T. Tizard.
Members	Professor A. V. Hill.
	Professor P. M. S. Blackett.
	Mr. H. E. Wimperis.
Secretary	Mr. A. P. Rowe.

The Air Defence Sub-Committee of the Committee of Imperial Defence

At about this time, but independently of the proposals for the C.S.S.A.D., air defence was being discussed by Members of Parliament and it was decided to set up an Air Defence Sub-Committee of the Committee of Imperial Defence

[1] Air Ministry File S.34763, Minute 2.

under the chairmanship of Sir Philip Cunliffe-Lister (later Viscount Swinton) to co-ordinate all Air Defence development at an inter-Service and inter-Department level.[1] Mr. Tizard was a member of this committee, and his own committee (the C.S.S.A.D.) reported to the Committee of Imperial Defence (C.I.D.) through its Air Defence Sub-Committee.

Mr. R. A. Watson Watt's Original Proposal on Radio Detection

In January 1935 Mr. H. E. Wimperis consulted Mr. R. A. Watson Watt, then Superintendent of the Radio Department of the National Physical Laboratory, on the possibility of using electromagnetic radiation to damage aircraft or aircrew. As a result of this informal approach, within two weeks Mr. Watson Watt, with the collaboration of one of his colleagues, Mr. A. F. Wilkins, produced a note showing that the quantity of energy required was far too great to be provided by any known method. Having established the impracticability of radiation for destructive purposes, Mr. Watson Watt added a comment that certain researches on which he had been engaged might be of great assistance in the problem of the detection and location of aircraft by radio.

The researches to which he referred had been carried out to investigate the properties of the ionosphere—a conducting region in the upper atmosphere having great influence on the long-range propagation of radio waves. For some ten years before 1935, scientists had been carrying out investigations and much effort had been and was being devoted to methods of determining the height of this region. In one method a short pulse of radio waves was sent out from a transmitter and on reaching the ionosphere was reflected and picked up by a receiver. By measuring the time taken by the pulse to travel to and from the region, the latter's height could be determined, since the speed of radio waves was known. The time taken was a minute fraction of a second so that normal mechanical timing devices were entirely inadequate for its measurement. A cathode-ray oscillograph was therefore used. In this instrument a beam of electrons was made to produce a spot of light on a fluorescent screen. The spot was moved uniformly across the screen by electrical means and both the transmitted pulse and the pulse received after " reflection " were made to deflect the spot downwards. The distance between these two deflections was thus proportional to height of the ionosphere. In practice, a regular succession of pulses was sent out and the horizontal traverse of the spot was synchronised so that the beginning of the horizontal trace was simultaneous with the emission of the transmitted pulse. The whole process was repeated at such a speed that persistence of vision made the path of the spot appear as a horizontal straight line with a kink corresponding to the received pulse ; the distance of this kink from the beginning of the line gave a measure of the height of the conducting region.

It was in work of this nature—though not exclusively so—that Mr. Watson Watt had been engaged, and it occurred to him that the same method could be used for the detection of aircraft, the aircraft taking the place of the " reflecting " region and its distance being found in the same manner as the height of the ionosphere.

These views were put to the Committee for Scientific Survey of Air Defence at its first meeting on 28 January 1935. The committee was agreed that " the problem of defence was largely one of detection of the positions of enemy

[1] Ministry of Aircraft Production, S.R.I. Folder.

aircraft" and asked Mr. Watson Watt to act on the ideas he had put forward.[1] An immediate recommendation was made to the Air Member for Research and Development by the C.S.S.A.D. that a suitable scientific staff from the National Physical Laboratory should be seconded to the Air Ministry for experiments to begin at once. The cost of the necessary apparatus was expected to be about £4,000 and it was proposed that Treasury authority should be requested for the National Physical Laboratory to assist with the experiments, at a cost not to exceed £10,000 for the first year. Air Marshal Sir Hugh Dowding, the Air Member for Research and Development, while appreciating the benefits of the system if it proved successful, was rather dubious at asking for immediate authority to spend £10,000 on a purely defensive project in case an offensive device should arise during the early course of the Committee's researches.[2]

First Practical Demonstration of the Radio Detection of an Aircraft

Mr. Watson Watt rapidly produced a plan which he hoped would successfully locate aircraft by a radio echo method, and submitted it as a memorandum to the C.S.S.A.D.[3] Acting on the advice of Air Marshal Sir Hugh Dowding, a demonstration with an aircraft was arranged to take place before Treasury approval was sought for N.P.L. research. This was held on 26 February 1935, primarily to determine whether sufficient electro-magnetic energy would be "reflected" from metal components of an aircraft structure for measurement purposes.[4] No attempt was made to determine the location of the aircraft. The source of continuous wave radiation was the 10 kilowatt Daventry Station beam operating on a frequency of 6,000 kilocycles per second (50 metres). The maximum strength of the beam was at an elevation of 10°, little energy being radiated at zero and at 20° to the horizontal. The beam was wider laterally, the radiation falling to half its maximum value at 30° on either side of the beam.

The receiving apparatus, which had not been specially designed for the test, was erected the night before by Mr. A. F. Wilkins (a Scientific Officer on the staff of the Slough Radio Research Station) at Weedon, Northants, about six miles from Daventry in the direction of the beam. The direct signal from Daventry was recorded as a linear oscillation on a cathode ray oscillograph, appearing as a single line. It was anticipated that reflection of the Daventry radiation from the moving metallic structure of an aircraft would cause phase interference with the direct signal resulting in a fluctuation of the length of the oscillograph line. The frequency of the fluctuations would depend on the position and ground speed of the aircraft and of the wavelength used.

It was arranged that a Heyford aircraft should fly at 6,000 feet to and fro between Daventry and a point 20 miles distant along the lateral centre of the beam. Four runs were made during the time available for the experiment but none of them was directly over the receiver on the ground as intended, although three passed very close. On the three runs easily detectable signals were obtained, the only disturbance being occasional "flicks" caused by atmospherics. On the fourth run, the aircraft was not "seen" and must have been well away from the beam. When the aircraft passed most nearly overhead, the oscillograph line fluctuated between lengths of one half and one and a quarter inches. The maximum range obtained was estimated as being about eight miles.

[1] Air Ministry File S.35290, Minute 2. [2] *Ibid.*, Minute 3.

[3] On account of its historical importance, this memorandum is reproduced in full at Appendix No. I. [4] Air Ministry File S.35290, Encl. 4A.

The arrangements for the test were not ideal and it was reckoned that 30 times the amplitude could have been obtained with a properly designed fixed receiver instead of the one used. The height and spacing of the aerial had not been accurately designed and the transmitter power was only 10 kilowatts. To obtain good results the wavelength should have been controlled in accordance with the reflective properties of the aircraft, but for the demonstration the wavelength was not under control. Mr. Watson Watt considered that for much of the time during which signals were obtained, the position of the aircraft off its intended track was such that reflection was mainly from the fuselage, for which the wavelength used was unsuitable.

It will be realised that this trial was not a test of the method proposed by Mr. Watson Watt in his memorandum, since continuous wave and not pulse radiation was used; also no range measurements were possible. Rather it was a crude demonstration of the fact that an aircraft would reflect radiation to an observable extent, carried out with apparatus readily available but hurriedly prepared.

In his report the Air Ministry representative at the demonstration said, " It was demonstrated beyond doubt that electro-magnetic energy is reflected from the metal components of an aircraft's structure and that it can be detected. Whether aircraft can be accurately located remains to be shown. No one seeing the demonstration could fail to be hopeful of detecting the existence and approximate bearing of aircraft at ranges far in excess of those given by the 200 feet sound mirrors."[1] The success of the demonstration was reflected in the first report[2] of the Committee for Scientific Survey of Air Defence which stated, " In the circumstances the result was much beyond expectation."

Preliminary Investigation Authorised

In view of the success which attended this demonstration, the Director of Scientific Research advised the Air Member for Research and Development that it provided, in embryo, a new and potent means of detecting the approach of hostile aircraft, one which would be independent of mist, cloud, fog or nightfall, and at the same time be vastly more accurate than present methods in the information provided and in the distances covered.[3] He pictured the existence of a small number or network of transmitting stations which would between them fill the entire sky over the eastern and southern part of England, using a frequency of probably 6 megacycles per second (50 metres wavelength). This radiation would cause every aircraft then in the sky to act as a secondary oscillator (whether it wished to or not) and these secondary oscillations would be received by a number of local receiving stations (equipped with cathode ray oscillographs) dotted around the coast much as acoustical mirrors might have been under the older scheme. These receiving stations would thus obtain continuous records of bearing and altitude of any aircraft flying in the neighbourhood (including those still 50 miles out at sea) and would be able to deduce course and ground speed. He recommended that there was every justification in requesting Treasury authority for the preliminary investigation.

The Orfordness airfield was suggested as being ideally situated for the immediate enquiry. It was secluded, had unused buildings in good condition

[1] Air Ministry File S.35290, Encl. 4A.
[2] A summary of the relevant sections of this report is given at Appendix No. 2.
[3] Air Ministry File S.35290, Minute 9.

that with little expenditure could be utilised as a radio laboratory, and was within easy flying distance from the Aircraft and Armament Experimental Establishment (A. and A.E.E.), at Martlesham. The erection of four 75-feet wooden masts and an additional hut would be needed, and apart from local telephone lines and a suitable power supply, no further work would be necessary to enable Mr. Watson Watt and the National Physical Laboratory staff to commence their research. It was proposed that the programme of work should be carried out under the direction of the Director of Scientific Research, Air Ministry, in association with Mr. Watson Watt and the Air Defence Committee.

Treasury sanction to go ahead with the scheme up to an expenditure of £12,300 in the first year was obtained.[1] This excluded the cost of aircraft required for co-operation in the research programme as the necessary services were to be obtained from the aircraft at Martlesham and other Service stations in the vicinity, flying in the course of their normal duties. Permission was sought from the Committee of the Privy Council for Scientific and Industrial Research for Mr. Watson Watt, together with three Scientific Officers and six assistants, to be seconded to the Air Ministry for work at Orfordness. The Department of Scientific and Industrial Research agreed to arrange for the services of the National Physical Laboratory to be made available for the Air Council, and for members of the Laboratory to work at Orfordness, but they could not agree to seconding members of their staff. This modification was accepted by Air Ministry and arrangements were put in hand for the work to begin as soon as possible. The Chief of the Air Staff had been advised of the plan and wished to be kept informed of the progress made in the experiments.

Choice of Frequency

A frequency of 6 megacycles per second (50 metres) was chosen for the initial experiments, which assumed that the aircraft had a horizontal metal component of its structure of the length of the wing span, responsive to the horizontal component of the electric field.[2] A higher frequency, say 43 megacycles per second (7 metres), would have been an advantage, as for a given range of detection a smaller power would be required. On the other hand, the pulse technique had been more fully developed for a frequency of 6 megacycles per second (50 metres) and determination of azimuth angles was difficult and inaccurate for a frequency of 43 megacycles per second (7 metres). The use of 6 megacycles per second (50 metres) would also secure some degree of secrecy, as the signals radiated would be received in foreign countries, and their nature and place of origin determined. It was reasonable to anticipate that foreign powers would assume such signals were associated merely with ionospheric research, known to be carried out at the Radio Research Station, Slough, and elsewhere.

Development and First Trials of Equipment

While preparations at Orfordness were in progress, Mr. Watson Watt and his staff at the National Physical Laboratory utilised their time in planning a scheme of work, obtaining supplies for a laboratory and workshop, and building an experimental transmitter for a frequency of 6 megacycles per second (50 metres).[3] This transmitter used Naval type N.T. valves and gave a peak

[1] Air Ministry File S.35290, Encl. 34A. [2] C.S.S.A.D. Minute of 6th Meeting.
[3] M.A.P./S.R.I. C.S.S.A.D. Folder No. 11.

output equivalent to a 20 kilowatt C.W. station. It sent out 50 pulses each second, *i.e.*, it had a pulse recurrence frequency or " p.r.f." of 50. An important factor in the design of the transmitter was the provision for specially brief pulses much shorter than the 100 to 300 microsecond pulses previously used in ionospheric research, the emitted pulse to be of any desired duration between 10 and 50 microseconds.[1] The transmitting aerial, consisting of a single half-wave dipole between the two transmitting towers, was not erected at Orfordness until 31 May, when aerial rigging commenced.

An ionosphere receiver was also installed and tried out, using batteries in the absence of a mains supply.[2] The first echo pulses from the ionosphere were received on 29 May, using temporary receiving aerials and power obtained from a temporary mains supply laid by the N.P.L. scientists themselves.[3] Later, a receiving aerial similar to the transmitting aerial was used. At this early stage, aerial arrangements for height-finding (*i.e.*, the measurement of angle of elevation) had not been provided.

Work to improve receiving gear was proceeding at the N.P.L. at Teddington. The first receiver was unsatisfactory in that it increased by some 100 microseconds the duration of the pulses injected. Two further receivers were therefore developed. Experimental work to reduce the effect of an excessively strong ground ray, and discussions on technique with computation and design work, occupied the greater part of their time after the N.P.L. staff had transferred to Orfordness.

A note on discussions with the staff at Orfordness on 29 and 30 May is of interest in its mention of the special difficulties which Mr. Watson Watt and his colleagues foresaw in obtaining long-range detection of " hedge-hopping " aircraft or of pilotless aircraft at, say, 2,000 feet, and their desire to go to shorter wavelengths to meet these difficulties. The note also contained an assurance that the matter of radio detection aids to anti-aircraft gunnery was being watched.

Results of Preliminary Trials to 31 July 1935

Promising results were obtained from the early practical demonstrations of the equipment. One of the first tests with an aircraft took place during the visit of the Sub-committee for the Scientific Survey of Air Defence on 15 June 1935, and was made under very unsatisfactory conditions. Not only was interference from other signals very heavy but there were thunderstorms in the neighbourhood which increased the receiver background noise considerably. In spite of this, however, it was possible to see echoes occasionally from the test aircraft, a Valencia aircraft flying at 15,000 feet in the most favourable direction for the aerials. A curve connecting range and time on the basis of the pilot's log was drawn at the conclusion of the test, and it was found that the few observed echoes were in good agreement with the log. A further test for the Committee was carried out early the following morning when it was thought that the interference would have subsided, but no better results were obtained.

[1] Narrator's Interview with Mr. A. F. Wilkins, O.R.S., H.Q.F.C.

[2] The names of the N.P.L. party of scientists who arrived at Orfordness on 13 May 1935 to instal the technical apparatus and commence development of the technique were Messrs. Bainbridge-Bell and A. F. Wilkins, Dr. E. G. Bowen (Scientific Officers), Mr. J. E. Airey (Assistant II), Mr. G. A. Willis (Assistant III).

[3] M.A.P./S.R.I. C.S.S.A.D. Folder No. 11.

On 16 July, a further demonstration was given to the Secretary of the Committee, who stated when summarising the results that it "would be difficult to exaggerate to the Committee the advance made in this short interval." During the demonstration a Bristol Type 120 aircraft was flown from Orfordness to Bircham Newton and back; the maximum height reached was 15,000 feet.[1] The frequency used was 12 megacycles per second (25 metres). On the outward run, to about 25 miles, the amplification was reduced to give a straight line datum, *i.e.*, there was no disturbance from interference or atmospherics. Up to this distance of 25 miles the aircraft response was obvious at a mere glance. The amplification was then increased and the datum line was disturbed; the aircraft response was, to the "untrained eye" of Mr. Rowe, quite definite until a range of 33 miles was reached. Mr. Watson Watt continued to record ranges up to 43 miles, at times which were subsequently confirmed by the dead reckoning record.

On the return run, Mr. Watson Watt detected the aircraft at 38 miles after it had been lost for about ten minutes; the response was obvious to Mr. Rowe at about 32 miles. Severe interference from morse signals was occasionally experienced, but at ranges less than 25 miles the aircraft response was obvious when the amplification was reduced to eliminate the morse signals. Accurate ranges were recorded to a minimum distance of 5 miles, below which ranges could then not be given with any accuracy. When the Bristol aircraft turned so that it presented its fuselage as a horizontal dipole, no response was observed.

In addition to the pre-arranged run with the Bristol aircraft, responses were observed from many other aircraft. On one occasion Mr. Watson Watt detected an unknown aircraft at 33 miles; the aircraft decreased its range from Orfordness and the characteristic aircraft response was obvious to Mr. Rowe at about 27 miles.

Performance Figures

In a report[2] on the work at Orfordness up to the end of July 1935, after only two months' research, the following performance figures were given as "obtained with a transmitter capable of some improvement, a receiver capable of considerable improvement, and an aerial system capable of very great improvement":—

(*a*) Maximum range to which a known aircraft has been followed	42 miles.
(*b*) Maximum range at which a known aircraft has been detected	39 miles.
(*c*) Maximum range at which an unknown aircraft has been detected	33 miles.
(*d*) Maximum range at which an unknown formation has been detected and diagnosed as a formation.. ..	25 miles.
(*e*) Maximum angle of elevation (neglecting curvature) to which a known aircraft has been followed	0° 40′.

Owing to interference from commercial radio signals, which was very heavy on the 6 megacycles per second frequency (50 metres) especially with the use of 75 feet masts, experiments were begun on about 11·5 megacycles per second (26 metres). It was found that this change in frequency also cured

[1] M.A.P./S.R.I. C.S.S.A.D. Folder No. 11. [2] Air Ministry File S.34763, Encl. 63A.

bad interference (Z-echoes), caused by reflection from the middle atmosphere, which had been causing signals on the oscillograph on 6 megacycles per second frequency; these spurious signals were usually negligible on the higher frequency. This interference was specially noticeable during 18 July when two thunderstorms separated by a few hours passed over Orfordness. During observations on 11·5 megacycles per second, Z-echoes appeared only while the thunderstorm was nearly overhead and disappeared when the storm passed away. A change to 6 megacycles per second during the storm showed exceptionally intense Z-echoes over the whole region 12 to 100 kilometres in height.

The main transmitter had been improved considerably and ran normally at 100 kilowatts rating on the new frequency of 11·5 megacycles per second. Design of a transmitter of twice this power was in hand and an experimental transmitter had been constructed and tested for a frequency of 37·5 megacycles per second. Receiver development was in hand under Mr. Bainbridge-Bell at the N.P.L., and two new wide-band receivers, one for use on 11·5 megacycles and one for 37·5 megacycles per second frequency, were nearing completion. The existing receiver had been modified for use on 37·5, 11·5 and 6 megacycles per second.

The following scientists were working the whole time at Orfordness: Mr. A. F. Wilkins, on transmitter and receiving aerial development and experiments on height measurement; and Dr. E. G. Bowen, on transmitter development.

Short Title for Radio Detection of Aircraft

The problem of a name for this system of detection of aircraft which would not immediately indicate the method of operation was solved by the initials "R.D.F.", a compression of the initials "R.D." for Radio Detection and "D/F".[1] This was intentionally misleading since, at the time, the problem of Direction Finding was receiving little attention.

Probable Service Applications of R.D.F.

From the research work carried out at Orfordness, the following five distinct uses for R.D.F. appeared probable:—[2]

(*a*) Long-range detection for the guidance of the R.A.F. interceptor fighter aircraft.

(*b*) Short-range detection and location, for the use of Army searchlights and anti-aircraft guns.

(*c*) Long-range detection apparatus for installation on board Naval vessels.

(*d*) Short-range detection for guidance of searchlights and anti-aircraft guns at Naval dockyards.

(*e*) Long-range detection of sea-going vessels for the information of the Navy.

Proposals for Improved Performance

Mr. Watson Watt, who had been spending some 50 per cent. of his time on radio detection development, mainly at Orfordness, stated that it was unlikely that any further substantial improvement could be effected on 11·5 megacycles

[1] Air Ministry File S.35982, Minute 4.

[2] *Ibid.*, Encl. 1A.

frequency (26 metres) until higher aerial towers of the order of 200 feet were available instead of the 75-foot masts employed.[1] It was thought that with no changes in the apparatus other than provision of mastheads 250 feet above sea-level on which convenient aerial arrays could be carried, an improvement of the order of two to one in range and the extension of operations to notably lower angles of elevation would be achieved. The vulnerability to interference by other radio signals, which was inherent in the 11·5 megacycles per second system (on 75-foot masts) could be very greatly reduced, without change of frequency, by the provision of the higher masts. Some of these improvements were dependent only on height above sea-level, so that high ground was advantageous ; some, on the other hand, were dependent on height above the ground at the mast-bases. A site for the erection of two 200-foot towers for the transmitter at Orfordness was agreed with the Officer Commanding, Aircraft and Armament Experimental Establishment, Martlesham Heath, with a conditional site for two more to be erected later if necessary, and it was recommended that sanction should be given for the erection of the first two towers.

It was also the view of Mr. Watson Watt that experience with two receiving stations at the ends of a moderate base-line was an urgent necessity before the planning of a chain of stations could be attempted, and it was thought that a great deal could be learnt by the use of the receiving station then operating at Orfordness, together with a separate receiving station some five to ten miles away. The need to develop a method whereby one range and one bearing could both be obtained from the same receiving site was also apparent.

There was no site at Orfordness for the suggested additional receiver development station but it was known that the coast at Bawdsey about ten miles south of Orfordness was 50 feet above sea-level. The acquisition of Bawdsey Manor at the mouth of the Deben River was suggested for a central radio laboratory.[2] The estate had some half-mile of 50-foot high coast-line and ample land and buildings for workshops, laboratories, and would provide living and messing facilities for the research staff.

First Proposals for an R.D.F. Chain

In a first forecast of the requirements of an R.D.F. network, Mr. Watson Watt had stated that it appeared probable that the ultimate network would be composed of equally spaced transmitters with receiving stations midway between transmitters. The receiving stations would have composite installations such that with one main long-range array and one direction-finder, two ranges and an azimuth would be visible on three dials side by side, without interconnection of stations by wire. Indication of angle of elevation would be provided on a fourth dial, so that each receiving station would be its own "control-room," capable of feeding complete data into the channels of communication without any linkage with other stations.

This forecast was followed by a memorandum by Mr. Watson Watt dated 9 September 1935, in which the state of development reached was set out.[3] This memorandum stated that development had led to the following of metal-framed aircraft of various wing spans to distances of 90 kilometres on a frequency of 11·5 megacycles per second and to detection at distances over

[1] Air Ministry File S.34763, Encl. 63A.
[2] *Ibid.*, Encl. 63B, 6 Aug. 1935.
[3] Given in Appendix No. 3, taken from M.A.P./S.R.I. C.S.S.A.D. Folder No. 11.

60 kilometres, measuring the distance of the craft from the observing station with an accuracy of the order of 1 kilometre. Tests had mainly been made on aircraft flying above 10,000 feet with a few trials at 7,000 and 5,000 feet and one at 1,000 feet. Comparable performances had been obtained on frequencies of 6, 10·71, 11·11, 11·54 and 12 megacycles per second although no success had been attained in a few trials on 37·5 megacycles per second. Experiments were being carried out on measuring the angles of elevation of the aircraft detected. The detection of low-flying aircraft might be obtained by additional mast height, and by selecting coastal sites well above sea-level. Research had shown that as a conservative estimate of average performance, with 75-foot masts, a detection range of 37 miles on aircraft flying at 13,000 feet could be expected.

The memorandum outlined a scheme for a chain of stations with transmitters every 20 miles along the coast to be defended, with receiving installations at each alternate station, *i.e.*, every 40 miles. Each set, transmitter and receiver, would require two masts, not under 200 feet high, situated on land not less than 50 feet above sea-level and not more than two miles from the coast. A range measurement by the station equipped with both transmitter and receiver would serve to fix the aircraft as lying on a certain circle surrounding the station. By measuring the time-interval between the pulse transmitted by one of the neighbouring stations (fitted only with a transmitter) and its reflection from the aircraft, the position of the aircraft could be tied down to a certain ellipse. Thus a transmitter-receiver station in conjunction with the transmitters flanking it could provide a fix on the aircraft. It was proposed not to introduce height-finding facilities to begin with, but the scheme was designed to allow the introduction of this and other improvements without substantial scrapping of equipment.

A chain of this character, it was stated, should be able to locate accurately all aircraft between the coast and the location frontiers, and count any reasonable number, say of the order of 30 per sector per five minutes. The frontiers were unlikely to lie at less than 83 miles for aircraft flying at 13,000 feet, 50 miles for 5,000 feet, 35 miles for 2,000 feet and 25 miles for 1,000 feet. These ranges could be increased with improved installations, but involving a substantial additional cost. The installation proposed could locate in plan position only, could not measure flying height, but included provision for minimising the effect of interference, especially of deliberate jamming.

The development of R.D.F. had so greatly exceeded the expectations of the Air Defence Sub-Committee of the Committee of Imperial Defence which had assumed that a range of detection of 50 miles would not be achieved for some five years, that at their fifth meeting it was recommended with the Air Council's agreement that a chain of radio detection stations covering the approaches to the coast from the Tyne to Southampton should now be established.[1] It was estimated that some twenty stations would be needed to provide detection and location of enemy aircraft at ranges between 65 and 5 miles from the coast. It was also recommended that Bawdsey Manor should be acquired and established as a centre for research work and headquarters for the organisation of a chain of stations.

[1] Air Ministry File S.35982, Encl. 40A and Minute 8 of 16 Sept. 1935.

First Air Staff Proposals

A conference was held on 24 October 1935,[1] with the Deputy Chief of the Air Staff in the chair, to discuss such matters as—

(*a*) the form in which the intelligence should reach the Fighter Group Operations Room ;

(*b*) manning ;

(*c*) technical organisation ;

(*d*) Service trials.

It was agreed that—

(*a*) Intelligence should comprise the position and number of the aircraft as a bearing and distance over the sea, with height to within 2,000 feet at extreme range, but with increasing accuracy to a limit of about 500 feet at the coast. Observations should be plotted at the R.D.F. station and telephoned at minute intervals to the appropriate Fighter Group Operations Room.

(*b*) Manning of the transmitter stations was to be undertaken by Wireless personnel from the nearest R.A.F. Station, the maintenance of the R.D.F. transmitter being regarded as part of the responsibility of the Station W/T personnel as a whole. Each receiving station would require four Oscillograph Operators plus one for relief for leave and sickness. These men would have to be specially trained, which would take initially a minimum of three months, with a further thirty days training annually, the operators being provided as the stations were constructed.

(*c*) The Service control of the R.D.F. organisation should be under the Signals Staff at Fighter Command Headquarters, and it was considered unnecessary to have officers in command of R.D.F. stations or groups of stations. It was thought that no advantage would be gained by linking the Observer Corps with the R.D.F. system.

(*d*) A scheme to cover the coast approximately between Southwold and the South Foreland should be worked out as early as possible to provide for training facilities and for Service trials to be carried out.

In November 1935, an ambitious programme was proposed by the Air Staff for seven stations to be available for operations with the Service in August 1936, and for the first three stations to be in operation by June 1936.[2] To achieve this programme, it was necessary that the Air Ministry should ensure within nine months, the selection of sites, the erection of 250-foot masts at each of the receiving and transmitter stations, the design and erection of suitable buildings to house the transmitter and receiving sets, and the supply of power from the grid system. The Department of Scientific and Industrial Research was to provide the radio apparatus on repayment, and the G.P.O. was to take the necessary action for providing line communications between the stations and a headquarters from which the Air Intelligence would be supplied to Fighter Command Operations Rooms. It was proposed that

[1] Air Ministry File S.35982, Encl. 27A.

[2] *Ibid.*, Encl. 33A and Minute 33, 15 Nov. 1935.

civilian personnel would operate the stations for the exercises which were to be held in August 1936, but that, if possible, Service personnel should commence training before that date.

The seven stations required by the Air Staff were to be in the neighbourhood of Dunwich, Bawdsey, Clacton-on-Sea, Shoeburyness, Birchington, South Foreland, and Dungeness, but due to the heavy works service involved it was decided to concentrate on five stations only, omitting Dunwich and Dungeness.[1] The Air Council were so impressed with the scheme that in their letter to the Treasury asking for financial approval, they stated that they had suspended construction of the Acoustic Mirrors for Sound Location. By the end of 1935, Treasury sanction had been received.[2]

[1] Air Ministry File S.35982, Encl. 33A and Minute 37 of November 1935.
[2] *Ibid.*, Encl. 42A and Minute 46.

CHAPTER 2

EARLY RESEARCH ON R.D.F., 1936-1937

The result of the recommendation of the Air Defence Research Sub-Committee of the Committee of Imperial Defence to acquire Bawdsey Manor as a centre for research work and headquarters for the organisation of a chain of R.D.F. stations, was that Air Ministry obtained Treasury sanction for the purchase of the estate.[1] The necessary buildings for research work were approved, together with accommodation and masts to establish Bawdsey as one of the chain of R.D.F. Stations.[2] Provision was made in the 1936 Air Estimates for the establishment of a scientific staff at Bawdsey comprising ten Scientific Officers and some twenty-six assistants, and arrangements were made between Air Ministry and the Department of Scientific and Industrial Research for staff of the National Physical Laboratory to be transferred to the Bawdsey Establishment.[3] Among the Scientific Officers were Mr. A. F. Wilkins and Dr. E. G. Bowen.

Admiralty and War Office Liaison at Bawdsey

The Admiralty appointed a scientific officer, Dr. A. B. Wood, for liaison duties with H.M. Signals School, Portsmouth, and it was agreed that the staff of the Bawdsey Establishment should act in an advisory capacity in connection with research at the Signals School.[4] In February 1936, the War Office asked permission for Dr. E. T. Paris of the Air Defence Experimental Establishment, Biggin Hill, to visit Bawdsey to investigate the development in short-range location of aircraft suitable for use with searchlights and guns, with a view to the Army Council nominating a small staff of scientific officers to work in conjunction with the Air Ministry staff and under the supervision of Mr. Watson Watt on this line of research.[5] This request was readily agreed, and eventually staff from the War Department were appointed to Bawdsey under Dr. Paris.

Transfer of Mr. Watson Watt from the Department of Scientific and Industrial Research to Air Ministry (1 August 1936)

The second interim report of the Committee for the Scientific Survey of Air Defence recommended the transfer to the Air Ministry of Mr. Watson Watt from the Department of Scientific and Industrial Research, where he had served since 1921 and, since 1933 as Superintendent of the Radio Department of the National Physical Laboratory.[6] The Chief of the Air Staff considered Mr. Watson Watt should be employed as Superintendent of Bawdsey Research Station as a whole-time Air Ministry official. A meeting was arranged between Mr. Watson Watt and a Principal Assistant Secretary of the Air Ministry (Mr. J. A. Webster) at which the proposed conditions of Mr. Watson Watt's employment were explained :—

> " To be in charge as Superintendent of radio detection work at Bawdsey Manor ; to advise the Air Staff on detection and location work (including the transmission of the results) in connection with all schemes of defence ; and to conduct research and technical development thereon as may be required."[7]

[1] Air Ministry File S.35982, Encl. 40A.
[2] Air Ministry File S.361120, Encl. 57A.
[3] Air Ministry File S.36728, Encl. 25A.
[4] Air Ministry File S.37506, Encl. 1A.
[5] Air Ministry File S.37518, Encl. 1A.
[6] Air Ministry File S.37745, Encl. 1A.
[7] *Ibid.*, Minute 8.

His position in the Air Ministry organisation was to be :—

> "In all matters of research and technical development he would be under the Directorate of Scientific Research and Technical Development ; and that, in so far as detection and location work in connection with Air Force defence schemes were concerned, his position would be that of an Adviser of the Air Staff and Signals on these matters."

Mr. Watson Watt thought the proposed organisation took too restricted a view of the magnitude and importance of the work and its urgency which, he felt, indicated the desirability of setting up a separate research system under a Director independent of the present joint directorate, for which he suggested the title of Director of Investigations on Communications,[1] with the following duties :—

(a) The special study of the whole of the problems involved in :

(i) the detection and location of approaching enemy aircraft ;

(ii) the most rapid determination of positional data for such craft ;

(iii) communication of data to Fighter Command and other units as required ;

(iv) expeditious plotting by automatic or semi-automatic means ;

(v) communication to fighters and other aircraft and provision in such aircraft of means for direct detection at short range to facilitate interceptions without intervention of a ground organisation.

(b) The inception, direction and direct conduct of research, technical development, and initial production and installation work required for the attainment of the ends indicated under (a) above.

(c) Initial arrangements for the training organisation to be developed.

(d) Maintenance of the special contacts required with other defence and civil departments.

(e) Duties of principal adviser to the Air Staff on all problems concerning this branch of home defence.

The Bawdsey Research Station he regarded as only incidental to these functions, and the tenure of its superintendentship by the Director as only incidental and temporary.

The Secretary of State for Air held the view that Mr. Watson Watt had made a most ingenious and valuable discovery which could be of the greatest possible value in enabling interceptor aircraft to deal effectively with enemy attack, and that Mr. Watson Watt should devote himself to this vital work by pursuing this discovery continuously and energetically.[2] He thought that although Mr. Watson Watt should have the closest liaison with the communications authorities at the Air Ministry and Post Office and, to a less degree, with the War Office in regard to their air defence duties, his primary place of duty should be at Bawdsey rather than in the Air Ministry. Following a discussion between the Secretary of State for Air, the Air Member for Research and Development, the Director of Scientific and Industrial Research, Mr. Tizard and Mr. Watson Watt, it was agreed that the latter should be transferred to the Air Ministry and take up an appointment on the staff of the Directorate of Scientific Research as

[1] Air Ministry File S.37745, Encl. 14A. [2] *Ibid.*, Minute 17.

Superintendent of Bawdsey Research Station, and to advise Air Staff on detection and location, including the transmission of R.D.F. information. The appointment took effect on 1 August 1936.

Plans for the First Five-Station Chain (1936)

It will be recalled that the ultimate needs of any scheme for locating aircraft approaching the coast are the continuous measurements of range, bearing, height and number of aircraft over the greatest practicable range of approach. As investigations and experiments progressed, it grew clear that the maximum range of location was largely governed by mast height ; that height could be obtained by using a special aerial system, as outlined in the original proposals, that the bearing of an aircraft could probably be measured by a suitable aerial system and that some idea of number could be obtained. It also became evident that interference from ground radio stations could largely be eliminated by employing special aerial arrays. A particularly attractive forecast of ultimate performance was that range, bearing and height could be obtained from one locating station, provided that aircraft were within the zone of detection.

The first three stations planned to be erected by June 1936 were a transmitting station at Orfordness (using the research equipment already installed, but with the addition of two 250-foot guyed masts, erection of which was in progress), a transmitting-receiving station at Bawdsey Research Station, and a transmitting station at Great Bromley. The five stations envisaged for the service trials in August were Bawdsey, Canewdon, and Dover as transmitting and receiving stations (each requiring one 240-foot tower for the transmitting aerial, and two such towers spaced by 500 feet for carrying the receiving aerials and height measuring systems), and Great Bromley and Dunkirk as transmitting stations only (needing one tower each).[1] The Canewdon site was approximately four miles north-east of Southend-on-Sea Municipal Airfield. The site at Dover was approximately half a mile north of Swingate Airfield and stood 400 feet above sea level. The Dunkirk site was midway between Faversham and Canterbury. These stations would work on one frequency only, 11·54 megacycles per second (26 metres) and report information to the headquarters where the reports would be sifted and the mean aircraft plot communicated to Headquarters, Air Defence of Great Britain, by landline. Each station would require technical buildings to house the apparatus, the transmitter hut being situated as near the transmitting tower as possible and the receiver hut midway between the two receiver aerial towers. The huts were to be separated by 500 feet.

It was expected that the erection of the 250-foot towers would be completed by May, ready for the aerial arrays to be installed, but by the middle of May it was seen that the contract dates could not be met.[2] The contractors were therefore instructed to concentrate on the transmitter and receiver towers at Bawdsey, Canewdon and Dover, and defer work on Great Bromley and Dunkirk until after the annual Royal Air Force air exercises had taken place. In July, only the first Bawdsey tower was in a state to permit of aerial installation. For those at Canewdon and Dover, it was now felt that they could not be finished before the end of September. On receiving this information, the Air Staff decided that the air exercises with the Royal Air Force to take place in September should be planned utilising only the one transmitting tower together with the 250-foot mast at Bawdsey. This respite allowed the scientific staff at

[1] Air Ministry File S.37186, Encl. 27A and Minute 6. [2] *Ibid.*, Minute 40.

Bawdsey to introduce modifications in the construction of the towers still to be completed. (It was essential to reduce backward radiation so that the plotting of aircraft over the sea should not be confused by responses from aircraft flying behind the station.) Owing to the need for a higher degree in accuracy of spacing of the reflector curtain from the energised curtain in the transmitter array it was found necessary to provide means for setting the spacing to any value between 20 and 23 feet so as to minimise the echoes from backwards radiation. It was suggested that the simplest method of meeting this requirement was to carry each aerial on a cradle which would run on horizontal extension arms at the appropriate levels, subject to the strength of the towers being adequate for this added loading.[1] The actual rigging, and setting in place of aerials and cradles was to be undertaken by the Bawdsey Research Staff, the supports being fixed by the contractors.

Research during 1936

Both Bawdsey and Orfordness were being used for research purposes until 1937. Two hundred and fifty foot guyed masts were erected at each place with the anticipated increase in range. Measurements of bearing and of height were made, but little progress could be made with height-finding until additional towers were available. Tests were made with formations of up to six aircraft, and it was found possible to deduce that one, two, three or more than three aircraft were being observed. This " counting " of the numbers of aircraft in a formation from the nature of the response seen on the cathode ray tube was a most important practical discovery. It ultimately enabled Controllers at the Operations Room during the War to decide on the size of the defending fighter force which had to be dispatched to meet an incoming hostile attack.

Direction Finding

The question of Direction Finding and the method of overcoming this problem has been described by Mr. A. F. Wilkins :—

> " However bold might now seem to be the decision to start work on this chain at a stage when ambiguity in pin-pointing was inevitable,[2] the anticipated troubles never had to be faced, as revolutionary development occurred towards the end of 1935. The need for some system of direction-finding had been obvious right from the beginning, and provision had, in fact, been made at Orfordness for a hut (known as " Y " Hut) in which research was to be performed. I cannot remember any proposals other than nebulous ones as to how D/F was to be done, until on arriving at Orfordness for one of his regular week-end visits, Mr. Watson Watt announced his proposals for the use of crossed horizontal halfwave aerials as the solution of the D/F problem. He had thought of this scheme on the way to Orford that day."

Investigation into the accuracy of Direction Finding was conducted at Bawdsey, using a single pair of crossed dipoles at 250 feet with the Orfordness transmitter.[3] A design for a full D/F array system was completed, the accuracy of which was found to be adequate. The whole aerial array required at a

[1] Air Ministry File S.37186, Encl. 65A.

[2] This ambiguity in establishing the location of an aircraft from a knowledge of its ranges from two or more stations was caused by the fact that the range position lines intersected at two points at least, only one of which was the true position of the aircraft.

[3] Bawdsey Research Station File B.R.S. 4/4, Encl. 21A, Dec. 1936.

receiving station to give bearing, range and height of an aircraft, could be carried on two wooden towers not less than 240 feet high, the transmitting station having one similar tower. After the initial difficulties of direction-finding were overcome, the original proposal for obtaining fixes by using the re-radiated impulses from the adjacent transmitters at the receiving station was dispensed with, and each station became both a transmitter and receiver. Accordingly, Great Bromley and Dunkirk (transmitting stations) required two extra masts. With the extra masts, each individual station in the chain would be independently capable of locating aircraft in height, bearing and range.[1] This would thereby increase the effective concentration of stations along the East coast, with better results in locating and following low-flying raids, owing to the smaller spacing between stations and the faster determination of the plan position of the aircraft by the observers.

Research and development continued rapidly. The number of frequencies used was increased and new apparatus designed. Work was proceeding on frequencies between 75 and 11·5 megacycles per second (4–26 metres wavelength). It was anticipated that mobile gear would be needed for the Service, and work was put in hand on the higher frequencies. A requirement for short-range location in aircraft had arisen and experiments were continued on the 75 megacycles frequency-band.[2] Little success was achieved using this frequency for detection from the ground, although Mr. Dewhurst made a long distance detection record by being the first to record a range of over 63 miles using this frequency. He was, however, unable to repeat the performance. It was felt that the ultimate need for a set which could be installed in Service aircraft would require a frequency of 300 megacycles per second (1 metre wavelength) and Dr. E. G. Bowen was put in charge of this research. Improvement of range was looked for in a better utilisation of energy in the transmitter, and in a reduction of receiver noise background by a re-design of the receiver on a frequency of 11·5 megacycles per second (26 metres) and an increase in gain of the 75 megacycles frequency-band receiver. The need for automatically communicating the information obtained from R.D.F. stations with no unavoidable delay to the Fighter Headquarters produced a "polar co-ordinate" repeater for use over telephone lines. This repeater utilised a screen on a cathode ray oscillograph tube, on which a spot appeared showing plan position of a formation on a grid.

First R.D.F. Air Exercise, 1936

The original plan for the 1936 exercises comprised a preliminary test in May, and then full-scale exercises with the Royal Air Force from 31 August to 11 September.[3] These trials were to be the responsibility of Headquarters, Air Defence of Great Britain (which was re-formed as Headquarters, Fighter Command, at Bentley Priory, Stanmore, on 14 July 1936, under the command of Sir Hugh Dowding). Aircraft capable of operating 100 miles from the coast were to be loaned from Coastal Command. Single aircraft and formations of up to nine aircraft were to carry out a series of approaches at different heights over the East Anglian coast. However, owing to delays, mainly in the erection of the 240-foot towers, the date of the exercises was postponed to October and then November. Only a small-scale test was

[1] Air Ministry File S.35982, Minute 66.
[2] Air Ministry File S.37929, Encls. 7A and 13B.
[3] Air Ministry File S.37364 gives all details of the first R.D.F. Air Exercise.

actually carried out in September, with aircraft supplied by Coastal Command –Anson aircraft from Manston and flying boats from Felixstowe. The R.D.F. apparatus at Bawdsey Research Station had one 250-foot mast and later one unfinished 240-foot tower for transmission, with the receiving aerials on the completed 240-foot tower. Range and bearing but not height measurements could be made. An Operations Room was improvised at Headquarters, Coastal Command, on the lines of the No. 11 Fighter Group Operations Room at Uxbridge, and by means of direct tie lines from Uxbridge the plots reported by Bawdsey were simultaneously reproduced in each Operations Room.

Seven flights were planned, six by day and one by night, and involved six to sixteen aircraft operating singly or in formations at a true air speed of 95 knots. The first flight serial, consisting of a formation of nine flying-boats flying at 10,000 feet and followed ten minutes later by a single Anson aircraft to make good the same track at the same height, took place on the morning of 17 September 1936. The reports from Bawdsey were irregular and not forthcoming until the aircraft were within 30 miles of the English coast. The positions given were very inaccurate and did not include bearing. On 18 September, two further flights were carried out consisting of a formation of six flying-boats, a formation of three Anson aircraft and one Anson flying at 10,000 feet. The reports from Bawdsey were very few and far between and the information was vague and for the most part inaccurate. Flight serial No. 3 in the afternoon of 18 September, consisted of four flying-boats and six Anson aircraft acting independently. The flying-boats flew at heights varying between 5,000 and 7,000 feet and the Ansons between 7,500 and 10,000 feet. A considerable amount of low cloud upset the flying programme, causing some of the aircraft to return without completing their runs. The information received from Bawdsey was almost negligible, and useless from an operational point of view.

The Air Officer Commanding-in-Chief, Coastal Command, decided to visit Bawdsey on 21 September, and further flights were postponed until after this visit was made. As a result it was decided to cancel further flight serials and substitute three simple flights by approximately six flying-boats flying in formation at a height of not less than 5,000 feet. Advantage of the flying on 22 September was taken by the Bawdsey staff for recalibrating their apparatus, and positions of aircraft were not reported by them. On 23 September a formation of five flying-boats flew on a track Felixstowe–North Hinder Light Vessel–Felixstowe at a height of 8,000 feet. The quality and frequency of the information supplied by Bawdsey showed a marked improvement on the previous results. Ninety reports were made in 90 minutes and the information supplied was far more comprehensive, the flight being followed with reasonable accuracy during the outward journey. However, on the homeward journey the ranges given in the reports indicated that Bawdsey had become confused between the two returning flights of aircraft.

On 24 September, a formation of five flying-boats was ordered to fly Felixstowe–Kentish Knock Light Vessel–West Hinder Light Vessel–Felixstowe at a height of 8,000 feet. During the outward flight the information given by Bawdsey was accurate to 3–6 degrees in bearing and 5 miles in range : aircraft on the outward tracks were followed up to a range of 45 miles, beyond which distance the errors increased rapidly. On the inward track the formation was picked up at an extreme range of 40 miles and followed homeward to a distance of 12 miles, when the errors in bearing increased from plus 5 degrees north to plus 16 degrees north. The information received in the reports varied from one to more than four aircraft. The range was always given but the bearings were sometimes missed.

The First Air Exercises Summarised

The tests were summarised by Headquarters, Coastal Command, who pointed out that it was not until after Bawdsey had recalibrated their apparatus on 22 September, that even reasonably accurate results were forthcoming.[1] The progress made after the recalibration could be gauged by a comparison between the number of reports received on 18 and 24 September. On 24 September, 124 reports were given in 115 minutes as opposed to nine reports in 60 minutes on the 18th. There was a tendency for " loose " bearings and ranges to be given. It was suggested that the increased accuracy of the plot received at No. 11 Fighter Group Operations Room may have been due to Bawdsey passing the bearing and distances by direct speech instead of using the more elaborate and somewhat untried cathode ray tube method. The report concluded: " While the results achieved are somewhat disappointing it is understood that unexpected difficulties were encountered with certain new equipment at Bawdsey. The Air Officer Commanding-in-Chief, Coastal Command, is very anxious that a further exercise of a similar nature should be held as soon as the new equipment is functioning properly. Until this exercise is held he considered that no attempt should be made to carry out the more ambitious programme originally envisaged for November." The Deputy Chief of the Air Staff, commenting on the trials, stated that their object was to enable the Air Staff to satisfy themselves that the system was sufficiently sound to justify its adoption on a more extensive scale. It had soon become obvious that the programme of flights originally devised was much too ambitious. One of the difficulties was apparently that the programme of construction of the R.D.F. stations concerned was very late and that there had been insufficient time for proper calibration. He did not think that the analysis of the results of the exercises should be regarded as representative of what the system could achieve. The Air Staff were proposing to repeat the trials as soon as the apparatus was ready and it was hoped that the results would then be more satisfactory. In the meantime, they were not yet in a position to say that the system had proved itself in practice.

With this conclusion the Chief of the Air Staff disagreed, expressing the view that the R.D.F. system was already proved.[2] He realised from a visit to Bawdsey in October that the apparatus and the personnel were not really ready for the experiment in September. The apparatus used included a new transmitter of a design which had not been thoroughly tried before the commencement of the trials, also one of earlier design. Further, it was found necessary to stop transmission from the 150-foot mast and instal hurriedly erected aerials on an unfinished 240-foot tower. At one time men were found working on the towers while the apparatus was being operated.

Measures following the First Air Exercise

As a result of a general discussion during a visit to Bawdsey by Professor E. V. Appleton after the September trials, it was decided by the Committee

[1] Air Ministry File S.37364, Encl. 86B.

[2] *Ibid.*, Minute 94.

that work should be concentrated at that Establishment for the purpose of obtaining consistently satisfactory results, including height measurement on a frequency of 11·5 megacycles per second, with the three self-supporting towers.[1] This involved the postponement of trials using Bawdsey, Canewdon and Dover, until the Spring of 1937. It was considered that insufficient attention had been paid to the engineering aspect up to that time, and Colonel A. G. Lee, Engineer-in-Chief of the G.P.O., visited Bawdsey to investigate what facilities the Post Office could offer. A G.P.O. Engineer, Mr. E. J. C. Dixon, was seconded to Bawdsey to co-operate with the scientific staff. It was agreed that in future experiments in the presentation of R.D.F. information by a cathode ray tube, data should not be relayed to Uxbridge, but that records should be transmitted to a point some 30 miles distant and back again in order that errors in the system could be examined before its introduction to Service users and until actual Air Staff requirements were known.

The revival of an early suggestion that a form of "Radio Searchlight"[2] might possibly be used to follow aircraft at relatively close ranges (after location at longer range by the Chain stations) had prompted research using a frequency of 75 megacycles per second (4 metres wavelength), employing a mechanically-swung beam. The G.P.O. Engineering Department now undertook to assist with the design of the mechanical equipment. (In the earlier discussions, Mr. Watson Watt had said in October that "he was loath to substitute the operational difficulties of radio beam technique for the simplicity afforded by floodlighting." He suggested that the situation should be reviewed when a "floodlighting" scheme had been provided for the Service.)[3]

Attachment of Service Personnel for R.D.F. Duties

The progress made with radio detection caused the Director of Signals to send a minute to the Air Member for Personnel with proposals for the training of Service personnel and the attachment of a Royal Air Force officer as Commandant of R.D.F. training.[4] Squadron Leader R. G. Hart, attached for Signals duties to Headquarters, No. 11 Group, was selected, and his duties in addition to training, included liaison with the Royal Air Force for administration and operation of R.D.F. Stations. This latter responsibility involved the development of the operational system for the applied use of R.D.F. in Home Defence. It was planned to train initially thirty airmen and thirty civilians at a school to be formed at the Dover R.D.F. Station. It was estimated that the course would last three to four months, after which time it would be possible to man stations as they were erected, and thus obtain experience of R.D.F. plotting without recourse to scientific staff at Bawdsey or the utilisation of Bawdsey Research Station. It had been found that Service trials and demonstrations had on occasions seriously held up development work.

Squadron Leader Hart visited the existing five station sites in December 1936, for the purpose of choosing the most suitable for the Training Centre, and a recommendation was made that buildings should be made available

[1] Minutes of C.S.S.A.D. 21st Meeting, Minute 137.

[2] It is convenient to use in a radio sense terms normally applied to visible light such as illumination, floodlighting, searchlight, telescope, etc.; this will be done without comment except where ambiguity is possible.

[3] Narrator's interview with Mr. R. A. Watson Watt.

[4] Air Ministry File S.39100, Encl. 1A.

at Bawdsey for accommodation, training, and messing of personnel.[1] Grounds for this decision were that more " casual " flying would be proceeding in the Bawdsey district, and closer co-operation obtained with the Research Establishment. In his memorandum, Squadron Leader Hart suggested the following establishment for a single watch :—

(*a*) One supervisor trained technically, of N.C.O. Wireless Operator Mechanic standard.

(*b*) One Mechanic of experienced L.A.C. Wireless Operator Mechanic standard to operate the transmitter.

(*c*) Two observers, of L.A.C. Wireless Operator standard to change duties every hour.

On the above basis the staff required for a 24-hour watch would be twelve (three N.C.O.s, W.O.M., three W.O.M.s and six Wireless Operators) all of whom would have to undergo special training in the use of R.D.F. apparatus. He suggested that supervisors and mechanics required the same course, but that observers could have a less extensive course and could complete their training at operational stations where they could obtain practice in observation on actual aircraft. On the assumption that four stations would be completed during 1937 this would necessitate the training of forty-eight airmen.

Bawdsey Research Programme for 1937

The Bawdsey research programme for 1937 contained the following items of first priority :—

Multiple waveband system for reduction of jamming.

Attainment of maximum radiated power in desired directions.

Improvement of accuracy in height determination at all ranges.

Improvement in accuracy of plan and height determination at ranges over 50 miles.

Synchronous working systems for a number of stations.

Communication systems to carry R.D.F. data to Fighter Headquarters.

Production of transportable ground installations for inland location by R.D.F. methods.

Less important items for research were :—

Mitigation of jamming by means other than wavelength change.

Improvement of accuracy in direction-finding in azimuth at short ranges.[2]

During 1936 development had been progressing at Bawdsey on the 23 megacycles frequency (13 metres wavelength), and after the September trials it was decided that the chain frequency should be established on 23 instead of 11·5 megacycles per second.[3] The advantages of the shorter wavelength of 13 metres were :—

(*a*) less interference from the ionosphere ;

(*b*) better coverage for a given mast height. (Heights were limited by mechanical and economic factors) ;

(*c*) less liability to jamming.

[1] Air Ministry File S.39100, Encl. 25A.
[2] Bawdsey Research Station File B.R.S. 4/4, Encl. 22A.
[3] Air Ministry File S.37929, Encl. 13B.

Height Finding

At this stage the first really practical height-finding system was introduced. The method normally employed by the Radio Research Station, and which was suggested by Mr. Watson Watt in his original proposals, made use of two horizontal dipoles some distance apart. The angle of elevation (and hence height) was determined by comparing the phase of the received signals in the two aerials. This system was very sensitive to changes in the bearing of aircraft and as there was no accurate system for determining azimuth in the early stages, trials were confined to determining elevation on aircraft flying on a previously-known bearing. Mr. Dewhurst, who was conducting the research on 23 megacycles, then tried a well-established system in which the signals from two horizontal dipoles at different heights up a mast were compared. The comparison was one of amplitude and not phase, so that the height-finding was independent of bearing. In practice, owing to inequalities in the aerial and surrounding ground there was some slight dependence on bearing. Even at a later date when reasonably accurate bearings could be obtained, it was this second method of height-finding which was generally used. The problem of sense-finding was solved by Mr. A. F. Wilkins, who employed switched reflectors behind the dipole aerials. The satisfactory solution of the problems of height-finding and sense-finding mark a notable step forward in the progress of R.D.F.

Bawdsey Air Estimates 1937[1]

The Air Estimates for 1937 were considerably increased and covered extensions in the laboratory accommodation at Bawdsey, and an increase in the scientific staff, which Mr. Watson Watt estimated would total 81 by the end of the year. These additions could reinforce the existing groups, who would have additional work as a result of design and development activities, and permit the formation of new groups to include work on :—

Cathode-ray direction-finding.

A.A. gun and searchlight control (War Office).

Jamming methods (including means for the mitigation or avoidance of jamming).

Identification of friendly aircraft.

Homing devices for defensive aircraft.

The estimates for wireless and electrical equipment alone amounted to £59,000, of which £12,000 was in respect of equipment for completing the four R.D.F. stations already under construction, viz., Great Bromley, Canewdon, Dunkirk and Dover. In presenting the estimates, the Director of Scientific Research stated :—

> " The technical advances recently made and the preliminary results of the Service Exercises make it clear that the future application of this research work on a large scale is virtually certain, and although big strides have been made in recent months, there remain a great many directions in which the technique will have to be improved and applied to special purposes."

[1] These estimates are given in detail in Air Ministry File S.39070.

R.D.F. announced to Chief Signals Officers

On 19 May 1937, Mr. Watson Watt gave a lecture on R.D.F. to the Chief Signals Officers of Coastal, Bomber and Fighter Commands and No. 11 Fighter Group. This was the first official disclosure of the subject to personnel of the Royal Air Force outside Air Staff and those directly concerned with its development for Service use under Squadron Leader Hart.[1] By July 1937 it was agreed that the Directorate of Signals should have direct contact with members of the Bawdsey Research Station on the following matters concerning the installation of the R.D.F. scheme[2] :—

(*a*) R.D.F. Policy.

(*b*) Operational matters relating to R.D.F.

(*c*) Manning of R.D.F. Stations for use by the Service.

(*d*) Training of Service personnel.

(*e*) Communications as they affect the R.D.F. System.

(*f*) Administrative matters connected with Service Stations.

The 1937 Service Trials

Further air exercises were held from 19 to 30 April 1937, the organisation for the trials being similar to that for 1936. Their purpose was to determine the value to the Royal Air Force of R.D.F. in its present stage of development.[3] It was the view of the Director of Scientific Research that the apparatus should obtain plan position by reference to map squares, and height of raiding aircraft, with some indication of the number of raiders. The R.D.F. information was to be transmitted by telephone to Uxbridge and Headquarters, No. 16 Group, Lee-on-Solent, and would subsequently be compared with the position of aircraft obtained by dead reckoning and D.F. The Commands were asked to suggest in their reports " the direction in which efforts should be made to improve performance from the user's point of view." The Air Officer Commanding-in-Chief, Fighter Command, raised the question of identifying aircraft as hostile or friendly, and it was arranged this should be attempted by friendly aircraft making a code recognition signal at a fixed distance of 30 miles from the area. It was anticipated that the resulting increase of signals traffic would not interfere with the main purpose of the Exercise. The Air Officer Commanding-in-Chief, Coastal Command, asked for the prohibition from the observed area of aircraft not engaged in the trials, and all Units were advised of this restriction ; it was deemed neither practicable nor desirable to ban civil aircraft from the prohibited area.

Results of the 1937 R.D.F. Service Trials. Report by Air Officer Commanding, No. 16 Group, Coastal Command[4]

(*a*) *Range*.—Most of the aircraft operating in the Observed Area were reported by R.D.F. with good accuracy for ranges up to 80 miles (the maximum range tested), except when an aircraft was masked by a stronger echo from another aircraft about the same distance from Bawdsey. The reason that some of the flights were not reported at all by Bawdsey might be that the operator could not observe more than one group of aircraft at a time.

[1] Air Ministry File S.40493, Encl. 26A.

[2] Air Ministry File S.41234, Encl. 17A.

[3] Air Ministry File S.40260 has full details of the 1937 Trials.

[4] Air Ministry File S.40260, Encl. 39c.

(*b*) *Bearing.*—The R.D.F. accuracy for bearing was not so good as for range, but gave useful indication of aircraft positions.

(*c*) *Height.*—The accuracy with which height was reported by R.D.F. was good above 8,000 feet, deteriorated as the height decreased, and was unreliable at heights below 5,000 feet.

(*d*) *Composition.*—R.D.F. reports of the number of aircraft in a formation were unreliable. During the approach of a raid it was very difficult to form an accurate opinion, from the R.D.F. reports received, of the number and dispositions of the forces taking part. The R.D.F. plots received from Bawdsey after the end of the Exercise, did however indicate this information to some extent by joining the points attributed by them to one aircraft or groups of aircraft. This information was not available to the Operations Room during the time that flights were being made, and as will be seen from the results, was not always right.

R.D.F. Accuracy

An interesting incident from the detailed analysis supplied by Headquarters, No. 16 Group, instances R.D.F. accuracy provided by the record of the flight of a flying-boat on 27 April when it left Felixstowe at 1125 hours on a course Kentish Knock–Galloper and thence back to Felixstowe. Bawdsey came on watch, and reported the aircraft's track from 1115 until 1225 hours when the aircraft landed. Two officers of Headquarters, No. 16 (R) Group were present at Bawdsey. At 1144 hours the flying-boat informed Lee-on-Solent by W/T of its position (over the first turning point), and its estimated time of arrival over the second turning point. This information was passed immediately by telephone to the two Royal Air Force officers at Bawdsey. These officers confirmed that the Bawdsey records accurately indicated the flying-boat's estimated track as regards both time and position. It was later noticed at Lee-on-Solent that the R.D.F. plot was not following the pre-arranged track of the flying-boat. Instead of recording a line towards the second turning point, Bawdsey showed a number of observations around the first turning point. At the time of these observations, it was believed in the Operations Room (as a result of the last signal from the aircraft), that the flying-boat was well on its way to the second turning point. At about 1230 hours, after the flying-boat had landed at Felixstowe, the pilot was cross-examined from Lee-on-Solent by telephone. He stated that he had been unable at first to pick up the first turning point, but had had to circle several times before identifying it. This diversion from the programme had been correctly indicated on the Bawdsey plot.

Views of the Air Officer Commanding-in-Chief, Coastal Command, on the 1937 Air Exercises[1]

Air Marshal Joubert, Air Officer Commanding-in-Chief, Coastal Command, in a letter to the Air Ministry, dated 21 May 1937, said that he wished to place on record his opinion that sufficient experience had been obtained to justify the erection of a chain of R.D.F. Stations. He based this view on the fact that, although it was not yet possible to locate with absolute precision an aircraft or a formation of aircraft flying at more than 30 miles from the coast, yet sufficient indication of enemy aerial activity could be regularly obtained up to 80 miles

[1] Air Ministry File S.40260, Encl. 41A.

from the coast to facilitate very greatly the task of Fighter Command. He made this interim recommendation because he felt there was no time to be lost in carrying out further trials on a large scale, and with the additional facilities for correcting observations that the increased number of stations would provide.

Views of the Air Officer Commanding-in-Chief, Fighter Command, on the 1937 Air Exercises[1]

Air Chief Marshal H. C. T. Dowding, Air Officer Commanding-in-Chief, Fighter Command, in his report dated 7 June 1937, was more reserved. He regarded the existing achievements of the R.D.F. system as being of great value to the defence of this country in so far as they indicated generally the approach of aircraft towards our shores. This was but a fraction of the benefit which he hoped would eventually be obtained from this system, but he emphasized that it was all that had been attained up to the present. A general view of the charts accompanying the report showed that the *average* track as plotted by Bawdsey bore no recognisable relation to the track flown by the aircraft and, although there were a few exceptions, even these plots were not sufficiently accurate to enable interceptions to be attempted before the coast was reached. He thought the principal reason for this was the inaccuracies of the R.D.F. observations in azimuth, particularly when other aircraft were in the neighbourhood. The observations for height also were sometimes very erratic. It seemed to him that the most important objective for technical development in this connection, was to improve the azimuth reading by some form of cut, or combination of the observations of two or more stations. The D.F. system for the recognition of friendly aircraft was a complete failure. This he attributed largely to defective liaison; he would expect no difficulty in obtaining satisfactory results if the whole system were under unified control; but the matter was at present of minor importance, since, even if the D.F. system had been successful, there were no recognisable plots on the Operations table to which the identifications could have been applied. He recommended that if, and when, another exercise of this type were held, it was important to ensure that Coastal Command, Bawdsey, and Fighter Command, used the same scale charts for recording, owing to the difficulty of making comparisons when the scales of charts differed. He regretted that the results of the exercise did not yet enable him to put forward definite proposals for the transference of R.D.F. plots to the various Operations Rooms concerned.

Technical Views by Mr. Watson Watt on the 1937 Air Exercises

A detailed technical report on the 1937 R.D.F. Service trials was prepared by Mr. Watson Watt. In it, he recorded that the apparatus used in the R.D.F. observations for this exercise was wholly designed and constructed at Bawdsey. The working frequency was 22 megacycles per second (13·5 metres wavelength), the transmitter power was approximately 40 kilowatts. The stand-by transmitter was used on one afternoon to enable permanent improvements to be introduced in the main set. The total lost time, wholly at the transmitting end, was 19 minutes in 60 hours operation: of this, 7½ minutes was due to an error of judgment as to starting time, and 4 minutes to experimental changes, unessential but thought worth trial in the midst of exercises. There were no failures in valves or components, either in transmitter or receiver. Aerials

[1] Air Ministry File S.40260, Encl. 43A.

and receivers were tested each day, but no changes in performance were detected nor was any repair or adjustment required. On no occasion during the exercise did interference by signals, atmospherics, or ignition systems produce troublesome interference. It was not found necessary to prohibit the running of internal combustion engines, save in the area of about 100 yards radius round the receiving aerials.

The direction of maximum sensitivity was designed to lie South-East, and the sensitivity was expected to fall substantially to zero along a line N.E. to S.W. through Bawdsey. The useful sector of operation was therefore expected to lie between East and South. The power radiated inland was reduced to about 1 per cent. of that radiated to seaward, and means for discriminating between craft inland and over sea were provided. No calibration corrections were introduced in the bearing and height determining gear, and no practice runs on formations of more than three aircraft had been made. The minimum objective to which design had been directed was a location range of 30 miles for a formation not below 5,000 feet. No provision was made for following raids into the zone of 8 miles radius surrounding Bawdsey. It was found during the exercise that effective locations could be made in the unfavourable sector West of South, nearly, in fact, to the South-West axis, but that the corresponding sector North of East was one of much lower relative sensitivity. This discrepancy was ascribed to distortion of the energy distribution from the transmitter by the stays of a temporary stayed mast, from which distortion of unforecastable amount had, in fact, been expected. It would appear that, after allowance for this extraneous distortion, the useful sector of the station is not less than 120°.

The time taken for the observation and transmission of positional data (plan position and height) varied between 12 and 22 seconds. Of this time, the observation occupied 8 to 14 seconds, both this and the reading and transmission time (forming the balance of the total) could be reduced by practice and the latter by the improvement of speech on the telephone lines, the poor quality of which involved frequent repetitions. It was clear during the exercise that the interpretation of the individual observations in terms of ground track and speed was notably easier in the Operations Room at Bawdsey itself than elsewhere. Preliminary experiments to facilitate a rudimentary raid identification system were made late in the exercise, and showed very considerable promise. They were being carried further. The charts available from Bawdsey contained only such interpretation as was effected during the period of observation, without improvement after the event, and were therefore representative of the material which could be made available at any R.D.F. filter centre. The need for such a centre had been clearly established in the exercise.

Mr. Watson Watt's Conclusions on Operational Performance

The performance of the system as it stood, in so far as it could be judged from an exercise carried out in weather conditions which, without affecting the observational conditions, were unfavourable for navigation on long tracks over sea, and employing comparatively small formations, is estimated in " Conclusions on Operational Performance " :—

" (a) Accurate plan location of close formations of six or more aircraft at heights of 10,000 or more feet can be effected at ranges of 100 or more miles from the coast, by co-operation of two or more R.D.F.

stations, in cases where the raid density in the 100-mile zone is not high and where observers can be provided to watch this zone without impairment of observations on nearer zones. (The height-reader and teller would normally be able to take this additional duty.)

(*b*) Plan location in similar circumstances can be effected by a single calibrated station with an accuracy in range better than 1 mile and an accuracy transverse to mean apparent track better than 5 miles in the 90-mile zone, 3 miles in the 70-mile zone, $1\frac{1}{2}$ miles in the 50-mile zone, $\frac{1}{2}$ mile in the 30-mile zone, and $\frac{1}{8}$ mile in the 12-mile zone. At 20 miles the range is accurate to a quarter mile. (A zone is taken as approximately 20 miles with control on the range named.)

(*c*) Plan location for formation of three or more aircraft at heights between 5,000 and 10,000 feet can be effected with high accuracy, by two or more stations, at ranges of 60 or more miles from the coast.

(*d*) Plan location in the conditions of (*c*) above can be made by a single station with accuracy better than 1 mile and an accuracy transverse to mean apparent track better than 5 miles in the 50-mile zone. In other (nearer) zones the improvement is in approximately the ratios shown in (*b*) above.

(*e*) The range of location for a single craft flying at a height of 1,000 feet is normally better than 20 miles, the accuracy of a single station location is better than 1 mile in range at 20 miles, the accuracy transverse to mean apparent track is better than 1 mile at 20 miles.

(*f*) The flying height of a formation can be determined with a consistency of 7 per cent. for flying heights of the order of 15,000 feet, at ranges of 50 miles, 10 per cent. for 10,000 and 40 miles. Whether these consistencies can be regarded as applying to the true flying heights is a matter to be determined by calibrations which can be made against flying data of exercise and in later experiments.

(*g*) The number of aircraft in a close formation cannot be determined with certainty at present. This determination will depend on experience not yet sufficiently acquired by observers. The discrimination among single aircraft, formations of three to six, and large close formations, appears likely to be made with considerable certainty by sufficiently experienced observers. Special flying arrangements will, however, be required to give experience with large formations."

The Exercise clearly showed a vast improvement in operation using the 22 megacycles per second frequency in place of 11·5 megacycles per second, which had been used during the 1936 trials. The performance and standard of the whole equipment—transmitter, receiver and aerials—were better. Direction-finding and height-finding were both carried out by means of a goniometer ; in the case of height a series of conversion curves were used to convert the goniometer reading and range into height. The D/F errors were not more than 2 to 3 degrees and it was possible to average out the zigzag of individual plots : about five to ten numbers were required before the true track of an incoming raid could be determined.

* * *

The opinions of the Air Officers commanding Coastal Command and Fighter Command, and the impressions of the Air Ministry representatives at the 1937 Service trials of the R.D.F. equipment installed at Bawdsey were all, in the main, very favourable. Although it was agreed that there was not yet precision in the location of formations of aircraft flying at more than 30 miles from the coast, there was no doubt that the air exercises had verified that sufficient experience had been gained to justify proceeding with the erection of a coastal chain of R.D.F. Stations. The exercise therefore provided a valuable impetus to the need for accelerating the construction of the Home Chain.

CHAPTER 3

INCEPTION AND PROGRESS OF THE R.D.F. HOME CHAIN, AUGUST 1937—THE MUNICH CRISIS, SEPTEMBER, 1938

After receiving the reports on the 1937 Exercise, the Deputy Chief of the Air Staff suggested to the Chief of the Air Staff that the R.D.F. equipment had shown itself sufficiently satisfactory to go into production.[1] He pointed out the five stations sanctioned by the Treasury in November 1935 were designed to provide data as a first step towards the complete chain of twenty stations recommended by the Air Defence Research Committee on 16 September 1935. These five stations were to have been ready by August 1936, but so far, only Bawdsey was in operation, with the possibility that all five would be completed by the end of 1937. It had been estimated that the complete chain would take two years to build, so that if the necessary work were not commenced until after the completion of the five-station chain, it would not be finished before the Spring of 1940 at the earliest ; probably later, bearing in mind the example of the five-station chain where construction had already lagged by more than a year. He therefore considered that further delay in the construction of the Main Chain as originally proposed could not be accepted and that there were ample grounds on which to approach the Treasury for the necessary financial backing.

The Chief of the Air Staff agreed that the scheme for the Main Chain should be put in hand, and the matter was discussed at a meeting between the Deputy Chief of Air Staff, the Director of Scientific Research, Mr. Watson Watt and others on 30 June, where the Air Staff requirement was stated :—[2]

> " That, by means of R.D.F., we should get warning as accurately as possible of the position of enemy aircraft approaching the coast between St. Catherine's and Lowestoft at a minimum height of 3,000 feet and at a distance of 40 miles from the R.D.F. station at this height. From Lowestoft to St. Andrews a lesser degree of accuracy could generally be accepted, and the Air Staff would be satisfied to have warning of aircraft approaching at 5,000 feet at a distance of 35 miles from the coast, except in four coastal areas, the Forth, Tyne, Tees and Humber, which in view of their importance and exposed condition required the same standard of warning arrangements as proposed for the St. Catherines-Lowestoft sector."

Air Ministry Memorandum No. 133 was accordingly drawn up and submitted to the Treasury Inter-Service Committee, who gave the necessary sanction at their meeting on 12 August 1937.[3]

Co-operation of Commercial Firms in Production of R.D.F. Equipment (1937)

Even before Treasury sanction had been given, tentative discussions on the production of R.D.F. equipment by commercial firms had been taking place. In January 1937, it had been recommended that the system of R.D.F. should be disclosed to the Metropolitan-Vickers Electrical Company Limited and that

[1] Air Ministry File S.35982, Minute 80 of 11 Jun. 1937.
[2] *Ibid.*, Minute 82 and Encl. 89A.
[3] *Ibid.*, Encl. 100A and Minutes 100/101.—This Memorandum is given in full at Appendix No. 4.

they be asked to carry out certain experimental and development work. However, as a result of a conference held on 22 January 1937 under the chairmanship of the Director of Scientific Research, it was decided that Metropolitan-Vickers should be informed only in respect of the transmission side of R.D.F. The receiving apparatus, it was decided, should be given to A.C. Cossor Limited for development. It was considered that there would be little risk as regards secrecy if the goniometer development were placed with another firm, and this was made the responsibility of the Radio Transmission Equipment Company Limited. It was recommended that the erection of aerial arrays should be the responsibility of the Bawdsey staff assisted possibly by G.P.O. workmen who might be made available.

After discussion between the Secretary of State for Air, the Chief of the Air Staff, and the Air Member for Research and Development, approval was given for the selected firms to be approached.[1] The staff of Metropolitan-Vickers were convinced that they would be able to design a satisfactory transmitter to meet the requirements (which called for hitherto unattained peak outputs), delivering the first experimental model, at a rough estimate, within nine months of the date of the contract, and thereafter at the rate of three transmitters every two months.[2] Arrangements were made for a member of the Company who would be in charge of the experimental work and design to visit Bawdsey to draft an outline working specification with the Bawdsey staff. Messrs. Cossor anticipated no difficulty in designing and producing the receivers provided adequate facilities were afforded to discuss technical details with the experimental officers concerned ; they were prepared to set aside certain special shops for experimental work and for the assembly of components made in the general shops. By limiting the assembly work to specially selected and trustworthy staff they were satisfied that secrecy could be ensured. They estimated that twenty receiving sets could be available in from twelve to eighteen months from the date the contract was placed.[3]

After Treasury authority had been granted for the Main Chain, the Directorate of Signals made a formal request to the Directorate of Equipment for the purchase from Metropolitan-Vickers of twenty sets of R.D.F. transmitting equipment to the specification B.R.S. 10001/B, each set comprising two complete transmitters ; and from Cossors twenty sets of receiving equipment to specification B.R.S. 10002/A.[4] Treasury authority allowed for the expenditure of £320,000 on the apparatus, the cost of transmitters and receivers being as follows :—

Transmitters ..	£21,000 for the first set (comprising two transmitters), £16,500 for the next four sets, and £14,500 for the remainder.
Receivers ..	£1,000 per set (comprising one Receiver).

On 28 October, Cossors were instructed to proceed with the manufacture of a further nineteen sets similar to the apparatus already being developed by them.[5] This contract was later increased to forty sets to cover one standby at each Station. On the 6 November, Metropolitan-Vickers were similarly instructed to proceed, the first set to be delivered within nine months, the next three sets by October 1938, and thereafter at the rate of three sets every two months.

[1] Air Ministry File S.39518.
[2] Air Ministry File S.40079, Minute 29.
[3] *Ibid.*, Minute 40.
[4] Air Ministry File S.42780.
[5] *Ibid.*, Minute 109.

Preliminary Siting of the Main Chain

In January 1937, at the request of the Director of Scientific Research, Mr. Watson Watt had produced a tentative outline of the requirements of an R.D.F. site.[1] In the first place there was the obvious requirement of proximity to G.P.O. cables, the National Electricity Grid, water supply, and access by road. As to the technical requirements, he stated that the site should be not more than half a mile from the coast and situated on cliffs overlooking the sea. Alternatively the site might be on high ground near the coast. The station might be set back from the coastline without loss of working range at the rate of 20 miles for every 100 feet gain of height above the average level of the country in front of the station. Obstructions in front of the station—buildings, trees and the like—and possible sources of electrical interference were to be avoided.

After the April, 1937 exercise, but before Treasury sanction had been given for the complete chain, Mr. Watson Watt urged that the available resources for R.D.F. production should be used to give preliminary cover over the greatest possible length of coast, leaving the chain to be strengthened in its second stage by the shortening of individual links as required.[2] He also set out the results of his preliminary investigation to determine the action required to erect a twenty-station R.D.F. Chain. He considered that even with extreme pressure exercised on all concerned and maintained throughout the whole time, it would take fully two years to produce the required twenty stations. His plan provided that the five-station Intermediate Chain from Dover to Bawdsey should preserve its existing spacing, but recommended that the Dunkirk station should be replaced by one at North Foreland because it was important to have the most advanced possible observation post on the south side of the Thames Estuary. He recommended that the Dunkirk site should be retained in its present state for use first as a base for inland R.D.F. experiments, and later as one of the additional full-scale R.D.F. stations required round the Thames Estuary. He also recommended that the Bawdsey operational station should be replaced by a station at or near Lowestoft.

The Main Chain stations outside the important front covered by the Intermediate Chain were to be separated by approximately 40 miles which would allow for detection of aircraft flying at moderate to great heights but not at low altitudes. The spacing suggested would not provide any margin for loss of any station by enemy action, and it was therefore desirable to have a second stage of the Main Chain to cover the provision of further stations for improved location of low-flying aircraft, and the reduction of risk of a break in cover by destruction of individual stations. Dunkirk was to be kept in view as a station in this later stage of the chain.

Siting of Main Chain Stations

The approximate positions suggested for the Main Chain stations were Portland or St. Albans Head, St. Catherine's Point, Worthing, Peacehaven, Ore or Fairlight, Dover, North Foreland, Canewdon, Great Bromley, Bawdsey, Lowestoft, Cromer, Skegness, Spurn Head, Flamborough Head, High Whitby, Seaham, Coquet Head, St. Abb's Head or Fast Castle, St. Andrews (Strathkiness),

[1] Air Ministry File S.35982, Encl. 68A (1) and (2).
[2] Air Ministry File S.40174, Encl. 2B.

St. Cyrus. The sites proposed had been selected from the map having regard to the required spacing of the Chain. It remained to examine in detail the positions chosen in order to determine the exact locations most nearly satisfying the requirements for a good R.D.F. site. Accordingly survey parties were formed including representatives of Bawdsey Research Station, Fighter Command, and the Air Ministry Works Directorate. Technical requirements were the first consideration, followed by vulnerability to attack from the air and the sea.[1] No real difficulty between technical requirements and those of the Works Services arose. Regarding vulnerability it was realised that as the sites would be between 2 and 10 miles from the sea they would mostly be visible from surface vessels, but as they were not considered good targets the risk of bombardment was accepted.

As a result of this survey Mr. Watson Watt recommended that fifteen stations, including the five stations of the Intermediate Chain already being built and modified to give full main station performance, would give almost the same cover originally calculated for the Main Chain of twenty stations.[2] He suggested that the sites for the remaining five stations should be delayed for eighteen months when the knowledge of R.D.F., which was growing rapidly, would have still further increased. It would then be possible to site them to the best advantage, either to reinforce the Main Chain where necessary or to extend it in a northerly or westerly direction. No question of moving any of the fifteen stations would arise, since each occupied the most favourable site which could be found anywhere in a length of front comparable with the main spacing between stations. The proposal for a first group of fifteen stations also allowed for a small reserve from among the equipments being manufactured. These proposals were agreed and the fifteen sites were selected, to include those of the original five-station or Intermediate Chain.[3] Further adjustment was still necessary, however.

Owing to opposition from local authorities, the site chosen at Alfriston (08) was replaced by one at Poling (08) near Arundel.[4] The relinquishment of the Fairlight site (06) meant its substitution by two stations at Rye (05) and Pevensey (07), necessitating increasing the number of stations to sixteen.[5] The site at Steng Cross (40) also had to give way owing to opposition from the landowner, and a site was selected in the Cheviots at Ottercops Moss (40). The sixteen sites thus became :—[6]

02	Dunkirk	04	Dover
05	Rye	07	Pevensey
08	Poling	10	Ventnor
22	Canewdon	24	Great Bromley
26	Bawdsey	28	High Street
30	Stoke Holy Cross	32	West Beckham
34	Stenigot	36	Staxton Wold
38	Danby Beacon	40	Ottercops Moss

Research on Operations and Filter Rooms, Communications, and Display (1937)

The Spring exercises for testing R.D.F. had thrown into relief the need for intensive work on a scientific basis on communications and Operations Room technique, including methods of transmitting and displaying the information

[1] Air Ministry File S.42747, Encls. 7A and 9A. [2] *Ibid.*, Encl. 7A.
[3] *Ibid.*, Minutes 6–10. [4] *Ibid.*, Encl. 36A. [5] *Ibid.*, Minute 53.
[6] These sites are indicated on Map No. 1.

obtained by the R.D.F. Chain. This line of research was no less important and urgent than that of the radio detection system itself, a point which was stressed by the Air Officer Commanding-in-Chief, Fighter Command. The Air Staff and the Operational Commanders considered that since raid reports would be received from several R.D.F. stations, and from other sources, such information must first pass through a Filter Centre for evaluation of the data supplied on position, track and speed of individual raids before it reached the Operations Room table. It was therefore agreed that research should be undertaken on methods of communication, interpretation and display of raid reporting information. This called for a separate laboratory and staff at Bawdsey formed under Mr. E. J. C. Dixon in August 1937, for the purpose of improving the technique and equipment of the standard type of Operations Room and the development of Filter Rooms.[1] A full-scale experimental Operations Room, modelled and equipped on the lines of the best existing Group Operations Room was provided at Bawdsey, and Warrant Officer R. W. Woodley at H.Q. No. 11 Group was temporarily attached to Bawdsey on account of his exceptional experience of Operations Room development and planning.

Communications for Raid Reporting

It was clear that a most efficient communication system between the reporting stations, the centres of control and the operational squadrons associated with them would be required. Since R.D.F. stations would be the main source of raid reporting traffic to be passed to Operations Rooms it was decided that the Superintendent of Bawdsey should become a member of the Technical Development Committee for Air Defence Communications, which had been set up in March 1936, under the chairmanship of the Assistant Engineer-in-Chief of the General Post Office, and whose members were representatives nominated by the Air and Army Councils.[2] The duties of this Committee were to make technical arrangements for the Air Defence landline system, including the standardisation of equipment to conform with the best modern technique and to deal with the safeguarding of landline installations in time of war. After the formation of this Committee, there was a considerable increase in the use of teleprinters for communications, and pneumatic tubes for internal distribution of messages in Operations Rooms. This was followed by the introduction of the Defence Teleprinter Network.

A scientist, who had been working on communications problems at Bawdsey, was transferred to the General Post Office Research Station, Dollis Hill in June 1937, to collaborate with the G.P.O. Transmission Group.[3] The remoteness of most R.D.F. stations from the G.P.O. trunk network and the realisation of the need for quick and accurate reporting led to the development of a transmission system which gave one secret (inverted) speech channel and four teleprinter or signalling channels. This system, however, was not adopted, and in its place one speech channel with a superimposed signalling channel was agreed upon. In co-operation with the G.P.O., work was also started on the development of optical and automatic switch devices for R.D.F. communications which, after the outbreak of war, led to the installation of automatic calculators at Chain Stations.

[1] Air Ministry File S.46357.
[2] Air Ministry File S.36965, Encl. 43B.
[3] Air Ministry File S.40089.

In the Air Ministry towards the end of 1937, the communications problem was energetically tackled by the Signals Branch with the aim of establishing communication links between R.D.F. stations and the Headquarters concerned as each R.D.F. station was completed.[1] The Air Staff considered the completion of the R.D.F. Chain so urgent that it was decided the communications system should be completed without delay, even if this eventually might prove uneconomical. It was decided that two routes, running through separate G.P.O. centres, would be provided to each R.D.F. station, so that interruptions to one route would not disrupt the system, and that the following circuits would be provided and divided between the two routes :—[2]

(*a*) Main reporting circuit.

(*b*) Spare reporting circuit.

(*c*) A lateral in each direction.

(*d*) Exchange line in each direction.

(*e*) Probable D/F circuits.

These cables were terminated at a Main Distributing Frame in the Receiver Hut.

By May 1938, sufficient experience had been gained from the two existing R.D.F. stations for future policy to be firmly determined. It was decided that the Central Filter Room should be located at Headquarters, Fighter Command, Bentley Priory, Stanmore.[3] All R.D.F. plots were to be reported to the Central Filter Room where they would be plotted on the table and built up into continuous tracks ready for telling to the Operations Rooms. The filterer officer would instruct individual R.D.F. stations as to which particular raids they were to report. From three tellers' positions in the Filter Room, lines would run direct to the three Fighter Group Operations Rooms (Numbers 11, 12 and the anticipated 13 Group). A line would also run from each teller's position to a plotter's position in the Fighter Command Operations Room. The incoming plots from the Filter Centre to the Groups would be relayed automatically to the Sectors under the Groups. High quality speech lines were necessary, especially in view of the fact that the information at the Groups would be redistributed simultaneously to a number of places. The possibility of teleprinters was borne in mind as a later development.

The original line requirement between each R.D.F. station and Headquarters, Fighter Command Filter Room, was four telegraph channels for plotting, and one speech channel to enable the Filter Room to be in touch with the R.D.F. station.[4] In December 1938, however, the G.P.O. refused to accept this proposal, and it was decided that the Post Office Research Station at Dollis Hill and the Bawdsey Research Station should together investigate the provision of a special circuit with control signalling injected at a suitable point of the speech spectrum, and having a sufficiently good intelligibility to enable plots to be passed without need of repetition. In the meantime, special circuits were used for plotting by speech, and R.D.F. stations were linked to the nearest Fighter Command Voice Frequency Centres, which, in the majority

[1] Air Ministry File S.37237, Encls. 203A and 204A.
[2] *Ibid.*, Encl. 227B.
[3] *Ibid.*, Encl. 236A.
[4] *Ibid.*, Encl. 314A.

of cases were the nearest Sector Headquarters. Finally, arrangements were made for two alternative landline routes between each new station and the Filter Room to be connected shortly after the station was occupied.

In March 1939, the Air Officer Commanding-in-Chief, Fighter Command proposed additional landline communications to be laid between the R.D.F. stations and the Fighter Sectors. In the event of the Filter Room, or important cables to the Filter Room, being put out of action, Sector Headquarters should be able to obtain R.D.F. information direct from the R.D.F. stations. This proposal was accepted by the Air Ministry, and the necessary lines were installed by the G.P.O. The lines could have been converted into teleprinter lines, making it possible for the R.D.F. stations to teleprint plots to plotter positions in the Operations Rooms, but although this facility existed, it was never used.

In accordance with usual procedure, all the cable and telephone equipment on R.D.F. stations was taken over from the G.P.O. by the Royal Air Force and became Air Ministry property, the G.P.O. laying the lines as an agency service, and in the event of failure, replacing and repairing them on a cost and time repayment basis.[1] The advantage of this arrangement was that the Royal Air Force could legally make alterations to the lines on the stations.

Calibration of R.D.F. Stations

The need for accuracy in locating aircraft detected by R.D.F. Stations brought the need for careful calibration into prominence. Calibration was not necessary to secure accuracy in the matter of range, for the type of terrain surrounding an installation had little effect on the timing of radio transmissions and reflections. The methods of determining bearing and height of aircraft were both materially affected, on the contrary, by the contour and quality of the earth in the neighbourhood of the R.D.F. equipment. Most of the signal picked up by the receiver arrived by the shortest path, or direct ray as it is called, but some of it was received after ricocheting off the surrounding part of the countryside. When a R.D.F. station was sited on perfectly flat smooth land, the behaviour of the reflected ray, as the ricocheting signal was called, could be anticipated and the equipment would give readings of bearing and height approximating to theoretical accuracy. The perfect site was rarely found in practice, however, with the result that accuracy of bearing was affected by reflected rays which ricocheted sideways, and accuracy of height was lost because some rays had been abnormally reflected in the vertical plane. The effect of the site on height-finding was, in point of fact, far more serious than it was on direction finding. In the latter an irregularly reflected ray was merely a contributory factor, but in height-finding the direction of the reflected ray was of basic importance in the calculation.

The type of site from which the greatest accuracy in height and direction finding was to be expected was a peninsular at sea level, around which the sea would act as a non-distorting reflector. Such sites had a grave disadvantage in practice, however, because the lack of effective height of the aerials imposed a serious limitation on the range of the equipment at low elevation. In order to obtain good low cover, therefore, accuracy of measurement was usually sacrificed to obtain maximum range. Although the best possible sites were

[1] Air Ministry File S.37237, Encl. 239A.

selected, errors of the order of 15 miles transverse to the line of shoot and of thousands of feet in height at long range were to be expected from an uncalibrated station.[1]

Methods of Calibration

The method of calibration was for the station to take readings on an object whose actual bearing and elevation were known. Corrections for the difference in the two could then be incorporated in the equipment. It was estimated that the average station required calibration for ten target heights at each of ten points on a semicircle of 30 miles radius centred on the station, for each of four wavelengths, so that four hundred primary observations, with a few check observations at other ranges, were required for each station. Two methods of calibration were adopted. The first method, that of taking observations on returns from London aircraft of R.A.F. Station, Felixstowe, was not very successful.[2] At that time there was no method of amplifying the signal from the calibration aircraft to make the indications distinctive and easy to read, and observations required much checking. The pilot reported his position by radio telephone when he was over points of known position, such as lightships, and several hours of flying were necessary to obtain these transitory observations. Moreover, minor modifications to the equipment were sometimes required, and as bad weather might then delay further observations, progress was often slow. It was held that observations on aircraft, while necessary, were not alone sufficient.

The second method, that of taking observations on returns from a dipole aerial carried on a kite-balloon, seemed more promising. An experiment in June 1937 was successful, and this method of calibration was made applicable to both Chain and transportable ground installations for location inland.[3] Bawdsey Research Station proposed the formation of a mobile section, comprising transport for taking the balloon and accessories to points within 20 or 30 miles from Bawdsey. Ascents were required to heights between 5,000 and 15,000 feet. This proposal was implemented in September 1937, when the inland station at Dunkirk, Kent, was calibrated by balloons flown at Manston, Eastry, Charing and the Isle of Sheppey.[4]

For stations on the coast, it was suggested that attempts should be made to procure from the Admiralty a vessel suitable for the work, which would involve cruising at distances up to 50 miles from the shore. As a temporary measure, it was suggested that a Royal Air Force surface craft should be allocated, to work at distances up to 20 miles from the shore, where useful calibration could still be done.[5] The formation of the mobile crew was approved, and the question of the allocation of a boat investigated. Progress was, however, slow. In February 1938, Bawdsey Research Station reported that calibration work had made no substantial progress during the preceding five months.[6] Until stations were calibrated, it was not possible to assess the requirements for a filtering process, or to study the general problem of recording and communicating data on a number of raids. Bawdsey urged that consideration should be given to the immediate provision of a balloon, having a ceiling of 7,000 feet, capable of operating out to sea at a distance of 30 miles from the

[1] Air Ministry File S.42719, Encl. 65A.
[2] Air Ministry File S.41722, Encl. 32A.
[3] *Ibid.*, Encls. 1A and 3A.
[4] *Ibid.*, Minute 4 and Encl. 23A.
[5] *Ibid.*, Minutes 5 and 6.
[6] *Ibid.*, Encl. 32A.

coast. If a ceiling of 7,000 feet were not immediately realisable, a ceiling of 5,000 feet would be useful. This recommendation resulted in the supply of a 60-foot Diesel Pinnace carrying a small balloon with a ceiling of 5,000 feet, with which a certain amount of progress was achieved.[1]

In September 1938, Mr. Watson Watt stated that if the Air Staff requirements for the R.D.F. Chain to be working on one wavelength by April 1939, and on all wavelengths by the end of December 1939, were to be met, two balloon units, working simultaneously, would be required for calibration.[2] He recommended that authority should be sought for the acquisition of two vessels capable of carrying LZ-A balloons, which had a ceiling of 7,000 feet and could be used for continuous operations. Financial sanction was given for the charter of two ships, and the Admiralty was approached regarding the loan of a trawler. As no trawler was able to be released, the S.S. *Ialine*, a motor tanker, and the S.S. *Recovery of Leith* were chartered.[3] The former, after fulfilling part of the programme, was considered too small for the duty, and, in December 1938, the vessel was returned to the owners, and the motor vessel *Miss Elaine* chartered in addition to the *Recovery of Leith*. Balloons continued to be used during 1939, a number of additional vessels being used for this purpose. However, it was realised that the method, in addition to its inherent slowness, would be seriously hampered in the coming winter and by restrictions on balloon flying in the event of war.[4] Consideration was therefore given to alternative methods.

Aircraft were known not to be very useful for azimuth calibration, since they could not fix their position accurately, nor could they stay in the same place to allow bearings to be taken on them with precision. On the other hand, for the purpose of height calibration they could be relied on to maintain accurate height, and also to keep on course to within the required accuracy which was less than was needed for azimuth calibration. These considerations suggested the use of autogyros for azimuth calibration. In December 1939, Fighter Command obtained three of these machines.[5] They were fitted with pulse transmitters to assist in taking accurate bearings and tests were carried out with the aircraft hovering over known landmarks. In March 1940, this method was approved as an alternative to balloons.[6] The autogyro was not much use for height calibration owing to its low ceiling and slow speed, and the use of orthodox aircraft for this purpose was continued with the carrying of a pulsed oscillator as in the case of the autogyro.

The story of calibration from this time onwards is one of continually increasing work as more and more stations were erected. The work was inevitably a source of some friction in that the technical staff, in their efforts towards perfection, were always anxious to re-adjust and calibrate stations, particularly when the equipment had been modified or the aerial system repaired, as frequently occurred. Fighter Command's concern, on the other hand, was to have the stations in as nearly continuous operation as possible. The sparing of aircraft for calibration flights was also a source of difficulty. The need for a generous allowance of calibration flying became more fully appreciated as time went on, for without it R.D.F. information could be unreliable and misleading.

[1] Air Ministry File S.41722, Encl. 43A.
[2] *Ibid.*, Encl. 65A.
[3] *Ibid.*, Encls. 75A and 87A.
[4] Air Ministry File S.42719, Encl. 17A.
[5] *Ibid.*, Encl. 18B.
[6] *Ibid.*, Encl. 29A.

Formation of a Directorate to be responsible for R.D.F. Development (June 1938)

The rapid development of R.D.F. during 1937 and early 1938 created the need for a separate authority at a high level to deal with the growing research and development. Mr. Watson Watt had advocated the formation of a separate R.D.F. Directorate as early as August 1936, at the time of his transfer from the Directorate of Scientific and Industrial Research to the Air Ministry.[1] At that time, however, the Secretary of State for Air was unwilling to undertake a re-organisation which would " entail a complete redistribution of responsibility for these communications and their development," and wished to centre the R.D.F. responsibilities at Bawdsey Research Station.

In practice, it was found that much liaison on R.D.F. matters had to be carried out away from Bawdsey. Mr. Watson Watt was consequently often absent from the Research Station, and at these times the duties of Superintendent devolved upon Dr. Paris, who in addition to supervising the work of the War Office group became involved in general administrative duties.[2] When, in March 1938, a concentration of effort was required on War Office work, it was found he could no longer carry out the duties of Deputy Superintendent. Consequently Mr. A. P. Rowe, previously Co-ordinator of Air Defence at the Air Ministry, was appointed to the Research Station as Deputy Superintendent, with the additional duty of supervising the Air Ministry programme. In view of this vastly expanded programme of R.D.F. research and development, a new Directorate was formed in June 1938, to deal with the development of all equipment required for radio communication, with Mr. Watson Watt as its Director.[3] It was named the Directorate of Communications Development (D.C.D.). The Research Station at Bawdsey was transferred to the new Directorate, Mr. A. P. Rowe becoming the new Superintendent in place of Mr. Watson Watt.

The Formation of No. 2 Installation Unit

It was the Air Staff plan that the Main Chain should reach a stage of completion by 31 December 1939. The responsibility for the organisation and planning of the installation programme had at first fallen upon Bawdsey Research Station. Close co-operation existed between the Research Station and the Directorate of Works in the design of suitable tower structures, buildings and electrical and other services, but the responsibility of co-ordinating the ground equipment and the internal layout of transmitter and receiver buildings lay with No. 10 Department of the Royal Aircraft Establishment, which had assumed this responsibility in January 1938.[4] The co-ordinating officer for all matters affecting the R.D.F. Chain was Squadron Leader J. W. Rose of this Department, he being the link between Bawdsey, the equipment contractors, and Air Ministry Works Directorate.

It was apparent early in 1938 that the work associated with the installation of R.D.F. stations to complete the Chain in accordance with Air Staff policy would increase considerably. Consequently in June of that year it was decided that a special Installation Unit should be formed to bring the R.D.F. Chain into operation.[5] The new unit became known as No. 2 Installation Unit. As its functions would be similar to those of the fitting Party of No. 1

[1] Air Ministry File S.37745, Encl. 14A.
[2] Air Ministry File S.37211, Encl. 35A.
[3] *Ibid.*, Minute 43 and Encl. 73A.
[4] Air Ministry File S.45121.
[5] *Ibid.*, Encl. 2A.

Maintenance Unit which was already functioning, it was decided that No. 2 Installation Unit should also be formed at No. 1 Maintenance Unit, which became the Accounting Unit. For administrative matters, No. 2 I.U. came under the authority of the Directorate of Equipment, the Directorate of Signals (which was responsible for co-ordinating the installation policy) and the Directorate of Communications Development. In July 1938, the Officer Commanding transferred his headquarters from the Royal Aircraft Establishment to the new Headquarters of No. 2 I.U. at Kidbrooke. In the same month, Mr. A. C. Gray of R.A.E. was appointed to assist him in the installation of the R.D.F. Chain. By August, the new Unit had begun work on extensions to the R.D.F. station at Bawdsey.

Completion of the Intermediate Five-Station Chain

It will be recalled that in the autumn of 1935 Air Ministry decided to erect a chain of five stations covering the Thames Estuary. This chain was to be ready by August 1936, with Bawdsey, Canewdon and Dover equipped with transmitters and receivers, and Great Bromley and Dunkirk fitted only with transmitters to enable the other three stations to fix or D/F the position of aircraft. Thus, regarding stations as centres providing location data, there were effectively only three. However, owing to shortage of staff and the intensity of research work, little of Bawdsey's effort could be spared for this five-station project so that even by the beginning of 1937 little progress had been made, though the masts had been erected.[1] The Superintendent of Bawdsey in January 1937 suggested that, since the Main Chain could not in any case be in operation before January 1939, consideration should be given to equipping fully the five stations of the Intermediate Chain and thus have them ready by the beginning of 1938, a full year before the completion of the Main Chain.[2] He suggested that Great Bromley and Dunkirk should be made into complete self-contained transmitter-receiver stations. This was possible since, as has been described, technique had developed to a stage where azimuth could be determined by a single station, the use of an adjacent transmitter for this purpose being dispensed with. There would thus be five stations each independently capable of determining range, bearing and height. Provision might also be made to mitigate the effects of deliberate jamming and to simplify the apparatus so that it could be operated by Service personnel.

These proposals were agreed by the Air Staff, and provision for the erection of extra masts and installation of the necessary equipment was made in the Main Chain scheme for which Treasury sanction was received in August 1937.[3] Extra land was accordingly acquired and the additional towers erected. At Dunkirk, however, it was found impossible to incorporate the existing transmitter tower in the new scheme, so three new towers were erected, the original tower being retained for experimental purposes. The construction of Great Bromley and Dunkirk proceeded concurrently with the early work on the remaining Main Chain Stations. By the end of July 1938, Great Bromley was completed, calibrated, and ready for operation, whilst that at Dunkirk was completed though not calibrated.[4] These stations together with Bawdsey, Dover and Canewdon were able to take part in the Home Defence Exercises of 1938 and, shortly afterwards, to provide R.D.F. cover for the Thames Estuary during the international crisis of September.

[1] Air Ministry File S.40493, Minute 9.
[2] *Ibid.*, Encls. 1A and 2A.
[3] Air Ministry File S.35982, Minute 66.
[4] Air Ministry File S.40493, Minute 52.

The 1938 Air Exercises

In August 1938, the annual Royal Air Force Home Defence exercises took place and were planned for the defence of a line from Lincoln to the Thames Estuary against air attack coming from East of this line.[1] For the first time there existed a chain of R.D.F. stations ready to give warning of incoming hostile raids. All five stations were operational, although Dunkirk had not been calibrated. One frequency only, 22·64 megacycles per second (13·25 metres), was used.

Bawdsey Research Station had decided that the success of R.D.F. in the exercises should be made the first claim on the work of the establishment. Scientists were attached to each station to assist the Royal Air Force personnel on duty at the transmitters, receivers, and landline termination equipment, and a close supervision was kept over the store and workshop organisations to ensure the most efficient maintenance of the stations. The power of the transmitters was stepped up as far as was practicable, to give the greatest possible R.D.F. cover. At Bawdsey itself, the civilian scientific staff took the rare opportunity of observing R.D.F. reactions in conditions of high raid density by carrying out a continuous watch with Royal Air Force operators, while at the other four stations a fixed period of three hours was made during which the scientists took over the manning of the sets from the Service personnel, and records were taken of all data received from the Chain stations. As a result of this detailed maintenance watch, the R.D.F. stations remained notably free from breakdowns throughout the exercises.

Results of the Exercises. The First Experience of Large Raids

The Exercises provided the R.D.F. Chain with its first experience of dealing with large numbers of aircraft, and the reporting system was inevitably swamped by the number of tracks which it was trying to report.[2] The situation was complicated by the fact that the aircraft which were simulating enemy raids had to begin their flights in a "neutral" capacity from their inland bases and fly out to sea through the R.D.F. illuminated area before they reached the predetermined point where they turned to fly in as "hostile" raids. This gave the R.D.F. stations a confused picture of friendly patrols, outgoing future "hostile" raids, circling masses of aircraft in their transitional stage, and incoming "hostile" raids. Echoes were also visible from aircraft as far as 80 miles behind the station, flying overland.

It had been discovered in a rehearsal prior to the exercises that if four stations produced information on four crossing tracks, which they did without difficulty, the resulting accumulation of plots on the Filter Room table was too great for the tracks to be filtered intelligently. The period for which each plot remained on the table had consequently been reduced from ten to five minutes. This meant that if a station were to maintain a continuous report on all the activity in its area, it would need to report each aircraft at least once in five minutes. During the busy periods of the exercises, so many tracks were visible on the cathode ray tubes of the R.D.F. stations that it was impossible to plot every one of them at five minute intervals, and even at the stations' existing rate of plotting, the Filter Room received more information than it could handle. In periods of great activity, therefore, all raids detected by the stations were not depicted on the Filter Room table.

[1] Air Ministry File S.45848 gives details of R.D.F. in the 1938 Exercises.
[2] Air Ministry File S.45848, Encl. 23A, para. 25.

The filterers were further handicapped in their work by the fact that many of the raids reported were not flying on definite tracks, but were circling in the neutral zone, preparatory to turning and becoming "hostile." The filtering of a track should have begun as soon as the track was reported by the R.D.F. stations, but at some periods of the exercises, filtering was only possible when definite tracks emerged from the clutter of circling aircraft. Sifting of the reports of individual raids was therefore troublesome; but the filtering of the information on the massed formations was even more difficult. Estimation of the number of aircraft in a formation from the echo which appears on the cathode ray tube could only be made reliably by experienced operators, and at that time none of the observers at the R.D.F. stations had had previous experience of echoes from large formations of aircraft. The R.D.F. estimation of raid strength was consequently very unreliable. The aircraft flew in very open formations, the echo from one massed raid being sometimes nine miles wide, and such echoes often masked smaller echoes from individual raiders, which flew to the coast unreported.

Height Reporting

Before the Home Defence Exercises took place, the Filter Room plotters had only had facilities to display on their filter tables the plan positions and the raid strengths which the stations reported. The R.D.F. stations were by that time, however, capable also of reporting the heights of the aircraft in their cover,[1] and the reports were considered sufficiently accurate to warrant the introduction of separate height counters, whereby height reports could be plotted in the colour corresponding to the colour on the plan position counters of the station, and also a distinctive filtered height counter which was displayed against the filtered track.

There was a tendency of the stations to report exaggerated heights on distant aircraft, due largely to the lack of experience of the height calibration section. It was technically impossible to read accurate heights at very low angles of elevation, and stations attempting to do so gave inaccurate information.[2] To offset this, orders were given for the height reading area to be curtailed and aircraft which gave indications of being below a certain angle were plotted with a non-committal "No Height" report. In 1938, the selected angle of elevation was too low, and aircraft flying just above this angle were consequently inaccurately measured. The error in reported height caused by an erroneous measurement of angle of elevation was greater at long ranges than at short ones, and as the aircraft approached the station the reported height would consequently be a little more accurate. Simultaneously, if the aircraft maintained a steady height, its angle of elevation from the station would increase, and would therefore be read more accurately. The net result was the apparent variation of accuracy of height measurement with range. Later, in 1940, the angle of elevation at which height measurement ceased was raised, and this tendency of accuracy variation then ceased to be apparent.

The Need for Low Cover

A disturbing feature of the exercise was the confirmation of the already anticipated inability of C.H. (Chain Home) stations to observe low-flying raids.[3] One low-flying aircraft flew towards the R.D.F. station at Dover,

[1] Air Ministry File S.45848, Encl. 26A. [2] Narrator's comment.
[3] Air Ministry File S.45848, Encl. 8A and Minute 35.

and actually passed over it without being reported. The distribution of the R.D.F. cover depended on a combination of the height of the aerials and the radio frequency on which they operated. The higher the aerial, and the higher its radio frequency, the lower would be the cover achieved. The C.H. frequency of 22·64 megacycles per second (13·25 metres) was comparatively low, and although the stations had been sited on high ground so that the effective height of their aerials might be as great as possible, their cover below 2° of elevation was scanty. As the C.H. installation was the only R.D.F. equipment then designed which had given any appreciable range of detection, the lack of low cover was an extremely serious matter.

Operations and Filter Rooms

In addition to the faults originating from the R.D.F. stations, errors were also made in filtering. Some filterers allowed their preconceived ideas on the direction the tracks would take to bias their translations of the R.D.F. plots, which resulted in wrong interpretations of accurate information. When such errors in filtering became realised, they were often only corrected gradually, in order that a continuous track might be kept, and this delayed the receipt of new data in the Fighter Operations Rooms. The plotters performed their duties accurately, but their efficiency dropped noticeably towards the end of long shifts. On this account it was decided that the maximum length of time that they should work should be four-hour shifts. The Bawdsey Filter Room, which had been specially treated acoustically, was much quieter than were the normal Operations Rooms, and similar treatment was recommended for all Operations Rooms.

The entire exercises were handicapped by bad weather conditions, causing an excessive amount of circling in the neutral zones, since visibility was poor and the aircraft found difficulty in locating their land and sea marks.[1] Electrical storms played havoc with the ordinary radio communications, but these storms did not seriously affect the R.D.F. performance.

Conclusions on the use of R.D.F.

As so many features of the exercises were new to the R.D.F. Chain, it was natural that its performance, though indicative of what could be achieved, was rudimentary.[2] The problem of the way in which the R.D.F. Chain and Filter Room reached a saturation point in dealing with a high density of raids was perhaps best appreciated by Bawdsey Research Station, who held that the best way of dealing with R.D.F. data during such periods had not been discovered. While Fighter Command and Air Ministry stressed the need for practising the existing system, the Research Station emphasised the need for operational research as distinct from operational training.

In spite of its many teething troubles, however, the R.D.F. system can be said to have shown signs of its future capabilities. Its performance had won the approval of the Air Officer Commanding-in-Chief, Fighter Command, who was the chief "customer". He considered that, for the first trial, the R.D.F. system had worked remarkably well. The intelligence system, which lacked experience, had not convinced the Air Ministry that it was ready to replace the

[1] Air Ministry File S.45848, Encl. 23A, para. 25, and Minute 13.
[2] *Ibid.*, Encl. 23B, paras. 96–98.

system of continuous air patrols, but it had shown enough promise for their eventual replacement to be forecast. The final opinion was summed up by the Deputy Director of Operations (Home), Air Ministry, in his report on the exercises :—[1]

> " (*a*) Although the conditions of this year's exercises led to standing patrols being adopted, it is considered that when all D/F and R.D.F. stations are completed, the standing patrols would not be needed, except for interception patrols when enemy raids were so numerous as to cause saturation on Group Operations tables.
>
> " (*b*) The artificial conditions caused by 'enemy bombers' setting out from within or near the defended area, and in many cases not going sufficiently far out to sea, led to difficulties and confusions which would not arise in actual warfare."

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[1] Air Ministry File S.45848, Encl. 18A.

CHAPTER 4

FINAL PREPARATION OF THE HOME CHAIN FOR WAR

The five-station chain had proved itself capable of prolonged operation during the 1938 Home Defence Exercises. At the beginning of September, when the Sudetenland problem became acute, the R.D.F. stations were brought into continuous operation. Between them, they afforded warning of aircraft at 10,000 feet to a distance of 80 miles from the coast between Suffolk and the South of Kent sufficient to provide warning of potential attacks on London and the Thames Estuary. But cover was also required for the north, in the areas of Forth–Clyde, Tyne and Humber. The Main Chain sites being insufficiently advanced, the situation was met by the emergency erection of three mobile installations, which were under construction for the overseas R.D.F. programme.[1] On 16 September 1938 the Director of Operations and Intelligence, Air Ministry, gave orders for the immediate completion of these mobile sets. Positions were found on two sites originally selected for Main Chain stations at Drone Hill (for the Forth–Clyde area) and West Beckham (for the Wash area). The third site was at Ravenscar (for the Tyne area), which, although it was not a Main Chain site, had been previously ear-marked as likely to give good early warning.[2] These sites were chosen for their height above sea-level, and it was hoped that the stations would provide warning of aircraft at 10,000 feet to a range of 60 miles.

On 25 September the erection of the stations was begun by No. 2 Installation Unit, under the direction of an emergency Installation Group which had been formed at Bawdsey Research Station under Mr. H. Dewhurst. Bawdsey's estimate for the erection of the stations, which comprised experimental hand-made transmitters and receivers housed in wooden huts with aerials erected on 70-feet masts, was three weeks, with calibration taking a minimum of one week after the installation had been completed.[3] The buildings of the "Advance" stations, as they were called, were erected between the Final Transmitter and Receiver sites in positions that avoided the possibility of their interfering with future work on towers, buildings and roads. Air Ministry was responsible for the provision of the exchange telephone links and private wires to Operations Rooms, while Bawdsey provided the inter-communication system.

Training of personnel at Bawdsey was intensified to meet the requirements of the new stations. There had been some slight controversy as to the ability of Service personnel as R.D.F. observers about the time of the 1938 Air Exercises. Mr. Watson Watt and the Deputy Director of the Bawdsey Research Station decided on an investigation under Mr. E. C. Williams on the accuracy of the R.D.F. Stations and the ability of the operators.[4] One outcome of this

[1] *See* Chapter 5 of this Volume.

[2] Air Ministry File S.46200, Encl. 7A.

[3] *Ibid.*, Encl. 25A.

[4] This was the forerunner of Operational Research Sections. Mr. Rowe and Squadron Leader R. G. Hart made an informal arrangement that if war broke out a small group of scientists would remain in the south when the Bawdsey Research personnel moved to Dundee, and form a Research Section at Headquarters, Fighter Command. That group became the first official Operational Research Section attached to a Royal Air Force establishment. So successful was this deliberate application of the scientific method to the operational use of weapons that Air Ministry decided to set up Operational Research Sections very widely in the Royal Air Force during the summer of 1941.

operational research was an agreement that Royal Air Force personnel who had been observing for some two or three hours daily for a period of six months were even more competent operators than the scientists who, by comparison, lacked experience on the observer side of R.D.F. operations. The technical establishment of each station comprised one Signals Warrant Officer, three aircraftmen Wireless and Electrical Mechanics, and three corporals and six aircraftmen Wireless Operators. Of these, the aircraftmen Wireless Operators could be picked from newly-trained ex-boy-entrants, but the Wireless and Electrical Mechanics needed to be tradesmen of some experience.

By 6 October all three stations were completed and handed over to the Royal Air Force crews for continuous operation. Drone Hill was capable of detecting aircraft at 7,000 feet at a distance of 60 miles out to sea, which would afford Edinburgh about 20 minutes warning of a raider flying at a speed of 240 miles an hour.[1] Ravenscar could detect aircraft at 10,000 feet at a distance of 80 miles, which would afford 30 minutes warning to the Middlesbrough–Newcastle area; West Beckham, owing to its low height above sea-level, could not detect aircraft at 10,000 feet at ranges greater than 30 miles. The stations' facilities for height-reading were inadequate, and this substantially decreased their usefulness for interception purposes; but apart from small, local faults, their performance as early warning stations was satisfactory. For the time being each station acted as its own Filter Centre, and it was proposed that the information should be passed to the local sectors. With the establishment of the Filter Room at Headquarters, Fighter Command, the new stations were connected normally to the Central Filter Room.[2]

While the first three "Advance" stations were still being erected, it was decided that five other "Advance" stations should be installed.[3] These were to be sited at Ventnor (Isle of Wight), Shotton (Yorkshire), Stenigot (Lincolnshire), High Street (Darsham, Suffolk) and Beachy Head. As the international crisis passed, however, it was decided to abandon the sites at Shotton and Beachy Head. At the other three, which were Final station sites for the Main Chain, aerial equipment, temporary huts and emergency power supplies were provided. As the work of aerial erection was the most protracted part of bringing a station "on the air," these provisions ensured that any emergency could be quickly met by using the experimental mobile transmitters and receivers from the Bawdsey Research Station, at the expense of denuding that unit of its research resources.

Transfer of Filter Room from Bawdsey to Fighter Command

It had previously been decided in May 1938 that a new Filter Room should be established at Headquarters, Fighter Command. During the Munich crisis, this new Filter Room was fitted out in the basement of the Headquarters at Bentley Priory. An operations table covering the central area was transferred from Bawdsey, and extensions to the north and south of the map were carried out by Fighter Command staff. A 54-pair telephone cable was laid from the new Filter Room to the main distribution frame at Fighter Command, and telephone wiring arrangements were made so that the contemplated Main Chain of stations might be connected to the Filter Room. In October 1938 these preparations were completed, and the new Filter Room at Bentley Priory took over the

[1] Air Ministry File S.46200, Encl. 52A. [2] Air Ministry File S.37237, Encl. 268A.
[3] Air Ministry Files S.42600 and S.42690.

duties of the Bawdsey Filter Room.[1] It was manned by Service personnel who had previously been responsible for the practical development and practice in the art of filtering.

Allocation of R.D.F. Frequencies

The frequencies which were to be allocated to the C.H. Chain of stations were the subject of discussion between Bawdsey Research Station and the G.P.O. The G.P.O. were anxious for the R.D.F. stations to avoid interference with the Cross-Channel Ultra-Short-Wave service between Dover and Calais (75 and 84·5 megacycles per second), the London Television service (44·78 and 41·67 megacycles per second), and the proposed Birmingham television service.[2] It was advisable for reasons of security to avoid the use of the 27–30 megacycles per second frequency band used by radio amateurs. The Lorenz Approach Beacons (30 to 40 megacycles per second) were another possible source of interference, but it was felt that if necessary the frequencies of these beacons could be altered. In November 1938, Bawdsey Research Station proposed that four frequencies in the band 25 to 52 megacycles per second should be allotted to each C.H. station. On 10 January 1939 a special meeting of the W/T Board was held, and the following four spot frequencies were allotted to the C.H. stations for use in peacetime: 22·69 megacycles per second (13·22 metres), 27·00 megacycles per second (11·00 metres), 48·00 megacycles per second (6·25 metres) and 50·50 megacycles per second (5·94 metres).[3] In peacetime, it would not be necessary for each C.H. station to operate on more than one frequency. These allocations were subject to the following restrictions :—[4]

(a) There should be 20 miles separation between any station using 22·69 megacycles per second or 27·00 megacycles per second, and any Cable and Wireless Company's receiving station.

(b) There should be no interference by stations using 48·00 megacycles per second and 50·50 megacycles per second with peacetime television programmes.

In March 1939 instructions were issued to Bawdsey to proceed with the design of aerial systems for the " Final " Chain on the basis of the following frequency schedule prepared for the stations by the Director of Communications Development :—[5]

		Frequency in Megacycles per Second.			
Station.	*No.*	22·69	27·00	48·00	50·50
Exmoor	18	—	x	—	—
Prawle Point	14	—	—	—	x
Ventnor	10	x	—	—	—
Poling	08	—	—	—	x
Pevensey	07	—	x	—	—
Rye	05	—	x	—	—
Dover	04	—	—	—	x
Dunkirk	02	x	—	—	—
Canewdon	22	—	x	—	—
Great Bromley	24	—	—	—	x
Bawdsey	26	x	x	—	—
High Street	28	—	x	—	—

[1] Air Ministry File S.4038, Encl. 6A.
[2] Air Ministry File S.45502, Encl. 13A.
[3] *Ibid.*, Encl. 10A.
[4] *Ibid.*, Encl. 23A.
[5] *Ibid.*, Encl. 25A.

Station.	No.	Frequency in Megacycles per Second. 22·69	27·00	48·00	50·50
Stoke Holy Cross	30	—	—	—	x
West Beckham	32	x	—	—	—
Stenigot	34	—	—	x	—
Staxton Wold	36	—	—	—	x
Danby Beacon	38	x	—	—	—
Ottercops Moss	40	—	—	x	—
Drone Hill	42	—	—	—	x
Douglas Wood	44	x	—	—	—
Stonehaven	46	—	—	x	—
Kirkwall	50	—	—	—	x

By the outbreak of war eighteen of these stations had been erected, but each could operate only on one frequency, in the 27–22 megacycles per second band.[1]

The Main Chain—Progress to the Outbreak of War

Reference has been made to the "Intermediate" and Main or "Final" Chains; that is, the five-station chain and the twenty-station chain originally proposed, and also to "Advance" stations. Roughly it may be said that the "Intermediate" Chain consisted of "Intermediate" stations destined to be enlarged to "Final" stations, whilst the remaining stations needed to complete the Main or "Final" Chain would be erected directly in the "Final" form. The "Advance" stations were mobile stations originally designed for overseas use but hastily erected at the time of the Munich Crisis to reinforce the "Intermediate" Chain. A brief description of each type of station is given below.

The "Advance" Type or A.C.H. Station

The equipment was housed in wooden huts and its aerials were mounted on two 70-foot, or in some cases 90-foot, towers. The receiver tower carried a single pair of crossed dipoles for direction-finding. The transmitting tower carried a single dipole and a reflector for sense-finding. The radio equipment was experimental in the earlier A.C.H. stations and later a type M.B.1 transmitter was used. Power was provided by a 9 kva. Meadows generator. These stations could only operate on one frequency and could not measure height.

The "Intermediate" Type Station (I.C.H.)

The I.C.H. station consisted of R.D.F. equipment housed in wooden huts. Its aerials were erected on 240-foot towers; the receiver tower carried a single pair of crossed dipoles with a reflector, and a single height dipole with a reflector at 80 feet, while the transmitter tower carried a three element array with a single curtain reflector. The equipment used was experimental, or in the case of later stations, an MB1 transmitter with an R.F.5 receiver. The station operated on one frequency only. Power was obtained from the mains, with a standby power supply of 7 kilowatts.

The "Final" C.H. Station

The "Final" C.H. station consisted of equipment housed in protected buildings. The transmitter aerials were erected on 350-foot steel towers, and carried a six-element array. The receiver aerials were erected on 240-foot

[1] Air Ministry File S.45502, Encl. 33A.

wooden towers, and carried a double stack of crossed dipoles with reflectors, and a single height dipole with a reflector at 80 feet. Each of the first twenty stations was equipped with two C.H. type transmitters, while the later stations of the Chain Overseas (C.O.) pattern were equipped with MB2 transmitters. Each station was equipped with two RF6 receivers, and was designed to be operational on any of four frequencies. The RF6 receiver was provided with anti-jamming devices. Power was obtained from the mains, with a standby power supply of 75 kilowatts.

The Accelerated Programme

It will be remembered that the existing five I.C.H. stations were brought into continuous operation for the Munich crisis, and that three A.C.H. stations were rushed up to cover the vulnerable areas of Forth, Tyne–Tees and Humber. Further measures were taken for a chain of thirteen stations to be provided in the event of a similar emergency, but at the expense of the Bawdsey research programme. It is true that in June 1938 two further sites had been chosen at the northern end of the Chain, stretching it from the Scottish border to Dundee.[1] Moreover, the Air Staff had agreed early in September to extend R.D.F. cover westward from the Isle of Wight to Start Point, but when the crisis arose no action was taken to obtain this extension.[2] It was evident, however, that more permanent measures needed to be adopted in order to be ready for the next political crisis. A meeting was therefore called by the Deputy Chief of the Air Staff on 6 October 1938 where it was agreed " That the R.D.F. Chain be hastened so as to be completed by 1 April 1939."[3]

From August 1937, when the Air Staff decision was taken to erect the Chain of stations, to the Munich crisis in September 1938, the time had been spent in the acquisition of the necessary sites and the erection on those sites of wooden towers. At no station had any steel towers been erected, and technical apparatus had been installed only at the five I.C.H. and three A.C.H. stations operational during the crisis. At the time of the meeting on 6 October 1938, the building of wooden towers at the sixteen sites originally chosen was far from complete. Three sites had four towers completed and one site had three. At none of the remaining sites had more than one wooden tower been completed, though eight towers were in course of erection. Four sites had no towers erected and two of the sites had not yet been acquired.[4]

It was apparent that if all the stations were to be erected by 1 April 1939, drastic measures would have to be taken. These were :—[5]

(*a*) That negotiations with landowners for acquiring sites should cease and compulsory powers of acquisition should be immediately applied.

(*b*) That manufacturers of steel masts should work 24-hours a day for seven days a week, both in the shops and in erecting the masts.

(*c*) That manufacturers of wooden masts should increase their output, in order to provide an extra number of wooden masts equivalent to the number by which steel masts fell short of requirement.

(*d*) That contractors of technical and electrical equipment should work to maximum output on a 24-hour day, seven-day week basis.

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[1] Air Ministry File S.42747, Minute 49.
[2] Air Ministry File S.41234, Encl. 55A, 61A and Minutes 57 and 59.
[3] *Ibid.*, Encl. 62A and Minute 63.
[4] Air Ministry File S.45174, Encl. 13A.
[5] Air Ministry File S.41234, Encl. 62A.

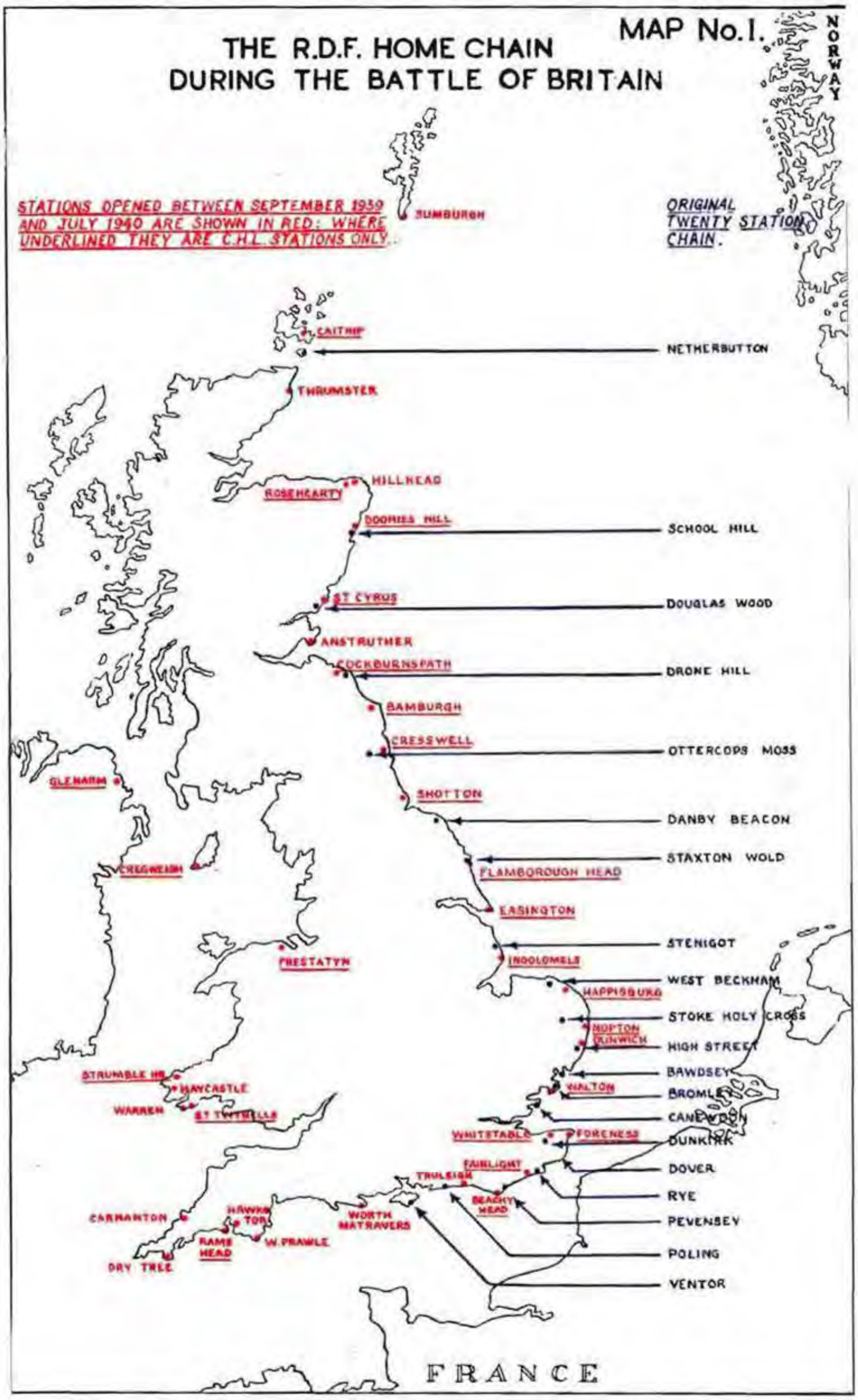
(e) That there should be no delay in obtaining financial sanction for the various works required, and in particular for the necessary Works Services involved. It would have to be accepted as a principle that the needs of security out-weighed financial considerations where R.D.F. was concerned.

If these conditions were fulfilled, it was thought possible to have a chain of eighteen stations operating on a semi-permanent basis, including the completion of the buildings, the partial completion of the total number of masts required, and the installation of the necessary receivers and transmitters.[1] In addition, it was thought possible to complete any two stations in the East Anglian salient to their final design, with all buildings completed, total number of masts erected and all necessary machinery installed. Action was immediately taken to bring the essential conditions into effect, and contracts were placed for six emergency transmitters, Type MB, and twelve emergency receivers, Type RF5.

By 15 October, Mr. Watson Watt (at that time Director of Communications Development) was able to define the emergency provision. He said that the stations would be limited to working on a single frequency without duplication of transmitter or receiver units, and with very restricted spares.[2] It was probable that not less than six of the stations would have full-powered transmitters, Type CH, made by Metropolitan Vickers ; the remainder would have mobile transmitters, Type MB, made by the same firm, or emergency transmitters manufactured at Bawdsey. The stations would be incompletely calibrated for direction-finding and height-finding, but calibration would proceed continuously as far as weather permitted. He considered that it would be necessary to accelerate the programme of provision of telephone lines to the Chain Stations, and to expand the training programme to provide for the considerable increase in personnel requirements. It would also be necessary to strengthen D.C.D. headquarters staff, Bawdsey Research Station staff for technical supervision of chain provision, and No. 2 Installation Unit staff for the fitting of stations. In November 1938, it was decided that in view of the lack of manpower available for erecting and lining-up stations, and in order to avoid interference with contractors working on the buildings for the "Final" programme, the "Intermediate" programme should be extended to embrace layouts of temporary wooden huts on the receiver sites, the layouts to be clear of the "Final" layouts.[3] This was held to be the best method of securing an "Intermediate" Chain by 1 April 1939, despite the extra cost thus involved at each of the outstanding eight stations.

It was essential in the interests of research, that the whole responsibility of the new programme should not fall upon Bawdsey. The installation of stations was therefore taken over completely by No. 2 Installation Unit, Bawdsey providing all the necessary drawings, sketches, instructions and materials to enable the unit working parties to proceed.[4] While the first stations were erected, Bawdsey provided assistance from its technical staff to train the No. 2 I.U. foremen. It was also Bawdsey's responsibility to provide scientific personnel immediately after the delivery of transmitters and receivers for testing the apparatus, lining-up the aerials, and for final calibration.[5] In

[1] The sites of these stations are shown on Map No. 1.
[2] Air Ministry File S.41234, Encl. 64A.
[3] Air Ministry File S.47412, Encl. 3A.
[4] Air Ministry File S.46200, Encl. 63A.
[5] Air Ministry File S.47412, Encls. 23c and 3.


MAP No. I.
THE R.D.F. HOME CHAIN
DURING THE BATTLE OF BRITAIN
NORWAY
STATIONS OPENED BETWEEN SEPTEMBER 1939 AND JULY 1940 ARE SHOWN IN RED: WHERE UNDERLINED THEY ARE C.H.L. STATIONS ONLY.
ORIGINAL TWENTY STATION CHAIN.
SUMBURGH
CAITHIP
NETHERBUTTON
THRUMSTER
HILLHEAD
ROSEHEARTY
DOONIES HILL
SCHOOL HILL
ST CYRUS
DOUGLAS WOOD
ANSTRUTHER
COCKBURNSPATH
DRONE HILL
BAMBURGH
CRESSWELL
OTTERCOPS MOSS
GLENARM
SHOTTON
DANBY BEACON
STAXTON WOLD
FLAMBOROUGH HEAD
EASINGTON
STENIGOT
INGOLDMELLS
PRESTATYN
WEST BECKHAM
HAPPISBURG
STOKE HOLY CROSS
HOPTON
DUNWICH
HIGH STREET
BAWDSEY
WALTON
BROMLEY
CANEWDON
STRUMBLE HD
HAYCASTLE
WARREN
ST TWYNELLS
WHITSTABLE
FORENESS
DUNKIRK
FAIRLIGHT
DOVER
TRULEIGH
RYE
BEACHY HEAD
PEVENSEY
CARNANTON
HAWKS TOR
WORTH MATRAVERS
RAME HEAD
W. PRAWLE
DRY TREE
POLING
VENTOR
FRANCE

December, to meet this responsibility, a new group was formed at Bawdsey under Mr. H. Dewhurst, consisting of seventeen of the staff previously engaged on research. It was this group which became the Base Maintenance Headquarters, and later formed the nucleus of Headquarters, No. 60 Signals Group, Royal Air Force. At the same time, the nucleus of a D.C.D. headquarters group was formed for the control of R.D.F. development.[1] This was known as RDC3, and later, on expansion, as RDC4.

Financial sanction for the I.C.H. programme was obtained on 14 November 1938. Such was the urgency of the programme that no delays were admissible, and where these might have been caused by the normal process of tendering for contracts, sanction was obtained from the Permanent Under-Secretary of State to dispense with the normal process and for contracts to be placed direct with the manufacturers.[2] Work had been put in hand before the sanction had actually been obtained, and by December, the following progress was forecast for the end of February 1939 :—[3]

(*a*) The erection of two wooden towers on each site.
(*b*) The erection of all necessary buildings.
(*c*) The erection of two 350-foot towers at Bawdsey, Canewdon and West Beckham.
(*d*) The availability of all essential mechanical and electrical supplies.

The urgency of the programme had forced the schedule of construction to be made without any margin for delays due to bad weather, unusual sickness among workmen, and other such factors, and when at the beginning of December severe weather conditions set in, the erection of wooden towers began to drop behind schedule. It was not surprising that contractors found great difficulty in inducing their men to work on the high timber structures during periods of strong wind and very cold weather. This delay in the erection of the masts threw the entire installation programme into jeopardy, since the installation of equipment and aerials was scheduled to follow the completion of the masts. The Superintendent of Bawdsey, in a strong protest to the Director of Communications Development stated that if it were not possible for the towers and huts to be provided by the dates specified in the schedule, it would not be possible for the Chain to be completed by 1 April 1939. He submitted that the effort being put into the erection of the masts did not seem to be commensurate with the sacrifices in research made by Bawdsey. This protest had the desired effect of accelerating the works programme, but by January 1939, there were still many sites where two towers had not been erected.

Conditions at some of the sites made constructional work extremely difficult.[4] At Ottercops Moss, the highest and most exposed site on the Chain, the weather since October had been so severe that constructional work had been impracticable. The greater part of the site was described as " a useless bog in which no satisfactory foundations could be found at a depth of 25 feet." Even the sites in Southern England presented difficulties. Rye was on a marsh exposed to high wind, and the general subsoil water was only a foot below surface level. The whole of the Pevensey site was under water, and the buildings were sited on silt subsoil. Their foundations had therefore to be taken 8 or 9 feet below ground level, the floor raised 18 inches, and continuous pumping was necessary to keep the trenches clear of water and running silt. To minimise the effects

[1] Air Ministry File S.4038, Encl. 6A.
[2] Air Ministry File S.47412, Minute 65.
[3] *Ibid.*, Encl. 21A.
[4] *Ibid.*, Encl. 46A.

created by the delayed erection of towers, departures from the scheduled order of installation were made. The Officer Commanding No. 2 I.U. installed ground R.D.F. equipment separately at sites where two towers did not exist, leaving the aerial installations to be completed when such towers became available, and the Bawdsey Research Station directed its first installation efforts to the four stations where two towers existed and aerial equipment had already been fitted.

By the end of January 1939, two stations (Ventnor and West Beckham) in addition to the five Thames Estuary stations had reached an operational stage as " Intermediate " Stations.[1] By the end of February, two more were ready for operation, and by 1 April, the target date for the completion of the programme, all but two of the stations were completed. The Chain therefore comprised sixteen I.C.H. stations, and the one A.C.H. station remaining at Ravenscar. At the remaining two I.C.H. sites, Ottercops Moss and Rye, the receiver towers were not completed, although all other apparatus had been installed. Consequently it was not until the end of May that the Officer Commanding No. 2 I.U. was able to report that all stations were capable of operation, and had been handed over to their Royal Air Force crews.

" Gap-Filling " Modifications

During the process of installation, another commitment had been given to No. 2 I.U. Since the earliest trials of R.D.F. it had been anticipated by the scientists that responses of uniform strength would not be received from aircraft in every position within range of a R.D.F. station. The cause of this variation of echo strength was the fact that the field of transmitted radiation from the R.D.F. station did not spread evenly at all angles of elevation, but varied. The variation was caused by a combination of the energy directly transmitted from the station aerials with the energy transmitted from the aerials and then reflected by the surface of the ground. The resulting field fell into regular regions of strong transmission and regions of zero transmission. The regions where the station was transmitting no energy were known as "gaps," and the regions where the energy was strong enough to return a recognisable response to the receiver were known as " lobes." Each gap was separated from the gap above and below it by the same number of degrees of elevation. The angle by which the gaps were separated was decided by two factors—the frequency of the station and the height of the aerials above the earth's surface. The conditions that governed the transmitter field also governed the receiver field, which consisted similarly of gaps and lobes.

As a result of the gaps described above in R.D.F. cover, the response given by an aircraft flying a steady course would periodically disappear from a station's receiver, reappearing again as the aircraft flew into the region of the next lobe. The disappearance of an aircraft on the instrument at one station was often unimportant, however, because the filter room would receive plots of the aircraft from a neighbouring station whose lobes covered the gaps of the first station. But when the Chain stations began to be used as experimental ground control stations of fighter interception aircraft, the fading became a serious difficulty. In the autumn of 1938 it became essential to find some method of filling the gaps.[2] The position of the lobes and gaps being dependent

[1] Air Ministry File S.45174, Encls. 30B and 34B.

[2] *Ibid.*, Encl. 163A.

on frequency and aerial height, it was necessary to find a way of varying one of these. In practice the frequency was retained and additional aerials were provided in such positions that they radiated lobes and gaps at different angles of elevation from those transmitted by the main array. In February 1939 instructions were issued for the fitting of an additional dipole aerial and reflector at all transmitters, permanently connected to the transmission line, and for the lower height receiver aerial to be rearranged as a crossed dipole, with an additional transmission line. This work ensured that the transmitter "gap-filler" was continuously radiating at a quarter of the strength of the main transmitter; while the receiver "gap-filler," which became known as the "B" System, could be switched into operation when it was needed, without prejudice to the height-finding facility of the station. Work on the installation of the "gap-filling" equipment was begun while the main installation programme was still in progress, and by the middle of August 1939 all the stations of the Chain had been fitted with the new aerials.[1] The alterations were an improvement but did not give entirely satisfactory results, and eventually the transmitter "gap-filler" was also controlled by the switch on the receiver, so that when it was brought into operation it could radiate the full power of the transmitter.

Defence of R.D.F. Stations

In October 1938, the policy for the passive defence of R.D.F. stations was :—[2]

(*a*) Technical buildings should be separated as far as was practicable.

(*b*) All technical buildings should be protected against a direct hit with a 25-pound bomb, made gasproof, and protected by revetments against the effect of blast and splinters.

(*c*) W/T towers should be multiplied, in order to provide facilities for quick change of transmitting and receiving frequencies, as a protection against jamming and damage to or destruction of one or two masts.

(*d*) The transmitter and receiver installations should be duplicated, and separate buildings should be provided for the transmitters and the receivers.

(*e*) Personnel not on duty should be accommodated in a camp sufficiently far from the R.D.F. station to form a separate target. Where possible, this small camp should be placed in natural cover, such as that given by trees. No action was to be taken to establish these camps in peace-time, but sites were to be ear-marked. On the outbreak of war, personnel would be accommodated in camouflaged tents, which would later be replaced by hutments.

It was decided in October 1938, that the R.D.F. equipment would not be buried deep underground. The advantages gained by doing so were slight in comparison with the technical disadvantages which would be involved. It was thought that R.D.F. stations offered a target which could only be attacked with success by low-flying aircraft, and to such aircraft the high masts would offer a considerable deterrent.[3] As the small sites were unsuitable for night attacks, it was expected that attacks would be limited to daylight hours, when the attacking aircraft could be intercepted.[4] One of the best methods of

[1] Air Ministry File S.45174, Encl. 45B. [2] Air Ministry File S.41234, Encl. 62A.
[3] *Ibid.* [4] *See* Parts 2 and 5 of Volume V for the interception technique.

assuring the defence of the R.D.F. stations, therefore, was to develop the interception technique to a point where hostile aircraft could be intercepted either at the coast or while they were still out to sea. It was agreed, however, that each station should be provided with eight machine guns, and should ultimately be provided with two-pounder pom-pom defences, and all R.D.F. stations were scheduled as Royal Air Force vital points.

Maintenance Organisation

During the time occupied by the construction of the I.C.H. Chain, the maintenance organisation which had grown with the original five stations continued. Spares for the equipment were requisitioned by Bawdsey Research Station, who stored them at Bawdsey Manor, and issued them to the stations as required.[1] When breakdowns occurred which were beyond the scope of the station personnel, assistance was sent from Bawdsey to deal with the faults. With the expansion of the R.D.F. Chain and its continuous employment, it was clear that a new scheme of maintenance responsibility was needed. R.D.F. commitments of the Bawdsey Research Station, both for home and overseas use, were increasing rapidly, and the accommodation at Bawdsey Manor was too small to house the quantity of spares needed by the continuously operating Chain of nineteen stations. Breakdowns on stations distant from Bawdsey were liable to be prolonged while assistance was on its way ; and the sending of such assistance might interfere with the research programme.

At a meeting on 14 April 1939 it was suggested that the Directorate of Equipment, Air Ministry, should assume the responsibility for the supply of spares, which could then be stored at the appropriate Maintenance Units. The Director of Equipment was unwilling to accept this responsibility, as so much of the I.C.H. Chain, which might have to remain operational for a period of two years before it was replaced by the "Final" equipment, had been assembled at Bawdsey from non-standard components. It was therefore decided as an interim measure, that the D.C.D. department RDC4 should assume the responsibility for the supply of stores. Bawdsey undertook to compile a schedule of the I.C.H. components, which would enable the Director of Equipment to accept the commitment as soon as possible. It was decided that each R.D.F. station should itself hold 100 per cent. supply of consumable spares, and that adequate supplies of other essential stores should be held at three suitably-located R.D.F. stations. It was also decided that a maintenance party should be established in a convenient position, from where it could be rushed to any R.D.F. station in need of its services. It was to cover three fields, and comprise—

(a) *Transmitter and Receiver Maintenance*
- 1 Scientific Officer.
- 2 Technical Officers.
- 3 Technical Assistants, Grade II or III.

(b) *Aerial Maintenance*
- 1 Technical Officer.
- 2 Assistants, Grade II or III.

(c) *Communications Maintenance*
- 1 Technical Officer.
- 2 Assistants, Grade III.

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[1] Air Ministry File S.2286, Encl. 1A.

The party was formed at Bawdsey, coming under the authority of the Director of Communications Development, and became known as the Base Maintenance Headquarters. It was decided to establish subordinate sections at three R.D.F. stations selected to house essential spares. These were known as Technical Maintenance Sections, and were the forerunners both of the later Radio Servicing Sections, and eventually the Royal Air Force Signals Wings of No. 60 Group.

The three technical Maintenance Sections were located as follows :—

Section.	*Area.*	*Distribution.*
Southern ..	Isle of Wight to Thames ..	Aerial parties and technical stores at R.A.F. Station, Hawkinge. Transmitter and receiver parties at Pevensey.
Eastern ..	Thames to Wash	Complete section at Bawdsey.
Northern ..	North of Wash	Aerial parties and technical stores at R.A.F. Station, Driffield. Transmitter and receiver parties at Staxton Wold.

These sections operated unchanged until September 1939, when the expansion of the chain to the north made the Northern Section too large and unwieldy an area. By that time Bawdsey Research Section had been renamed Air Ministry Research Establishment (A.M.R.E.) and transferred to Dundee, and a fourth technical maintenance section was formed there, which became responsible for the stations between the Forth and the Shetlands. The original Northern Section then became known as the North-Eastern Section, the new one becoming the Northern Section.

The maintenance system finally evolved, therefore, was that all technical stores were supplied through Base Maintenance Headquarters, who demanded the stores from D.C.D. and could also, when necessary, buy the non-standard items direct from civilian firms by local purchase order.[1] This local purchase power was increased, in August 1939, to an allowance of £100 for a single order within a limit of £1,000 a month, for the maintenance of the Chain. The raising of contracts to the firms was carried out by the Director of Equipment, Air Ministry, as requested by Air Ministry Research Establishment.

It had been realised that Bawdsey, with its exposed position, conspicuous towers, and continuously radiated signals, would, in time of war, offer a very likely target for air attack and it was inadvisable for the Research Station and the Base Maintenance Headquarters to remain there. As already stated a site was found for the Research Station near Dundee, but the Base Maintenance Headquarters needed a more centralised position. In June 1939 accommodation was found at Carlton Lodge, Leighton Buzzard. On 1 September 1939 the evacuation of the Research Station to Dundee, and of the Base Maintenance Headquarters to Carlton Lodge was effected.

Training of Personnel

As the I.C.H. stations became operational, the problem of providing trained crews to man them became an urgent one. In August 1938 the Air Ministry had accepted the responsibility for recruiting and training personnel for the

[1] Air Ministry File S.4038, Encl. 6A.

C.H. Chain, for the mobile ground equipment used by the Army and the Royal Air Force, and for R.D.F. apparatus used in Royal Air Force aircraft.[1] In addition, it had undertaken to train a limited number of instructors to assist the training programmes of the Admiralty and the War Office. Bawdsey Research Station housed the only R.D.F. training facilities in the Royal Air Force, and even these were very limited. When, in September 1938, training was accelerated to provide crews for the five I.C.H. and three emergency A.C.H. stations, the largest number of trainees which could be accepted at one time was 11 Wireless Operator Mechanics for maintenance duties and 9 Wireless Operators for operating duties. To bring the personnel of the eight stations to full establishment, which necessitated the training of 2 Senior N.C.O. Mechanics, 3 Corporal Mechanics, 13 Aircraftmen Mechanics, 9 Corporal Operators and 27 Aircraftmen Operators, training at Bawdsey had been greatly speeded up ; but the accelerated installation programme continued to keep ahead of the training programme.

The wartime establishment of an R.D.F. station was :—[2]

1 Warrant Officer, in charge.
3 Wireless Operator Mechanics, maintenance.
3 Corporal Wireless Operators, i/c watches.
6 Wireless Operators, watchkeepers.

The requirement of trained personnel to man the home chain of nineteen stations, and three mobile stations for the overseas programme, was 286 men ; and, with the provision of 50 per cent. reserve, the total number of men required was 429.

In November 1938, it was suggested that an R.D.F. school capable of training fifty operators at a time should be established with eight receivers incorporating training devices, and a staff of nine instructors. The site was selected for it at the Royal Air Force station at Tangmere.[3] Building was begun, and it was hoped that the school would be ready by June 1939. The length of the course was two months ; so the earliest output of fifty operators could not be expected before August 1939. An interim programme was therefore evolved.[4] Two sets of six instructors were trained at Bawdsey, and distributed among the operational stations of the Chain. Training attachments, manufactured at Bawdsey, were provided for the receivers of these stations, and the instructors were able to train two crews of operators each in three months. The training of the mechanics was more difficult, as the apparatus at the stations, being in continuous use, was not often available for demonstrations of servicing and repair.

By the beginning of 1939, it became apparent that requirements for R.D.F. personnel for both ground and airborne equipment at home and abroad would be very great. By April 1939, the total possible requirements had risen to :—

Operators :

For the Home Chain and Overseas programme ..	876
For Airborne R.D.F.	600

Mechanics :

For the Home Chain and Overseas programme ..	389

[1] Air Ministry File S.3910, Encl. 162A.
[2] Air Ministry File S.43697, Encl. 68A.
[3] Air Ministry File S.39100, Encl. 192A.
[4] *Ibid.*, Encl. 193A.

The training facilities of the proposed school at Tangmere would obviously be too small to deal with these requirements and the Director of Training, Air Ministry, was asked to provide a larger school. In the meantime, it was decided to train six operators at each of the 19 Chain stations, which would yield an output of 114 men every six weeks.[1] Approval was sought for an instructor to be established at each station, who, in addition to training the operators, would also try to train six mechanics every three months. For this programme, each of the stations would need an extra receiver and a training attachment. It was decided also that selected reservists should be sent for training to the I.C.H. station. The employment of women as R.D.F. operators was considered, as it had already been decided that women could be employed as plotters. Mr. Watson Watt (D.C.D.) had expressed the opinion in February 1937 that they might make better operators than men, but at Air Ministry it was considered that it was not known how women would react if flustered by heavy air activity. In June 1939, a site for the large training school required was selected at the Royal Air Force station at Yatesbury, in Wiltshire.[2] This school was to be capable of training courses of 126 operators on a one-shift basis, or 252 operators on a two-shift basis, and 126 mechanics.

Administration of R.D.F. Stations

Personnel for the manning of the stations were drawn from the trades of Wireless Operator and Wireless Operator Mechanic, as no R.D.F. trade existed.[3] At first, these men remained on the strengths of their original stations, and were expected to be returned to these stations at the end of their R.D.F. training. But in October 1938, it was decided to absorb them into the permanent R.D.F. organisation, and withdraw them from their parent units. As they remained in their original trades, however, it was necessary to provide training not only in R.D.F. but in the normal wireless operating technique.

When R.D.F. stations were first taken over by the Royal Air Force, Fighter Command was generally responsible for their administration and each station was administered by the nearest Fighter Command station ; personnel were based on this parent unit.[4] In times of emergency, it was necessary for R.D.F. stations to be manned continuously, and the personnel were then billeted in the local villages. Normally, it was possible for one crew to man the R.D.F. station, leaving the other two crews at the parent unit, where they were available for training in their basic trades. No definite ruling had been made on the duration of time for which they would remain on R.D.F. duties. In November 1938, Fighter Command suggested that the system should be altered.[5] Some of the R.D.F. stations were at great distances from their parent units, West Beckham, for example, being 70 miles away from Wittering, and this made administration difficult. Fighter Command proposed that the responsibility for the administration of the R.D.F. stations should be transferred to their nearest Royal Air Force stations, irrespective of the Commands in which these stations were. A list of the proposed parent units was prepared, which included stations of all the three operational Commands, but avoided where possible the allocation of more than one R.D.F. station to each parent unit.[6] This proposal and the suggested distribution were accepted by the Air Ministry. To preserve

[1] Air Ministry File S.39100, Encl. 199A. [2] Air Ministry File S.48327, Minute 33. [3] Air Ministry File S.39100, Minute 28. [4] Air Ministry File S.43697, Minute 38. [5] *Ibid.*, Encl. 63A. [6] *Ibid.*, Encl. 66A.

secrecy the stations were described as " Air Ministry Experimental Stations " (A.M.E.S.). Although the new allocation was more convenient geographically than the old one had been, the change contained the seed of future confusion, as the R.D.F. stations now came under any one of three different administrative systems. The R.D.F. stations were secret, entry to them by the parent unit was restricted to the commanding officers of the stations, and few of the administrative officers were familiar with them. In some cases, the parent units had no operational association with their R.D.F. stations, and some of them displayed very little interest in their affairs.

In November 1938, a design was approved for the small camps which were to be the living quarters of the R.D.F. stations, and the establishment was increased to include a cook, an aircrafthand assistant cook and cleaner, an aircrafthand N.C.O. to assist the warrant officer in charge, and an aircraftman clerk.[1]

Chain Operations (1939) prior to the Outbreak of War[2]

In March 1939, a new state of tension arose in Europe. German troops moved into Czechoslovakia. Fighter Command was given the responsibility of ensuring that Britain would not be surprised by air attack delivered before a formal declaration of war. Guns and searchlights were brought to prepared positions in the inner artillery zone ; the Air Raid Warning system was made ready to be put into action at immediate notice ; skeleton crews were brought into the Operations Rooms and the essential telephone lines were taken over from the G.P.O.[3] In April the R.D.F. Chain was brought into continuous operation. Fighter Command, with an Operations Table depicting the aerial activity over and around all the watched areas of the British Isles, was the authority best suited to issue the National Air Raid Warnings. Authority was vested in the Air Officer Commanding-in-Chief, Fighter Command, therefore, to issue an initial warning in the event of a hostile formation crossing the three-mile sea boundary of the British coast with the obvious intention of flying inland.

The Air Officer Commanding was also given the authority to intercept and engage the first raiders as soon as they had crossed the international boundary, and to intercept subsequent formations without regard to the limit of territorial waters.[4] He could also order action to be taken by the anti-aircraft gun defences. In order that such formations could be easily identified as hostile raiders, it was arranged between the three Services that prior notification should be given to Fighter Command of any friendly formation of six or more aircraft by day or of any number of single aircraft by night, flying within 120 miles of the coast between Saint Abb's Head to Dover. This area was modified in June to include the coast between the Humber and Dover. At the beginning of June, German aircraft began to operate in the North Sea and the English Channel. These flights were officially assumed to be training flights, but as one of them covered the entire British coast from Wick to Selsey Bill, there was a strong appearance of reconnaissance.[5] The aircraft did not, however, violate the territorial boundary, and consequently no offensive action was taken against them. Fighter Command, however, took the opportunity of testing and practising its interception system.

[1] Air Ministry File S.43697, Minute 74.
[2] Details of the equipment of the chain of nineteen stations as at the end of June 1939 are shown at Appendix No. 56.
[3] Air Ministry File C.S.1033, Encls. 1A and 4A.
[4] *Ibid.*, Encls. 4B, 10A and B.
[5] *Ibid.*, Encls. 8A, 21A, 23A.

The I.C.H. Chain, so hurriedly installed, supplied the information necessary for the Air Raid Warning System, but in its existing state was not able to provide the accuracy and reliability required for interception purposes, and the continuous watch was a serious strain on the apparatus. By the end of June 1939 it was obvious that certain essential modifications and maintenance would have to be carried out on the stations if they were to continue to provide efficient early warning cover, and to reach a state of full war preparedness. They were required by the Air Staff to reach such a state by 7 August 1939. On 26 June the Superintendent of Bawdsey Research Station undertook to complete by August the following requirements stipulated by the Director of Communications Development :—[1]

(*a*) The " Intermediate " Chain should be " cleaned up ".

(*b*) Vertical gap fillers should be fitted and connected at eighteen stations.

(*c*) Rough height-finding should be provided at all stations except Ventnor (whose site was technically unsuitable for height-finding).

(*d*) D/F and height calibration should be done for all stations.

(*e*) Anti-spark (the afterglow cathode ray tube) and anti-C.W. (the I.F.R.U.) should be fitted at all stations (except at two stations using old and unsuitable receivers).[2]

It was impossible for stations to remain operational while they were being serviced. The servicing programme was at variance with the Fighter Command requirement that the whole chain of stations should be available during their Group exercises and the annual Home Defence Exercise. The servicing required would also interfere with the 24-hour watch system. To enable the work to be carried out, a compromise was effected.[3] Each R.D.F. station was paired with one of its neighbours, the programme being arranged so that one of each pair was always operational while the other was being modified and serviced. The " cleaning-up " operations were begun on 22 June. Bad weather handicapped the work, but by 7 August the programme had been substantially fulfilled.[4] All of the stations had been overhauled, and the calibration of ten stations was the only outstanding commitment. The performance of all stations was good, with the exception of Ottercops, whose cover was considered insufficient.

Formation of the Inter-Service Committee on R.D.F. (November 1938)

The construction of the Early Warning Chain was the first operational R.D.F. commitment, but R.D.F. was beginning to develop applications in many other branches of the three Services. By the middle of 1938 these applications were so numerous that close co-ordination on R.D.F. research and development became essential. It was, therefore, decided to form an Inter-Service Committee for this purpose, with the following terms of reference :—[5]

(*a*) To examine the progress of research and development on R.D.F. from the point of view of strategic and tactical applications.

(*b*) To decide relative priorities in R.D.F. research and development.

(*c*) To recommend to the Vice-Chiefs of Staffs relative priorities in application and production.

[1] Air Ministry File S.47214, Encl. 157A.
[2] An anti-jamming device which is described in Chapter 14.
[3] Air Ministry File S.47214, Encl. 148A, Minutes 150 and 151.
[4] *Ibid.*, Encls. 157A-C.
[5] Minutes of the Inter-Service Committee on R.D.F.—AHB/IIE/68.

(*d*) To recommend to the Vice-Chiefs of Staffs provision for research, development and production in R.D.F.

(*e*) To recommend to the Vice-Chiefs of Staffs the action required to avoid or mitigate mutual interference between R.D.F. and other organisations.

(*f*) To arrange facilities for large-scale tactical trials and operational research work involving one or more of the Services.

(*g*) To consider, and, if necessary, recommend to the Vice-Chiefs of Staffs submissions from Service R.D.F. Panels.

It was proposed that the committee should have three panels, one for each Service, which would deal with detail work on the application of R.D.F. to the individual Service. The terms of reference of the panels were " To consider and report to the Inter-Service Committee on matters within the terms of reference of that body, predominantly affecting one Service." The first meeting of the Inter-Service Committee on R.D.F. was held on 2 November 1938, under the chairmanship of Air Vice-Marshal W. S. Douglas.

Extensions to the Home Chain

On 19 January 1939, the Deputy Chief of the Air Staff held a meeting to consider the extension of the R.D.F. Chain in the light of the increase in the Fighter Force to a 50-Squadron basis.[1] After closely considering suggestions made by the Air Ministry and Fighter Command, D.C.A.S. decided that the only extensions justified on the grounds of strategy were :—

(*a*) To extend the Northern flank of the chain to Scapa, to give early warning of air attack on the Fleet, by the provision of two full-scale stations at Kirkwall and Stonehaven.

(*b*) To extend the Western flank of the chain by two reduced-scale stations, one at Prawle Point to extend R.D.F. observations beyond Portland to cover the waters in which convoys would be passing, and to give warning of attack in the Bristol–South Wales industrial area from the South ; and the other at Exmoor, to extend the observation to the Bristol Channel, and to reinforce the cover of the Prawle Point station. (Reduced-scale stations operated with two instead of four frequencies, and though they gave the same performance as full-scale stations in plan location and height-finding, were thus a little more vulnerable to jamming. D.C.A.S. considered that, in view of the remote positions of the two stations, these disadvantages were acceptable.)

(*c*) To provide three mobile sets, as a reserve for stations damaged by attack, or to strengthen the chain at points of weakness.

Treasury sanction was therefore sought and obtained for these stations, and sites were chosen at Netherbutton, near Kirkwall ; School Hill, near Stonehaven; West Prawle, near Plymouth ; and Simonsbath on Exmoor.[2]

In May 1939, the question of R.D.F. cover for the defence of the Forth–Clyde area, Birmingham, Liverpool, and Belfast was raised at an Air Ministry meeting called to discuss future R.D.F. requirements for the defence of Great Britain. The Air Officer Commanding-in-Chief, Fighter Command, pointed out that the

[1] Air Ministry File S.41234, Encl. 69A.
[2] *Ibid.*, Minute 122 of 13 Jul. 1939.

Observer Corps areas of Lancaster and Carlisle were sparsely populated, and communications there were poor.[1] He believed that R.D.F. might give better results there than the Observer Corps. The Director of Communications Development agreed with him, and suggested that a station should be placed on the Isle of Man. Such a station would be capable of detecting aircraft over the sea at a height of 3,000 feet at a range of 60 miles, or, at a height of 10,000 feet at a range of more than 100 miles, although the mountainous nature of the North-Western coast of England and of the adjacent coast of Scotland would prevent detection far inland. Similarly, detection could not occur far inland over Ireland, but Belfast would be covered. As the height indications of such a station would not be good, he proposed that a second station should be located at Stranraer, where plan location would be poor, but height-finding accurate.

The R.D.F. cover for the rest of Britain was reviewed. It was decided that the station at Simonsbath (Exmoor) was not likely to give the results that had previously been expected of it, in that its cover in the English Channel would not be good. It was therefore decided to abandon the station. This meant that a gap would exist between Ventnor and Prawle Point. The Air Officer Commanding-in-Chief, Fighter Command, however, felt that small gaps in the screen were not greatly important, particularly at the western end of the Chain, as the enemy could be detected and probably intercepted before he had reached the gap. On the northern coast, another small gap existed at the approach to the Moray Firth, but it was considered improbable that the enemy would know of such a gap and be able to navigate through it. More concern was felt over the inability to track raids over the Scottish Highlands ; but as it was considered technically impossible for R.D.F. to operate in mountainous areas, and the area was too sparsely populated for an Observer Corps network to be organised, reliance had to be placed on seaward detection and the local Forth–Clyde Observer Corps posts. The defence of Belfast presented an easier problem than did that of the defence of vital points elsewhere in Britain, as Belfast constituted the only likely target for enemy raids approaching Northern Ireland, and fighter aircraft would therefore know where to find the enemy. The result of the meeting was agreement to establish two full-scale Chain stations at Stranraer and the Isle of Man, with the following priority of provision :—

(*a*) The immediate establishment of an I.C.H. station at Stranraer.

(*b*) The establishment of a full-scale C.H. station on the Isle of Man, following immediately upon the completion of Netherbutton to full scale.

(*c*) Following upon the provision of the station on the Isle of Man, Stranraer to be built to full scale.

Both the two new stations were to illuminate a full circle of 360°. It was also decided that the abandoning of the station at Simonsbath would necessitate the strengthening of the station at West Prawle, by the addition of a second line of shoot.

Emergency Provision of R.D.F. Cover for Scapa Flow (June 1939)

When Treasury sanction had been obtained for the northern stations at Netherbutton and Stonehaven, there had been no provision for their establishment in "Advance" or "Intermediate" form before they were erected as "Final"

[1] Air Ministry File S.41234, Encl. 87A.

stations.[1] It was a matter of urgency that the Royal Naval base at Scapa should be given immediate R.D.F. cover, and it was decided to transfer the temporary station from Ravenscar to the Scapa site as soon as the Ottercops I.C.H. station was completed. The selected site for the Scapa station (Netherbutton) had not been finally purchased, but authority was obtained for No. 2 Installation Unit to transport the station by local contract and to take local contract action for the works side of the project.[2] In order that the station might be erected in the shortest possible time, a new site was chosen. On 1 May 1939, Ravenscar was dismantled, and the equipment reached the Royal Naval Dockyard, Rosyth, by 5 May.[3] Masts dismantled from Drone Hill were at the quayside at the same date. It was hoped to erect at Netherbutton within a fortnight, when the station would immediately be put into continuous operation. The Officer Commanding No. 2 I.U. arrived at Kirkwall on 1 May. There, he had to mark out and agree with the local agent the boundaries of the proposed site, arrange for the work on the site such as excavations for tower foundations and the laying of concrete roads, arrange for the estimates to be accepted, interview G.P.O. officials for line terminations and ducts, and liaise with contractors for the transport of huts and towers from Stromness, before beginning the work of installing the equipment. It was due to this officer's drive that the installation was completed on 25 May. The Bawdsey installation party arrived on 23 May, and by the 26th, the RF2 receiver and the TM1 transmitter had been installed and tested. The aerials and transmission lines were then erected and phased on a line-of-shoot of 130° and a test run was arranged for 1 June. During this test, a Blenheim aircraft flying at 8,000 feet was detected at a range of 60 miles when flying on the station's line-of-shoot, and at 30 miles when flying nearly 90° from the line-of-shoot, where the cover was weakest.[4] The performance of the station was considered satisfactory, and Netherbutton was handed over to the Royal Air Force on 2 June 1939.

Decision to Equip the R.D.F. Chain with C.D. Apparatus for the Detection of low-flying Aircraft (August 1939)

The inability of the C.H. stations to detect low-flying aircraft had early been realised, and this disadvantage had been thrown into prominence during the Home Defence Exercises of 1938. Air Ministry interest was therefore aroused when the War Office R.D.F. equipment known as the C.D. set (Coastal Defence), which had been developed for the detection of ships from the shore, began to show signs that it could detect not only ships but also low-flying aircraft.[5] The C.D. set had been under development by the War Office group at Bawdsey since 1936. It differed radically from the C.H. type of equipment in that, while the C.H. covered its illuminated area by " floodlight " and located the bearing of its target by means of radio goniometer, the C.D. covered its illuminated area by means of a sweeping radio " searchlight " beam.[6] The beam could be swung anywhere over the area, and automatically registered the bearing of any target it illuminated. The narrow beam of the C.D. was achieved by the use of multiple aerial arrays. A bay of four full-wave aerials placed horizontally end-to-end gave a horizontally narrow beam ; while each bay consisted of a stack of four aerials one above the other, to give a vertically narrow beam. The resulting aerial array, consisting of a total of thirty-two

[1] Air Ministry File S.41234, Minute 122. [2] Air Ministry File S.47412, Encl. 99A.
[3] *Ibid.*, Encl. 117A. [4] *Ibid.* Encl. 132A. [5] Air Ministry File S.45843, Encl. 8A.
[6] Air Ministry File S.42928, Encl. 6B.

half-wave aerials, was mounted on a frame which had to be rotated by hand. To make this possible, the aerials, and therefore the wavelength of the C.D., had to be small, and a wavelength of less than two metres had been adopted. To obtain a narrow beam it is essential that the aerial system shall be of large dimensions compared with the wavelength used; thus a short wavelength allows a narrow beam without too bulky an aerial system.

The success of an R.D.F. system in detecting low-flying aircraft is dependent on its aerial system being a large number of wavelengths above the neighbouring land or sea to minimise the interference between the direct radiation from the aerial and its reflection by the surface of the earth. The lower cover of the C.D. was achieved by the employment of short wavelength, and the placing of the aerials at a great height from the ground either by the use of high towers or by siting the station at the edge of a high cliff.[1] The development of the apparatus had been delayed because it was difficult to obtain valves capable of transmitting a high power on what was then considered a very short wavelength. In view of this difficulty, the development of C.D. set had been placed on a lower priority than that of C.H. equipment which was giving promising results. But research had not been abandoned, and the group of scientists working on the C.D. set were even then looking ahead to the time when the wavelengths used would be measured in centimetres rather than metres.

Slow progress was made at first, but in June and July 1939, the War Office scientists, working under Dr. Paris at Bawdsey, began to make considerable advances with the apparatus.[2] It was named C.D.2, and, in addition to locating ships with great accuracy, located aircraft flying at 500 feet at ranges up to twenty-five miles with far greater accuracy than could a C.H. Mr. Watson Watt recommended the placing of a C.D.2 at every C.H. station in the Chain. On the 3 August 1939, the Assistant Chief of the Air Staff agreed to this recommendation, and action was taken to obtain 24 C.D. sets for the Air Ministry.[3] When modified for use against aircraft, the C.D. stations became known in the Royal Air Force as C.H.L. (Chain Home Low-Cover) stations, and it is under this name that they are henceforth referred to in this narrative.

The Main Home Defence Exercise 1939

On 8 August 1939, the R.D.F. Chain participated in the annual Main Home Defence Exercise.[4] By that time, the R.D.F. stations and their Filter Room at Stanmore had been in continuous operation long enough to have developed a standard procedure, and their performance was very different from their experimental debut of 1938. The Exercise consisted of the defence of a line from the Humber to the English Channel, and lasted for a period of three days. The R.D.F. system was in operation throughout this time. In his report on the Exercise, Air Chief Marshal Sir Hugh Dowding, A.O.C.-in-C., Fighter Command, commented :—

> "The R.D.F. System worked extremely well. The Bawdsey staff had made strenuous efforts to calibrate and overhaul all stations used in the Exercise, and their work is much appreciated. The Filter Room at Command Headquarters worked well, and the system, although doubtless capable of improvement as the result of experience, may now be said to have settled down to an acceptable standard.

[1] Air Ministry File S.42928, Encl. 21A.
[2] Minutes of the Inter-Service Committee on R.D.F.—AHB/IIE/68.
[3] Air Ministry File S.1686, Minutes 1, 4, 5, 14 and 20.
[4] Air Ministry File S.1659, Encl. 10A.

" Two partial gaps were discovered in the R.D.F. screen, one north-east of the Norfolk coast and one south-west of Dover.

" Members of the Bawdsey staff were in the Command Filter Room throughout the Exercise, and their report has been very helpful. Counting of numbers by R.D.F. was inconsistent throughout the Exercise. This will doubtless improve with training, but for the time being, R.D.F. can only be relied on to give a very rough indication of the strength of raids. The plotting in the Filter Room is capable of considerable improvement ; the " telling," on the other hand, was excellent."

The ineptitude of the plotter as compared with the other personnel was a feature noticeable in all the Operations Rooms.[1] The Service plotters, who were drawn from the unskilled trade of Aircrafthand General Duties, were liable to reposting to aircrafthand duties at the end of their period of training, which tended to decrease their interest in plotting. The Volunteer Reserve plotters were better, but remote sectors were unable to recruit the full number of one and a half watches of Volunteer Reserve plotters. The Air Officer Commanding-in-Chief, Fighter Command, recommended that the aircrafthands who were trained as plotters should remain on plotting duties for a period of fifteen months, three of which should be occupied by training, so that experience would improve their standard of plotting.

A new R.D.F. feature of the Exercise was the fitting out of several types of bomber aircraft with an automatic identification device, known as I.F.F. (Identification of Friend or Foe).[2] This I.F.F. set, which was carried in the aircraft, contained a receiver sensitive to the C.H. frequencies, which, on the reception of a C.H. pulse, triggered a transmitter which sent back an amplified pulse to the receiver of the C.H. station.[3] Aircraft equipped with I.F.F. were thus recognisable at the C.H. stations by their frequent emission of this amplified pulse. The development of I.F.F. had been continued at Bawdsey concurrently with the other R.D.F. applications, and, by an effort on the part of the Bawdsey Research Staff, some of the bombers were equipped with I.F.F. sets in time for the Exercise. As it had not been possible to carry out Service trials of the equipment, it was not surprising that technical failures occurred on a large scale ; but the Bawdsey staff were confident that these could easily be remedied. The performance of the identification device was sufficiently impressive to cause the Air Officer Commanding-in-Chief, Fighter Command, to forecast its eventual necessity to all friendly aircraft, and the Inter-Service Committee on R.D.F. to estimate a requirement of 24,800 sets for aircraft of the Royal Air Force and the French Air Force.

[1] Air Ministry File S.1659, Encl. 10A, para. 22.
[2] I.F.F. is dealt with fully in Volume V, Part 1.
[3] Air Ministry File S.1659, Encl. 10A, para. 25.

CHAPTER 5

R.D.F. OVERSEAS—PRE-WAR

By the autumn of 1937 proposals were forthcoming that R.D.F. should be included in the defence organisations of British territories overseas. The United Kingdom was to have prior claim on the initial supply of R.D.F. equipment when it came off production and there was little likelihood that R.D.F. apparatus would be available for use overseas for at least a year.[1] Nevertheless, R.D.F. missions visited Overseas Commands ; sites were selected, and plans drawn up.

R.D.F. Missions to Overseas Commands

Despite the many difficulties in the supply of equipment, the Chief of the Air Staff, Air Chief Marshal Sir C. L. N. Newall, ordered that Mr. A. P. Rowe, the Co-ordinating Officer for Air Defence in the Air Ministry Radio Development Department, should proceed to the Mediterranean on 2 October 1937.[2] The purpose of this visit was to inform the Air Officer Commanding, Royal Air Force, Malta, and the Air Officer Commanding, Royal Air Force, Middle East, of the newly developed R.D.F. system for the detection of enemy aircraft by radio. In addition, this officer was to report on how best R.D.F. could be used in Malta and the Middle East and to suggest sites for the erection of the necessary stations.

About the same time, the Deputy Chief of Air Staff thought that the Director of Scientific Research, Mr. H. E. Wimperis, who was visiting Australia, should visit some of the Far Eastern Ports on his return journey, which would be near mid-1938. The places it was suggested he should visit were Singapore, Hong Kong and Aden, the intention being that he would make a report of the problem of erecting and operating R.D.F. stations in the Far East.[3] Mr. Watson Watt prepared a memorandum for the guidance of Mr. Wimperis in his impending consultation with the Air Officer Commanding, Far East, on the methods by which R.D.F. could be employed for the defence of Singapore against air attack, suggesting possible sites for stations. Mr. Wimperis's " Missionary Journey," for so he termed it, was naturally of longer duration than that undertaken by Mr. Rowe, whose report was available by 24 November 1937.[4]

R.D.F. Recommendations for Middle East

Among the places visited by Mr. Rowe were Malta, Alexandria, Cairo, Suez, Ismailia and Port Said. After considering the requirements of both secrecy and mobility he recommended most strongly the use of mobile R.D.F. equipment for both Malta and Egypt.[5] In Malta the erection of the 240-foot Fixed Aerial Array Towers would have provided too conspicuous a target to an enemy from both sea and air. In Egypt, the erection of such fixed installations would necessarily have involved permission from the Egyptian Government—dictated by Egypt's new status under the Anglo-Egyptian Treaty of 1936. This would have placed the secrecy of R.D.F. in jeopardy. It was considered that full use of R.D.F. overseas would only be gained in conjunction with a highly-organised defence system, and the maintenance of secrecy had to be weighed against the comparatively small advantage which would be derived from R.D.F. installations at ports abroad without the support of a fighter organisation. It was

[1] Air Ministry File S.40952, Encl. 54A. [2] *Ibid.*, Encls. 18A and 34B.
[3] *Ibid.*, Encls. 10A and 49A. [4] *Ibid.*, Encl. 42A. [5] *Ibid.*

decided that the only places where benefit would outweigh the risk to the security of the new radio technique were Malta and Egypt, where it could be of considerable use in conjunction with the existing passive defences.

The British Air Attaché, Rome, considered there was an important peacetime application for R.D.F. in Malta, as the island was on a direct line between Sicily and Tripoli, and it was likely that movements of Italian aircraft would be observed, thus supplementing Intelligence sources. This would also provide an excellent means of training personnel in its use. Owing to the isolation of the island, the warning of the civilian population and A.A. defences of an approaching attack, in addition to the above function, led Mr. Rowe to recommend the despatch of a mobile R.D.F. set to Malta as soon as production permitted.

In Egypt, where the political factors were accepted as precluding the erection of permanent stations anywhere but in the Suez Canal Zone, Mr. Rowe suggested that the use of R.D.F. within the near future seemed to be confined to the provision of early warning at strategic points such as Alexandria, and recommended that a mobile set should be sent, complete with power supply, in order to test the most likely sites for the protection in war of Egypt and the Libyan border.

Although attention was focussed chiefly on the claims of Malta and Egypt for R.D.F. cover, every consideration was being given to its extension to all strategic bases abroad. In December 1937 Sir H. Tizard, Scientific Adviser to the Air Council, in consultation with the Senior Air Staff Officer of Air Headquarters, Royal Air Force, Aden, selected a suitable R.D.F. site in Aman Khal Fort, Aden.[1]

Initial Decision on R.D.F. Policy for Malta and the Middle East

After consideration of Mr. A. P. Rowe's report, the Chief of the Air Staff decided on 7 February 1938 that two mobile R.D.F. sets should be prepared, with the object of sending the first available equipment to Malta and the second one to Egypt.[2] The Chief of the Air Staff urged also that the use of R.D.F. should be extended to Singapore without waiting for the report of the Scientific Officer visiting Singapore to be received. The main object in providing these mobile R.D.F. installations was to establish the operational value of R.D.F. at places where prior warning of an enemy attack would be of great value to garrisons where no air defence organisation similar to that for Home defence was in existence.[3] The Air Staff also advised that all relevant matter concerning R.D.F. and its value in defence against air attack should be put before the Joint Oversea and Home Defence Committee of the Committee for Imperial Defence, with the object of determining the scope of this equipment for use at defended ports abroad.

Queries were forwarded to the Bawdsey Research Station, how best the supply of two mobile R.D.F. sets for overseas use could be met. In order to meet this commitment in the shortest possible time it was decided[4] that :—

(a) The R.D.F. installations then operating at Dunkirk in the Home Chain should be modified for overseas mobile use—thus becoming available for shipment by August 1938.

(b) A second set should be obtained by ordering a receiver through trade channels while the transmitter was to be made and general assembly carried out at the Bawdsey Research Station. This equipment was to be available by November 1938.

[1] Air Ministry File S.40952, Encls. 55A and c.
[2] *Ibid.*, Minute 47.
[3] *Ibid.*, Encl. 44A, para. 12.
[4] Air Ministry File S.44211, Encls. 2A and 8A.

(c) A third set should be produced by the modification of R.D.F. equipment which had been housed in Army lorries during earlier tests,[1] and might be retained at Bawdsey for the training of personnel.

A minute was sent by the Director of Operations and Intelligence, Air Ministry, to the Secretary of the Joint Oversea and Home Defence Committee,[2] in which the established uses and possible further applications of R.D.F. were disclosed, its limitations explained, and the approximate costs of such installations estimated. In addition, the details of the number of personnel required to operate the different types of stations, the existing provision for their training, and the difficulties of production of R.D.F. equipment were explained. The then-existing intention of the Air Staff to send mobile R.D.F. equipment to Malta and Egypt for experimental purposes was made known to the Committee. Finally, the minute asked for the consideration of the Joint Oversea and Home Defence Committee which of the defended ports overseas were to be provided with R.D.F. and the priority in which the equipments were to be provided.

This disclosure was discussed at the next meeting in March 1938, and a considerable broadening of the R.D.F. policy resulted. The Admiralty and War Office representatives issued a Joint Memorandum to the Committee in which a priority list for the provision of R.D.F. detection equipment was given.[3] This was :—

(a) Air Defence of Great Britain—Detection of aircraft.
(b) Major ports abroad—Detection of aircraft.
(c) Fleet bases abroad—Detection of ships.
(d) Minor defended ports abroad—Detection of aircraft.
(e) Fleet bases and naval anchorages at home—Detection of ships.
(f) Defended ports at home other than (e) above—Detection of ships.
(g) Defended ports abroad other than Fleet bases—Detection of ships.

Bearing in mind the limitations of production the immediate requirements were :—

(a) Air Defence of Great Britain—Detection of aircraft with large fixed sets.
(b) Seven overseas port areas, Singapore, Hong Kong, Malta, Aden, Gibraltar, Ceylon and Alexandria—Detection of aircraft.

This was indeed a heavy programme when one considers that the Research Station at Bawdsey was struggling to produce three sets of Mobile Equipment.

Mr. Wimperis had by now visited Hong Kong, Singapore, Colombo, Trincomalee and Aden, and had submitted a detailed report on the possibilities of R.D.F. in these localities.[4] This was to prove of the greatest assistance in determining the policy of R.D.F. for the Far East.

Secrecy—its retarding effect on production

It was inevitable that the stringent secrecy restrictions of R.D.F. information would hold back production. This question was raised at the next meeting of the Joint Oversea and Home Defence Committee, the 54th Meeting, on 20 May 1938.[5] At this time only two radio firms were employed on the manufacture of R.D.F. sets and each made roughly one half of the apparatus, thus giving additional secrecy. The Deputy Director of the Scientific Research and Experiment Department of the Admiralty pointed out that a recent

[1] Air Ministry S.44211, Encl. 10A.
[2] Air Ministry File S.40952, Encls. 56A, 57A.
[3] *Ibid.*, Encls. 62A and B.
[4] Air Ministry File S.44211, Encls. 26A and B.
[5] Air Ministry File S.40952, Encl. 64A.

account in an American newspaper, the "Herald Tribune" on 21 March 1938, had given a very accurate and comprehensive description of the R.D.F. idea.[1] The Admiralty thought consideration should be given to the whole question of whether it would not be desirable to publish the fact that Britain had R.D.F. apparatus, describe the general principle on which it worked and even quote ranges, exaggerating them in order to have a deterrent effect on potentially-hostile nations. It was suggested also that in view of American knowledge of R.D.F. and possible development by them unknown to Britain, it might have been worth while to offer to exchange information with the American Government. In this manner too, assistance might also be obtained in the development of the apparatus from American wireless firms who were highly skilled and working in close touch with their Government. Air Chief Marshal Sir Hugh Dowding pointed out that although it was quite impossible to conceal the existence of the R.D.F. stations themselves, it was essential in his view to safeguard the secrecy of the actual apparatus. Broadening the basis of manufacture might compromise secrecy. The Meeting decided :—

(a) To invite the Admiralty and War Office to notify the Air Ministry of a forecast of their essential needs for the immediate future of the various types of R.D.F. sets they would require for all purposes, at home and abroad.

(b) To invite the Air Ministry, on receipt of these forecasts, to consider :—

(i) the extent of the existing industrial capacity available for R.D.F. production ;

(ii) what acceleration could be made in production, if existing secrecy restrictions were to some extent relaxed without compromising the secrecy of the vital elements in the apparatus.

Subsequent correspondence from Air Ministry pointed out the fallacy of the argument that other nations were in possession of information on R.D.F.[2] The "reflection" of radio waves from aircraft was known generally several years before. Other nations had worked on methods involving search by a highly directive transmitting beam ("radio searchlight") and a highly directive receiving beam ("radio telescope"). The term "R.D.F." did not refer to this, the essence of R.D.F. being "radio flood-lighting" of a large volume with a static watch over the whole volume, giving range-finding, azimuth-finding, and height-finding on any one, and all in turn, of many aircraft in this "floodlit" volume, without losing sight of the others. With this clarification of the meaning of R.D.F., the Joint Oversea and Home Defence Committee decided not to press for any public statement of the knowledge, but merely urged a greater production within the limitations of essential secrecy regulations.

The impending use of R.D.F. overseas meant an ever-widening circulation of information on this subject within the Services. With the erection of R.D.F. stations, it was to be no longer possible to maintain secrecy in regard to its existence. Air Ministry therefore notified all Royal Air Force Commands at home and abroad during April 1938, of the fact that in the near future one or more mobile R.D.F. stations were to be despatched to certain Commands overseas.[3] It was laid down that the subject of R.D.F. should never be

[1] Air Ministry File S.40952, Encl. 66B.
[2] *Ibid.*, Encl. 66A.
[3] Air Ministry File S.35982, Encl. 119A.

discussed in public places or with anyone not essentially concerned. It was stressed that the strictest secrecy should be preserved in regard to :—

(*a*) The technical aspect of R.D.F. and the equipment of stations.

(*b*) The tactical employment of R.D.F. in the detection and interception of aircraft.

(*c*) The organisation of R.D.F. in a defence system.

The Munich Crisis and the R.D.F. Overseas Programme

The Munich crisis interfered with the programme for the use of R.D.F. overseas. In connection with the emergency preparations, the three mobile R.D.F. stations prepared at Bawdsey Research Station were used to augment the Home Chain on the East Coast.[1] The provision of R.D.F. cover at Malta and Egypt was therefore once more delayed owing to shortage of equipment. At this stage the mobile R.D.F. sets were not now expected to be manufactured before June 1939, but due to a determined effort to speed up production, the planned mobile equipment for both Malta and Egypt was delivered at an earlier date.[2]

The War Office advised Air Ministry during the first week of April, 1939, of a scheme for Mobile (M.B.) and Fixed (C.H.) R.D.F. stations for gun defended areas overseas.[3] All these stations were to be maintained and manned by Royal Air Force personnel. These requirements were therefore a Royal Air Force responsibility, and were submitted to the Inter-Service Committee on R.D.F. for approval as follows :—

Priority No.	*Destination of Set.*	*M.B. Stations. Category A.*	*M.B. Stations. Category B.*	*C.H. Stations.*	
1	Malta ..	1	—	1	In each case the C.H. Station replaces an M.B. Station.
2	Alexandria ..	1	—	1	
3	Aden	1	—	1	
4	Gibraltar ..	1	—	1	
5	Port Said ..	1	—	1	
6	Suez	1	—	1	
7/8	Singapore ..	1	1	1	
9	Cairo ..	1	—	1	
10/19	Field Force ..	—	10	—	
20	Hong Kong ..	1	—	1	
21	Rangoon ..	1	—	—	
22	Trincomalee	1	—	—	
23	Freetown ..	1	—	—	
24	Haifa ..	1	—	—	
25	Mersa Matruh	—	1	—	
26	Port Sudan ..	—	1	—	
27	Colombo ..	1	—	—	
28	Penang ..	1	—	—	
29	Trinidad ..	1	—	—	
30	Kilindini ..	1	—	—	

Note.—Category A—Unlikely to be moved. Category B—Mobile role.

[1] Air Ministry File S.44501, Encl. 39A and Minute 40. S.40952, Encl. 79B.
[2] Details of this are given later, under the progress made at individual bases.
[3] Air Ministry File S.44211, Encl. 47A and B.

In view of the interruption in the delivery of anti-aircraft equipment to certain ports, the Inter-Service Committee deferred their agreement to R.D.F. equipment at Rangoon, Colombo, Penang, Port Sudan and Kilindini.[1]

At the 68th meeting of the Joint Oversea and Home Defence Committee on 11 July 1939, the position of the production of R.D.F. stations was outlined in some detail by Mr. Watson Watt, as Director of Communications Development at Air Ministry.[2] He explained that there were three stages of provision to be considered. Firstly, the " Advance " provision of sets then in production, of the type which had been sent already to Malta and Egypt. Secondly, there was an " Intermediate Scale," *i.e.*, similar equipment to that already provided, using only one frequency, but with high 240-foot towers. Thirdly, there was the " Final Scale," having permanent buildings and provision for four frequencies. Although production was not due to start until mid-September 1939, it was stressed that the deliveries of radio gear were now likely always to be ahead of the execution of the Works Services required ; nine months was the normal figure for the execution of the works for a station. It was thought that this time could be reduced to six months, but the provision of timber for the 240-foot towers took time. Only Douglas fir from British Columbia or Jarrah wood from Australia were suitable. As a result, the technical equipment, though not produced at the date of this meeting, would always be on sites overseas awaiting the completion of the Works Services. The meeting therefore agreed that the production of R.D.F. sets and their provision for ports abroad had now reached a satisfactory position and that there did not seem to be any means of materially improving the rate of production.

Progress of Installations prior to the Outbreak of War

The only overseas bases actually to receive R.D.F. Mobile Stations before September 1939 were Malta, Egypt and Aden. The progress made in these territories and elsewhere is shown in the following paragraphs.

Malta

One Mobile R.D.F. station arrived in Malta on 21 March 1939.[3] Erection was begun immediately on the site selected at Dingli as a result of Mr. A. P. Rowe's visit late in 1937. The first tests indicated that the site was most satisfactory ; a range of 50 miles all round for aircraft flying at 5,000 feet was obtained. Despite the experimental nature of this equipment, it proved of such a vital and immediately urgent service that it was reorganised on a semi-permanent basis by the provision of a duplicate electric power supply plant and a stone building, pending the arrival of the permanent C.H. equipment.[4] Good progress was made with the planning of the permanent R.D.F. station requirements also nearby at Dingli. Thus, at the outbreak of war, although working on mobile equipment, the island had reasonably satisfactory R.D.F. cover.

Egypt

By 28 April 1939 the mobile R.D.F. station had been unloaded at Alexandria. Extensive tests over a period of one month were carried out on a site at El D'Aba.[5] Owing largely to transmitter defects arising from lack of spare

[1] Air Ministry File S.44211, Encl. 49c.
[2] Air Ministry File S.40952, Encl. 111A.
[3] Air Ministry File S.47124, Encls. 21A, 41A.
[4] *Ibid.*, Encls. 63A, 99A.
[5] Air Ministry File S.47125, Encls. 24A, 31A.

replacement parts, the tests were not completely conclusive. However, it was agreed that the mobile (M.B.) R.D.F. set was not sufficiently efficient in range for the defence of Alexandria. At that time a continuous sea patrol off the Egyptian coast was the intended method for early warning of the approach of hostile aircraft. It was therefore decided that 240-foot permanent aerial masts would have to be erected in the vicinity of Alexandria in order to obtain adequate R.D.F. cover and obviate the necessity of the sea patrol.[1] This raised two points of difficulty, namely :—

(*a*) Such masts could not be made in Egypt. Only Australia or Canada could supply the timber required.

(*b*) Delicate negotiations were necessary with the Egyptian Government to obtain its approval for the erection of permanent stations at Alexandria and Wadi Natrun without infringing essential conditions of secrecy.[2] The matter was handled successfully by the British Ambassador, Sir Miles Wedderburn Lampson, enabling plans to be made for the erection of permanent stations to cover the Alexandria–Cairo–Suez–Port Said Area.

With the outbreak of war then, only one mobile R.D.F. station was functioning in Egypt and this was not to the satisfaction of the Command.

Aden

Although this important base had been visited as early as December 1937, by Sir H. Tizard, Scientific Adviser to the Air Council, for consultation with the local Command authority on a suitable R.D.F. site, it was not until July 1939 that the final site was selected when Mr. Atherton, a technical officer of Bawdsey Research Station, went to Aden by air to choose a site for a mobile R.D.F. station.[3] The personnel and equipment were then en route by sea. On the arrival of this equipment on 12 August 1939, the erection of the station was begun. The outbreak of war occurred just as the aerial towers were being erected.

Singapore

During the visit of Mr. H. E. Wimperis to this important base, a meeting took place at the Headquarters, Far East, in April 1939, at which the Officers Commanding the three Services were present. Mr. Wimperis attended this meeting and advised the Officers Commanding on the progress of R.D.F., its advantages and limitations.[4] The Air Officer Commanding, Air Vice Marshal A. W. Tedder, pressed for the erection of a single R.D.F. station near Singapore as soon as possible, to determine any local peculiarities which might exist there as being common to this area. A site was selected at Bikut Pengerang, some 15 miles to the east of the city.[5] Because of lack of equipment, no R.D.F. cover could be provided for Singapore by the time war broke out.

Hong Kong, Colombo, Trincomalee and Gibraltar

R.D.F. sites had been selected for these ports but it was impossible to supply the necessary equipment. No R.D.F. cover was available therefore when war broke out.[6]

[1] Air Ministry File S.47125, Encl. 32A.
[2] Air Ministry File S.5734, Encl. 4C and D, and Air Ministry File S.47125, Encl. 53A.
[3] Air Ministry File S.1056, Encls. 11A, 13A, 21A and 29A.
[4] Air Ministry File S.44211, Encl. 26D, para. 6. [5] *Ibid.*, Encl. 26B. [6] *Ibid.*, Encl. 26A.

India

Towards the end of January 1939, the Air Officer Commanding, Royal Air Force, India, Sir Philip Joubert, requested the loan of a mobile R.D.F. station for making experiments as to the feasibility of employing R.D.F. on the Frontier and in defence of the four main ports.[1] The Chief of the Air Staff, Air Chief Marshal Sir C. L. N. Newall, had to inform the Air Officer Commanding, India, that no such set would be available for at least a year, as the whole output of this equipment had been allocated to higher priorities. Despite further correspondence on this subject in the form of urgent requests from the Air Officer Commanding, India, war broke out without any provision of equipment.

Disclosure of R.D.F. Information to the Dominions

Resulting from a discussion between Mr. Watson Watt and the Deputy Chief of Air Staff, it was suggested that the Dominions should be informed in general terms of R.D.F., a brief paragraph to be inserted in the draft of the Chief of the Air Staff's quarterly Dominions Liaison Letter dated September 1938. However, on the instructions of the Chief of the Air Staff, it was deleted so that they could be advised in a separate communication, the circulation of which could be reduced to an absolute minimum.[2] The War Office and Admiralty were opposed to disclosure at this time and the matter was raised to Cabinet level, as it was considered necessary to advise the Dominion Governments concerning a defence weapon which was already in operation in this country. Approval was given for the Secretary of State for Air to convene a meeting for the purpose of expounding the position as regards R.D.F. to representatives of Canada, Australia, New Zealand, and South Africa, and of concerting arrangements for communicating this information to the Governments of the Dominions in question. The Secretary of State accordingly arranged to see the respective High Commissioners on 24 February 1939, when a statement, which had been prepared in conjunction with the Admiralty and War Office, was made. This statement which described the use of R.D.F. as a weapon and the progress made is considered worthy of inclusion in this narrative and is as follows :—

"STATEMENT ON R.D.F. FOR THE DOMINIONS REPRESENTATIVES

It has been found that wireless waves are reflected by aircraft in flight, and a technique of causing and measuring such echoes has been developed, by means of which it is possible to determine the range, bearing and height of distant aircraft. The system, which is called R.D.F., enables a single ground station to determine the position and height of single aircraft and formations in a wide and deep forward sector, and also to give some information about the size of each formation. The system is particularly suitable for dealing with high-flying raids, and it enables continuous watch to be maintained over the sector under observation.

The information provided by an R.D.F. screen enables the Fighter organisation to effect interception further forward than is possible with ground observation by observers or by means of acoustical apparatus ; and in fact it has been shown as a result of tactical exercises that it is possible by means of R.D.F. to intercept the enemy on the coast or, in favourable circumstances, out to sea.

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[1] Air Ministry File S.1315, Encl. 1A and D, 2D.
[2] Air Ministry File S.40952, Minutes 73–75, Encl. 73A, and S.50307, Encl. 12A.

The range at which aircraft can be detected by this means depends on the height at which they are flying. The higher they fly the greater the range of detection. Aircraft flying at 10,000 feet can be detected at a distance of approximately 100 miles to within an order of accuracy of 1 mile. At 1,000 feet on the other hand the effective range of the apparatus falls to the order of 20–30 miles. The height of the aircraft can be measured to within 500 feet, and as has already been stated, an estimate can be made of the number of aircraft in a formation.

A chain of R.D.F. stations is in the process of construction along the whole of the east coast from Portsmouth to the Tay. Of the 18 stations required to cover this front, 12 are now working and the remainder will be working by the early summer of this year.

There is a number of other applications of the R.D.F. principle which are now under development. A type of R.D.F. apparatus has now been developed which can be carried in reconnaissance aircraft for the detection of surface ships. Its effective range exceeds that of normal visibility in British waters and is independent of visibility conditions either by day or night. This equipment will greatly increase the effectiveness of reconnaissance over the sea, by increasing the area searched by each aircraft in a sweep, by increasing the closeness with which the area can be searched, and by extending to conditions of darkness and of restricted visibility the times at which sweeps can be carried out.

Another form of R.D.F. equipment is being developed for use in ships. Its function is to give long range warning of the approach of aircraft to enable a naval unit either at sea or in harbour to be ready for air attack.

There are other types of R.D.F. apparatus under trials for application to the ranging of anti-aircraft guns and the direction of searchlights on an enemy aircraft. Finally a type of apparatus is being developed for coast defence purposes, by means of which the presence of ships can be detected, and their position determined with sufficient accuracy for barrage fire.

The Dominions Governments will no doubt desire to study the R.D.F. technique, in order that advantage may be taken of our knowledge and experience in connection with the development of their own future plans for defence. It is suggested that, as and when the plans of the Dominions Governments reach the point when a study of the technical and operational aspects of R.D.F. appears desirable, facilities to examine the working of the system in this country will be given to an Air Staff and a technical representative from the Dominions Governments.

We do not think that other countries have got as far as we have in this technique. The need for the greatest secrecy in regard to the information that I have just given you is therefore obvious, and I would accordingly ask you to treat it as most secret."

At the meeting it was agreed that the High Commissioners should cable their Governments to the effect that they had been informed of a security device connected with air defence which was of sufficient importance to warrant the despatch of a physicist to this country at an early date to study it. The following physicists were given facilities for studying the scientific development of R.D.F. at Bawdsey :—

Canadian Government ..	Dr. J. T. Henderson.
Australian Government ..	Dr. D. F. Martyn (Senior Radio Physicist of the Commonwealth Radio Research Board).
New Zealand Government ..	Ernest Marsden, C.B.E. (Secretary of the D.S.I.R., New Zealand).
South African Government ..	Major-General Hoare (S.A. Ministry of Defence) and Major Wilmott.

On the departure of these representatives to advise their respective Government authorities, copies of drawings, descriptive data and blue prints were supplied.[1]

Australia

In the case of the Australian Commonwealth certain types of equipment were requested, to ensure that in the event of an emergency arising which would interfere with deliveries from Great Britain, full information would be available to admit of local production.[2] It was proposed that the Commonwealth should proceed with the production of ship detection sets for use in aircraft and in coastal gun batteries in any event, but at our request they agreed not to undertake production until we were satisfied this would not involve grave loss of secrecy. In June 1939, a request was made by the Right Honourable S. M. Bruce for a ship set (Type 79Z) for installation in H.M.A.S. "Perth," to which the Admiralty had to reply that these sets were still in the experimental stage, and blue prints and specifications would not be available before the autumn, while the actual equipment could not be supplied for over a year.[3]

The forecast of the initial requirements in R.D.F. equipment for Australia based on data discussed at the 3rd meeting of the Inter-Service R.D.F. Committee on 13 June 1939, was :—[4]

C.O. Stations	5
Mobile Stations	1
Gun Laying Sets	6
Coast Defence Sets	6
A.S.V. Sets	6
I.F.F. Set	1
S.A. equipment	1

The production of this equipment was to be reserved to Great Britain; Australia was to provide the aerials and Works Services for the erection of these stations.

New Zealand

As a result of demands from New Zealand after the disclosure of R.D.F. information to its representative in London, the approved initial requirements of R.D.F. sets were :—[5]

C.O. Stations	2
Mobile Stations	3

[1] Air Ministry File S.50307, Encl. 46A. [2] *Ibid.*, Encl. 43A. [3] *Ibid.*, Encls. 53A and c.
[4] Air Ministry File S.41234, Encls. 111A and 121A. [5] *Ibid.*

Canada

The Canadian Government requested blue-prints of the R.D.F. equipment used in C.H. stations and the Air Ministry approved of their issue.[1] During April 1939, the Canadian Government raised the point of the manufacture of R.D.F. equipment in the Dominion. Up to the outbreak of war, however, no production had been commenced there, as production of this equipment had been reserved to Great Britain only, in the interests of secrecy. It was agreed in June 1939, by the Inter-Services R.D.F. Committee that the following equipment should be supplied initially to Canada :—[2]

C.O. Stations	2
M.B. Stations	6
A.S.V. Sets	15

South Africa

Following the disclosure of R.D.F. information to the Dominions, a preliminary discussion was held on 23 March 1939, between the Deputy Chief of the Air Staff and Major General Hoare, of the South African Ministry of Defence, on the subject of the possible requirements of R.D.F. in the Union.[3] The increased importance of Cape Town in the chain of Imperial Communications in the event of the Mediterranean being closed was visualised. R.D.F. aids to the Cape Town defences required were :—

(*a*) Three Coastal Defence (C.D.) sets for ship detection from the shore ;

(*b*) Sets for ship detection from aircraft ;

(*c*) One mobile M.B. set primarily for co-operation with fighter aircraft, but also to be used in a subsidiary role in connection with air raid warning systems. The Inter-Service R.D.F. Committee proposed that the initial scale of issue of R.D.F. equipment to South Africa would be :—[4]

C.O. Stations	2
M.B. Stations	5
Coast Defence Sets	5
A.S.V. Sets	15

Eire

No information on the development of R.D.F. was given to the Government of Eire. During April 1939, a request was received from the High Commissioner for Eire for Irish officers at present in this country to visit a Fighter Group Operations Room, for the purpose of studying our methods of fighter control.[5] Permission was given but instructions were issued on the advice of the Committee for Imperial Defence that every precaution was to be taken to avoid the R.D.F. topic, although its existence was not to be denied. If it became necessary, the Irish officers were to be told that Standing Orders were that the subject could not be discussed, and any request for information would have to be put through higher authority. If this situation arose, the Air Ministry were informed that a decision would have to come from the Cabinet.

[1] Air Ministry File S.50307, Encls. 46A and B, Minute 32.
[2] Air Ministry File S.41234, Encls. 111A and 121A.
[3] Air Ministry File S.4052, Encl. 95A.
[4] Air Ministry File S.41234, Encl. 111A.
[5] Air Ministry File S.50307, Encl. 36A.

R.D.F. Overseas prior to the War, summarised

It is clear from the foregoing that, though plans were in an advanced stage to exploit fully the advantages to be gained from the use of R.D.F. at defended ports overseas, Malta alone had satisfactory R.D.F. cover when the war commenced. Despite careful planning, the delay in establishing R.D.F. stations overseas during 1938 and the first half of 1939 was due to the shortage of radio equipment for the purpose and to the extension of the Home Chain of R.D.F. stations immediately after the Munich Crisis of September 1938. The subsequent time-lag between planning and actual installation overseas was caused largely by the period required for the Works Services in erecting such stations—approximately six to nine months, varying with local conditions.

Proposed Provision of R.D.F. to France

On 16 March 1939, at a meeting of the Committee of Imperial Defence, it was pointed out that on balance this country stood to gain more than we had to lose by taking the French completely into our confidence with regard not only to our plans but also in the matter of such secret equipment as R.D.F. on the grounds that, as the French were to be our allies, it was to our advantage that they should be as effective as possible. Accordingly, the Committee decided that the forthcoming Staff Conversations should include disclosure to the French of most secret equipment, such as R.D.F., subject to the stipulation that such of our secret equipment as the French desired to adopt must be manufactured in this country.[1] . The Committee appreciated that this conclusion was somewhat in conflict with the Cabinet decision " That the Chiefs of Staff should have authority to impart to the French such information as to our plans and resources (*other than certain technical details*) as is necessary to ensure co-ordination in peace and efficient co-operation in war."[2] The Minister for Co-ordination of Defence was invited to bring the conclusion regarding R.D.F. of the Committee for Imperial Defence to the notice of the Cabinet for their approval, which was given on 30 March 1939.[3]

Disclosure of R.D.F. information to the French Air Staff was made in Air Staff discussions under this Cabinet sanction. Initial scales of demand of R.D.F. equipment by France were formulated in conference between the French Mission, the Director of Contracts, and the Director of Communications Development at Air Ministry.[4] The initial requirements for the purpose of the French Defence Service were :—

C.O. Stations .. 14 Transmitters,
14 Receivers,
and accessories for 7 stations.

The French to provide their own Works Services and aerials.

M.B. Stations .. 47 complete stations for the French Army.

In addition a forecast was made of requirements for 128 Gun Laying sets for the French Army, and 300 I.F.F. sets for the French Air Force.

Arrangements were made for six French officers, two from each of the three Services, to be attached to the Bawdsey Research Station for an eight weeks'

[1] C.I.D. 1546B, para. 3, sub-para. (*d*). [2] Cabinet 6 (39). [3] Cabinet 16 (39).
[4] Air Ministry File S.41234, Encls. 111A, 114A and 121A.

course on R.D.F. which commenced on 5 June 1939.[1] During this course these officers not only were instructed in the operation of a R.D.F. station but also saw the collation of information and its use in Operations Room technique.

The Inter-Service R.D.F. Committee considered the initial demands for R.D.F. equipment by the French among the tentative estimate of the total requirements of the full R.D.F. programme for both home and overseas.[2] These demands were accepted at the meeting on 11 July 1939, it being agreed that the production of R.D.F. equipment was to be reserved to Great Britain. By September 1939 none of the equipment had been supplied. The outbreak of war occurred with the French in possession of R.D.F. information, other than production details, and six of their officers trained in its use.

[1] Air Ministry File S.1336, Encl. 1A. [2] Air Ministry File S.41234, Encl. 121A.

CHAPTER 6

THE R.D.F. HOME CHAIN FROM THE OUTBREAK OF WAR TO THE FALL OF FRANCE (SEPTEMBER 1939–JUNE 1940)

The development of the Early Warning Chain of R.D.F. stations up to the outbreak of war has already been described. The Chain had never been tested fully, only the stations between Bawdsey and Dover having taken part in full-scale exercises. Technical imperfections were known to exist ; production difficulties of equipment for the further expansion of the R.D.F. cover were great, and the personnel required to man the stations and filter rooms were not available in the strength or experience required. The Home Chain had been placed on a 24-hour watch-keeping basis at Easter 1939, and on 24 August 1939 the code-word " Afidock " was passed to Headquarters, Fighter Command, bringing it to a war basis.[1]

Very severe air attacks were expected in the early stages of the war but, in fact, these did not occur. At the outset then, the chief value of the home R.D.F. screen was that it rendered standing patrols by fighter aircraft unnecessary, thus conserving the small number of aircraft available to the Royal Air Force at the opening of hostilities. Without the R.D.F. chain of stations our aircraft would have had to maintain patrols, involving wastage of aircraft, the fatigue of pilots, and the heavy consumption of petrol before the enemy started to attack this country in strength. The R.D.F. Home Chain thus enabled aircraft and crews to be conserved for the Battle of Britain.

R.D.F. Chain at the Outbreak of War

When war was declared on 3 September 1939, the R.D.F. Chain in operation connected to the Stanmore Filter Room consisted of eighteen C.H. stations.[2] The two remaining C.H. Stations of the twenty-station Chain, at Netherbutton and School Hill in the north, were operating locally but were not reporting to the Central Filter Room.

None of these stations was a " Final " installation. In the rapid expansion of the R.D.F. Chain before the war along the south and east coasts, it had been necessary to establish improvised apparatus in temporary accommodation in order to provide the maximum of R.D.F. cover in the minimum of time.[3] Most of the stations were poorly phased and calibrated, although Great Bromley, with experimental facilities for avoiding D/F and height errors, was a notable exception. The measurement of the height of an aircraft was limited to below about 7° angle of elevation from the station. In addition the height estimation was unreliable at low angles of elevation.[4] Thus the plotting of very high or very low-flying aircraft was beyond the scope of the available equipment. Back-to-front sense discrimination was provided, that is, the operator could tell whether an aircraft was in front or behind the R.D.F. station when the aircraft was within a reasonable angle of the line-of-shoot. There was, however, no side reflector, so that ambiguities could occur when the aircraft was at right angles to the line-of-shoot. Since no high-powered vertical gap fillers were in use, it was possible to miss high-flying aircraft altogether.

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[1] Headquarters, Fighter Command O.R.B., Aug. 1939 (Signals Branch).
[2] These locations are indicated on Map No. 1.
[3] Sir Henry Tizard's R.D.F. Committee, Interim Report, 28 Nov. 1939—A.H.B./IIE/5, Encl. 3A, para. 4 and para. 7 (*b*).
[4] O.R.S. Memorandum on *Chain Performance in Peace and War*.

During the first days of the war there were many mis-identifications of tracks due to our own aircraft lacking I.F.F. (Identification—Friend and Foe) equipment and also to the inability of damaged bombers returning to this country to fly in the pre-arranged lanes for making a landfall. On 6 September 1939, the plotting of twenty unidentified aircraft tracks in the Thames Estuary by R.D.F. and the Observer Corps caused intercepting fighter aircraft to attack each other.[1] Three friendly aircraft were shot down, one by anti-aircraft fire, although no hostile aircraft were present. In addition, many false alarms were given by sirens to the civilian population.

To effect an improvement in the use of R.D.F. in air defence, two measures were applied as vigorously as circumstances would permit. The first was to effect a more accurate interpretation of the available R.D.F. information and an improvement in the efficiency of the control of our fighter aircraft. The second was to increase the technical efficiency of the existing R.D.F. cover and to increase the number of R.D.F. stations. Neither of these measures was capable of instant implementation. The success of the former would depend largely on the skill, speed, and experience of all ground personnel, from the Controller, down through the Filter Room staff, to the R.D.F. operator. Such experience could only be gained as operations continued and there was the additional difficulty of the shortage of trained R.D.F. personnel. The efficiency of the Filter Room was increased on 7 September 1939 by the appointment there of Controllers, these officers becoming known as Filter Officers on 20 September.[2] On this date also, the first W.A.A.F. watch were on duty at the Stanmore Filter Room.

During the first month of the war, the Air Officer Commanding-in-Chief, Fighter Command, laid down that experiments should proceed at Bawdsey in the first instance, to achieve the interception of enemy aircraft by a Controller operating the R.D.F. receiver himself, with no plotting of tracks, the intercepting fighter aircraft being directed to the enemy bomber by radio telephone by the same Controller.[3] He would bring the two aircraft together, both in range and bearing, on the R.D.F. cathode ray tube itself. In practice, it was found that the drawbacks of this method were that the Controller had too much to do. While solving the interception problems in his head he had to operate the R.D.F. receiver and also exercise control of the fighter aircraft by radio telephone. Moreover during such interception control, the normal raid reporting work of the station ceased. From these experiments, Squadron Leader Tester, who had acted as the Controller, developed a simple plotting R.D.F. method giving successful interception with a minimum of interference to the normal R.D.F. plotting.

The identification of friendly aircraft in use at the beginning of the war had proved unsatisfactory.[4] The provision of I.F.F. equipment for all aircraft was regarded by the Air Officer Commanding-in-Chief, Fighter Command, as of the utmost importance.[5] Accordingly, during September, 500 I.F.F. sets were being made by hand and an order was to be placed for 10,000 sets, the design for which was almost completed. These sets were to operate on the frequencies of the Home Chain Stations, but later sets would respond to the G.L. (Gun Laying) R.D.F. equipment as well.

[1] Headquarters, No. 11 (Fighter) Group, O.R.B., Sept. 1939.
[2] Headquarters, Fighter Command Signals Branch, O.R.B., Sept. 1939.
[3] Air Ministry File S.43174, Encl. 61c, para. 2.
[4] The full story of identification systems is given in Volume V, Part I.
[5] A.H.B./IIE/68—Inter-Service Committee on R.D.F., Minutes of 4th Meeting, para. 39.

By 19 September two of the Home Chain stations were working on full power, thus extending their range. Plans were being implemented to enable the remainder of the Chain to be similarly equipped at the rate of about one per week.[1] The Main Chain was also being extended by three further stations with a possible fourth near Kinnaird Head to cover the approach to Scapa Flow.

The most immediate requirement was cover against low-flying aircraft, based largely on the need for giving protection to coastal convoy shipping. Trials had been carried out at Bawdsey using the type C.D. (Coastal Defence) R.D.F. set, its effectiveness being well demonstrated in the detection of both surface ships and low-flying aircraft.[2] The Inter-Service Committee on R.D.F. agreed to the Air Ministry requirement of twenty-four of these sets which were to be installed at C.H. stations, though all the sets were not to be available before the end of the year. A priority list of the areas of installation of these equipments was as follows :—

Thames Estuary.	Firth of Forth.
Flamborough Head to the Wash.	Tyne and Tees Area.
Southwold to Clacton.	Scapa Flow.

These sets became known as C.H.L. sets (Chain Home Low Cover) and Pye Radio, Ltd., were given the order to manufacture them immediately.[3] The full operational capabilities of this equipment were not known until after the sets were manufactured. If its sole function was to be the detection of low-flying raiders then it was essential to site the station at the coast, because any inland site could be expected to produce standing echoes on the cathode ray tube which would impede the operator considerably. Over the sea, the range of a C.H.L. station was thirty-five miles but the effect of land reflections on this range was quite unknown.[4] Arrangements were therefore made to carry out practical tests as soon as the equipment became available.

Radio stations near the coast with such prominent features as 240-foot aerial towers obviously presented an attractive target to the enemy—the more so if his Intelligence discovered the purpose of such stations. A conference was held at Air Ministry on 24 September 1939 to consider the means to be adopted for the protection of R.D.F. stations against air attack, as the stations in their " Advance " and " Intermediate " stages depended on light A.A. defences—also in short supply.[5] The conclusions of this conference were considered by the Chief of the Air Staff and he directed that :—

(*a*) Stand-by mobile R.D.F. stations were to be provided, kept in reserve and so disposed that any one might be quickly moved and installed to provide cover where necessary to replace any Chain station which had been put out of action. A reconnaissance for suitable sites for these mobile stations was to be carried out.

(*b*) The " Intermediate " sets, when replaced by Main Chain " Final " sets at each R.D.F. station, were to be used for stand-by purposes and housed in buildings which were to be sunk to ground level at least 300 yards from the main buildings and were to be turfed over for concealment.

Steps were at once taken to implement these directions but owing to the general shortage of equipment, progress was slow.

[1] A.H.B./IIE/68—Inter-Service Committee on R.D.F., Minutes of 4th Meeting, para. 34.
[2] *Ibid.*, para. 38.
[3] Air Ministry File S.55153, Encls. 27A and 43A.
[4] *Ibid.*, Encl. 45B.
[5] Air Ministry File S.47412, Encl. 168A and B.

By the middle of October 1939, a very serious position had been reached with regard to the paucity of certain essential R.D.F. spares.[1] Radio valves, condensers, and resistors for the Chain stations were in extremely short supply, and as a result the Chain operated on a hand-to-mouth basis. These deficiencies of radio parts, which should have been in stock at each C.H. station, resulted in the unserviceability of Chain stations for unnecessarily long periods. Certainly, had the Chain suffered the effects of hostile action, its maintenance might well have become an impossible problem due to the lack of replacement parts. Air Chief Marshal Sir Hugh Dowding, Air Officer Commanding-in-Chief, Fighter Command, made urgent representations to the Under Secretary of State for Air stressing that the Air Defence of Great Britain was in jeopardy owing to the lack of spares for the maintenance of the Home Chain of R.D.F. stations.[2]

A meeting was held at Air Ministry on 19 October, under the chairmanship of Air Vice Marshal R. H. Peck, Director-General of Operations, to discuss the measures necessary to produce an immediate improvement in the reliability of the R.D.F. Chain.[3] Decisions were taken on the broad methods of accelerating the production of R.D.F. spares. Because of this shortage the Air Officer Commanding-in-Chief, Fighter Command, had taken every opportunity provided by weather conditions and other operational considerations, to rest the apparatus in Chain stations. He was also informed by this meeting that the life of the radio valves used could be prolonged considerably by a reduction of 15 per cent. in the power output. This would have produced only a small falling-off in the range of detection. The performance of the R.D.F. Chain was causing some concern. Perhaps too much was expected of it in its existing form. The Director of Signals, Air Ministry, had put forward a scheme for a Communications Command which would unify control and ultimately provide a solution for the various maintenance problems which were the principal difficulty as far as the C.H. stations were concerned.[4] This matter was being considered by the Assistant Chief of Air Staff.

Although the Air Officer Commanding-in-Chief, Fighter Command, was reassured that efforts were now being made for the adequate provision of spares, he was not satisfied with the existing machinery of the Chain organisation.[5] In his reply to Air Ministry on 20 October 1939, he pointed out several factors which did not tend towards efficiency in the working of the R.D.F. Chain. Fighter Command was responsible for operating the R.D.F. stations but the organisation for maintaining them was not under its direct control, but under the Research Branch which had been responsible for designing and erecting them. A few of the many R.D.F. failures which had occurred were due to faulty operation and lack of detailed technical knowledge on the part of the operators, although the general standard in the circumstances was highly creditable. These personnel had been intensively trained for a short period and then sent out to distant and often inaccessible localities where adequate supervision was difficult, yet the responsibility for the efficiency of these personnel devolved upon Fighter Command. The actual Chain equipment in use had not been properly calibrated and modernised, largely due to the insistence of the Air Staff that a 24-hour watch should be maintained for the six months prior to the outbreak of war. Air Chief Marshal Sir Hugh Dowding therefore suggested that a small committee should be formed, under the

[1] Air Ministry File S.51906, Encl. 38A.
[2] Air Ministry File S.2286, Encl. 1B.
[3] Air Ministry File S.51905, Encl. 49B.
[4] *Ibid.*
[5] Air Ministry File S.2286, Encl. 2C.

chairmanship of Sir Henry Tizard, to investigate the working of the R.D.F. system and to make recommendations for its improvement. The Air Staff immediately approved this suggestion and the committee was set up, composed as follows :—[1]

Sir Henry Tizard, K.C.B., A.F.C. (Chairman).
Air Marshal Sir Philip Joubert, K.C.B., C.M.G., D.S.O.
Director of Communications Development.
Director of Signals.
A representative of Director-General of Operations.
A representative of Fighter Command.

Sir Henry Tizard's R.D.F. Committee

There was no delay in dealing with this important question of the improvement of the working of the R.D.F. Chain. The Committee held its first meeting within two days of being set up, and produced a detailed interim report by 28 November 1939.[2] After examining the existing technical imperfections of the C.H. stations then working, the Committee pointed out that it was a surprising fact that the stations were working so well. Although in the remainder of their report they dealt with defects rather than the successes of the Chain, the Committee stressed that it was not with the object of criticising the remarkable technical achievements and progress made in the past but rather to help in bringing about improvements in the future.

The Committee then commented on certain defects in the operation of the chain which were of special importance to Fighter Command. Coverage was insufficient owing to lack of stations, lack of special equipment such as the new C.H.L. sets for the detection of low flying aircraft, and lack of sufficient power supply. All these defects would disappear when the new equipment, already planned and in production, was available. There was also a loss of coverage which resulted in the observed track of an aircraft disappearing. The underlying cause of this defect, the gaps between the lobes of R.D.F. transmission, was well understood and could be removed by improved installations, though some cases might need investigation by scientific personnel. There were serious errors in bearing and height, but the notable exception of the station at Great Bromley showed that this specially designed equipment, combined with careful calibration, could eliminate such faults. There was a real inability to track with certainty aircraft flying above 25,000 feet at moderate ranges which called for special experiments. On some occasions operators had reported aircraft which were behind them as if they were in front, with consequent confusion. Instrumental defects had contributed to this confusion in the early days of the war, but there had been no defects since and only mistakes by operators could account for such ambiguities, provided that the aircraft were well within range.

The Committee decided that everything which could have been done to remove criticisms of the C.H. Chain in operation was now being done under the present system, but expressed their conviction that the operation of the Chain would not be satisfactory until the system of responsibility was changed. They recognised the important contribution to the defence of this country which the Chain had made whilst most of the responsibility had rested on the Director of Communications Development, but feared that unless the system of responsibility were changed, the position in another year's time would be

[1] Air Ministry File S.2286, Encl. 8A. [2] *Ibid.*, Encl. 9A and B, and A.H.B./IIE/5, Encl. 3A.

unsatisfactory. It was therefore strongly recommended in the report that there was much to be said for the formation of a separate Command solely for the purpose of organising the various means of tracking aircraft. The Director of Communications Development was to have experimental control of a complete operational R.D.F. Unit in at least one station in the Chain in order that new experimental equipment could be installed or altered. Such a station would be primarily a research unit and secondarily an operational unit reporting its observations into the main R.D.F. system.

In submitting this report to the Chief of the Air Staff, Sir Henry Tizard pointed out the unanimity of the views of the members of his Committee, except on the question of when such a change of responsibility should occur.[1] The Chief of the Air Staff did not concur with these views but upheld the view of the Air Officer Commanding-in-Chief, Fighter Command, that he should control and administer the R.D.F. Chain, leaving the training of R.D.F. personnel to some outside organisation like a Signals Group.[2]

First C.H.L. Emergency Programme

While the question of improvement in the complete organisation of the R.D.F. Chain was under consideration, concrete progress was being made in establishing increased coverage. As an interim measure only, on 12 October 1939, a trawler screen, which might be described as fulfilling the role of a ship-borne Observer Corps, was temporarily posted in the North Sea to augment R.D.F. information.[3] This screen reported by wireless telegraphy to the R.D.F. stations at Stoke Holy Cross and Stenigot. Within the limitations of aural and visual observation, its timely reporting was quite a success. An increase in the range of observation of this trawler screen by fitting R.D.F. sets on the ships themselves was not possible as no R.D.F. set suitable for trawlers had yet been designed ; no ship smaller than a cruiser could carry and use such a set as the C.D. equipment.[4]

By November, seven C.H. stations of the 20-Station Chain were working on full power. This gave an estimated increase of coverage per station of 30 per cent.[5] The C.H.L. programme was being pushed ahead with all speed, and on 1 November the first of these stations came on the air at Fifeness, to be followed shortly by Foreness and Walton (7 December), Easington (19 December), Shotton (24 December), Happisburgh (25 December), Dunwich (1 January 1940), Cockburnspath (26 January), and Dover (11 February).[6] The completion of this first "crash" C.H.L. programme was an achievement, as the extremely severe winter weather severely retarded progress. These C.H.L. sites were in exposed coastal positions and much of the equipment had to be man-handled on to the sites and dragged into position.[7]

This programme for the establishment of C.H.L. stations was begun originally because of the inability of the C.H. stations to "see" low-flying aircraft, and was intended to give protection to our coastal shipping convoys against direct enemy air attack. It was, however, carried out with emergency speed because

[1] Air Ministry File S.2286, Encl. 13A. [2] Air Ministry File S.4038, Minute 3.
[3] Headquarters, Fighter Command Signals Branch, O.R.B., Oct. 1939.
[4] A.H.B./IIE/68—Inter-Service Committee on R.D.F., 5th Meeting, Minutes, page 5.
[5] A.H.B./IIE/5, Encl. 3A, para. 5. Sir Henry Tizard's R.D.F. Committee, Interim Report.
[6] Headquarters, Fighter Command Signals Branch, O.R.B., November/December 1939 and January/February 1940. These locations are shown on Map No. 1.
[7] Air Ministry File S.45174, Part 1, Encl. 78B.

of the enemy's use of mine-laying aircraft.[1] The original intention of establishing one C.H.L. set on each C.H. station had to be left in abeyance, the sites of the C.H.L. stations being selected to combat to the maximum effect the new enemy tactics. Owing to the delay in the production of C.H.L. sets, G.M. sets (Modified Gun-Laying sets) were used in lieu, though the term C.H.L. station was used because of the role they were employed in. Each C.H.L. station was placed under the administrative control of the nearest Royal Air Force station as its parent unit and linked by telephone lines to the Filter Room.

Second C.H.L. Emergency Programme

Owing to the increasing tempo of enemy attacks upon our shipping a second "crash" programme of C.H.L. station installation was started in January 1940 to give additional East Coast R.D.F. cover.[2] C.H.L. stations were installed at Ingoldmells, Flamborough Head, Bamburgh, Cresswell (near Morpeth), Doonies Hill (near Aberdeen), Rosehearty (Kinnairds Head) and St. Cyrus (near Montrose). All these seven stations were working before the end of February 1940.

The strain of these two "crash" C.H.L. programmes, one immediately following the other, was felt most of all by No. 2 Installation Unit, Kidbrooke, and it became necessary to call on personnel normally employed on C.H. fitting work.[3] Mr. Watson Watt expressed concern that C.H. installation in a dependable form was being delayed by the installation work on C.H.L. stations. He stressed the point that the C.H. Chain had given valuable military results—not so far demonstrated by the C.H.L. installations. Above all, a good C.H. system, which had not yet been developed fully, was essential to the successful functioning of the C.H.L. system, the latter being designed to supplement the work of the C.H. Chain. As a result of these observations, Air Ministry agreed that No. 2 Installation Unit would revert to devoting itself wholly to C.H. station work.

Plans for the extension of the R.D.F. Chain to the South-West and West Coasts

Enemy aircraft were now making deeper penetrations ranging over the western districts of England and the Irish Sea—though not in strength. The Home Chain covering the East and South coasts only was obviously insufficiently extensive to provide the necessary early warning system. This was so urgent a requirement that on the 2 January 1940, the Prime Minister accorded the highest order of priority to the provision of R.D.F., the Air Staff having pointed out the gaps of greatest importance in our defences.[4] These were :—

Area.	*Deficiency.*
Weymouth—Torquay.	High and low cover.
Bristol Channel.	High and low cover.
Liverpool.	Low cover.
Clyde.	High and low cover.
Cromarty Firth.	Low cover.
Central Scotland.	High cover.
Shetlands (No Observer Corps).	High cover.
Devonport.	Low cover.
Scillies.	High cover.

[1] Air Ministry File S.1686, Minute 49, Encls. 12A and 28A.
[2] Air Ministry File S.3142, Minute 17, and Encl. 107A.
[3] Air Ministry File S.44282, Part 1, Encl. 287A.
[4] W.P.G./40/327 and Air Ministry File S.1686, Encl. 113A.

The Chief of the Air Staff approved a list of additional C.H. and C.H.L. stations as the minimum requirement to fill these gaps :—

C.H. Stations.	*C.H.L. Stations.*
Portland Bill.	Rye.
Lyme Regis.	Poling.
Bristol Channel (2).	Ventnor.
Clyde.	Pevensey.
Ben Nevis.	Scapa.
Shetlands (2).	Cromarty.
Orkneys.	Clyde.
Scillies.	Liverpool.
	Bristol Channel (2).
	Devonport.
	Weymouth.
	Scillies (anti-submarine).

The Director of Communications Development submitted this list to the Air Ministry Research Establishment during January 1940, in order that the general siting problems arising from these proposed extensions could be faced.[1] A special survey party was formed in order to speed up the work, having representatives from the Director of Signals, Fighter Command, the Director of Communications Development Department, and the Directorate of Works, together with a G.P.O. representative—thus establishing the correct degree of liaison between the interested Departments, a feature which had been lacking in previous sitings.[2] For such an urgent and large programme of extensions to the Home Chain in the South and West it was obvious that only the minimum requirements could be supplied. At a meeting at Air Ministry on 27 February 1940, it was decided that for these new stations the scale of provision would be two frequencies (instead of the normal provision of four frequency working) with unprotected buildings wholly above ground.[3]

Formation of No. 60 Signals (R.D.F.) Group

The Tizard Committee had pointed out the inadequacy of the organisation for maintaining and controlling the existing Home Chain at the end of November 1939, and suggested the formation of a separate Command for this purpose.[4] In December, it was decided to form an R.D.F. Group with the least possible delay. Establishments were developed and some fifty technicians from the Director of Communications Development's Department were transferred to this new Group under Mr. H. Dewhurst, who had been running the Maintenance Establishment previously. On 23 February 1940, the new formation, known as No. 60 Group, was formed at Leighton Buzzard under Air Commodore A. L. Gregory, taking over from No. 2 Installation Unit the responsibility for all Chain maintenance and modifications.[5] There were twenty-two C.H. stations and fifteen C.H.L. stations in operation at this time. Most of the C.H. stations were incomplete and plotting instructions were vague. They were working on " Intermediate " equipment with optical convertors for height estimations, though one electrical calculator for this purpose planned

[1] Air Ministry File S.44282, Part 1, Encl. 254A.
[2] A.H.B./IIE/64—*The Organisation of No. 60 Group*—Encl. 10A.
[3] Air Ministry File S.44282, Part 1, Encl. 317A.
[4] A.H.B./IIE/64, Encl. 1A, and Air Ministry File C.S.2824, Encl. 8A.
[5] Headquarters, No. 60 Group, O.R.B., February 1940.

in February 1939, was ready for testing at the C.H. station, Poling.[1] There was a large legacy of outstanding work to be hurried on. For aerial installation and phasing alone there were eighty receiving towers and one hundred and sixty C.H. aerial arrays awaiting immediate attention. A vast programme of work therefore confronted the new Group.

The responsibilities of No. 60 Group were laid down as :—[2]

(*a*) Planning and developing the operation of the R.D.F. Home Chain to meet operational requirements.

(*b*) Continuously examining and, where necessary, improving the operational, technical and administrative efficiency of the Home Chain, including the well-being of personnel.

(*c*) Examining new developments in R.D.F. with a view to their adoption and efficient tactical application.

(*d*) Liaison through Air Ministry with the Admiralty, War Office and R.A.F. Commands abroad on R.D.F. questions.

(*e*) Supervision of installation, calibration, equipment, maintenance and manning of the Home Chain.

(*f*) Assisting Air Force Units by technical liaison in the maintenance of all aircraft equipment.

(*g*) Ensuring the training needs of R.D.F. operating personnel were adequately and promptly represented to the Air Ministry.

(*h*) Collating and disseminating technical information concerning the operation and maintenance of R.D.F. apparatus.

Because of the numerous interests involved the chain of responsibility was necessarily complicated. Briefly, technical policy was to be controlled by the Air Ministry, but operational control in all its aspects remained under the Air Officer Commanding-in-Chief, Fighter Command. It was estimated that it would be April 1940 before No. 60 Group would be able to assume full duties, because the change-over of control had to be sufficiently smooth not to interfere with the efficient working of the Chain.[3]

The inception of the new Group was not without its troubles. Prior to its formation, personnel of the Air Ministry Research Establishment, No. 2 Installation Unit, Signals Staff from Headquarters, Fighter Command and representatives of the Director of Communications Development had all had access to R.D.F. stations and all had some responsibilities in connection with the drive for greater efficiency of the Chain. As No. 60 Group took over its responsibilities, the former state of affairs tended also to continue due to the zeal of the individuals concerned.[4] Thus the No. 60 Group new organisation received some interference from the formerly directly-interested parties. A firm attitude was taken by the Director of Signals, Air Ministry, who sent a signal to all Commands and Departments concerned stressing that entry to all R.D.F. stations was forbidden unless the purpose and details of such visits had been approved by the Air Officer Commanding No. 60 Group.

By 1940 the maintenance of the Chain was found to be beyond the capacity of the four Maintenance Sections, owing to the large increase in the numbers

[1] O.R.S./4/10/2, *Electrical Calculators and Optical Converters*, and Air Ministry File C.S.2824, Encl. 8A.

[2] Air Ministry File C.S.2824, Encl. 13A.

[3] A.H.B./IIE/66, R.D.F. Organisation—General, Encl. 2A.

[4] *Ibid.*, Encl. 6A and 11A.

of R.D.F. stations. The total of stations operating and proposed by that time amounted to thirty-three C.H. and forty C.H.L. This situation was to be aggravated by the planned duplication of frequency channels and the resulting increased maintenance work. In addition, the handling and issue of spares and technical knowledge had become centralised at the former Base Maintenance Headquarters, Leighton Buzzard.[1] Both for security against enemy action and for facility in distribution, a much more effective decentralisation of equipment was necessary. The Air Officer Commanding, No. 60 Group therefore recommended on 3 April 1940, that the various R.D.F. stations should be grouped into Radio Wings, each Wing being administered and technically maintained by a Unit which would replace the inadequate Maintenance Sections. These Units, named Radio Maintenance Units and later Radio Servicing Wings, eight in number, were formed on 10 July 1940.[2]

Calibration of Chain Stations

By January 1940, a few R.D.F. stations had been re-calibrated and re-phased for both height and direction finding, but technical experts were doubtful that these calibrations would remain true for any worthwhile period.[3] The variation was due mainly to the fact that end-sealing insulators were not fitted to the receiving transmission lines. A further complication was that there were no recognised methods for phasing the receiver aerial arrays and no two scientists used the same method for aerial phasing. When a method was eventually prescribed it involved frequency-measuring instruments of a standard accuracy. Such instruments for the frequency range of the C.H. stations were then non-existent. Thus the R.D.F. information passed to Filter Officers was in many cases based on information which was probably inaccurate.[4] On 25 March No. 60 Group became responsible for the calibration of all Chain Stations. To face this enormous task there was one detached flight of aircraft from the Special Duty Flight, St. Athan, which combined height and performance calibration duties with interception training for Ground Controllers at Bawdsey. Three autogyros and two pilots, together with two balloon ships and balloons, completed the resources available. To illustrate the inadequacy of the equipment, during the first seventeen days of December 1939, ninety-nine flights were ordered but only thirty were attempted. Only twelve were fully successful and six partially so. From the outbreak of war until the end of March 1940, balloons had calibrated only two stations for direction finding, whilst autogyros, since the middle of January, had calibrated five stations.

It was obvious to the Air Officer Commanding, No. 60 Group, that the calibration of stations was actually falling behind the rate at which new stations could be established, even though Fighter Command had rendered assistance by providing aircraft for performance testing. He therefore recommended that each new Radio Wing should have personnel, technical equipment, and aircraft established on it for adequate calibration. Experimental work continued to attempt to discover simpler methods of calibration of R.D.F. stations.[5] An establishment was agreed in August 1940, but owing to the shortage of aircraft it was not until after the Battle of Britain that the requirement could be satisfied. The whole Chain was then re-calibrated in some 12 weeks.

[1] A.H.B./IIE/66, para. 5. [2] Headquarters, No. 60 Group, O.R.B., July 1940.
[3] Air Ministry File S.42719, Encl. 22A.
[4] A.H.B./IIE/66, Encl. 3A, para. 6, and Air Ministry File S.42719, Encl. 22A.
[5] *Ibid.*, Encl. 3A, para. 11, and Air Ministry File S.42719, Encls. 36Y and 51B.

R.D.F. Personnel

From the beginning of the war there had been a shortage in R.D.F. personnel, both for operating and for maintaining the Chain stations. At the end of November 1939, experimental crews of W.A.A.F. operators were sent to the C.H. stations at Poling and Dover. It was considered by January 1940 that they were quite capable of carrying out the work under Royal Air Force N.C.O.s, so further W.A.A.F. courses were arranged at Bawdsey and W.A.A.F. operators were subsequently generally introduced in Chain stations.[1] The training of R.D.F. mechanics, also originally at Bawdsey, were transferred to No. 2 Radio School, Yatesbury, on 18 January 1940.

Not only had the manning of the Home Chain to be considered. By April 1940, the overseas demands for R.D.F. personnel had risen and some sixteen Transportable or Mobile R.D.F. Units had been formed and manned for use overseas.[2] As a result, No. 60 Group and No. 2 Installation Unit were generally below their establishment in personnel and faced with an overload of work in their increasing responsibilities.

[1] Air Ministry File S.3523, Encl. 8A, Air Ministry File S.47112, Encl. 25A, and No. 2 Radio School, O.R.B., January 1940.

[2] A.H.B./IIE/66, Encl. 10A.

CHAPTER 7

R.D.F. IN THE FRENCH CAMPAIGN, 1939–1940

Prior to the outbreak of war the French technique for warning against hostile aircraft was based principally upon their " *Système de Guet,*" which was similar to the British Observer Corps organisation. This was supported, rather weakly, by a radio system of aircraft detection which the French had developed independently, called " *Détection Electromagnétique* " (*D.E.M.*).[1] This consisted of a chain of alternate radio transmitters and receivers, producing a rough plan position of aircraft by observations on the beating produced between the direct wave from the transmitter to the receiver and the " reflected " wave from the aircraft. This system was inferior to R.D.F., having an approximate range of thirty miles and not giving satisfactory results on more than one aircraft.

The limitations of the French system of raid-reporting were realised by both the French and British Governments. After the disclosure of British R.D.F. information to the French Mission under General Gamelin during April 1939, plans were drawn up for the initial requirements in R.D.F. equipment for the French. It was inevitable that they would require a further considerable supply of apparatus in the near future but the whole of this R.D.F. equipment was to be manufactured in Great Britain for secrecy reasons.[2] No R.D.F. stations had been supplied to France by the time the war commenced, though some French Officer technicians had been trained in our R.D.F. technique.

R.D.F. for the British Field Force—Initial Requirements

Preparations for war included plans for the despatching of three mobile (M.B.1) R.D.F. sets to France with the British Field Force. It was thought that the eventual requirements might be four of the new type mobile (M.B.2) stations.[3] However, the development of the M.B.2 sets proceeded very slowly and the M.B.1 transmitter in production gave disappointing performances : thus when the Chief of the Air Staff called for three complete M.B. stations at the outbreak of war, the only set available was one M.B.1 which was being used for research and development purposes at Bawdsey. The set was re-erected, tested and despatched to France. It was erected on a site between Calais and Gravelines and commenced operating on 24 September, the Unit having previously reported to Headquarters, No. 60 Wing, Allonville.[4]

In order to meet the requirement for two more mobile R.D.F. stations, the Bawdsey Research Station was instructed to develop a mobile set from whatever apparatus was available, giving the best possible range on aircraft and all-round searching. The Army type Gun Laying (G.L.2) set was being produced in quantity, so this was adapted for M.B. purposes.[5] The resulting sets, given the nomenclature " G.M.", were supplied to two other R.D.F. units which proceeded to France during the first week of October 1939.

[1] Air Ministry File S.2538, Encl. 6A.
[2] Air Ministry File S.1306, Encl. 6B, Air Ministry File S.41234, Encls. 111A and 102A, and C.I.D. 1546B, para. 3.
[3] Air Ministry File S.45967, Encl. 121A.
[4] Air Ministry File S.1796, Encl. 2A (Folder No. 1).
[5] Air Ministry File S.45967, Encls. 117A and B, Encl. 140B, and Air Ministry File S.179 Encl. 7A (Folder No. 2), and Encl. 23A (Folder No. 3).

Initial Deployment of R.D.F. Stations in France

As no experience had yet been gained with a mobile R.D.F. set deployed inland to operate over an area of military activity, it was quite possible that the apparatus might not prove satisfactory. The primary source of raid reporting was therefore a Wireless Intelligence Screen (W.I.S.) in the British zone in Northern France, consisting of Army Observer Posts linked directly to Wing Headquarters by wireless telegraphy.[1] A simple code, based on the British Observer Corps system, was used for rapid reporting of observed aircraft. By this means the Wing Headquarters had a modicum of intelligence on which to direct fighter aircraft.

On 23 September 1939, at a meeting at Headquarters, Air Component of the British Field Force, in connection with the re-deployment of the R.A.F. component in France, it was agreed that one mobile R.D.F. station should be established in the Calais area to provide early warning of low-flying aircraft approaching down the Belgian coast or attacking from seaward across the southernmost portion of the Belgian coast.[2] The second mobile R.D.F. set was to extend the R.D.F. screen south-eastwards to cover the Field Force and to provide the maximum possible warning of the approach of enemy aircraft over Belgium. The locations of the third and subsequent sets were to be related to a comprehensive plan aimed at providing continuous R.D.F. cover for the area occupied by British Forces and the likely avenues of approach thereto. According to these decisions the three available mobile R.D.F. stations were sited near Calais, at Escobecques, near Lille and at Bar-le-Duc respectively.[3] The siting of the R.D.F. stations conformed to the plans already in force for the Wireless Intelligence Screen, and thus the set at Bar-le-Duc was for the protection of the Advanced Striking Force and the other two sets were for the British Expeditionary Force and the Air Component.

The French Grand Plan—R.D.F. Proposals for France

A French chain of sixteen Chain Overseas Stations (C.O.) extending from Abbeville to the Mediterranean was envisaged as the "Grand Plan" for providing R.D.F. cover for the whole of France's threatened frontiers.[4] This was discussed at a conference held in the Air Ministry between representatives of the French Government and the Director of Communications Development on 3 October 1939, after British participation in the selection of suitable sites. The chain was to be in three sections, reporting to three filter centres, and to be built firstly between Abbeville and Auxerre, for the defence of Paris; secondly, on the North-Eastern Frontier; and thirdly, covering the Mediterranean coast and Rhone Valley. A fourth chain had been suggested to give warning of the approach of aircraft to the Franco-Italian frontier.[5] It was considered, however, that the R.D.F. system would be impracticable there on account of "permanent echoes" from the mountains. It was therefore suggested that an improved version of the French *D.E.M.* system would be all that was necessary.

Deliveries of C.O. station equipment from Britain were not scheduled to begin until April 1940. It was therefore agreed to supply some mobile G.M. stations to operate on or near the sites selected for the French Chain stations.

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[1] Air Ministry File S.1306, Encls. 16A and 17A.
[2] *Ibid.*, Encl. 29A.
[3] A.H.B./IIH/147—D.H.O. Folder, "*R.D.F. in France*," Encl. 6A.
[4] Air Ministry File S.45967, Encl. 189A, para. 23.
[5] A.H.B./IIH/147, Encl. 2A.

In addition, fifty Gun Laying (G.L.2) sets were to be supplied in January 1940, and twenty I.F.F. sets (modified to a special frequency range covering the band 30–37·5 megacycles per second) by 1 November 1939.

A training programme for French personnel was to be put into effect through the provision by the British of three M.B.1 installations complete with aerial towers. Three Scientific Officers were to be lent to the French to set up the equipment and instruct their training staff.[1] Actually two such officers went to France for this purpose, Mr. J. F. Atherton and Mr. E. N. Shaw of the Directorate of Communications Development, Air Ministry. The French Army and Air Force training was to take place at Montpellier and the Naval training at Cannes.

There was a meeting in October between the Chief of the Air Staff and the Air Officer Commanding-in-Chief, Bomber Command.[2] The latter expressed the opinion that R.D.F. in France might be found to be not worth while. It was therefore arranged that a mission, headed by Air Marshal Sir Philip Joubert[3] and including Mr. Watson Watt, would go to France and, after examining the situation, make the necessary recommendations. The first meeting in France with the French representatives, General d'Harcourt, *Inspecteur et Commandant Superieur de l'Aviation de Chasse*, and Commandant Cazenave, of the *Ministère de l'Air*, took place on 2 November 1939 at the residence of Air Marshal A. S. Barratt commanding No. 1 British Air Mission. The discussion was limited to the method of deploying British R.D.F. mobile sets to cover the British Forces and the approaches to Paris, though there was a tendency for the French representatives to turn the conversations towards the French R.D.F. Chain.[4] Sites were agreed for the first eight mobile R.D.F. sets required to provide cover for the British Forces in the field. These would require two filter rooms to be established, the French being responsible for the provision of the necessary landlines. The information from these filter rooms would be utilised by British Fighter stations in France and French *Groupes de Chasse* for active air defence, and by the French *Système de Guet* for inclusion in the air raid warning system.

A further joint conference which was necessary to consider the permanent R.D.F. facilities of the French Grand Plan was held on 7 November, under the chairmanship of General de Division Jullien, *Inspecteur Général Technique des Transmissions de la Défense Nationale*. Some thirty-three officers attended, being representatives of the Navy, Army and Air Forces of both France and Britain.[5] The meeting accepted proposed sites for mobile (G.M.) R.D.F. sets at Bolougne, Lille (two posts), Arras, Cambrai, Avesnes, Sedan, Verdun (Damvilliers), Mont Haut (east of Rheims), Bar-le-Duc and Troyes. Each site had been considered in regard to its suitability from the point of view of landline communications, and whether these would link up with the French Grand Plan stations.

The two filter centres were to be sited at Arras and Rheims and would be called respectively Nos. 1 and 2 Filter Centres. Again, the availability of French landlines was a deciding factor in the choice of these locations. Each

[1] Air Ministry File S.45967, Encl. 189A, paras. 11 and 17.
[2] Air Ministry File S.2538, Encl. 3A.
[3] Air Marshal Sir Philip Joubert de la Ferté was attached to the Department of the Chief of Air Staff for R.D.F. duties on 28 October 1939. He became Assistant Chief of Air Staff (Radio), and held the appointment until June 1941.
[4] A.H.B./IIH/147, Encl. 1A.
[5] Air Ministry File S.B. 65067, Part I, Encl. 94c.

R.D.F. station was to be linked to its nearest filter-room (plotters' circuits) and to its adjacent R.D.F. station (reserve circuits).[1] Nos. 1 and 2 Filter Centres were to be connected to each other and to No. 1 Filter Room, Headquarters Fighter Command, Stanmore, for control circuits. Thus R.D.F. information from the stations on the South coast of England would be available in France.

The conference then proceeded with a consideration of the French Grand Plan, Mr. Watson Watt outlining this in some detail. The meeting accepted his proposition unanimously for the suggested locations and uses of the proposed C.O. chains.[2] The French Naval representatives were very keen to have their own coastal chain of stations as soon as possible. The question of frequencies in use for R.D.F. caused considerable discussion. The British mobile R.D.F. sets in France were operating on 40 and 56·6 megacycles per second, thus interfering with French Fighter aircraft radio telephony and preventing five or six squadrons from operating fully. The French Air Ministry representative, feeling rather strongly on this point, demanded on what French authority these R.D.F. sets were operating in France. It was explained that the lack of such authority was on the grounds of secrecy and that the use of these frequencies by the French Air Force had not been realised by the Royal Air Force. It was subsequently agreed to change the working frequencies of R.D.F. to avoid this clash.

During the visit of the R.D.F. Mission to France the working of the three R.D.F. stations already deployed in the field was examined. The set sited north of Calais in a marsh, was working. The set at Escobecques near Lille was not yet functioning. It was erected but the transmitter was unserviceable. The third set, at Bar-le-Duc, was unserviceable due to a burnt-out resistance. It is not surprising that the Mission decided that no information worth recording had so far been obtained.[3] This was traceable to the complete lack of organisation both on technical, administrative and tactical grounds. No specific unit or formation appeared to be in control of the three R.D.F. stations. The personnel manning them seemed to be living under difficult circumstances. The officers in charge, "young scientists," appeared to be lacking in knowledge of Service methods and procedure. It was evident that some administrative and signals supervision of these and future stations would have to be introduced in France.

Proposal for the Formation of an R.D.F. Wing in France

On his return with the R.D.F. Mission from France in November, Air Marshal Sir P. B. Joubert, in a Minute to the Chief of the Air Staff, pointed out the disorganisation and consequent inefficiency in the situation, and requested authority to set up a separate administrative and operational Headquarters for the purpose of running the developing R.D.F. mobile chain and the Wireless Intelligence Service.[4] The Air Marshal stressed that there was no question of withdrawing any of the existing R.D.F. sets, as suggested by the Air Officer Commanding-in-Chief, Bomber Command, but rather that a vigorous effort should be made to produce the additional sets required for the chain and to organise a proper system of filtering and reporting.

[1] A.H.B./IIH/147, Encl. 6A. [2] *Ibid.*, Encl. 2A.
[3] Air Ministry File S.2538, Encl. 7A, and A.H.B./IIH/147, Encl. 6A.
[4] *Ibid.*, Minute 1, para. 6.

The fourth and fifth mobile (G.M.) R.D.F. stations arrived in France by the middle of November 1939. The fourth unit was sent to a site at Desvres, where considerable difficulty was experienced in setting up owing to the extremely boggy state of the ground.[1] The fifth R.D.F. unit was sited at Bendrel (Vimy Ridge) but this location was unsuitable by virtue of the large number of permanent echoes which cluttered up the cathode ray tube, caused by steel hoisting gear, large slag heaps, factory chimneys, and other industrial equipment in the immediate vicinity of the site. Meanwhile, considerable liaison work was carried out with the French authorities. Plans for the filter centres at Arras and Rheims and the associated line equipment were agreed between General Jullien, General Technical Signals Inspector of the French National Defence and Air Marshal Sir Philip Joubert.[2] In addition, the extension of the chain of G.M. stations was constantly under review and plans were drawn up for the subsequent deployment of G.M. sets Nos. 6 to 13 inclusive near sites intended later for permanent C.O. stations in the French Grand Plan.[3]

Formation of No. 5 Signals Wing in France

As a result of the recommendations made after the return of the R.D.F. Mission from France, it was decided by the end of November that in order to co-ordinate the arrangements in France for the siting, technical maintenance, control, and administration of all R.D.F. units in France and their associated filter centres, an organisation designated an Air Information Wing should be set up.[4] This was to work under the technical direction of the Assistant Chief of Air Staff (Radio) at Air Ministry but under the operational and administrative control of the British Air Forces in France. Suitable accommodation was obtained at Allonville for the use of the Air Intelligence Centre of the new Wing. This was to be used as a temporary filter centre until the construction of the Arras Filter Centre was complete. The composition of this new unit was met in December 1939 by the establishment of No. 5 Signals Wing, the original title "Air Information Wing" being abandoned.[5] It was decided that the Headquarters would undertake the technical control and specialised maintenance of all R.D.F. stations, filter centres, and Wireless Interception Screens in France; also the Continental Air Movement Liaison Unit and the D/F Identification Service. It was intended that the then-existing British Air Raid Reporting Liaison Sections with the French for the purpose of liaison between Fighter Command and the French aircraft detection system was also to be absorbed by the new Wing, but this was never put into effect.

The move of No. 5 Signals Wing to France began on 30 December 1939 and was completed by 20 January 1940. No. 1 Filter Centre was also formed and moved to France during this period under the control of No. 5 Signals Wing.[6] Both the Wing and Filter Centre were located initially at Allonville, the construction of the Arras Filter Centre and its associated landlines being far from complete. There had been a considerable shortage of spares for G.M. sets in France, so that unserviceability of R.D.F. units in the field had been prolonged by lack of replacement components.[7] The setting-up of the new Wing with a Section to deal with the maintenance of G.M. equipment enabled Air

[1] Air Ministry File S.1796, Encl. 59A. [2] Air Ministry File S.2538, Encls. 21A, B and C.
[3] Air Ministry File S.1796, Encl. 61A.
[4] Air Ministry File S.2538, Encls. 17A and 20A, and Air Ministry File S.1796, Encl. 56A.
[5] A.H.B./IIH/147, Encl. 12A. [6] Air Ministry File S.58993, Encls. 21B and C.
[7] Air Ministry File S.2937, Encls. 4A and B.

Ministry to instruct the manufacturers to deliver spares to Hendon airfield direct for despatch by air to the Signals Wing H.Q. It was arranged that the Equipment Section of the Wing Headquarters should include one month's holding of stores.

Progress of R.D.F. Cover in France under No. 5 Signals Wing

In the despatch of the Air Officer Commanding-in-Chief, British Air Forces in France, Air Marshal Sir A. S. Barratt, it is stated that " active steps " were commenced in January 1940 to build up an R.D.F. Screen on which a more up-to-date Allied Air Defence organisation could be based.[1] The raid reporting screen was intended to extend eventually from Dunkirk to Strasbourg, though in February only five R.D.F. stations were working, located at Desvres (Boulogne), Calais, Escobecques (near Lille), Ficheu (Arras) and Bar-le-Duc. Information from these R.D.F. stations was being filtered at No. 1 Filter Centre, Allonville. Plans were in hand for the deployment of fifteen mobile (G.M.) R.D.F. stations, which were to be increased later to forty. The sixth R.D.F. unit arrived in France early in February and was held at No. 5 Signals Wing Headquarters until hard-standings were ready at Damvillers, and until a replacement receiver trailer arrived from England.[2] The building programme, in the hands of the French, on the Arras and Reims Filter Centres and the work on R.D.F. station sites proceeded slowly. It was considerably delayed by adverse weather conditions during the winter, so progress in extending the mobile chain of R.D.F. cover was slow. No. 6 R.D.F. set was eventually sited at Le Cateau by the end of March.

For all the R.D.F. stations then operating, No. 5 Signals Wing was having difficulty in obtaining aircraft for calibration flights. These were essential if accuracy was to be obtained. The urgent need for aircraft to be allotted to the Wing specifically for performance-testing of individual stations and to obtain scientific data was stressed vigorously in correspondence to Air Ministry.[3]

The work falling on No. 5 Signals Wing Headquarters was quite heavy during March 1940. To enable the Wing to concentrate on the efficiency of the R.D.F. screen, the Wireless Intelligence Screen was transferred from the Wing, and its control divided between Headquarters, Advanced Air Striking Force and the Royal Air Force Component of the Field Force.[4] Planning was going ahead to meet the extension of the R.D.F. mobile system in the event of the Allied Armies moving forward into Belgium. As far as the actual development of the Mobile R.D.F. Chain was concerned, No. 5 Signals Wing was frustrated by circumstances beyond its control. In April 1940 the Wing was informed verbally by Air Ministry that delivery of further G.M. sets to France had been held up, the sets which should have been sent out for erection at the remaining G.M. sites having been side-tracked for other purposes.

It was not until 21 April 1940 that preparations were complete at the Arras Filter Centre, and No. 1 Filter Centre then moved to Arras from its temporary location in the Chateau d'Allonville.[5] The new centre at Arras was

[1] A.H.B./IIH2/414, *Despatch on British Air Forces in France, 15 January–18 June 1940*, Air Marshal A. S. Barratt, page 6, and A.H.B./IIH2/178, " No. 5 Signals Wing—Administration," Encl. 10A.

[2] A.H.B./IIH2/190, Headquarters, British Air Forces in France File, Encls. 1, 4A, and 24A.

[3] A.H.B./IIH2/178, Encl. 28A.

[4] *Ibid.*, Encls. 12A, 33A, and Air Ministry File S.2538, Encls. 26A and B.

[5] *Ibid.*, Encl. 49A.

underground, built beneath an old ammunition store under the city walls, and the galleries ran into the side of a hill. It was of permanent design ; on the lower floor was the ground floor of the filter room with its plotters' table in the centre. The telephone system was housed in three small rooms—the main frame room, the telephone exchange and the accumulator room. The offices of the Commanding Officer, Adjutant, Scientific Analysis Officer and the Senior French Liaison Officer were also on the ground floor. Above this was a gallery surrounding the filter room, from which the Filter Officers controlled operations and the French Air Movements Liaison Section worked. The French Grid was used on the plotting table, so all plots passed from Stanmore had to be converted from their English Grid references. Immediately after the move of No. 1 Signals Centre to Arras, some twenty French officers and one hundred and fifty French airmen were attached for liaison and training in the British technique of running a filter room.

Dissatisfaction of French with lack of progress

On 12 March 1940 a further R.D.F. conference was held in Paris between the French and British representatives.[1] The French were keen to have some of their technicians and operators appointed immediately to R.D.F. stations then working. The lack of the large permanent C.O. stations was also causing them anxiety, particularly as no firm date for their supply was forthcoming from the British. General D'Harcourt stated that the programme of supply of R.D.F. equipment was considerably behind that promised him by Air Marshal Sir Philip Joubert during his visit to France in March.[2] Despite the British inability to meet the supply of R.D.F. sets for agreed installations in France about this time, the French increased their demands for equipment by requesting R.D.F. cover for the South of France to protect that coast in the event of hostilities with Italy.[3] The Air Ministry had no alternative but to inform the French that no further R.D.F. stations were available.[4]

In view of the French dissatisfaction with the failure of the British to supply them with R.D.F. sets, British co-operation was offered to undertake R.D.F. production in France. General Jullien, however, indicated that there was no such urgency. Mr. Watson Watt had been one of the British representatives at the R.D.F. conference in Paris in March 1940, and largely by chance he discovered that the French had taken independent action in the production of R.D.F. equipment. Mr. Watson Watt visited the laboratories of Messrs. L.M.T. (*Le Materiel Telephonique*), a subsidiary of the International Telephone and Telegraph Company corresponding to the British Standard Telephones and Cables. Here he had a discussion with the Director, Mr. E. M. Deloraine, and was informed that after these laboratories had been requisitioned on 2 September 1939, he had been ordered to construct and instal near Toulon for the French Navy an R.D.F. station working on a frequency of 48 megacycles per second. Mr. Watson Watt declared this was a breach of the conditions imposed by His Majesty's Government when R.D.F. was disclosed to the French, whereby all manufacture of R.D.F. was reserved to Britain.[5] It was later learnt that another firm, *Messrs. SADIR* (*Société Anonyme des Industries Radioélectriques*), had been given the task of producing a 150-megacycles frequency Coastal Defence set. Two other firms, *Messrs. Radio Industrie*, and *Messrs. Société des Compteurs*

[1] A.H.B./IIH2/177, " R.D.F. Organisation in France," Encl. 1A.
[2] Air Ministry File S.4746, Encl. 8A.
[3] *Ibid.*, Encl. 8A, and S.2538, Encls. 28A and B.
[4] Air Ministry File S.4746, Encl. 3A.
[5] C.I.D. 1546B, para. 3.

had also been brought into the field. A London associate of the latter firm, *Société de Compteurs*, later innocently offered to help Britain by supplying details of a system of aircraft location ! Dissatisfaction was expressed with the method, though not the aim, of the French Government in bringing French contractors into the secret of R.D.F. without prior consultation or even informing the British authorities of the breach of agreement.[1] General Jullien offered no explanation of the French failure to consult British authorities but at once countered with some heat, saying that he regretted he had not taken this action earlier, the British having failed to deliver a single one of the sets promised. He admitted the high value of the British original disclosure of R.D.F. information to the French, but was obviously expressing the general dissatisfaction of the French with British supply measures.

Of the independent action by the French in disclosing R.D.F. secrets to their own firms, Mr. Watson Watt effectively commented—" Having thus torpedoed secrecy on performance specification, our Allied Navy closed the water-tight doors between their chosen contractors and ourselves, maintaining the completest secrecy about how we had overcome difficulties which they left their new agents to face *de novo*. It would be difficult to find a more effective way of jettisoning all the good and retaining all the bad in secrecy." General Jullien agreed that complete interchange of technical information was essential, but did not propose a mechanism to bring this about.

Dissatisfaction with the mobile R.D.F. screen in operation

Early in May 1940, the Air Officer Commanding-in-Chief, British Air Forces in France, communicated with Air Ministry on the failure of the mobile R.D.F. screen in practice, and the slow progress being made in the extension of the chain beyond its very limited existing area.[2] He instanced a case where a German aircraft flew in from the coast at 20,000 feet, passed right over the R.D.F. area as far as Arras and Lille (where there were R.D.F. stations) and was not plotted by any of the R.D.F. stations in France, although plots of this aircraft were being received from the Filter Room at Stanmore in England from Home Chain stations on the south coast of England. Air Marshal A. S. Barratt stated that despite efforts under No. 5 Signals Wing to build up an effective R.D.F. screen between January and May 1940, the results from this screen could only be described as disappointing.[3]

The No. 1 Filter Centre itself was working, but on quite inadequate material. The information passed from this centre was regarded by both General D'Harcourt and Group Captain Fullard, Officer Commanding No. 14 Group, as of "nuisance value only."[4] The continuous parts of tracks given were too brief, there was a failure to obtain a good range on high-flying aircraft, and there was no identification of aircraft, friend from foe. These were not faults of the centre but of the raw material of the information supplied to the centre by individual R.D.F. stations. Group Captain Fullard complained with justification of complacency about these stations, and General Jullien's criticism that the Filter Centre at Arras—" a very expensive centre "—was useless, was true to the extent that no useful information was coming from it at the time.

[1] Air Ministry File S.4746, Encl. 3A.
[2] A.H.B./IIH2/189. Headquarters, British Air Forces in France File, " R.D.F. Policy," Encl. 8A.
[3] A.H.B./IIH2/414, para. 22.
[4] Air Ministry File S.4746, Encl. 13A, para. 11.

A picture of the actual performance of each R.D.F. station in the field during the major battles of France is given in an interim report on 17 May 1940, from Mr. Watson Watt to the Director of Signals, Air Ministry, after his visit to France on 13 May.[1] The details were as follows :—

No. 1 *Station* ..	(M.B.) Calais. Good set on a poor site. Plots of aircraft at 60 kilometres distance agreed within 5 kilometres with plots taken by Dover C.H. station on the same aircraft.
No. 2 *Station* ..	(G.M.) Le Treport. Set partly modified for one-way looking to the North. Very few plots, performance appeared poor.
No. 3 *Station* ..	(G.M.) Escobecques (near Lille). Poor set on a poor site, plots local activity only but had no operational value whatsoever.
No. 4 *Station* ..	(G.M.) Descres (near Boulogne). Bad set on an excellent site. No plots seen at all during the inspection.
No. 5 *Station* ..	(G.M.) Ficheux (near Arras). A good site. The set was partly modified for one-way looking but was clearly ill-adjusted when seen. It was unserviceable due to electrical power failure of the Lister diesel engine on the night that Arras town was bombed.
No. 6 *Station* ..	(G.M.) Le Cateau. This was the best G.M. set in use, most completely modified for one-way looking but the coverage diagram was unduly narrow. Plots of over 100 kilometres were obtained along the line of shoot to the North but the ranges were very short at 60° of this line.

Summarising, Mr. Watson Watt observed that none of these stations was of substantial operational use in its existing state, numbers 3, 4 and 5 having no operational value whatsoever. He recommended their withdrawal to No. 5 Signals Wing for modification.

The Reims Filter Centre was rapidly nearing completion in May 1940, work having been pushed ahead rapidly after the set-backs due to the severity of the previous winter.[2] The termination of the landline facilities and the internal wiring of filter room equipment was being done by British G.P.O. engineers. Filter room personnel intended for No. 2 Filter Centre had been trained at No. 5 Signals Wing Headquarters and were ready for drafting in to Reims when required. The French stopped work on the No. 2 Filter Centre early in the opening stages of the Battle of France. As a result, the six British G.P.O. engineers and all their terminating equipment were withdrawn on 15 May to No. 5 Signals Wing H.Q. The buildings were subsequently blown up. As no additional R.D.F. stations had been erected in the Reims area, the delay in the preparing No. 2 Filter Centre had had no material effect on the Mobile R.D.F. Chain. All R.D.F. units in the field had concise instructions from No. 5 Signals Wing Headquarters on the emergency action to be taken in event of having to abandon the station due to enemy action.[3] No. 6 Mobile R.D.F. Station was urgently recalled from Le Cateau, being in the path of the German advance, and the unit was evacuated to No. 5 Signals Wing Headquarters.

[1] Air Ministry File S.4746, Encl. 13A, para. 1. [2] A.H.B./IIH2/178, Encl. 53A.
[3] A.H.B./IIH2/177, Encl. 10B, and No. 5 Signals Wing, O.R.B., May 1940.

The evacuation of No. 5 Signals Wing from France

On 17 May, the Officer Commanding No. 5 Signals Wing received instructions from the Headquarters, Air Component of the Field Force to evacuate his Headquarters, together with No. 1 Filter Centre, to Abbeville.[1] The Filter Centre at Arras, which had been in use for a month only, was destroyed before it was left. Instructions were issued to all mobile R.D.F. Units except No. 1 to join the Wing at Abbeville. No. 1 Unit was dismantled, part of the equipment salvaged, the remainder destroyed and the unit was evacuated through Calais. On 19 May orders were received to proceed to Le Havre. Here No. 1 Filter Centre and the remaining five R.D.F. units ceased to exist as separate units, being absorbed into No. 5 Signals Wing.[2] Two days later the Wing was instructed to retire to No. 2 Base Area, Nantes ; the road party with technical vehicles spent two days and nights en route due to the traffic congestion on the roads. The rail party of personnel journeyed nearly five days in cattle trucks to reach Nantes.

The use of R.D.F. in its inadequately mobile form was impracticable for the fluid warfare which had developed, and Headquarters, British Air Forces in France recommended to Air Ministry that No. 5 Signals Wing should be evacuated to England with all its equipment.[3] On 2 June, orders were received by the Wing to entrain for Cherbourg, the main rail party sailing on the following day for Weymouth.[4] The prime movers and technical equipment were embarked for Southampton on 6 June.

Causes of Failure of R.D.F. in France

In view of the strong opinions voiced by Senior Officers in the French Campaign and by Mr. Watson Watt, the application of R.D.F. in the form of modified G.L. sets must be regarded as an almost complete failure. The limitations of the technical equipment supplied to the mobile R.D.F. units was the largest single contributory factor. These R.D.F. sets, produced under emergency conditions, were inadequately tested for use in the field. The technique of an R.D.F. watch over land was previously untried. The chief limitations of the equipment when functioning normally were :—[5]

(*a*) Short range due to low height of towers (70 feet).

(*b*) Low transmitter power, also reducing the range.

(*c*) Blind patches in a vertical plane, often resulting in an aircraft not being observed.

(*d*) Uneven range in various directions in the horizontal plane due to the configuration of the ground.

(*e*) The available information for observed aircraft was inadequate for operational use because :—

- (i) there was no satisfactory height estimation ;
- (ii) there was no identification of enemy and friendly aircraft.

Even within the range restrictions imposed by the equipment, these sets were not always sited to best advantage by the experts responsible for the selection of locations well in advance.[6] As a result, the station then had no operational value whatsoever although the personnel manning it were working quite satisfactorily.

[1] No. 5 Signals Wing, O.R.B., and A.H.B./IIH2/414, Appendix "S," page 5.
[2] *Ibid.* [3] Air Ministry File S.1796, Encl. 73A. [4] No. 5 Signals Wing, O.R.B.
[5] Air Ministry File S.1796, Folder 1, Encl. 18A.
[6] Air Ministry File S.4746, Encl. 3A, para. 1, and S.2973, Encl. 20A.

The officers in charge of these R.D.F. units in France were very keen and were mainly Volunteer Reservists of good technical knowledge. They submitted helpful ideas and suggestions to Air Ministry for improving the performance of their R.D.F. equipment.[1] They were, however, lacking in experience and knowledge of Service methods.[2] For the first four months in France the units were neglected by the higher formations and, as a result, they were permitted too much laxity to experiment with their equipment, making unofficial modifications in an attempt to overcome the defects in their apparatus. Aerial systems were changed and even frequencies were altered on occasions to improve the performance figures of the station. Although these are healthy signs of initiative and enterprise, technical development by experiment is not the work of units in forward areas during a campaign.

The stations were seriously hampered throughout the whole period by lack of spare parts for replacement and repair purposes. During the initial months there was no source from which technical supplies could be obtained quickly.[3] Up to the end of 1939 there were not even stores references in the Royal Air Force vocabulary or secret equipment lists for ordering these components. The parts themselves were in extremely short supply. Arrangements had to be made for delivery from the manufacturers to be flown directly to France. There was undoubtedly a lack of organisation in the supply of spare parts for these G.M. sets. Even towards the end of the campaign, spares were arriving very slowly; demands raised in March had not been met in May.[4] This is not a reflection on the equipment organisation; many of the parts demanded were unavailable for the simple reason that they were not even manufactured. With no complete spare R.D.F. transmitter and receiver available on each unit, a station would be off the air for varying periods for routine servicing or for breakdowns. The infrequent availability of aircraft to make runs over the stations for calibration and performance checking was a serious drawback to the operational efficiency of stations.[5] No. 5 Signals Wing made strong attempts to remedy this state of affairs.

The reliability of any radio equipment is never greater than the reliability of its electrical power supply. Each station had one Lister Diesel-Electric Generator only. Spare Listers were not available and were not expected to be available until May 1940.[6] As a result, R.D.F. stations were off the air owing to power supply failure at times when they were most urgently required. No. 5 Station at Ficheux, near Arras, was unserviceable for this reason when Arras town was bombed during May 1940.[7]

The timely evacuation of R.D.F. units from France effectually prevented the capture of equipment of considerable security value. Concern was felt however regarding the extent of any compromise which might occur as a result of the disclosures of R.D.F. information which had been made to the French. A note on this aspect appears at Appendix 57.

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[1] Air Ministry File S.1796, Encl. 59A.
[2] A.H.B./IIH/147, Encl. 6A, and Air Ministry File S.1796, Folder 2, Encl. 6E, and Folder 6, Encl. 6A.
[3] Air Ministry File S.1796, Folder 5, Encl. 6B, and Air Ministry File S.2937, Encls. 1A and 4A.
[4] Air Ministry File S.1796, Encls. 18A (Folder 1) and 67A.
[5] A.H.B./IIH2/178, Encl. 28A.
[6] Air Ministry File S.2937, Encl. 5A and Minute 19.
[7] Air Ministry File S.4746, Encl. 3A, para. 1.

CHAPTER 8

PROPOSALS FOR EXPANSION AND PROGRESS OF R.D.F. ABROAD, SEPTEMBER 1939–JULY 1940

At the outbreak of war the Joint Oversea and Home Defence Committee, which had considered R.D.F. requirements prior to the War,[1] had lapsed and in consequence no central record was available of the progress in the provision of R.D.F. for ports abroad, though material changes had taken place in the general situation. The Port Defence Committee of the Chiefs of Staff Committee, War Cabinet, therefore reviewed the position in December 1939 in the light of the effect of the War on the relative importance of ports. Special consideration was given Rangoon and the Indian ports[2] The situation regarding the supply of R.D.F. was, however, so obscure that further consideration of the order of priority of supply for ports overseas was deemed unprofitable. The Air Ministry was therefore invited to circulate the required information to the Committee and include details regarding siting reconnaissance and the works services for installations of sets already approved.

The Director of Plans, Air Ministry, prepared a note for circulation to the Port Defence Committee on 18 January 1940 stating that it was not possible to give a definite rate of production, because as the production of one type was advanced the others were retarded, and the completion of the home emergency programme was the first consideration in this respect. Subject to unforeseen emergencies it was estimated that M.B.2 sets would be available by May 1940, C.H.L. equipment would be available by June 1940, and C.D. sets could not be produced while they were only in the development stage. The note was considered immediately by the Port Defence Committee. It was thought worth while to provide the maximum possible scale of R.D.F. at ports where fighter aircraft would be operating defensively, but at ports where only A.A. guns were installed a C.H.L. set would suffice. It was agreed that Alexandria, Aden, Malta, Port Said and Singapore should be equipped with both C.O. and C.H.L. sets, in that order of priority, and that Gibraltar, Haifa, Freetown, Trinidad, Trincomalee and Hong Kong should next be equipped with C.H.L. sets only.[3] Port Sudan, Rangoon, Colombo, Penang, Bombay, Calcutta and Karachi were to be included in the order of priority at a later date, and it was also suggested that Canada and South Africa would find it desirable to order R.D.F. equipment for Halifax, Vancouver and the Cape.

At this same meeting of the Ports Defence Committee there was a discussion on the inadequacy of the machinery for allotting R.D.F. equipment. It was suggested that the best means of securing a reasoned order of priority would be for the Deputy Chiefs of Staff to deal with this matter in a similar manner to that in which they had already dealt with the allotment of A.A. guns. The Air Ministry, as the responsible department for supplying R.D.F., would be able to prepare a statement every month showing authorised demands, the probable production, and the proposed allocation.[4] The approval of the Deputy Chiefs of Staff Sub-Committee was invited to this proposal.

[1] *See* Chapter 5—R.D.F. Overseas—Pre-War.
[2] Air Ministry File S.40952, Encls. 121A, 123A, 124A and 127A. [3] *Ibid.*, Encl. 131B.
[4] *Ibid.*

The Inter-Services R.D.F. Committee met on 9 February 1940, to consider how the requirements of the first five important ports could be satisfied. The provisional programme agreed upon was :—[1]

Alexandria	M.B.1 (already there)	C.H.L. in May	M.B.2 in mid-March.
Aden	M.B.1 (already there)	C.H.L. in May	M.B.2 at end of March.
Malta	M.B.1 (already there)		
Malta	M.B.2 in April	C.H.L. in May	M.B.2 at end of March.
Port Said	M.B.2 in April	C.H.L. in May	
Singapore	M.B.2 in April	C.H.L. in May	

Instructions were also given by the Committee for the preparation of a statement to show proposed production, authorised requirements and suggested allocation of the various types of R.D.F. stations for submission to the Deputy Chiefs of Staff for their approval. In this manner the Committee was to receive guidance on the strategical aspect of the allotment of the principal types of R.D.F. sets.

Pressure from the Middle East for more R.D.F. installations

In January 1940, three sites had been selected for R.D.F. stations in Egypt at Alexandria, El D'Aba, and 20 miles West of Helwan. The Air Officer Commanding-in-Chief, Middle East, concurred with the suitability of these sites to guard against attacks from Libya, but urged that the allocation was insufficient as he desired to prepare for the threat of German bombers from Bulgaria.[2] He also wanted a further two mobile (M.B.) sets to be provided as potential cover for a proposed air contingent proceeding to Turkey. Air Ministry was unable to meet this request. The scientific officer, Flight Lieutenant Atherton, attached to Headquarters, Middle East, had by March 1940 completed his report giving siting recommendations for C.O. and C.O.L. stations.[3] These were as follows :—

C.O. Stations	Ikingi Maryut
	Wadi Natrun
	Cairo
	Damietta
	Ismailia
C.O.L. Stations	Aboukir
	Port Said
	Cairo

Although in complete agreement with these proposals, the Air Officer Commanding-in-Chief, Middle East, realising the time taken to site and erect R.D.F. stations of these types, was not satisfied with the actual provision of R.D.F. cover for the Middle East, and pressed in a personal signal to Air Ministry in July 1940 for the supply of :—[4]

6 further M.B. stations for Egypt.
1 (additional) station for Aden.
At least one, preferably two, for each of Mombasa, Khartoum and Port Said.
1 or 2 (additional) for Malta.

[1] Air Ministry File S.40952, Encl. 136A.
The term "C.H.L." ceased to be used for overseas low cover sets in February 1940 ; they were then called "C.O.L." stations. The chief difference between C.O.L. and C.H.L. equipments was that the former were semi-tropicalised.
[2] Air Ministry File S.5734, Encls. 13A, 16A and Air Ministry File S.47125, Encl. 90A.
[3] Air Ministry File S.47125, Encl. 128A.
[4] *Ibid.*, Encl. 172B.

The representations of the Air Officer Commanding-in-Chief, Middle East, could not be ignored. There has been some delay in implementing the decisions of the Port Defence Committee meeting of January 1940, as this committee had been acting on information which later proved to be inaccurate.[1] At a further meeting on 22 May 1940, a decision was taken that R.D.F. cover against high-flying and low-flying air attack was to be provided at all the ports for which C.O. sets were to be supplied and also at Kilindini. In addition, on 2 July 1940, the Air Ministry wished Port Sudan to be added to the list. The following revised order of priority for the provision was recommended by the Inter-Services R.D.F. Committee (upon which the Port Defence Committee was then represented) :—

1 Alexandria (Ikingi Maryut)
2 Cairo (Gebel Qatrani)
3 Wadi Natrun, Egypt
4 Damietta
5 Suez (Ismailia)
6 Additional station in Egypt
7 Malta[2]
8 Aden
9 Gibraltar
10 Haifa
11 Singapore
12 Khartoum
13 Port Sudan
14 Kilindini
15 Freetown
16 Trinidad
17 Hong Kong
18 Trincomalee
19 Rangoon
20 Colombo
21 Penang

$\left.\begin{array}{l}\text{18 Trincomalee}\\\text{19 Rangoon}\\\text{20 Colombo}\\\text{21 Penang}\end{array}\right\}$ Deferred

This proposal, approved by the Treasury Inter-Service Committee, was the stage reached at the time of the emergency at home occasioned by the fall of France.

Egypt

The mobile R.D.F. station, situated at El D'Aba on the Egyptian coast mid-way between Alexandria and Mersa Matruh, had been working for six months by November 1939 when Air Chief Marshal W. P. Mitchell, the Air Officer Commanding-in-Chief, Middle East, rendered a report on the performance of this station to the Under-Secretary of State for Air.[3] He explained that the original intention to use this R.D.F. station in its mobile form to test the suitability of various sites in Egypt for R.D.F. working had not been carried out, since the political situation in Egypt at the time and the necessary provision of R.D.F. cover against air attack for the Fleet in Alexandria harbour

[1] Air Ministry File S.44211, Encl. 69A. These decisions of the Port Defence Committee were given earlier in this chapter.
[2] Malta. The plans for the C.O. station were temporarily suspended owing to enemy bombing, but there was no suspension of the C.O.L. provision.
[3] Air Ministry File S.47125, Encl. 80A.

had precluded such site-testing. The Air Chief Marshal expressed his grave concern at the limited range of this mobile station and its inability to determine the height of aircraft. He pressed strongly for a C.H. station to be provided as soon as possible. Replying at the end of November 1939 the Air Ministry informed the Middle East Command that the priority for the provision of R.D.F. stations in Egypt had been reduced owing to increased commitments in the United Kingdom and France under the initial condition of war.[1] However, in order to improve the performance of the mobile R.D.F. equipment already in use, 250-foot high special timber masts already promised for the aerial system of the mobile R.D.F. set were provided. These were rushed out in January 1940 by the Navy at "emergency speed."

Meanwhile in anticipation of the arrival of a further two M.B. sets, plans were made for their installation on sites at Aboukir and Ikingi Maryut, near Alexandria. Consequently it was decided to erect the 250-foot masts at Ikingi Maryut immediately they arrived.[2] The mobile M.B. station at El D'Aba was withdrawn for overhaul and re-erected near Aboukir for the purpose of giving warning to the A.A. guns against possible long-range German aircraft attack. The selection of sites for R.D.F. stations had not been easy. It was essential that firm foundations for buildings and the erection of towers should be available and although many sites were found which were satisfactory with regard to height above sea level, the presence of shifting sand dunes, sand quarries, antiquity excavations and the like enforced a renewed search for other sites with firm foundations.[3]

Another difficulty was the absence in the Command of technical officers who were experienced in the operation and maintenance of R.D.F. installations. Knowledge of the behaviour of radio components under Middle East conditions was scanty even with the experts who were eventually sent out. Humidity played havoc with the installations until tropicalisation of all sets was effected.[4] Considerable assistance was, however, afforded to the Command when R.D.F. technical officers from England arrived. Flight Lieutenant Weakes, of the Air Ministry Research Establishment, was sent to Egypt to assist with the erection of the aerial arrays on the new 250-foot masts, and early in February 1940, two officers, Flight Lieutenant J. F. Atherton and Flying Officer Cotten of the Directorate of Communications Development, Air Ministry, also arrived to give technical assistance with the existing equipment and to make recommendations for future development and siting of R.D.F. stations throughout the Command.[5] Flight Lieutenant Atherton paid a visit to the mobile A.M.E. station at Aboukir at the end of February 1940. His technical report, submitted to the Director of Signals, Air Ministry, gives a detailed account of the performance of this M.B. station[6]. He found that the equipment gave a slightly reduced range estimation, and that some indication, rough only, of the height of an aircraft was being obtained.

By May 1940 the work at Ikingi Maryut was proceeding rapidly; transmitter and receiver huts and a power house had been built.[7] The 250-foot aerial towers were in the last stages of erection. In order to improve the power supplies, two 25-KVA 3-phase Diesel-electric generators were being sent from England. The two expected M.B. sets had also arrived, one of which was to be located on

[1] Air Ministry File S.47125, Encls. 87A and E, 94A, and Air Ministry File S.5734, Encl. 8A.
[2] Air Ministry File S.47125, Encls. 47A, 48A, and Air Ministry File S.5734, Encl. 19A.
[3] *Ibid.*, Encl. 47A. [4] *Ibid.*, Encl. 94A. [5] *Ibid.*, Encl. 100C.
[6] Air Ministry File S.47129, Encl. 122A and B. [7] *Ibid.*, Encl. 147A.

the old site at El D'Aba. There was a temporary set-back on this site, however, the transmitting aerial tower being completely destroyed by gales.[1] Early in June the R.D.F. cover was vastly improved, although still far from perfect. The two new M.B. sets were now in operation and, with the original M.B. set formerly installed at El D'Aba, formed a three-station chain,[2] Ikingi Maryut–Aboukir–El D'Aba. Ikingi Maryut had 250-foot masts and the other two had 70-foot masts.

As has already been stated the Air Officer Commanding-in-Chief, Middle East, was still not satisfied with the existing R.D.F. cover or the plans for the future. He requested a further six M.B. stations for Egypt by personal signal to Air Ministry.[3] Air Ministry pointed out that additional supplies were governed by availability of radio gear and trained crews to man it, but two further M.B. sets and crews were diverted to the Middle East at the beginning of July 1940. The higher power M.B.2 transmitter and the R.F.7 receiver were in fact ready in the United Kingdom for despatch to Ikingi Maryut.

The 250-foot high aerial towers at Ikingi Maryut must have attracted the attention of the enemy Intelligence, for the station was bombed twice on 16 July 1940.[4] Fortunately no damage was done to the M.B. equipment or the masts, but the technical stores were damaged. The transmitter and receiver were removed from their huts and placed below ground and urgent demands for replacement valves were sent to the United Kingdom. Thus, at the time when Britain was facing its most critical hour after the Dunkirk evacuation, R.D.F. stations in Egypt were also receiving the enemy's attentions.

Malta

At the outbreak of war the only R.D.F. installation working in Malta was the M.B. set situated at Dingli at a height of 800 feet.[5] Technically the equipment was giving a good performance. The transmitting aerials were arranged to " illuminate " over a full 360° so that all round R.D.F. cover was obtained. The aerial system was mounted on four wooden telescopic towers 70 feet high. In order to improve working conditions and mitigate the effects of high temperature on the set, the equipment was housed in stone buildings. The results obtained were good for the equipment in use. Single aircraft were detected at 70 miles at 10,000 feet and at 30 miles at 2,000 feet. No height measurements were possible with this equipment. Unfortunately, with only one set, the necessary servicing limited the watch to approximately 12–16 hours per day.[6] In order to give the full 24 hours daily R.D.F. cover to the Island, a second M.B. set was sent to Malta early in July 1940. This was sited at Dingli also, and thus continuous watch coverage was achieved. In consequence of hostile bombing it was necessary to defer part of the proposed installation of the permanent C.O. sets at Dingli.[7]

Aden

Considerable delays occurred before the mobile R.D.F. station was operational at the site at Aman Khal Fort, although the equipment had arrived at Aden just before the outbreak of war.[8] The original difficulties were due to labour

[1] Air Ministry File S.47129, Encl. 145A.
[2] Air Ministry File S.47125, Encl. 166A.
[3] *Ibid.*, Encls. 172B, 173A, 176A.
[4] Air Ministry File S.5734, Encl. 43A.
[5] Air Ministry File S.47124, Encl. 106C.
[6] *Ibid.*, Encl. 106B.
[7] Air Ministry File S.44211, Encl. 67A.
[8] Air Ministry File S.1056, Encls. 29A, 30A, 34A, and A.H.B./IIE/70, R.D.F. Overseas Folder, Minute 19.

troubles and lack of knowledge of tower erection. The completion of the Works Services did not end the delay, and the Air Officer Commanding, Aden, asked for assistance from Air Ministry. A technical officer was despatched to investigate the trouble.[1] The packing case containing the receiver had been flooded by a cloud-burst during installation, necessitating some re-wiring which was done incorrectly owing to the absence of blue-prints. In addition persistent breakdowns of technical components occurred and the tropical, humid climate was affecting the soldered joints.[2] The officer observed in his report that much of the initial inefficiency of this station had been due to the personnel not being experienced enough to use the equipment, and that a more thorough testing of the radio gear sent overseas should have occurred in the United Kingdom prior to despatch. Lack of stores and other facilities made experimental work on site a very difficult and haphazard proceeding.

By March 1940, the station was operating but only on the seaward quadrant. Further investigation showed that lack of performance on the landward side was due to a long range of hills in the hinterland causing permanent echoes. After continued experience, R.D.F. operators became sufficiently skilled to distinguish aircraft indications among the permanent echoes. By the time Italy declared war the station was working satisfactorily. One Army G.L. set was installed by the garrison, and H.M.S. "Carlisle," which periodically visited Aden, was also equipped with a G.L. set. Continuous R.D.F. cover was thus maintained, despite periodical overhauls or temporary breakdowns, by amicable inter-Service co-operation.[3]

By July 1940, Malta, Egypt and Aden all had some measure of R.D.F. cover. Fortunately, the R.D.F. equipment on Malta was functioning best, and it was there that efficient raid reporting was required most of all. Progress in the installation of R.D.F. equipment overseas had been slow. The non-availability of apparatus, shipping delays in wartime, and the lack of experience in the operation of R.D.F. equipment in hot climates, all contributed a delaying effect on the overseas R.D.F. programme.

[1] Air Ministry File S.1056, Encls. 38A and 58E.
[2] *Ibid.*, Encls. 52A and 58E.
[3] *Ibid.*, Encl. 61A.

CHAPTER 9

THE HOME CHAIN UNDER THE THREAT OF INVASION (MAY–JULY 1940)

When the Germans moved into Denmark and simultaneously launched their invasion of Norway on the night of 8 April 1940, the Air Component of the British Expeditionary Force for Norway was already assembled at the Royal Air Force Station, Uxbridge. This included four Transportable Radio Units destined to give R.D.F. cover for the ground forces after landing. An R.D.F. reconnaissance party of two officers visited the Narvik area immediately after the Expeditionary Force had landed, and toured the district. They reported that M.B. and G.M. transportable R.D.F. stations would be valueless there because of the extremely mountainous nature of the terrain.[1] Only C.H.L. stations would have had any real value. The Officer Commanding the Air Component of the North-West European Force therefore decided on 29 May that there was no immediate need for R.D.F. facilities in North Norway, and the Transportable Radio Units did not embark.

After the evacuation of the Expeditionary Forces from Norway the Germans held an extended coastline facing the north-eastern coast of Britain. Some improvement in R.D.F. cover in this area was necessary and three further C.H. stations were proposed immediately for the north-east of the British Isles, at North Unst, Sumburgh and Sanday.[2] The Inter-Services R.D.F. Committee also approved C.H.L. stations commensurate with the above commitments, in order to cover the Orkneys and Shetlands area.

The Fall of France and Emergency Extension of the Home Chain

As the enemy advanced towards the Channel during May 1940, not only was additional R.D.F. cover required in Britain along its north-eastern coast, but also for the western districts. On 25 May, at a meeting at Air Ministry, the Director of Home Operations laid down the priority of requirements as :—[3]

(*a*) Defence of London from the Channel Approaches.

(*b*) Strait of Dover to the Humber.

(*c*) Lizard to Bristol Channel.

(*d*) Liverpool to Clyde.

(*e*) Humber to Shetlands.

To meet the demand for increased cover, the following R.D.F. stations were required :—C.H.L. stations at Rye, Pevensey, Poling, Rowe Head, Black Head, Dunkirk, Hopton, Skendleby, Flamborough Head ; C.H. stations at Hawks Tor and Lizard ; both C.H. and C.H.L. stations at Swanage, West Prawle, Newquay, Tenby, Stranraer, Antrim. A pool of twelve M.B.2 mobile stations was to be formed for Advance stations or to replace stations knocked out by enemy action.

[1] Air Staff Folder, *Component Field Force No. 2—Observer Sites and Wireless Screens*, A.H.B./IIH5/1/61, Encl. 12A.

[2] Minutes of the Inter-Services R.D.F. Committee, 11th Meeting, 6 June 1940, A.H.B./IIE/68.

[3] Headquarters, No. 60 Group File 60G/S.400/AIR, "C.H. Policy—New Stations," Encl. 9B.

No. 60 Group undertook the task of co-ordinating this programme of eight C.H. stations and fifteen C.H.L. stations. The target date for the C.H.L. " crash " programme was 8 July 1940.[1] No specific date was fixed for the completion of the C.H. installations. To assist in temporary cover, the Group had already available some six mobile M.B.2 stations. During May it was decided to increase the reserve pools. Two pools of twelve mobiles each were formed for the north and south areas of the Chain.[2] In order to facilitate No. 60 Group's effort in meeting this emergency expansion, No. 2 Installation Unit was handed over to the Group on 7 June 1940, and later in the month its establishment was raised from 343 to 508 personnel. Experienced personnel to fill this increase were difficult to find, however, and the Unit had to continue working below strength. It was made responsible for :—[3]

(*a*) Completion of the East Coast C.H. stations to four-frequency working and the West Coast Chain to two frequencies.

(*b*) Completion of the mobile stations programme.

(*c*) Modification to C.H.L. stations of eight mobile G.M. stations.

(*d*) Assembly, testing and despatch of all R.D.F. equipment for stations overseas.

(*e*) All heavy maintenance work at home beyond the capacity of the Radio Maintenance Units.

(*f*) The fabrication of all parts to cover replacements not normally available through contractors.

(*g*) Installation of any additional stations in the Home Chain.

(*h*) Assembling, testing and installation of mobile C.H.L.s then being initially introduced into service.

(*i*) Any necessary modifications of all types of Ground Home R.D.F., both fixed and mobile.

(*j*) The " cleaning-up " of existing C.H.L. stations and installation of duplicate transmitters and receivers at those stations.

Technical Modifications to C.H.L. Stations

The last item was a heavy commitment, as major improvements to C.H.L. equipment were being made.[4] At the end of May 1940, the Air Ministry Research Establishment had experimented with a motor-driven C.H.L. aerial array at Douglas Wood Station capable of sweeping through 180° in 65 seconds. In May a turntable and mast had been evolved which carried both the transmitter and receiving aerial arrays on one gantry. Previously, all aerial rotation on C.H.L. stations had been done by hand turning ; the minimum rate of sweep allowed being eight minutes for a coverage of about 180°.

In June a cathode ray tube display using a radial time base, called the Plan Position Indicator (P.P.I.), was suggested as a means of increasing the speed of plotting.[5] In this tube the time base, normally horizontal and stationary in cathode ray tubes in other R.D.F. stations, rotated in conformity with the rotation of the aerials, giving a plan picture of the aircraft's position, doing

[1] No. 60 Group File 60G/S.400/AIR, Encl. 9B.
[2] A.H.B./IIE/68, R.D.F. Inter-Services Committee, 9th Meeting, 11 May 1940.
[3] A.H.B./IIE/64, Folder, " Organisation of No. 60 Group," Encl. 19A.
[4] Air Ministry File S.55153, Part II, Encl. 38B and 79A, O.R.S./4/1/2.
[5] A.H.B./IIE/68, Minutes of Inter-Service R.D.F. Committee.

away with the need for direction finding by the goniometer method. It covered up to 60, and later 90-mile ranges. The new tube was installed at the C.H.L. station at Foreness for testing.[1]

By the second week of July 1940, the date of the first large-scale day attack by enemy aircraft on shipping in the English Channel, the Chain had been enlarged by C.H.L. stations at Gaitnip (Orkneys), Poling, Worth Matravers (28 May), West Prawle (15 June), Beachy Head (16 June) and Carnanton (26 June).[2] C.H. stations were ready for operations at Worth Matravers, Hawks Tor (29 May), West Prawle (15 June), Goon Hilly Down (later Dry Tree) (20 June), Carnanton and Warren (24 June). A new Filter Room was opened at No. 10 Group Headquarters near Bath to which stations from West Prawle westwards all reported. To keep pace with these new installations, the training of personnel to man them had been stepped up. On 12 June 1940 Yatesbury Radio School opened a training centre for W.A.A.F. R.D.F. Operators.[3]

During May and June 1940, the Germans increased their use of aircraft for mine-laying operation in British port areas. Although the approach of the hostile aircraft was usually observed by the Chain, when the enemy adopted diversionary tactics of mixing mine-laying aircraft with bombers proceeding inland or high-flying decoy aircraft, difficulties were experienced in identifying the mine-layers. The mine-laying aircraft usually dived, with its engine throttled back, to the low altitude necessary to lay the mines safely. Experiments were conducted to determine if C.H.L. stations could observe the mine after it had been released from the enemy aircraft. The actual location of the mines was of great importance: since their presence resulted in the closing of harbours to all shipping until the laborious process of sweeping the entire navigational channels had been completed. The experiments were not successful, although the C.H.L. station reports on the exact location of the enemy aircraft's dive position were of some help.

With the fall of France the danger of invasion across the English Channel became imminent. The Admiralty asked the Royal Air Force, through the medium of the Inter-Service Committee on R.D.F., whether warning of the approach of troop-carrying craft, mine-sweepers, coastal motor boats, mine-layers and other surface craft could be given by the C.H.L. stations at Dover, Foreness, Walton, Dunwich, Walcott and Swanage.[4] The Air Officer Commanding-in-Chief, Fighter Command, was reluctant to accept the commitment because of the difficulties involved. The stations were in any case pre-occupied with watching for aircraft and would undoubtedly be fully engaged during raid periods. There would be no means of identification as our own surface vessels were not fitted with I.F.F. equipment. Moreover some means of passing the information was necessary, and probably a special plotting organisation would have to set up at a Naval headquarters, with direct telephone lines. The Inter-Service Committee recommended the erection of a new C.H.L. station in the Foreness area, manned by Royal Air Force personnel, solely for the purpose of locating surface craft. Stations at Dover and Bawdsey were made more capable of reporting surface craft at the same time as they

[1] This was typical of the way in which operational R.D.F. stations were the subjects of research and development at that time.

[2] No. 11 (Fighter) Group, O.R.B., May/June 1940. These locations are shown on Map No. 1.

[3] No. 2 Radio School, O.R.B., June 1940.

[4] A.H.B./IIE/68, Minutes of Inter-Service R.D.F. Committee, 11th Meeting, 6 June 1940.

searched for aircraft, by the installation of long after-glow type cathode ray tubes. This device caused indications of aircraft or ships to persist on the tube for a period of some seconds after it first appeared, thus making the work of reporting a number of simultaneous indications much easier.

At the beginning of July the Air Ministry agreed to allow watching for surface craft to be undertaken, provided that previous warning to expect hostile surface craft was given to the station, or in weather conditions which were adverse to air reconnaissance, or in cases of the concentration of ten or more ships ; and otherwise, whenever possible.[1] Land-line communications from C.H.L. stations to appropriate regional Naval headquarters were provided, and the Admiralty published a memorandum showing which C.H.L. stations were required to do this work, the stations lying along the south-east coast being the most important.

If invasion were to occur, it was anticipated that simultaneously with the approach of sea-borne forces, enemy troops would probably be landed in this country from gliders. How much information C.H. and C.H.L. stations would be able to give, or even whether they could detect non-metal gliders, was not known.[2] It was thought that such gliders would be released from the German towing aircraft some distance from our shores. Investigations were therefore undertaken as a matter of urgency by Fighter Command. During the next four weeks Air Ministry Research Establishment conducted experiments and issued a report on the R.D.F. observation of non-metallic gliders. An isolated aircraft with a glider in tow produced a characteristic echo which, by a splittng effect, indicated the release of the glider. The latter could then be observed as a separate and distinct echo, but of smaller magnitude than the echo of a power-driven aircraft at a similar range. The maximum range at which a glider could be observed by a C.H. station was of the order of 30 miles. It was apparent, however, that the complex echo concentration to be expected in the case of a substantial number of aircraft with gliders would render positive identification of gliders unlikely. Mr. Watson Watt expressed the view that the common-sense way to identify an echo from a glider was by noting its relatively low speed over the ground.

Since the Home Chain was designed to give R.D.F. cover to seaward only, it was clear that once the gliders had passed the coast R.D.F. information on them would cease. The need for inland-looking or alternatively inland-sited R.D.F. stations now arose to cover the South-East of England. One mobile G.M. station from the reserve mobile pool was therefore sited inland in Kent and three existing C.H. stations on the Norfolk and Suffolk coasts were to keep an inland-looking watch in addition to their normal one by bringing their second receivers into operation. These were the stations at Canewdon, High Street and West Beckham.[3]

During May 1940 Headquarters No. 60 (Signals) Group foresaw new R.D.F. difficulties if the enemy resorted to mass raids.[4] C.H. stations could not present a clear picture of more than about twelve tracks at a time. Their rate of plotting was hardly fast enough to allow a minimum rate of one plot on each of these tracks every two minutes. In addition, tracks of aircraft which merged close together became easily confused. To alleviate difficulties when large numbers

[1] A.H.B./IIE/68, Minutes of Inter-Service R.D.F. Committee, 13th Meeting, 4 July 1940, the Admiralty Memo.

[2] *Ibid.*, 11th Meeting, 6 June 1940, para. 6, sub-para. (iv). [3] *Ibid.*, para. 2, sub-para. (*c*).

[4] Headquarters, No. 60 Group File 60G/S.1/4/AIR, " Filter Room Procedure," Encl. 5A.

of aircraft might have to be plotted, Headquarters, No. 60 Group submitted to Fighter Command that a second cathode ray tube should be added to work in parallel with the existing tube as a " sorter." It was evident that in conditions of heavy activity, stations would be unable to plot all the aircraft showing on the tube ; nor would filter room plotters be able to make use of them.

The Research Section at Headquarters Fighter Command took up this suggestion and passed it to the Telecommunications Research Establishment. There, elaborations on a simple tube in parallel were visualised as a matter of future policy, eventually emerging in 1942 in the " Console ". It was unfortunate that the original suggestion was not acted upon, as mass raids had to be reported during the Battle of Britain on C.H. stations using the single tube. The idea was ultimately tried out during September 1940 when the stand-by receiver, R.F.5, was manned as a " sorter tube " at Pevensey and proved very helpful. C.H.L. stations were even more quickly saturated by large raids than C.H. stations. Their rate of sweep and plotting were slow, so that to follow more than two tracks was almost impossible.[1] There were some allegations of lack of conscientiousness in sweeping on the part of C.H.L. Operators. These were hardly justified. The hand operated aerial turning gear gave endless trouble and, in a wind of 35 m.p.h., it was often impossible to control the rotation. Scanning in these circumstances became exhausting and often gave good reason for pauses in the normal rotation procedure. Furthermore, in periods of fairly heavy aerial activity the cathode ray tube was so full that often nothing could be gained by turning the aerial.

Although remarkable progress had been made with the extensions to the Home Chain of C.H. and C.H.L. stations during May and June 1940, the R.D.F. raid reporting system was by no means perfect when the assault of the *Luftwaffe* began in July. The C.H. stations had not reached their planned " Final " stage and the C.H.L. stations were all of an emergency non-prototyped form. A compromise had been made between the desire for technical perfection and the necessity to have the fullest possible R.D.F. raid reporting system functioning as quickly as possible.

[1] Headquarters, No. 60 Group File 60G/S.51/6/Ops., " Ops. Procedure—C.H.L. Searching," Encl. 1A.

CHAPTER 10

R.D.F. RAID REPORTING DURING THE BATTLE OF BRITAIN

The Battle of Britain is taken as beginning on 10 July with the attacks on British shipping in the English Channel and continuing until October when, after the bombing of London, the assault gradually declined as a daylight operation. The offensive was an essential preliminary to the invasion of England by the Germans and was planned to take place in stages during which shipping, ports, docks and coastal towns, Royal Air Force airfields and installations, and finally the city of London were successively the targets for attack.

As far as the R.D.F. Home Chain was concerned the performance and organisation of the equipment were to be thoroughly tested, as were also the skill and endurance of the operating and maintenance personnel. Jamming and bombing of R.D.F. stations were experienced. It was to be shown whether the results of the scientific research and technical organisation built up in the previous five years could provide the Air Defence organisation with the early detection and continuous recording of movements of hostile aircraft, information which was essential to enable the Fighter Squadrons to defeat them.

The R.D.F. Chain at this time was by no means in the fully developed and highly trained state which it attained in the later stages of the War. Technically there was still much to be desired. The transmitters and receivers were fairly reliable and effective, but the aerial systems had not been developed to the stage of a satisfactory prototype. The search for the best type of aerial to suit all stations was still going on at the time of the Battle of Britain and did, in point of fact, continue until a much later date. Scientists who could have been concentrating on the solution of aerial problems had continually been called away from their laboratories, from the time of the Munich crisis onwards, to assist in the setting up of aerials on stations being brought into operation at emergency priority.[1]

Careful calibration was necessary before reliable height finding could be expected from the aerials in use. The task of calibration entailed the flying of helicopters and balloons in the English Channel and was only permissible in certain conditions of weather to give some measure of safety from hostile interference. Moreover, although Fighter Command was sometimes critical of the accuracy of height finding, they were naturally reluctant to allow stations to spend time on anything but the primary task of watching for hostile raids. The stations were capable, after calibration and in the hands of an experienced operator, of giving accurate heights. Even so, there was always a source of height error, in that the only method of calculation then available contained a chance of ambiguity, which could not be resolved at the R.D.F. station save by virtue of the experience of the operator.[2]

[1] Constant work on aerial arrays and feeder lines was necessary in any case during the Battle of Britain period because a satisfactory method of weather-proofing had not been found, and the entry of water into the feeder lines caused performance to deteriorate gradually to the point where replacement was unavoidable.

[2] There was also another source of error in height finding. Height reading was a cumbersome process, especially for inexperienced operators, during which it was possible to lose the broad picture in plan position of the raid or raids being reported. It was the practice, therefore, to read only one height for every four plots or so. Enemy formations were frequently reported while many miles from the coast and still engaged in gaining additional height. The result was that British fighter aircraft sent to intercept them found them noticeably higher than had been reported.

Estimation of the number of aircraft present in an observed formation was also dependent on the skill and experience of the individual operator. The difference between the indications given by one, two or three aircraft was easily distinguishable, but formations of twenty, sixty or a hundred and fifty gave responses of varied shape, size and characteristics which could only be "counted" by an operator who had seen similar indications previously, and had learnt what they represented.

There was therefore an urgent need for operators who had considerable experience, in addition to a normal facility for accurate perception and quick thinking. The need, moreover, was rapidly increasing, and the supply lagged behind, causing an acute shortage of trained personnel. Successive extensions of the Chain had been made to give increased cover, and the decision on 25 April to instal an additional eight C.H. and fifteen C.H.L. stations had seriously overloaded the training facilities available. The operators' course had to be shortened to three weeks duration, in which young men and women who had just been called up were hurriedly instructed in the elements of the new trade, before being posted straight to operational R.D.F. stations. An effort was made to offset the rawness of the newly fledged operators by careful selection of the best possible material before training.

First Phase of the Battle of Britain, 10 July–7 August

Although 8 August 1940 is the day popularly known as the beginning of the Battle of Britain because it was then that air fighting over England began, the real commencement of air attacks was on 10 July when the German Air Force started a series of raids on British shipping convoys in the English Channel and to a less degree in the Thames estuary.[1] The German policy during this period was towards the establishment of superiority over the waters of the English Channel and the exhaustion of our Metropolitan Fighter Force.

Between 10 and 19 July, German air operations were of one type. A force of bomber aircraft would form up over the French coast, fly directly to a shipping convoy, bomb and retire quickly, leaving a fighter escort to act as rearguard and fend off the attacks of British fighters.[2] R.D.F. Chain stations on the south coast were able to observe the German bombers forming up in the air at their rendezvous, usually in the Pas de Calais or Cherbourg areas. These activities were reported to filter rooms and operations rooms, and Controllers despatched fighters to intercept. The target being in the English Channel, however, and the Germans having the advantage of a slight start added to that of height, the bombing was usually over before the British fighters could intercept. Later there were occasions, as for example off Selsey Bill on 21 July, when warning was sufficient to allow defensive fighters to appear over the convoy, and the enemy retired without attacking.[3]

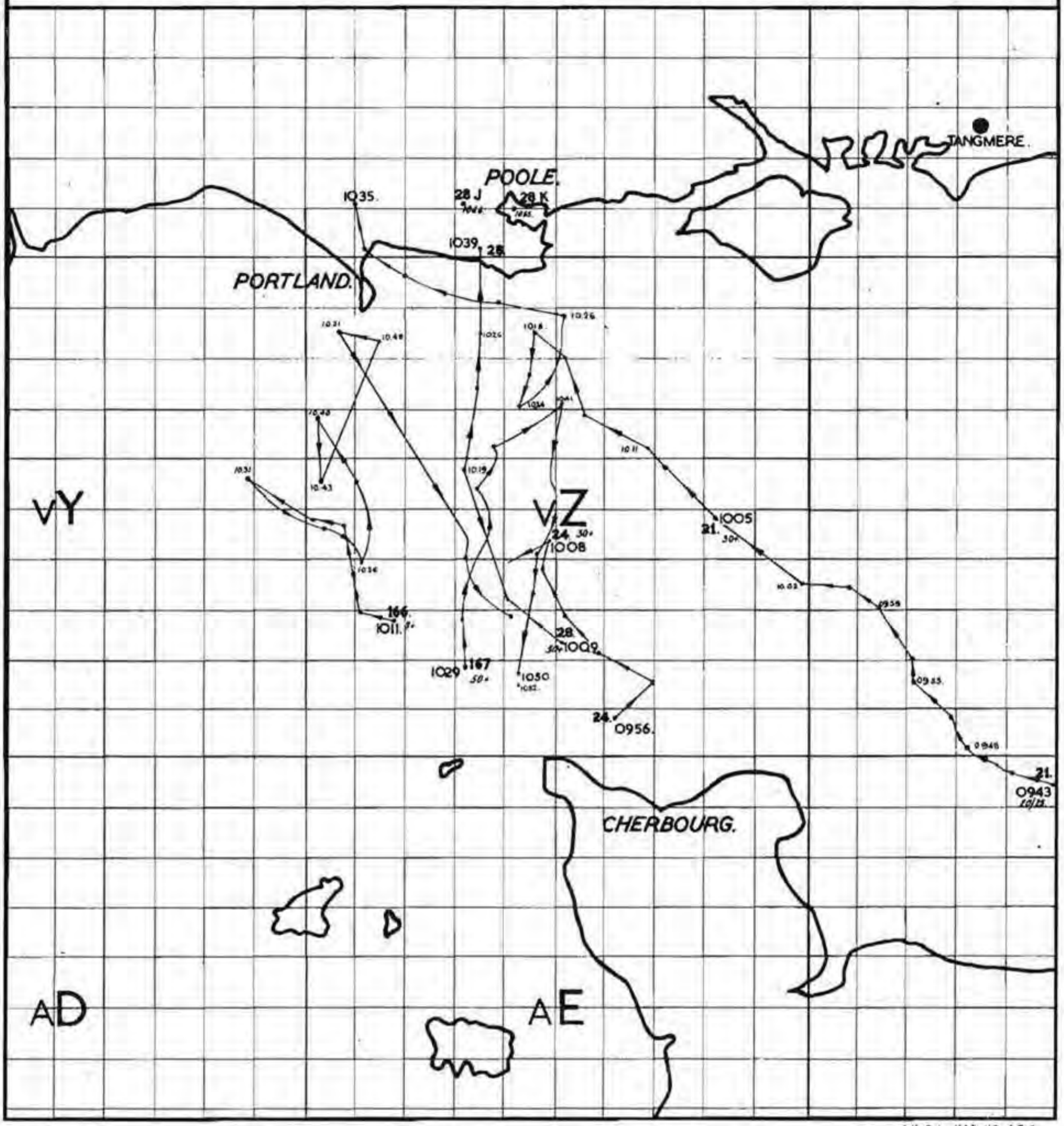
The increase in aerial activity during the opening phase of the battle presented a new air picture on the cathode ray tubes of the south coast R.D.F. stations; the number of indications showing on the tubes was so large in comparison with previous experiences that the work of the R.D.F. operators became much more exacting. However, the raid reporting system stood up well to these new stresses. Operating personnel quickly became adept at reporting the increased activity and, as the air battle approached more nearly to the

[1] Daily summary of Naval Events, 10–17 July 1940.
[2] R.A.F. Narrative *The Battle of Britain*, pp. 59 and 60.
[3] *Ibid.*, p. 64.

MAP No. 2

HOSTILE AIRCRAFT TRACKS IN BATTLE OF PORTLAND - POOLE

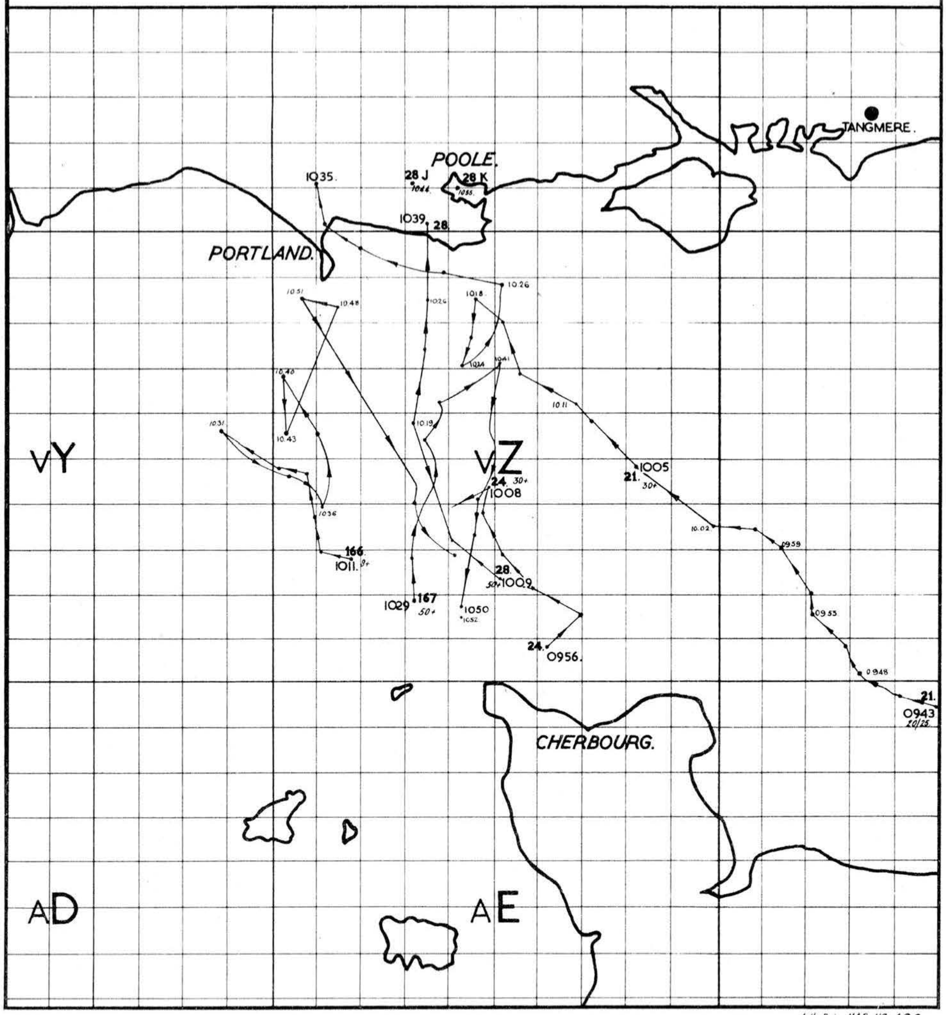
11 AUGUST 1940 – 10.12 HRS. 11.12 HRS.



A.H.B.I. MAP No. 463.

MAP Nº 2

HOSTILE AIRCRAFT TRACKS
IN BATTLE OF PORTLAND - POOLE
11 AUGUST 1940 – 10.12 HRS. 11.12 HRS.



A.H.B.I MAP. Nº 463

coastal locations of the R.D.F. stations themselves, a marked stiffening of the already high morale and keenness of the stations' personnel became most apparent.

Of the technical performance of the R.D.F. stations themselves, the ranges attained were satisfactory and the bearings well within the standard of accuracy required in practice. Generally the C.H. stations attained a radius of nearly 200 miles in the most favourable circumstances and had an average effective range of about 80 miles.[1] Their limitations against low-flying aircraft below 1,000 feet had been countered by the C.H.L. stations introduced in the earlier "crash" programme. These C.H.L. stations had a restricted effective range of 30 miles but were fairly accurate in azimuth or bearing readings.[2]

Second Phase of the Battle of Britain, 8–18 August

During this period of the German air onslaught, the attacks were pressed against the Fighter Command organisation, including the bombing of coastal airfields and some south coast R.D.F. stations. Coastal towns were also bombed. The enemy during this period resorted to great variety in his attacks. His methods included (*a*) casting about over the Channel to make tracking difficult, (*b*) the extensive use of decoy flights to distract the Controller from the main attack, (*c*) two- and three-pronged heavy attacks from bases as far apart as Calais and the Cherbourg area, and (*d*) the quick-mounting of direct attacks; such rush tactics reducing the period of R.D.F. warning to the Controller.

The following example of R.D.F. plotting gives an idea of the scale of activity in one area at that time.[3] On 11 August 1940, between 1005 and 1009, the following German formations were plotted in the central Channel, all of them on a course to Portland and Swanage :—

"(*a*) The force was originally plotted as it emerged from the Baie de la Seine thirty or more aircraft strong; at 1005 hours this was 30 miles south of St. Catherine's Point.

(*b*) A force of fifty or more aircraft was about 15 miles north of Cherbourg at 1005 hours.

(*c*) A smaller force, plotted as 'nine plus,' was 26 miles north-west of Cherbourg at 1009 hours."[4]

These reports were made during the German attack on Portland which was only one of the three main operations on 11 August. The other two were attacks on convoys off Orfordness between 1200 and 1100 hours, and a series of attacks in the Strait of Dover which continued during the whole of the morning.

Attacks on R.D.F. Stations

R.D.F. stations were usually regarded as secondary targets for air attack during war. C.H. stations, with their 350-foot transmitter steel towers and 240-foot aerial array wooden towers, were unavoidably conspicuous but it was not until 12 August that the enemy showed any attention to the Home Chain stations on the south coast. The nature of his attack on that date, however, indicates that these stations were primary targets for attack, though there

[1] A.H.B./IIHI/18, *The Battle of Britain*. Despatch by Air Chief Marshal Sir Hugh C. T. Dowding, A.O.C.-in-C., Fighter Command, para. 54. [2] *Ibid.*, para. 56.

[3] Fighter Command "Y" Form, 11 August 1940. [4] See Map No. 2.

is no direct evidence that the enemy fully appreciated the paramount importance of the stations.[1] The following attacks were suffered by Chain stations on 12 August :—

Pevensey.—At 0932 hours on 12 August three German aircraft attacked Pevensey successfully. Casualties were caused amongst the Army ground defence detachment and consternation was caused amongst station personnel by a direct hit on the N.A.A.F.I. The R.D.F. equipment escaped damage. Power cables were cut but repairs were effected and the station was functioning again during the afternoon of the same day.

Rye.—A quarter of an hour after the Pevensey attack the Chain station at Rye was attacked by six *Me.110s*. All huts were destroyed with the exception of the transmitter and receiver blocks. The normal working of the station was restored within three hours. The diary of a German Lieutenant taking part in this attack was recovered from his body when he was killed on 15 August. This revealed that the R.D.F. station was the primary target. Although not interfered with by A.A. or fighters, their bomb-aiming was affected by a strong wind from starboard and all the bombs fell wide of the main buildings.[2]

Dover.—At the same time as the attack on Rye, Dover was also attacked. Considerable damage was done to the huts inside the compound and slight damage to the aerial towers but no vital damage was done and the station continued to function on emergency equipment.

Ventnor.—At 1140 hours two large German forces over the Cherbourg peninsula began to move across the Channel. These were plotted at "150 plus" and "30 plus." The larger force headed for Portsmouth and subsequently bombed it, the smaller force attacked the R.D.F. station at Ventnor. Just as the enemy bombers commenced to dive on the station from a height of about 10,000 feet our Fighters, Nos. 152 and 609 Squadrons, intercepted them. No. 152 Squadron got to some of the bombers before they released their bombs while No. 609 Squadron engaged their German fighter escort.[3] Ventnor R.D.F. station was nevertheless heavily and accurately dive-bombed by about fifteen *Junkers 88s*. Casualties were fortunately extremely light, one soldier on station defence duties being wounded. The majority of the surface buildings on the station were destroyed, despite assistance from the local fire brigade—lack of water on the site hampered their efforts. Repair work was not immediately possible, the site having to be evacuated owing to the presence of delayed-action bombs.

Dunkirk.—On the same day this station also was lightly attacked. A 1,000-lb. bomb dropped near the transmitter block, two huts were destroyed but there was no vital damage and the station continued to operate.[4]

Pevensey.—A single aircraft, which had been plotted the whole way across the Channel, passed over the station, turned, and bombed from a low altitude on the way back during the afternoon of 14 August. Although the bombs fell within the C.H. station compound and the receiver block was hit, the station remained operational throughout.

[1] Headquarters, Fighter Command Signals Branch, O.R.B., 12 August 1940.
[2] Royal Air Force Narrative *The Battle of Britain*, p. 113.
[3] Consolidated Combat Reports, No. 152 and No. 609 Squadrons, 12 August 1940.
[4] Royal Air Force Narrative *The Battle of Britain*, Appendix III.

On 16 and 18 August raids were made on Ventnor and Poling R.D.F. Stations :—

Ventnor.—This station was still inoperative from the previous bombing on 12 August, and efforts were being made to repair it, when on 16 August, at 1315 hours, it was again subjected to attack. Although good R.D.F. warning had been given of the approach of enemy aircraft, two other raids were proceeding simultaneously on airfields at Gosport and Lee-on-Solent and heavy fighter engagements were occurring in mid-Channel, so the German aircraft reached their objective before they were intercepted.[1] Five *Junkers 87s* dive-bombed the station, seven H.E. bombs being placed successfully in the target area. After this latest attack all buildings except two above ground and those below ground were unusable and the aerial towers had suffered damage. This gap in the Home Chain was not replaced until 23 August, when a reserve mobile station was then functioning at Bembridge on the Isle of Wight.[2]

Poling.—On 18 August at 1400 hours the C.H. stations reported three enemy formations : "80 plus" north of Cherbourg, "20 plus" east of Cherbourg and "10 plus" north-west of Le Havre. These formations reached the coast at 1425 hours and were then two formations of dive-bombers ultimately responsible for the bombing of airfields at Thorney Island, Ford and Gosport and the R.D.F. station at Poling. These formations were intercepted five times by our fighters but pressed home their attacks despite heavy losses. Approximately 90 bombs were dropped at Poling and the station was badly damaged. Emergency mobile equipment was installed but it could not give as comprehensive information of enemy movements as the permanent station had done. Air Vice-Marshal Park warned his Operations Controllers to this effect on 25 August. The actual situation at Poling is a little obscure at this time as the records of the Signals Branch at Fighter Command Headquarters imply that this station was out of action for the remainder of the month.[3]

On 12 August the Air Officer Commanding-in-Chief, Fighter Command signalled the C.H. stations at Dover, Rye, Pevensey and Ventnor expressing his satisfaction and pride in the behaviour of the W.A.A.F. personnel in the face of enemy attack.[4] In his Despatch on the Battle of Britain, Air Chief Marshal Sir Hugh C. T. Dowding comments that the operating personnel of these C.H. stations which were attacked, and particularly the women, behaved with great courage under threat of attack and actual bombardment.

Immediately after the attacks on the south coast R.D.F. stations on 12 August, the Air Officer Commanding No. 60 Group inspected the stations and was delighted with the spirit of the personnel under attack.[5] On his way back to Headquarters No. 60 Group he called at Headquarters Fighter Command to report to the Air Officer Commanding-in-Chief. The latter showed great insight into German psychology when he stressed that in view of the fact that the R.D.F. stations were kept on the air, the enemy would cease his attacks. On the question of more A.A. protection, Air Chief Marshal Sir Hugh Dowding

[1] Royal Air Force Narrative *The Battle of Britain*, p. 188.
[2] Headquarters, Fighter Command Signals Branch, O.R.B., 23 August 1940.
[3] *Ibid.*, 18 August 1940. [4] *Ibid.*, 12 August 1940, and A.H.B./IIHI/18, p. 134.
[5] Personal Diary of Air Commodore A. L. Gregory, A.O.C., No. 60 Group.

was firm in his decision that no more guns would be sent to A.M.E. stations for this would have been at the expense of the A.A. defence of aircraft factories. He amplified this by adding that if five R.D.F. stations were wiped out he could carry on using the mobile reserve, but not if he were robbed of a single aircraft from the factories.

These heavy attacks on the Home Chain stations coupled with sustained attacks on No. 11 Group airfields which occurred during the same period were part of the German plan of an offensive against Fighter Command. Why these attacks were not maintained just as they were seriously affecting the south-east portion of the Chain is not known. After the war a questionnaire on the Battle of Britain was addressed to *Generalfeldmarschall* Milch, former Inspector-General of the *Luftwaffe* and Secretary of State for Air and *Generalleutnant* Galland, who commanded the German *Jagdgeschwader* 26 (about twelve enemy fighter squadrons) during the Battle of Britain. They agreed that they thought that serious damage had been done to one or two R.D.F. stations but that, in general, they considered them to be difficult targets to damage effectively.[1] Neither seemed to realise fully how vitally important were the R.D.F. stations to the Fighter Command technique of interception or how embarrassing sustained attacks on them would have been.

The pool of M.B.2 Mobile R.D.F. stations which was formed as a result of the meeting on 11 May 1940 of the Inter-Services R.D.F. Committee had proved its value in filling the breach made in the Home Chain at Ventnor.[2] The buried Intermediate equipment had acted as a replacement at Poling also.

The damage done to R.D.F. equipment and aerial masts as a result of enemy attacks was studied carefully by Signals staff officers to decide whether any change in policy with regard to dispersal of technical equipment was necessary.[3] In view of the probability of an increasing scale of attack in the future, the Assistant Chief of Air Staff (Radio), Air Marshal Sir Philip Joubert, decided that no more C.H.L. stations were to be erected within half a mile of C.H. station compounds and that the 40 foot gantries used for supporting aerial arrays should only be used in places where there was no high ground available, thus making the majority of C.H.L. stations less conspicuous.

All future C.H.L. stations were to be erected so that they could also cover both high and low-flying aircraft.[4] It will be remembered that they were originally used only for low-flying aircraft. This decision was taken so that the C.H.L. stations might provide some measure of cover against aircraft at all heights in the event of C.H. stations being rendered unserviceable.

Attacks on the North-East Coast

So far, apart from small numbers of night raiders and enemy minelaying aircraft, the Battle of Britain had been fought out entirely in the south of England. On 15 August the enemy tried a change of tactics by attacks on north-eastern districts. The Commander-in-Chief, Fighter Command, believed this new course was taken by the Germans on the assumption that our fighter strength had been withdrawn from the north to meet attacks in the south.[5]

[1] Royal Air Force Narrative *The Battle of Britain*, Appendix No. 37.
[2] A.H.B./IIE/68, Minutes of R.D.F. Inter-Service Committee, 9th Meeting.
[3] Air Ministry File S.3522, Encl. 35A. [4] *Ibid.*, Encl. 43A.
[5] A.H.B./IIH1/18, *The Battle of Britain*. Despatch by the Air Officer Commanding-in-Chief, Fighter Command, para. 195.

A raid of " 20 plus " from Norway was plotted many miles out to sea opposite the Firth of Forth at 1208 hours on 15 August. A second raid of " 10 plus " was observed 20 minutes later and a third of " three plus " was also in evidence, all heading for the Tyne area. Meanwhile a new threat was also detected by R.D.F., some " 30 plus " enemy aircraft making for the coastline 100 miles south, near Scarborough. This latter estimate of numbers proved very low, as the force was subsequently found to be one hundred enemy aircraft approximately. The early warning from the north-eastern Chain stations was ample for successful interceptions to be made. Our pilots claimed over thirty enemy aircraft without loss. A.A. guns also accounted for six hostile aircraft This was the first, and the last, attack on targets in the north-east to be made in daylight during the Battle of Britain. The enemy bombers and *Me. 110* received such a drubbing that the experiment was never repeated. The defences there were on the alert and the Chain stations in that area had made no small contribution to the outstanding successes of our Fighter organisation.

Third Phase of the Battle of Britain, 24 August–6 September

During this phase the German air attack continued. The targets were almost all airfields in the No. 11 Group area, but the more important inland Royal Air Force stations were included in these heavy attacks. Because of the greater distance the enemy aircraft had to fly, the R.D.F. stations were normally capable of giving a longer warning and therefore were generally of even more value to the Controller.[1] The ratio of the number of successful day interceptions by our fighter aircraft to the number of sorties flown was therefore good during this period.

The Germans adhered to their plan of maintaining formations over the Strait of Dover in such strength that the Controller was unable to decide whether or not an attack was imminent despite the R.D.F. information. This difficulty was increased as occasional feint attacks were made by their fighter formations, thus tending to reduce the effectiveness of R.D.F. warnings from the operational point of view.

There was a failure by the R.D.F. to give warning during this period. A small enemy force which crossed the Norfolk coast at 0750 hours on 24 August was completely undetected by R.D.F. and bombed Great Yarmouth. The probable explanation of this failure was the use of the three East Anglian C.H. stations at Canewdon, High Street and West Beckham for an inland-looking watch in addition to their normal watch to seaward.[2] The additional responsibility was cancelled some four weeks later.

Generally, the standard of R.D.F. warning was high. The new C.H. stations on the south-west coast were giving excellent range results, detecting all German formations over the Cherbourg peninsula and giving ample warning to the Controllers of No. 10 Group.[3] Estimation of the numbers in enemy formations continued to be on the low side throughout the whole of this phase of the battle for the reason already given. The heights given by R.D.F. were usually reasonably accurate, and attempts by Controllers and Squadron Commanders to improve on information supplied to them were discountenanced by No. 11 Group Instructions to Controllers Nos. 10 and 12.

[1] Royal Air Force Narrative *The Battle of Britain*, p. 283.
[2] A.H.B./IIE/68, R.D.F. Inter-Service Sub-Committee, 13th Meeting, para 2, sub-para.(*c*).
[3] R.A.F. Narrative *The Battle of Britain*, p. 270.

Fourth Phase of the Battle of Britain, 7–30 September

Instead of continued attack on No. 11 Group airfields and R.D.F. stations which had been anticipated, the enemy changed his tactics on 7 September and began his mass attacks on London. It was on this date that the "Alert No. 1" —invasion imminent and likely to occur within the next 12 hours—was given. The large numbers of aircraft used by the enemy and the numbers of formations employed simultaneously from different directions made detailed R.D.F. reporting very difficult. On 9 September 1940, a comprehensive operational instruction was issued by No. 60 Group to all R.D.F. stations. It required a regular watch to be kept on the vertical gap filler to avoid missing raids; in future, height was to be passed with each plan position in order that the Controller would have more accurate height information, and "Mass Plotting" was to be introduced.[1] "Mass Plotting" was a system of reporting raids by batches or waves instead of by individual aircraft and gave a better picture of enemy bulk activity. It was also called "Macroscopic" reporting, and had been evolved locally and used unofficially by several C.H. stations prior to the No. 60 Group Instruction.[2] Before the official introduction much of the value of this effective "macroscopic" reporting from R.D.F. stations was lost as Filter Room was still trying to filter individual tracks.

On 7 September, 380 enemy aircraft broke through to London to attack the docks area and a series of heavy night raids on London began. The number of aircraft appearing on the R.D.F. tubes was at times too great to be reported by the operator accurately enough to give a clear picture. On occasions the amount of information passed was sufficient to swamp the Filter Room. Fair warning of the approach of raids was being given by R.D.F. stations, however, rarely giving less than 10 minutes' notice before the Germans crossed the coast.[3] More often the warnings were some 20 minutes in advance. But the R.D.F. stations, so at least both the Commander-in-Chief and Air Vice Marshal Park complained, were not giving sufficiently precise information either of plan position, numbers, or height for interception to be certain at this time. Nor was it possible to distinguish between fighter and bomber aircraft. Once the raids crossed the coast the tracking of the raids was bad, for the Observer Corps could not be expected to plot through thick cloud to the 20,000–30,000 ft. at which the Germans were flying.

The use of high flying aircraft put the R.D.F. stations also at a disadvantage. At high altitude the gaps between the lobes of transmission were wider than at medium heights, and continuous tracks of aircraft and formations became impossible to obtain. By the second week in September No. 11 Group attempted to counteract the enemy's high-flying tactics and to supplement R.D.F. information by despatching single reconnaissance aircraft from a Spitfire squadron to patrol at maximum height the usual enemy routes across the coast. Having located advancing hostile aircraft they reported to the Sector Controller by R/T the numbers, composition, route and altitude of the German force. Towards the end of the month No. 421 Flight was formed, fitted with V.H.F. R/T and in direct communication with Group Operations Room, especially for these reconnaissance duties.

[1] No. 60 Group File 60G/S.1/11/OPS., "R.D.F. Operational Instructions."
[2] No. 60 Group File 60G/S.1/AIR/OPS., "Procedure, A.M.E. Stations," Encl. 27A.
[3] R.A.F. Narrative *The Battle of Britain*, p. 481.

Jamming of R.D.F. Stations

Throughout this fourth phase of the battle it is interesting to note that although active reconnaissance of R.D.F. stations was carried out by enemy aircraft, there was no attempt to interfere with the function of the R.D.F. Chain by further bombing of important stations. The enemy now resorted to radio jamming in an effort to neutralise the early warning given by these stations. The first enemy jamming was experienced in September 1940 when Dover C.H. Station was jammed by Frequency Modulated Continuous Wave and Dover C.H.L. Station by short bursts of Continuous Wave transmissions.[1]

Fortunately such an enemy policy had been anticipated, and anti-jamming equipment fitted to the R.D.F. stations. This consisted of the Anti-Jamming Tube and Filters (invented March 1939), the Intermediate Frequency Rejector Unit (invented July 1939), the Intentional Jitter which was able to unlock pulses locked to the mains, and the Automatic Gain Control which cut down the gain at the beginning of the trace where aircraft "echoes" and ground reflections were very strong, leaving normal gain at far ranges where echoes were weak.[2] It was thus possible to plot through the jamming. The effect of the enemy counter-measures on the efficiency of the C.H. stations was very slight, but depended noticeably on the efficiency of individual operators. Canewdon, Dunkirk, Rye and Pevensey also experienced Continuous Wave interference, but continued to work through the jamming.[3] The jamming of C.H. stations was never expected to cause a total failure of the early warning system since it was estimated that the enemy would have to employ some 320 jammer transmitters to jam successfully the number of frequencies in use in the Home Chain. The C.H.L. stations were a more serious problem as only sixteen transmitters would be required to jam the C.H.L. frequencies successfully. At the end of September, the Air Ministry Research Establishment suggested the formation of a specialised body of experts to deal with anti-jamming, in case the enemy persevered with this form of radio attack on the Home Chain.

The Fifth Phase of the Battle of Britain, October 1940

The fifth and last phase of the battle occurred throughout the month of October. This phase saw the decline of the enemy's attacks on London and an increase in the night bombing of London and the arms-producing centres of the Midlands, the aircraft industry in particular being selected for attack.[4] Some idea can be gained of the falling off of the daylight attacks by the fact that of the estimated 9,000 tons of bombs dropped on this country during the month, only 1,000 tons, one-ninth of the total, was dropped by day. Although the German concentration on night bombing relieved the pressure on the day-fighter organisation of Fighter Command, there was little relief for the R.D.F. personnel and Operations Rooms staffs, who were rarely free from intensive work. Adequate warnings were given of hostile raids, but the night defence of London and the industrial centres devolved largely on Anti-Aircraft Command and the Civil Defence Services; Fighter Command operated night-fighter aircraft but had no efficient counter to the German night raider during this period.

[1] Air Ministry File S.44413, Encl. 9B. [2] *Ibid.*, Encls. 27B and 28B. [3] *Ibid.*, Encl. 42B.
[4] R.A.F. Narrative *The Battle of Britain*, p. 545.

The Problem of the Night Raider

During the Battle of Britain period the normal day-time methods of interception was used at night, with searchlights attempting to illuminate and hold the enemy bombers. In June, when the enemy attacked in some strength, six were shot down by our night-fighter aircraft. This attack was, however, made at comparatively low altitude (8,000–12,000 feet) and thereafter the Germans resorted to greater heights where the searchlights became practically ineffective.[1] A further handicap in the air defence system was that the " sound plot " track transmitted from the Observer Corps at night was too inaccurate to be of use for controlled interception by fighter aircraft ; height indications were little better than guesswork.

As the Home Chain stations gave no further information once the enemy had crossed the coast, some ten Army Gun Laying (G.L.) sets were borrowed for inland plotting. Within limited range (about 40,000 feet) this set gave accurate position plots and could read heights to within 1,000 feet at average ranges. These sets were installed in the Kenley Sector on the usual line of the enemy approach to London.[2] The plots were reported by telephone direct to Kenley Sector Operations Room and a much more accurate picture was given of the enemy bomber's position by half-minute plots. The track of the intercepting fighter was obtained from direction-finding by Sector Fixing stations. Unfortunately we had no aircraft really suitable for use as night fighters. Better R.D.F. methods of ground control of interception aids were under development at this time. The month of October saw a quickening of research and experiment in the problem of night defence and the creation of a number of reviewing bodies, notably a War Cabinet committee under the chairmanship of the Prime Minister.[3]

Expansion of the Home Chain during the Battle of Britain

While the Battle of Britain was in progress, the Home Chain was extended round the coast in low power form under the co-ordination of No. 60 Group. During July 1940 one C.H. station at Hayscastle Cross and eleven C.H.L. stations were put into operation at Whitstable, Hopton, Skendleby, Bempton, Carnanton, Tannach, Glenarm, Cregneish, Prestatyn, Strumble Head and St. Twynnels.[4] In August, School Hill C.H. Station and Foreness II, Anstruther, Cromarty and Deerness C.H.L. Stations were opened. In September, Hollingbury, Bride, Scarlet and Newin C.H. Stations and Dunwich, Shotton and Doonies Hill C.H.L. Stations were completed. Branscombe, Trerew and Castell Mawr C.H. Stations and Cresswell, Bamburg, St. Cyrus and Roschearty C.H.L. Stations all opened during October. A total of nine C.H. stations and twenty-two C.H.L. stations was thus erected during the Battle of Britain period. In order to avoid congestion on the filter room table through aircraft or formation from being told individually, it was arranged that these C.H.L. stations would tell to a local C.H. station, where available, which would tell a combined plot to the filter room. During September a new Fighter Group, No. 9, was formed in the north-west area at Preston. The Group had its own filter room to which R.D.F. stations north of Hayscastle Cross reported.

[1] A.H.B./IIH1/18, *The Battle of Britain*. Despatch by the Air Officer Commanding-in-Chief, Fighter Command, paras. 233/4. [2] *Ibid.*, para. 240.

[3] The progress made by this Committee is given in Volume V of this narrative, together with a full account of all the R.D.F. aids to interception.

[4] No. 60 Group O.R.B., July–October 1940.

Value of the contribution of R.D.F.

The air struggle was fought out without any large deviation from the technique of raid reporting and fighter control organisation evolved for defence in air exercises before the war. The battle was unique in that it was the first occasion in the history of warfare on which this scientific and co-ordinated early warning and control system had been employed in a major air battle. The Royal Air Force, though inferior in numerical strength, had the tremendous advantage which this system gave. The *Luftwaffe* was flying without remote ground control during the battle and, as far as possible, flew according to pre-arranged plans. The Royal Air Force fighter aircraft under effective ground control thus had a much greater flexibility of attack than the German fighter screens had in defence of their bomber formations. Whereas the British system of raid reporting was designed to give an economical scale of effort in that it usually avoided the necessity of standing patrols, the German bombers required a constant escort of defensive fighter aircraft which rose as high as five fighters to each bomber aircraft.

The first link in the operational system of control was the R.D.F. stations. This source of information was vital to the defence, and it is one of the mysteries of the battle that the Germans made so few and relatively small efforts to disrupt the R.D.F. Home Chain in the south and south-east of England. The fact that the battle was brought to a successful conclusion is one reason for considering that the Home Chain reporting system fulfilled its function creditably. The performance was remarkable having regard to the short training and lack of experience of so many of the operating and maintenance personnel, and to the difficulties in handling and keeping serviceable equipment which was not, as a whole, in a finished state. A false impression would be created if the minor limitations of the R.D.F. cover were not appreciated, but although the R.D.F. stations occasionally failed to locate an enemy formation, they never failed on a single occasion to locate a major attack. The information they supplied was occasionally imprecise, especially their height-finding and estimations of numerical strength. Nevertheless, the performance of the Home Chain during the Battle of Britain may be assessed from the Despatch of the Air Officer Commanding-in-Chief, Fighter Command, Air Chief Marshal Sir Hugh C. T. Dowding, who said of R.D.F.—" The system operated effectively, and it is not too much to say that the warnings which it gave could have been obtained by no other means and constituted a vital factor in the Air Defence of Great Britain."[1]

[1] A.H.B./IIH1/18, *The Battle of Britain*. Despatch by the Air Officer Commanding-in-Chief, Fighter Command, para. 57.

CHAPTER 11

THE R.D.F. HOME CHAIN, AFTER THE BATTLE OF BRITAIN UNTIL DECEMBER 1941

The successful termination of the Battle of Britain in October 1940 brought considerable relief to the whole country and to the hard-pressed organisation of Fighter Command, of which the R.D.F. Home Chain formed part. The months which followed would not permit of complacency, however, as the initiative still rested in the hands of the enemy. Although the Germans had received a considerable military set-back in the stemming of the *Luftwaffe* during the Battle of Britain, they still had a supremacy in material. Their invasion forces and shipping were intact at the beginning of the winter of 1940. There were no signs that the expected invasion of Britain would not occur at the next favourable opportunity, the spring of 1941.

At the 39th Meeting of the War Cabinet Defence Committee on 31 October 1940, the Prime Minister stated "Our power of survival depends on the maintenance of the life of this island—this postulates continued superiority in air defence and the successful countering of night bombing. That we must keep our sea lanes open goes without saying."[1] The basic principles underlying the need for expansion of the R.D.F. Home Chain conform to Mr. Churchill's statement during the period covered by this chapter, for in broad outline these may be summarised as :—

(*a*) Counter-invasion.

(*b*) More efficient raid-warning ; assisting in superiority in air defence.

(*c*) Development of an adequate western R.D.F. Chain giving increased cover to our western sea approaches.

In common with other forms of Home Defence the R.D.F. Home Chain, as yet far from complete despite its valuable contribution during the Battle of Britain, entered into a phase of intensive preparation to counter possible invasion during 1941. During this vital period when Britain and her Empire alone stood against the might of the German forces, the changes in R.D.F. policy were not governed by the threat of invasion alone. The new experience of mass raids, the continual night raids over London and ranging over the western coasts and Northern Ireland, the wave-hopping low-level attacks against coastal objectives, and the beginning of the Battle of the Atlantic all called for a bold R.D.F. policy. Policy and planning may be bold but their fruition is dependent on production and trained man-power. During the period under consideration in this chapter the climax was reached when the R.D.F. installation programme, fraught with many practical difficulties, seriously lagged behind the policy, and the organisation was strained to the limit.

The Installation Programme, October 1940

Of the many plans which had been made for an increase in the R.D.F. cover consequent upon the fall of France and the occupation of Norway and Denmark, none had been completed by October 1940, although No. 60 Group had forged ahead with the extensions of the Home Chain as quickly as possible.

[1] War Cabinet Defence Committee (Operations), Minutes of 39th Meeting.

Towards the end of September the Group had requested guidance from Air Ministry as to the relative priorities of the outstanding work. Although the operational needs were constantly changing and the installation programme was almost entirely dependent on the progress of Works Services and the supply of technical information by the Experimental Establishments, the following order of priority was laid down :—[1]

(*a*) The completion of the East Coast Chain to two frequencies. It will be remembered that in its " Final " form, this portion of the Chain, including the northern stations, was to be fitted to four frequencies working.

(*b*) In view of the approach of winter and the requirement for improved coverage and height-finding in the west, the item of second priority was the completion of the " Advance " C.H. stage in :—

(i) the South-West

(ii) the West

(iii) North-West, including Castle Rock, Islay and Deerness—in Northern Ireland, the Outer Hebrides and the Orkneys respectively.

(*c*) The commissioning of the " Buried Reserve " which had been planned for the original 20-Station Chain, on stations between Ventnor and Stenigot. This should have been on very high priority but was placed third in order to allow for the supply of technical information and the completion of the Works Services.

(*d*) The fitting of second long wave aerials to the C.H. stations between Ventnor and Stenigot.

(*e*) The fitting of second long wave aerials to stations between Stenigot and Skaw.

(*f*) The fitting of the second short wave aerials of the East Coast Chain.

The C.H.L. stations working at this time had been installed at emergency speed earlier in the year and a technical " clean-up " was necessary in order to standardise and improve them. For example it was hoped to fit automatic turning gear to all of them in place of the hand-operated turning gear. The work on the mobile pool of R.D.F. stations could not be included in any priority list. This had always to contain eight such units which were dispersed at the Radio Maintenance Units. The number requiring building up at any particular time depended entirely on the extent of enemy action.

During October 1940, C.H. stations had been opened at Branscombe, Trerew and Castell Mawr and C.H.L. stations at Cresswell, Bamburgh, St. Cyrus and Rosehearty. In the following month Downderry, Trevescar and Castle Rock C.H. stations and Downhill C.H.L. station were put into operation.[2] Nevertheless, the installation programme was falling badly behind. The Air Officer Commanding, No. 60 Group attributed this to the complexity of the organisation, a large number of authorities being involved.[3] In addition to No. 60 Group there were the Director of Signals, the Director of Communications Development, Headquarters Fighter Command, the Director of Works, No. 2 Installation Unit, the Director of Equipment, the General Post Office,

[1] Air Ministry File S.41234, Part II, Encl. 72A.

[2] Headquarters, No. 60 Group, O.R.B., October/November 1940.

[3] A.H.B./IIE/66, Folder " R.D.F. Organisation—General."

and the civilian firms of Messrs. Pye and Messrs. Metropolitan Vickers. At the end of August an establishment had been made at No. 60 Group for a Chief Engineer of Group Captain rank to assist in the co-ordination of the installation programme but this post was not filled until the 14 December.[1] Shortage of personnel on No. 2 Installation Unit and the Radio Maintenance Units caused delay—unavoidable because of the acute shortage of trained R.D.F. personnel generally.[2]

On 21 December 1940 Air Ministry Signals Staff suggested that much delay in the R.D.F. installation programme was due to lack of co-ordination of the authorities involved.[3] It was suggested that an " R.D.F. Dictator " should be appointed and recommended that No. 60 Group should be made a Royal Air Force Command to give it the necessary powers for co-ordinating the installation programme and to be responsible for the many R.D.F. stations functioning all round the coasts of the British Isles.

Mr. R. A. Watson Watt, as Scientific Adviser on Telecommunications (S.A.T.), wrote a minute to the Secretary of State for Air during the same week calling for an immediate examination of the problem of delays in R.D.F. construction.[4] He pointed out that the effort in the installation of R.D.F. coastal stations had not yet been proportioned to the size and urgency of the programme. Large as the number of individual persons engaged might be, it was relatively small to the need. The six months lateness in the East Coast programme and the rudimentary state of the R.D.F. cover in the West indicated that a more powerful organisation was needed. Stressing that the partial failure in R.D.F. installation was due to planning on too small a scale and to dispersal of interest and effort, he summarised the work involved by stating, " We are attempting to build a radio network several times larger than any other in the world in a time several times smaller than that allowed for building earlier and smaller networks. . . . If we propose to set up all the stations of several B.B.C.s within a few months, would we put the contracts in the hands of a civil engineering firm primarily engaged on other work (as is the Directorate-General of Works), of a public utility company primarily engaged in the daily operation and maintenance of the existing undertaking (as is No. 60 Group), and of an electrical engineering drawing office with a total strength of twenty-six (as has the Royal Aircraft Establishment drawing office concerned) ? " The Scientific Adviser on Telecommunications (S.A.T.) urged that even so late in the installation programme a single engineering enterprise should be found or set up which would have the whole responsibility without division or distraction, of installing R.D.F. stations. The internal R.D.F. equipment—thanks largely to past delays in installation—was now available in quantity which would not limit the rate of completion. This single enterprise would thus feel that it had, with undivided responsibility, the undivided support of all who could implement the War Cabinet instruction for the highest priority for R.D.F.

As an afterthought, in a second Minute to the Secretary of State for Air, Mr. Watson Watt suggested that the Ministry of Aircraft Production be asked to undertake the provision of the complete R.D.F. stations, thus adding construction to their then existing responsibility for design, lay-out, and

[1] Headquarters, No. 60 Group, O.R.B., August 1940.
[2] Air Ministry File S.48327, Folder 123A.
[3] A.H.B./IIE/66, Folder.
[4] A.H.B./IIE/74/2, Under-Secretary of State for Air's Committee on R.D.F. Construction, Minutes, Encl. 2A.

provision ; M.A.P. were to let the whole construction and installation contract, undivided, to a selected major civil engineering firm.[1] Such a revolutionary suggestion focussed considerable attention on the problem of delay in R.D.F. installation. All the authorities involved were in complete sympathy with the objective which the S.A.T. wished to achieve. The Under-Secretary of State for Air urged that any course to be followed should not be arrived at impetuously but should have due consideration and final certainty that it was the one most likely to give what was wanted in the shortest time.[2]

The Air Member for Supply and Organisation (A.M.S.O.) welcomed the relief that the Directorate-General of Works would have received if the proposal to put the R.D.F. installations in the hands of a firm of civil engineering contractors were feasible.[3] But he thought that no consulting engineer existed who could manage the difficulties of this problem and certainly no contractors who could handle all the work. Headquarters, No. 60 Group also pointed out that no firm could be found who were first-class experts in civil engineering, electrical engineering, high-frequency radio engineering and automatic telephone equipment, though large firms could be found who were first-class in one activity or another.[4] No. 60 Group therefore defended the existing organisation in that the best service was being obtained from the best sources. The Group outlined the fourteen stages in the process of producing an R.D.F. station and made suggestions for the improvement and speeding-up of R.D.F. construction.[5] It was stressed that another factor productive of delay was the embodiment in the programme of untried and experimental equipment. This tendency required rigid control.

At a conference on 1 January 1941, the Secretary of State for Air directed that a sub-committee should be formed under the chairmanship of the Under-Secretary of State for Air and including the Air Member for Supply and Organisation, the Assistant Chief of Air Staff (Radio), the Director-General of Works, the Director of Signals, the Scientific Adviser on Telecommunications and the Director of Communications Development, with the following terms of reference :—[6]

(*a*) To consider the best organisation for dealing with long-term problems on R.D.F. construction.

(*b*) To consider the exact nature of the bottle-necks which were checking the work then in hand and the best means of overcoming them.

This R.D.F. Construction Committee were required to report within one week, so urgent was the need for a decision on the speeding up of construction.

At a meeting of the Committee on 6 January the whole field of R.D.F. construction was surveyed thoroughly by the various authorities represented.[7] It was clear that the idea of single units to do R.D.F. work exclusively in the various departments was already taking shape, for this had already occurred in the Works Branch and in the Royal Aircraft Establishment Drawing Office. It was felt that this principle should motivate the whole organisation so that those working on the different aspects of R.D.F. construction would be freed from all other duties and given a single-minded purpose. After detailed discussion on all the causes of delay,[8] the Committee rejected the idea of making

[1] A.H.B./IIE/74/2, Encl. 2B. [2] *Ibid.*, Encl. 1A, para. 5. [3] *Ibid.*, Encl. 6A.
[4] *Ibid.*, Encl. 3A. [5] This outline is given at Appendix No. 5.
[6] A.H.B./IIE/74/2, Encls. 4A and 12B. [7] *Ibid.*, Encl. 12B.
[8] *See* Appendix No. 6 for Minutes of this meeting.

a civil engineering firm responsible for future construction of R.D.F. stations. In order to foster the idea of single responsibility within the authorities concerned, it was considered that the most effective way of speeding up R.D.F. work was by the formation of a special technical committee (subsequently known as the R.D.F. Chain Committee) formed from senior representatives of the different interested departments in the Air Ministry and the Ministry of Aircraft Production. Each representative on this committee had the responsibility of following up his particular speciality in relation to R.D.F. construction so that the committee was invested collectively with the powers previously held by many. The constructional programme provided for one hundred stations in the next fifteen months in England alone, so it was recommended to the Secretary of State for Air that this high-level standing R.D.F. committee should be formed and meet weekly.

The R.D.F. Chain Committee

The R.D.F. Chain Committee was formed on the instructions of the Secretary of State for Air and met first on 17 January 1941. Its broad terms of reference were to review the current position of R.D.F. construction work, to define objectives and agree programmes, to endeavour to stage out the work and arrive at target dates for its completion, and generally to watch progress and co-ordinate the work throughout the different stages.[1] The Chairman of the Committee was the Assistant Chief of Air Staff (Radio), Sir Philip Joubert, and included the Director General of Works, the Director of Signals, the Director of Communications Development, the Scientific Advisor on Telecommunications, a representative of Finance nominated by the Permanent Under-Secretary, Deputy Directors of Home Operations and Planning and a representative from Headquarters, Fighter Command. This committee had a common and collective responsibility for the speeding up of R.D.F. construction, but was not a committee which worked by vote because each representative had his own responsibility and could not be voted down. As a committee it had absolute power as far as the progressing of R.D.F. installation was concerned but it could not become involved in the discussion of radio techniques, which was the responsibility of the Inter-Services R.D.F. Committee.

In the course of the first meeting of this Chain Committee, the whole organisation then existing for the construction of R.D.F. stations was examined.[2] The re-organisation of Signals 4 (the Section of Air Ministry concerned with R.D.F.) was recommended, to form a Directorate of R.D.F. under the Director General of Signals. The strengthening of the Director of Communications Development's Directorate was also considered necessary. The mobilisation of outside firms was found to be possible, Messrs. Metro-Vickers, Marconi, Standard Telephones and Cables, Cossor, and the General Post Office —all were found to be in a position to render valuable assistance in drawings and erection work. Progress reports of the stations under construction were discussed and the supply position of the provision of equipment investigated. Altogether there appeared to have been formed a vigorous means of control which would provide the impetus and drive for accelerated R.D.F. construction. This was essential before April 1941 when the threat of invasion would again be imminent.

[1] A.H.B./IIE/74/2, Encl. 12B, para. 14, and Encl. 17A.
[2] *See* Appendix No. 7 for list of R.D.F. stations existing and projected, January 1941.

Although the drive for a speed-up in the R.D.F. constructional programme had to be produced by Air Ministry, No. 60 Group were to play a significant role in the actual work. Accordingly, in order to strengthen the Group, it was re-organised in January 1941.[1] The Radio Maintenance Units were made self-accounting Signals Wings which were to take over from the parent units the administration of the stations of the Chain. The eight Maintenance Units became Nos. 70 to 77 Wings and shortly afterwards a ninth Wing, split off from No. 76 Wing, came into being as No. 78 Wing. The Wings were based on a geographical division of the whole of the British Isles in much the same manner as the original Radio Servicing Sections had been responsible for C.H. and C.H.L. stations in set geographical areas of the country. No. 60 Group Headquarters and the Wings were given increased establishments to enable them to face the large programme of the completion of existing stations and their responsibilities in the new stations to be opened.

Difficulties in Manning R.D.F. Stations

The many problems which faced Air Ministry in the rapid expansion of the R.D.F. Chain were not only those of construction. It will be remembered that during the autumn of 1940 a shortage of trained R.D.F. personnel was becoming acute and that Air Ministry was giving close attention to the important question of selection and training of personnel for R.D.F. duties.[2] The personnel deficiencies were not only numerical. The Scientific Advisor on Telecommunications had expressed the view that the R.D.F. apparatus was capable of providing better information than the operational crews were obtaining. Both Mr. Watson Watt and the Air Officer Commanding No. 60 Group had suggested the formation of a corps of W.A.A.F. officers of advanced scientific education. At an Air Ministry meeting on 4 October 1940, it was decided to create an establishment on C.H. stations of one Flight Officer and three Assistant Section Officers (W.A.A.F.) per station.[3] The Flight Officers were to be women with University degrees and several years of experience in Physics, and were to act as scientific observers for the Scientific Research Section and to be responsible for the efficiency of operating personnel. The Assistant Section Officers, of less experience though still of graduate standard, some to be recruited from the best of the existing Radio Operators, were to work on a watch system in charge of operations. It was hoped that this latter establishment would check the rate of flow of expert operators into non-radar commissions and offer a career in their own trade. The first Supervisors' Course began in March 1941. This had the essential advantage of having A.M.R.E. Scientists to give part of the course. Personnel of the required educational standard were not always available, but officers of a lower standard were trained successfully.

During the latter part of 1940 such a large programme was envisaged for R.D.F. both at home and overseas that it was realised that the supply of skilled Radio Mechanics in the United Kingdom would be inadequate. R.D.F. Operators could be trained in a period of four weeks but efficient Radio Mechanics required several years of radio servicing experience behind them as a background to specialised work in R.D.F. Signals were therefore sent to the Dominions of Canada, South Africa, Australia and New Zealand to

[1] Headquarters, No. 60 Group, O.R.B., January 1941.
[2] Air Ministry File S.3523, Encl. 8A, and Air Ministry File S.48327, Encl. 13A.
[3] Air Ministry File C.S.14822, "Supervisory Officers—W.A.A.F."

try to recruit suitable candidates as technical officers and airmen mechanics.[1] A similar signal was sent to the British Ambassador in the United States attempting to get U.S. citizens of suitable qualifications to volunteer. On 18 June 1941 the existence of R.D.F. was made public in the House of Commons by the Leader of the House, and on the same day Lord Beaverbrook appealed to America for technicians to form a civilian Technical Corps.[2] The name given to the science of R.D.F. was "Radiolocation."[3] On 23 June, "Radiolocation" formed the subject of a W.A.A.F. recruiting poster in an effort to obtain more volunteers with a sufficiently high standard of education for these important duties.

The formation of a Radio School in Canada was proposed in August 1940 and its organisation was planned. However, at that time the transfer of the Air Training Schools from Britain under the Commonwealth Training Plan was taking place, and Canada had very heavy commitments under this scheme. After giving further consideration to this matter, Air Ministry felt that there was not sufficient justification in pressing the Canadian Government to establish a Radio School.[4] However, in July 1941 No. 31 Radio School opened at Clinton, Ontario, for training Canadian and American R.D.F. Mechanics, these latter being enrolled in the Civilian Technical Corps.

A second R.D.F. School in the United Kingdom was a necessity during the Autumn of 1940 if the expanding Home Chain were to be manned. The figures furnished by the Director of Organisation at the end of August give testimony to this urgent requirement :—[5]

(a) *Existing training facilities at No. 1 Radio School, Yatesbury, for Radio Operators.*

Airmen	126 every three weeks.
W.A.A.F.	54 every three weeks.

(b) *Present strength of Trained R.D.F. Operators.*

Airmen	402
W.A.A.F.	147
Total ..	549

(c) *Requirements of R.D.F. Operators to April* 1943.

Airmen	2,095
W.A.A.F.	1,205
Total ..	3,300

From the estimates available it appeared that by January 1941 there was a requirement for 800 trained personnel. This could not be met unless a second Radio School were formed.[6] There was some indecision about the location of the school, Northern Ireland and Prestwick being considered, but the Royal Air Force Station, Cranwell, was the final decision. The establishment for the school was settled at the beginning of December 1940. Some

[1] Air Ministry File S.48327, Enclosed Folder 123A, Encls. 3A–7A.
[2] *The Times*, 19 June 1941. [3] *Ibid.*, 23 June 1941.
[4] Air Ministry File S.48327, Folder 123A (Encl. 1A) and Encl. 124A.
[5] *Ibid.*, Folder 123A (Encl. 11A). [6] *Ibid.*, Folder 123A (Encl. 22A) and Encl. 126B.

Works Services were necessary and it was not until 10 March 1941 that No. 2 Radio School was formed under the control of No. 27 Group, Technical Training Command, and training commenced. By the end of 1941 it became evident that the output of Radio Operators and Radio Mechanics was exceeding the rate at which they could be absorbed into new R.D.F. stations being erected at home or despatched overseas.[1] Sufficient Radio Operators existed to cover all requirements up to 1 May 1942, and a reduction in intake of personnel into training schools was therefore arranged. For the first time the Home Chain was adequately manned numerically.

The Capacity of the R.D.F. System

Towards the end of 1940 additional attention was given to obtaining the maximum benefit from R.D.F. information derived from the Home Chain reporting system.[2] Examination showed that information was being lost not only at the source but also in subsequent passage through the Filter Room to the Operations Room table. The Stanmore Research Section at Headquarters, Fighter Command, which carried out the examination, was responsible for advising on the organisation and working of the R.D.F. Chain. Their responsibility covered the operation and technical performance of stations both as individual units and as a whole, including lay-out of equipment, procedure, and communication systems. Their field of investigation included filter rooms. They also advised on the selecting, training and efficiency of personnel, and on the general policy concerning the research and production of R.D.F. equipment. In order to enable the reader to appreciate fully the work of the Stanmore Research Section in connection with raid reporting, a brief explanation of the duties of the individual operators and others composing one watch at a typical R.D.F. station in early 1941 is attached at Appendix 58.

The investigations of the Stanmore Research Section were directed primarily towards finding the weakest links in the raid reporting system. It was discovered that the saturation limit, defined as the maximum number of tracks which could be reported in a given time, was reached in the process of telling, and of filtering, much more quickly than at any other point in the system.[3] In fact it was calculated that tellers and filterers could only handle about one-third of the number of tracks which the rest of the system could deal with in the same period of time. Secondly, it was shown that, provided each station had its own telephone line to the filter room, there was no slowing down of information at that link. If, however, one telephone line was shared by a C.H. and a C.H.L. station, a reduction in the flow of tracks became apparent; moreover the hold-up was even greater where two C.H.L. stations shared a line with a C.H., as was sometimes the case. The attempt made at the time of the Battle of Britain to reduce congestion at the filter room by making two neighbouring stations share one line was thus shown to be harmful to the system as a whole. It caused even worse congestion at the reporting station. Arrangements were made, therefore, for every station, whether C.H. or C.H.L., to have a direct telephone line to the filter room with effect from 13 March 1941.

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[1] Air Ministry File C.S. 9742, Encl. 5A.
[2] Air Ministry File S.41234, Part II, Encl. 92A.
[3] *Ibid.*, Part II, Encl. 92A, p. 12.

Improvements at the Filter Rooms

The existing Filter Room at Stanmore was already crowded and incapable of accommodating further personnel around the plotting table. The Research Section had decided that the personnel there were already fully employed in the handling of the incoming R.D.F. information for the No. 11 Group area only, whereas they were attempting to attend to the areas covered by Nos. 11, 12 and 13 Fighter Groups.[1] With the introduction of other improvements recommended by the Research Section at the C.H. and C.H.L. stations themselves, it was anticipated that the output of R.D.F. information from these stations would be doubled in the near future. There appeared to be no escape from this difficulty other than the division of the Filter Room table into units covering smaller areas. It would then be possible to enlarge the scale and redesign the tables so that the required number of filterers could be seated round the enlarged perimeter of each new filtering unit. Since the new tables would each require a separate room, it was reasonable to make the new filtering units correspond to Group areas where these were also convenient from the standpoint of R.D.F. coverage, and to place the new Filter Rooms near their respective Group Headquarters, providing adequate telephone facilities for easy liaison between adjacent Filter Rooms. Other advantages which would attend this re-organisation were :—

(*a*) Closer liaison with the responsible Fighter Groups.

(*b*) Simplification of communications, as the R.D.F. stations would be connected to geographically proximate Filter Rooms instead of all being connected to Stanmore.

(*c*) Increased protection against disorganisation of the whole system by enemy action.

Filter Rooms were already working at Fighter Groups at Box (No. 10 Group), Preston (No. 9 Group) and Kirkwall (No. 14 Group) so there was every reason to anticipate that a similar organisation extended to Nos. 12 and 13 Groups would be successful. Headquarters, No. 60 Group had originally recommended that plotting should be decentralised from Fighter Command down to the Groups as early as June 1940. It was therefore decided in December 1940 to decentralise the Stanmore Filter Room and split it between the Fighter Groups throughout the country.[2] This was in accord also with a scheme to decentralise the Air Raid Warning control from Fighter Command Headquarters to the Headquarters of each Fighter Group.[3] Naturally such an undertaking required considerable time to complete the technical work, largely that of the G.P.O., in the installation of the many telephone lines required. It was not until September 1941 that the division was complete, the Stanmore Filter Room then being used solely for the No. 11 Group area, new Filter Rooms being opened for Nos. 12, 13 and 14 Groups, and another established at No. 82 Group for the Northern Ireland Area.

Improvements at C.H. Stations

Apart from some recommended improvements in the aerial systems by the Stanmore Research Section, the principal scope for increased efficiency in each station was an improvement in the conditions of working.[4] In particular the radio equipment controls required re-disposing to permit the most rapid

[1] Air Ministry File S.41234, Part II, Encl. 92A, Section IV, p. 15.
[2] Headquarters, Fighter Command Signals Branch, O.R.B., December 1940.
[3] Home Office File GEN.93/82, Peck Committee.
[4] Air Ministry File S.41234, Part II, Encl. 92A, p. 19.

and convenient manipulation. Another very important factor leading to slow observing was the time spent in attempting to correlate correctly echoes on the tube with their designated track. This difficulty in matching plots and tracks at the station end of the telephone line imposed a heavy burden on the whole reporting system. Not only did it distract the observer, but it also led to indecision, confusion and waste of valuable time in interrogations to and from the Filter Room. The major improvements required therefore at the C.H. station could be summarised as :—

(a) Some form of " Tracker," which would enable the Filter Room to designate a track on its first plot and to obtain all subsequent plots from the C.H. station with their correct track designation without the need of further interrogation.

(b) The reorganisation of the equipment controls to facilitate the work of the observer and supervisor.

The Tracker

A Tracker was installed in experimental form at Dunkirk during March 1941.[1] It required the addition of a second cathode ray tube installed near the one manned by the observer, and connected electrically to show the same indications. Close underneath the time-base or trace on the second tube, a long roll of paper passed over a thin roller and moved downwards at a slow but constant speed under the power of an electric motor. A range scale was given by equi-spaced vertical lines marked on the paper. Whenever a new echo appeared on the trace, its position was marked on the paper in the appropriate position, and labelled with the letters and numbers designating the particular track as soon as this was received from the filter room. Subsequent movements of the echo along the trace were thus marked at the tracker tube and by drawing a line through successive recordings of the same aircraft, a range-time curve for each track appeared. A movable range marker pointer on the observer's tube was coupled with a similar marker on the tracker tube in such a way that they moved together, and thus the tracker observer should never have been in doubt as to which particular track the reporting observer was working on.

The introduction of the tracker enabled the R.D.F. station to keep a check of all echoes appearing on the tube, together with the filter room designation of the track. Previously the observer had to rely on memory alone when making reports and when answering cross-questions from the filter room. A considerable clarification of work resulted and the track handling capacity of the stations increased. The additional equipment was soon approved for all C.H. stations and installation proceeded during the remainder of the year.

The Console

To facilitate the work of the observer and supervisor, the several pieces of equipment that they were required to manipulate were mounted together as a single unit called, for simplicity, the " Console ".[2] This development went far beyond No. 60 Group's original requirement from which it had arisen ; the proposal being for the addition of a second cathode ray tube as a " sorter " in parallel with the observer's tube. Although this elaboration deferred its introduction, the elaboration appears to have been worth while. The " Console "

[1] Air Ministry File S.41234, Part II, Encl. 92A, p. 21. [2] *Ibid.*, Part II, Encl. 92A, p. 22.

was introduced at Dunkirk R.D.F. station in experimental form in March 1941. So great were the advantages of this new layout of controls that it was immediately termed, unofficially, the " Wurlitzer " by R.D.F. station personnel —a compliment to the easy availability of the controls, suggestive of the cinema organ. The chief components of the Console were :—

(*a*) The second cathode ray tube unit together with its tracker.

(*b*) The plotting map.

(*c*) The horizontal polar diagram of the station on which was indicated the bearings at which the electrical calculator did not read heights.

(*d*) The vertical polar diagrams for various azimuths or bearings which also showed the upper and lower cut-off points on the electrical calculator for the height systems.

(*e*) An improved standby " Manual Convertor " for obtaining heights in case of unserviceability of the electrical calculator.

(*f*) A calculator display panel similar to that on the receiver.

(*g*) A master switch for the use of the supervisor, causing the display " No height " and informing the operator that height could not yet be obtained.

Improvements at C.H.L. Stations

For efficient working the rate of sweep of the rotating aerials had to be increased to a speed greatly exceeding that which was possible by the manual turning gear. Consequently a mechanical drive was required, the speed of which was variable at will to serve both the requirements of the C.H.L. stations with a linear time-base and also those with a radial one.[1] The mechanical drive needed a reserve of power sufficient to maintain operations during high winds. The development of this mechanical turning gear was not without its difficulties as the C.H.L. stations in use were not standard, having been erected during the earlier 1940 programme, the majority with separate transmitter and receiver aerials.[2] The change to mechanical turning of a common aerial for both the transmitter and receiver took place throughout 1941.

Those few C.H.L. stations which were fitted with the Plan Position Indicator (P.P.I.) were proving more efficient than the earlier stations with the normal cathode ray tube horizontal time-base display. The radial time-base of the P.P.I. enabled the operators to give good macroscopic reports and also to pass all other information with considerable thoroughness, since a plan picture of the aerial activity of the whole sector was continuously presented to the observer. The only disadvantage of the method of presentation was that the range was limited to about 60 miles. This was, however, no great drawback since the picture presented by C.H.L. stations was superimposed on the longer range raid reporting of the main C.H. Chain.

Triple-Service CD/CHL Stations

In a consideration of problems connected with defence against invasion, the War Cabinet Defence Committee on 31 October 1940 agreed to recommend that the provision of R.D.F. for detecting enemy surface craft and for coastal artillery should receive a higher priority than was being accorded at the time.[3] The three Services were all considering their separate requirements and it became obvious that a certain amount of overlapping of R.D.F. cover would

[1] Details of this have been given in Chapter 9.

[2] Air Ministry File S.3522, Encls. 60B and 63A.

[3] War Cabinet Defence Committee (Operations), D.O. (40), 39th Meeting.

occur if each Service had its own chain of stations. A letter from the Admiralty to the Air Ministry on 8 January 1941 urged the necessity of co-ordination of the supply, erection and manning of C.H.L. stations since the three fighting Services employed, or intended to employ C.H.L. stations for the following purposes :—[1]

Air Ministry	..	For location of low-flying aircraft.
Admiralty	..	For locating enemy vessels approaching a harbour or passing through a channel.
War Office	..	For locating and ranging on enemy vessels approaching the coast or attempting an invasion.

Up to the beginning of 1941 Air Ministry had erected a large number of C.H.L. stations, some forty-four in all with sixteen more projected ; some of which afforded the Admiralty a part-time service. The Admiralty had erected six stations only and the War Office had not erected any, though a great deal of experimental work had been carried out in connection with siting and design. The Ministry of Aircraft Production had supplied all the radio equipment so far. The Admiralty pointed out the strong similarity between the Naval and Military requirements though there were some differences in detail ; both Army and Navy desired to prevent the enemy from approaching our shores. The Air Ministry had already proved that their C.H.L. stations could meet Naval requirements in the location of surface targets—demonstrated by the part-time service some of these stations were giving for the Admiralty. The Admiralty, therefore, recommended that the Air Ministry, by reason of experience and organisation, would be best suited to undertake all C.H.L. work for the three Services.

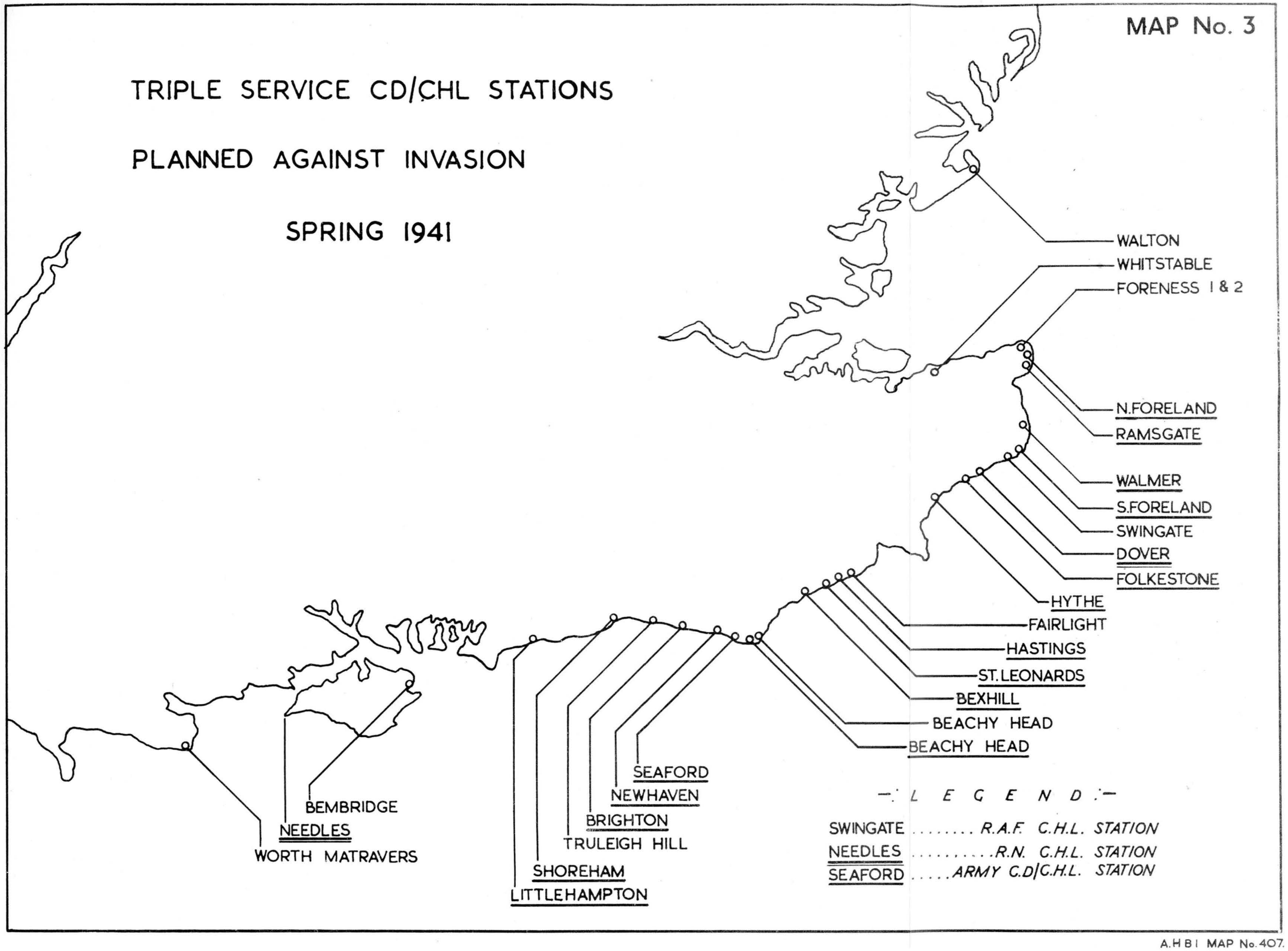
The Admiralty proposal was considered at the sixteenth meeting of the Inter-Services Committee on R.D.F. on 30 January 1941, and after a short preliminary discussion, it was decided to appoint a small sub-committee of six members, two from each Service, under a chairman, to consider the requirements of the three Services with respect to C.H.L. stations and to recommend to the main committee plans to meet these requirements. This C.H.L. Planning Sub-Committee met immediately and submitted an interim report within two weeks. A realistic view of the situation was taken, in that its recommendations were governed by the development which could be undertaken before 1 April 1941, by which date invasion might be imminent. It was the period until the 1 April which was covered by the interim report, thus excluding all considerations of an ideal or theoretical character. Some twenty-four C.H.L. stations were planned to be completed within this period.[2]

The value of the reports from these stations (termed C.D./C.H.L.—Coast Defence/Home Chain, low-looking) would have been rendered nugatory unless accurate and swift filtering was assured. It was considered that this could only be carried out in the nearest Naval Operations Room where it was necessary to maintain plots of all friendly ships, naval, merchant and fishing, round the South-East coast of England. To achieve this it was necessary to fit I.F.F. sets (Identification Friend and Foe) in all naval vessels operating in this area, and there had to be a great tightening up of the reporting and plotting organisation for merchant and fishing vessels.

[1] A.H.B./IIE/68, Inter-Services Committee on R.D.F., Minutes of 16th Meeting, Appendix " A."

[2] A.H.B./IIE/67, " C.H.L. Planning Sub-Committee " (Interim Report).

The locations of the twenty-four C.D./C.H.L. stations erected as a result of these plans are given on Map No. 3.


MAP No. 3
TRIPLE SERVICE CD/CHL STATIONS
PLANNED AGAINST INVASION
SPRING 1941
WALTON
WHITSTABLE
FORENESS 1 & 2
N.FORELAND
RAMSGATE
WALMER
S.FORELAND
SWINGATE
DOVER
FOLKESTONE
HYTHE
FAIRLIGHT
HASTINGS
ST.LEONARDS
BEXHILL
BEACHY HEAD
BEACHY HEAD
SEAFORD
NEWHAVEN
BRIGHTON
TRULEIGH HILL
SHOREHAM
LITTLEHAMPTON
BEMBRIDGE
NEEDLES
WORTH MATRAVERS
LEGEND:
SWINGATE .... R.A.F. C.H.L. STATION
NEEDLES .... R.N. C.H.L. STATION
SEAFORD ..... ARMY C.D/C.H.L. STATION
A.H.B.I MAP No. 407.

fp 138

In addition to the normal Royal Air Force telephone lines to the parent C.H. station, each C.D./C.H.L. station required lines to the nearest Naval Operations Room and separate military lines to the Local Defence Commander and the nearest coast battery.[1] At the station end of these lines it was recommended that two P.P.I.s should be fitted, one for the use of the Royal Air Force operator and the other one for the Army and Navy. This latter P.P.I. was to have a shorter range scale (0–25 miles). Since P.P.I.s were in short supply, a priority list of stations to be fitted was drawn up.

Prior to the proposal of Triple Service Stations, the Army were developing plans for their coast defence stations separately from the Royal Air Force. The total number of C.D./C.H.L. stations now required to cover the British coastline in the final form of a single warning chain comprised :—[2]

Royal Air Force	60 stations.
Army	60 stations.
Total	120 stations.

Despite the seemingly large number of C.D./C.H.L. stations involved, this would be a great economy over the originally projected Army and Royal Air Force separate chains.

The C.H.L. Planning Sub-Committee recommended that trials be carried out with a single suitably-equipped station serving the three Services to test the efficiency of the scheme, a CD/CHL station at the Needles being selected for this purpose. This station, the first of the War Office stations to operate, was ready on 10 June 1941 and was followed by 1 August with twelve more War Office constructed CD/CHL stations.[3] In view of the shortage of trained personnel, the CD/CHL Planning Sub-Committee agreed that initially these stations should be manned and maintained by the Army. When the CD/CHL station at Needles was inspected by two radiolocation specialist Royal Air Force officers it was found to be well below standard for aircraft detection.[4] They recommended that the Royal Air Force should not take over the station from the Army until it was installed to the operational standard required by Filter Room. This policy was adopted and it was the end of 1941 before the transfer of Army CD/CHL stations to the Royal Air Force began. Fortunately the Germans never mounted the threatened invasion, for this CD/CHL station programme was far behind its planned schedule and would not have been of much real assistance in the spring of 1941.

Detection of Very Low-Flying Aircraft

Early in 1941 it was apparent that the enemy appreciated that aircraft could evade detection by R.D.F. by flying very low on their approach to the coast. On the Eastern Scottish coast many attacks were made on convoys and targets near the coast by enemy aircraft flying at heights between 50 and 100 feet above the sea,[5] notably in the neighbourhood of Kinnaird's Head, Firth of Tay, Cromarty Firth and Scapa Flow. The Air Officer Commanding-in-Chief, Fighter Command, drew the attention of Air Ministry to this weakness, pointing out the necessity of developing suitable equipment. The Stanmore Research

[1] Air Ministry File S.45860, Encl. 79A, and Air Ministry File S.3522, Encl. 78A.
[2] A.H.B./IIE/67 (Final Report).
[3] Air Ministry File S.8696, Encls. 1A and 8A.
[4] *Ibid.*, Encls. 24A and 41A.
[5] Air Ministry File S.3522, Encl. 80A.

Section were asked to carry out a detailed investigation of each individual low-flying raid undetected by R.D.F. in order that information could be compiled on the important weaknesses in the existing Chain.[1] In March 1941 the Telecommunications Research Establishment at Worth Matravers was asked to examine all possible methods of improving the range performance on aircraft flying at 50 feet, a 50 mile range being desired, either by modification of the existing apparatus or by the design of new.

Several alternatives were possible to obtain low-angle coverage :—[2]

(a) Using the existing C.H.L. stations, four methods suggested were :—

(i) increasing the effective height of the aerials ;

(ii) increasing the output of the transmitter ;

(iii) using larger aerial arrays ;

(iv) increasing the receiver sensitivity.

(b) Using a much shorter wave-length (ultra high frequency)—requiring a major change in equipment.

Of these methods only one was possible to give immediate results, namely an increase in transmitter power, which was boosted to 200 kilowatts during March. The prospect of increasing the receiver sensitivity was not encouraging, and although it was being studied by various research groups, no satisfactory solution to this problem was expected in under six months. The size of aerial was considered to be ample for practical purposes. Some trouble had been experienced with rotating aerials in high winds, so that any increase in size could only aggravate the problem. The only alternatives were either to increase the height of the aerials or to change the equipment and work on a much higher frequency. Experiments were carried out simultaneously along both these lines.

To obtain increased aerial height, the C.H.L. station could be re-sited on higher ground. However, this normally meant moving further inland, and any increase in height gained would be subject to a loss of coverage due to moving further from the coastline. The only solution was to raise the height of the C.H.L. aerial by the use of a 200-foot tower near to the coast. Such stations became known as C.H.L.(T) stations.

The second method of obtaining low angle R.D.F. coverage by using a much higher frequency, also appeared to be a practical proposition for detecting the very low-flying raider. The development of a new type of valve, the cavity magnetron,[3] by a Birmingham University research group, Professors M. L. Oliphant, H. T. Randall and Mr. H. A. H. Boot, during 1940 had opened up the possibility of R.D.F. transmitters of sufficient power on a frequency of 3,000 megacycles per second.[4] The General Electric Company (G.E.C.) rapidly improved on this valve and went into production.[5] By November 1940 the Telecommunications Research Establishment demonstrated a somewhat primitive form of ultra-high frequency ground R.D.F. equipment capable of following a submarine to 7½ nautical miles from the equipment.[6] By April 1941 the Royal Navy had an improved set of this type, termed the Type 271, in production. This set worked on the very high frequency of

[1] Air Ministry File S.3522, Encls. 82A and 85A. [2] *Ibid.*, Encl. 86B.

[3] *See* Appendix No. 8, " The Development of the Magnetron Valve."

[4] C.V.D. Report, May 1941, " Magnetron Development in the University of Birmingham."

[5] G.E.C., Ltd., Lab. Report No. 8717.

[6] Air Ministry File C.S. 12138, Part I, Encl. 1A.

3,000 megacycles per second and it was considered possible to use it for the Home Chain requirements against very low-flying raiders. The Type 271 used a 4 feet 6 inches paraboloid reflector, giving a sharp beam of some six degrees angular width. In the original equipment, separate transmitter and receiver aerial systems were used and their turning gear was hand-driven. For the Air Ministry requirement it was necessary to develop this along similar lines to the C.H.L. station development, with common aerial working and the addition of mechanical turning gear. Both C.H.L. on high towers and the Naval Set Type 271 were proceeded with experimentally but tests were not carried out until 1942. The remainder of this programme for R.D.F. cover against the very low-flying raider is dealt with in Chapter 16.

Defence of R.D.F. Stations

The attacks on R.D.F. stations during the Battle of Britain had given first-hand experience of their weakness under bombing. There was every reason to expect more such bombings and under the threat of invasion, direct attack by enemy paratroops and saboteurs. As the Buried Reserve would not be available for some considerable time, it was essential for precautions to be taken on the existing stations. The aerial feeder lines were very vulnerable, so all receiver feeder lines had to be provided with earth traverses, and balks of wood and hurdles covered with sandbags or earth were placed across the top of the traverses to protect the feeder lines from rock falling as a result of nearby explosions.[1]

Increasing the height and thickness of blast walls round permanent receiving and transmitting blocks and an improvement in the camouflage of vital points were undertaken to give better protection. Such precautions were not considered adequate for the more exposed stations in the South-East.[2] Certain caves in the cliffs of Dover, at that time used for storing ammunition, were requested for R.D.F. equipment and personnel in order that the vital R.D.F. station at Dover could be maintained in the face of the heavy scale of air attack to which the area had been subjected. If this installation proved successful, further similar systems were contemplated at Beachy Head and Ventnor.[3] Such "Cliff C.H." stations were to have the aerials and reflectors mounted on the face of the cliff: no masts being necessary. After the August attacks on the South-Eastern R.D.F. stations during 1940 the enemy never attacked them again, so the "Cliff C.H." station was not constructed. There was a change in the standard lay-out of the C.H. station from the vulnerable East Coast type of station to the more dispersed type used in the West Coast Chain.

R.D.F. for Northern Ireland and Eire

After the fall of France, although the most direct threat to this country was that of invasion of the South-East of England, there was the danger that the enemy might avoid a frontal attack and attempt to attack this country by a flank movement through Eire. At the 39th Meeting of the War Cabinet Defence Committee at the end of October 1940 the possible German invasion of Eire was discussed.[4] It was agreed that "although the threat of invasion generally was becoming more remote, it is possible that, during the winter months, Ireland might be invaded with the object of increasing the scale of

[1] A.H.B./IIE/168, Air Marshal Joubert's Folder "R.D.F. Station Defence," Encl. 30A.
[2] War Cabinet, Chiefs of Staff Committee, 280th Meeting, C.O.S. (40).
[3] A.H.B./IIE/168, Encls. 45A, 52A, 58A and 83A.
[4] War Cabinet Defence Committee (Operations), 39th Meeting, D.O. (40).

attack on our shipping and Western ports." Plans had therefore to be drawn up by the Chiefs of Staff for the defence of Eire as soon as political considerations permitted access to that country.[1] From the R.D.F. viewpoint the primary requirement was to give cover to the Irish Sea and its approaches, although by December 1940, the Chiefs of Staff had approved that the requirement was for range and height-finding facilities up to distances of 100–200 miles to seaward round the entire coast.[2]

A preliminary reconnaissance showed that to give adequate cover to vital points on the coast of Ireland fourteen C.H. and fourteen C.H.L., stations would be necessary in addition to those stations already operational in Northern Ireland. It was considered that the Observer Corps system as employed in Britain would be impracticable on account of the paucity of communications in Eire and in any event, the possibility of sabotage. Reliance had therefore to be placed on G.C.I. sets inland and a Wireless Intelligence Screen with W/T communications similar to that used during the French Campaign. Some eight G.C.I. sets were estimated to meet this requirement.[3] This project made a heavy call on available equipment, as it had to be operational by March 1941. It was obvious that there would have to be some drastic speed-up in production of equipment or the Middle East R.D.F. programme would have to be retarded. Air Staff had laid down the priority of R.D.F. cover required as :—

(*a*) North Channel.
(*b*) To fill gaps in R.D.F. coverage in St. George's Channel.
(*c*) To fill gaps in R.D.F. coverage in Irish Sea.
(*d*) To provide cover for possible fleet anchorages in the Shannon, Queenstown, Berehaven and Loch Swilly.

Between June and December 1940, some sixty new R.D.F. stations had been erected and manned either at home or overseas. The additional thirty-six R.D.F. stations now requested for Ireland were a commitment which could not possibly be met.[4] To cover the bare requirements laid down by Air Staff, Air Ministry Signals Staff could only offer four mobile R.D.F. units and seven C.H.L. stations with one spare set for each. No G.C.I. stations were available but six were being fabricated for use in Britain and it was suggested that two or three of these equipments would have to be released for Eire. These stations would have provided the minimum cover for the Air Staff plan. All stations were to report to the appropriate sector plotting table by R/T, these sectors having been planned to cover the various regions of Ireland. Each sector was to tell its tracks by broadcast so that the neighbouring sectors could intercept the information.

Meanwhile additional sitings of R.D.F. stations in Northern Ireland and the Isle of Islay were carried out.[5] Since the control of Fighter squadrons during the first phase of any invasion of Eire would be exercised from Northern Ireland, it was essential that this vital base area should have adequate R.D.F. warning. At this time there were two C.H.L. and two C.H. stations working in Northern Ireland. Surveys showed that it was necessary to instal three C.H. stations, four C.H.L. stations, four G.C.I. stations and one Mobile Radio Unit to complete the Northern Ireland R.D.F. cover. The Mobile Radio Units required for Eire were under construction, and the provision of personnel

[1] Air Ministry File S.4990, Encl. 2A.
[2] Air Ministry File S.7464, Minute 2.
[3] Air Ministry File S.4990, Encl. 16A.
[4] *Ibid.*, Encl. 17B.
[5] *Ibid.*, Encls. 20A, 21A, 81A.

to man them continued in February and March 1941.[1] Two M.R.U.s were shipped to Northern Ireland in April, Nos. 245 and 246 M.R.U.s, while Nos. 247 and 248 M.R.U.s also earmarked for this commitment were retained in a Maintenance Unit in England. The latter two M.R.U.s were subsequently released from the Eire programme for duties overseas. To control the development of R.D.F. stations in Northern Ireland, a new Wing, No. 79 Signals Wing, was established on 24 September 1941.

The circumstances which had required the planning of R.D.F. cover for Eire ameliorated towards the end of 1941. During November disbandment instructions were issued for the personnel and material then massed in Northern Ireland, but Nos. 246 and 247 M.R.U.s were retained there and sited to give R.D.F. cover on the N. Ireland/Eire border in February 1942. This period of the threatened invasion of Eire, of some sixteen months duration, had no adverse effect on the development of the Home Chain. It provided a certain small impetus to the rate of production of the equipment but had the disadvantage of deferring for some months the shipment of additional Mobile Radio Units to other overseas theatres.

Further Operational Considerations of R.D.F. during 1941

In addition to the danger from undetected very low-flying aircraft, enemy activity at night was the other most serious threat during the winter of 1940–41. The night attacks on London diminished towards the end of October but a series of raids on the provinces began.[2] Coventry (15 November), Southampton (18 November), Birmingham (12 December), Sheffield (13 and 16 December), Liverpool (21 and 22 December), Manchester (23 and 24 December), Cardiff (3 January 1941), and Swansea (18–22 January) were the chief targets. These towns were raided repeatedly throughout the first half of 1941. London was still a main target, notably on 31 December when there occurred a very damaging incendiary attack; and on 17 and 20 March 1941 when London was attacked by 500 and 400 aircraft respectively. The normal raid strengths varied between 100 and 400 enemy bombers.

The conditions of greatest stress on the R.D.F. system at night were essentially different from those by day during the Winter of 1940–41. Enemy aircraft flying by night crossed our coasts singly, moving in parallel tracks confined to a narrow belt often no more than 10 miles in breadth.[3] These so-called "crocodiles" of enemy aircraft were commonly encountered over the South-East coast and occasionally in the Thames Estuary, and the reporting of detailed and accurate information on them involved considerable difficulties. A typical "crocodile" had the following structure :—

Average speed of aircraft ..	180 miles per hour.
Influx strength	One aircraft crossed the coast every 4 minutes (*i.e.*, 15 per hour).
Typical width	15 miles.
Linear distribution along the "crocodile".	One aircraft every 12 miles on average.
Average superficial density ..	One aircraft per 180 square miles.
Average volume distribution ..	Since the aircraft flew between 10,000 and 20,000 feet, there was an average of one aircraft per 345 cubic miles.

[1] Air Ministry File S. 4990, Encls. 44A, 100A, 107A, 119A and 135A and B.
[2] Headquarters, No. 11 Group, O.R.B.
[3] Air Ministry File S.41234, Encl. 92A.

When a " crocodile " passed near or over a C.H. station the number of echoes on the cathode ray tube with a 100-mile range was $100/12 = 8 \cdot 3$. There were also echoes from enemy aircraft not in the main crocodile. The picture was complicated by echoes of aircraft behind the station and echoes from our own aircraft. Altogether the number of echoes to be examined was hardly ever less than 20 in these circumstances. Experiments had shown that the greatest number of plots, complete with heights, which could be passed under ideal conditions and competently placed on the Filter Room table was about six per minute. In practice the number was nearer three to four plots per minute. Thus to report 20 or more responses on the tube a period of some five minutes was needed. In such circumstances continuous and accurate filtering became difficult and the tracking of individual aircraft obscure.

From our own predicted scale of activity against the enemy it was anticipated that the enemy might propose to send some thousand planes to bomb a limited metropolitan industrial area. Under such conditions the one-dimensional display on a C.H. station cathode ray tube interpreted by microscopic reporting would have been useless.[1] In the spring of 1941 the new system of macroscopic reporting was ordered. This consisted of dealing not with single aircraft but the average properties of collections of aircraft by giving :—

(*a*) the mean plan position and superficial extent of one or more large formations together with their boundaries and progress, or

(*b*) the breadth, direction and strength of one or more " crocodiles ".

The microscopic method of reporting the full details of height, speed, number and direction was only retained for dealing with small enemy formations. The improvement of R.D.F. information as a result of macroscopic reporting played some small part in the general improvement of our night defences, though this was largely due to the maturing of the new G.C.I./A.I. technique. G.C.I. stations were in operation early in 1941 and A.I., Mark IV—the first successful form of A.I. aircraft equipment—was in use in British night fighter aircraft.[2] On the night of 11 May 1941 three hundred and sixty enemy aircraft attacked London and a record number was shot down.[3] After that night, attacks were made in much less strength, and died away at the beginning of July, with the transfer of the major portion of the enemy bomber strength to the Russian front.

Proposals to use C.H.L. Stations offensively

By the middle of 1941 offensive sweeps were being carried out as normal routine by Fighter Command over the French coast. The bombing of selected targets in the occupied countries was also part of Air Staff policy. The possible use of C.H.L. stations for " offensive " operational requirements was under consideration. In such circumstances it was necessary to keep the C.H.L. beam directed on to a " friendly " target rather than to search continuously for hostile aircraft. The aerial turning gear then being introduced was particularly suited to this use. The system suggested was that our attacking

[1] With the introduction of "macroscopic" reporting, the old method of giving information of each aircraft individually began to be known, for the sake of distinction, as microscopic reporting. The literal meaning of the word microscopic has no application in this sense.

[2] The G.C.I./A.I. technique of night interception is described fully in Volume V.

[3] Headquarters, No. 11 Group, O.R.B.

aircraft should fly on a C.H.L. beam which could be locked to pass right over the desired target. The aircraft was to be controlled by R/T and, when its range was the correct distance from the C.H.L. station to the target, bombing instructions could be given. This proposal, made by Mr. Edmund Dixon of the Directorate of Communications Development, was received with interest by the Signals Branch at Air Ministry. A written report of these proposals was requested together with any actual data available, to be laid before Air Staff with a view to obtaining the allocation of some four C.H.L. stations forthwith for this work.[1] This suggestion must be regarded as the forerunner of "Oboe", radio aid to bombing, which is described in Volume III.

Termination of the "Buried Reserve" Chain Programme

It will be remembered that in September 1939 the Chief of the Air Staff had directed that the Intermediate R.D.F. sets of the original twenty-station Home Chain, when replaced by the Main Chain "Final" sets, were to be used for stand-by purposes and housed in buildings which were to be sunk to ground level and turfed over for concealment.[2] This was a long-term policy for the maintenance of serviceability of the Chain stations in face of air attacks which might render their "Final" R.D.F. sets unserviceable. In such circumstances, the personnel would have been transferred to this "Buried Reserve" equipment, situated some 300 yards from the main buildings.

This reserve programme could only be put into effect as each station in the Chain received its final equipment. Even then the amount of work involved in excavations and buildings was enormous, as damp-proof, force-ventilated buildings below ground level were necessary. None had been completed at the time of the Battle of Britain. As a result of the enemy attacks on the south coast Chain stations, No. 60 Group was instructed to proceed with the installation and commissioning of the "Buried Reserve" stations between Ventnor and Netherbutton on high priority.[3] The Chain station at Stenigot was selected as a prototype by No. 60 Group and work began during October 1940. By the end of November the "Buried Reserve" programme had been sanctioned for thirty-seven C.H. stations. In addition 100 per cent. reserves in mobile form for all C.H. stations to be assembled in two pools, one at Sealand and the other at Halton, had been approved by the Treasury.[4] The Air Ministry R.D.F. Panel decided that, without prejudice to the right to provide 100 per cent. reserve mobile installations for the future, this last line of mobile reserves was to be limited to 50 per cent. of the total number of C.H. stations.

By December 1940 the twelve south-west stations between Ventnor and Warren (South Wales) had been included in the "Buried Reserve" programme. Some of the difficulties of implementing it were causing concern. The construction required a very large contractor's effort. The labour available at this stage in the war was only just sufficient to proceed rapidly with the main R.D.F. stations. All the authorities concerned were agreed that effort was not to be diverted from the main stations, so this meant that the "Buried Reserves" were not to be completed until well into 1942.[5] Excavation

[1] Air Ministry File S.8143, Encl. 61A.
[2] This was given in Chapter 6 of this volume. Air Ministry File S.47412, Encl. 168A, also refers.
[3] Air Ministry File S.3859, Encls. 5A, 7B and 21A.
[4] A.H.B./IIE/69, Air Ministry R.D.F. Panel, Minutes of Meetings, July–September 1940, Encls. 5C and 6A.
[5] Air Ministry File S.3859, Encls. 23A and 26A.

difficulties arose, associated with unexpected rock formations requiring blasting, and on some sites the waterlogged ground caused the abandoning of the construction. It soon became apparent that reserve cover could be supplied more cheaply and more quickly by methods other than burying the reserve equipment.

Partial abandonment of the programme began in March 1941 when the decision was taken not to continue with the twelve stations west of Ventnor.[1] Air Staff considered the matter further and on 6 March a decision was taken to abandon the burying of the Reserve equipment of those C.H. stations upon which excavation had not been started, reducing the number by seventeen and leaving the original twenty-station Chain Reserve to be completed. The reserves for the stations not to have a " Buried Reserve " were to be built above ground in a ferro-concrete building and termed " Remote Reserves ". Later, even the " Remote Reserve " programme was cancelled for south-western stations in June 1941.

The prototype " Buried Reserve " station at Stenigot was ready for operation in August 1941 and was put on a one month test to collect operational data.[2] This station had 110-foot towers and generally its operational performance was below that of the main station. Dampness was a constant source of loss of power. The Deputy Director of Radio, Air Ministry, after a visit to the Buried Reserve station at Dunkirk, wrote that he " was very forcibly impressed with the futility of this type of station. It is only just buried and therefore vulnerable to anything approaching a direct hit . . . I cannot see how the Buried Reserve can ever be made dry, and therefore can only assume that they will require considerable maintenance ".[3] The Deputy Director, continuing, recommended that the " Buried Reserve " situation should be reviewed, feeling that with the exception of Dover there was no justification in completing or maintaining a " Buried Reserve " at any other station on the south or east coast.

There was little enthusiasm for the " Buried Reserve " programme by autumn 1941. Most of the original twenty-station Chain had, by this time, their Buried Reserves either completely finished or well on their way to completion. It would have been an act of doubtful wisdom completely to have ignored the thousands of pounds and man-hours spent on these stations as well as the equipment—Post Office, electrical and radio—which had been manufactured especially for them and which could not be put to any other use.[4] To have abandoned the programme altogether at this stage would not have been cutting losses but, rather, a serious waste. As a result, the programme continued into 1942 before completion ; the work was not allowed to compete or interfere with other installation work of the Chain. Throughout 1941 there was a tendency to regard the " Buried Reserve " programme as both extravagant and unnecessary. There are many such references in correspondence on the subject, leading one to query whether the original Air Staff decision on the " Buried Reserve " taken in September 1939 was ill-advised.[5] But the position in 1941 was vastly different from that in 1939. Originally, when the decision was taken, no satisfactory mobile R.D.F. station had been developed whereby gaps in the Chain could have been filled after enemy action. Moreover, it will be recalled that the " Buried Reserve " stations were to be equipped with

[1] Air Ministry File S.3859, Encls. 30A, 33A and 42A. [2] *Ibid.*, Encl. 87A.
[3] *Ibid.*, Encl. 81B. [4] *Ibid.*, Encl. 81A. [5] Narrator's comment.

apparatus thrown up on the conversion from the "Intermediate" to the "Final" state of the Home Chain—a sound and economical proposition. The partial abandonment of the scheme is not an admission that the scheme was ill-advised, rather was it a wise precaution in view of the circumstances at the time.

The Calibration of R.D.F. Stations

In previous chapters on the development of the Home Chain the problem of calibration of C.H. stations has been discussed. Although every effort was made to adjust the rate of calibration by No. 60 Group from the outset, the non-availability of suitable aircraft and crews and the shortage of calibration equipment had slowed down the work. During the autumn of 1940 Air Ministry expressed the opinion that the calibration situation could not be considered satisfactory and, with a view to investigating the reason for this lack of progress, a special conference was called at Air Ministry.[1] Representatives of Air Ministry Signals Staff, the Scientific Adviser on Telecommunications, No. 60 Group, and the Research Establishment met under the chairmanship of the Assistant Chief of Air Staff (Radio). An appreciation of the difficulties of calibration was taken and the necessary action commenced to obtain better-equipped aircraft for the task and the provision of height calibration and other test equipment. The technical aspects of calibration were re-examined by the Director of Communications Development Staff because some of the results were not attaining the standard of accuracy desired.[2] It was pointed out that the cost of calibration was high—approximately £800 per frequency for each station—but that the R.D.F. receiver was not merely an aircraft detection device ; when properly calibrated and in the hands of a skilled operator it was a measuring instrument capable of giving results of considerable accuracy. Full technical details of the necessary steps in calibration were laid down and circulated to No. 60 Group.

The production of the height calibration gear and special oscillators to be carried on the calibrating aircraft was a slow process, and the rate of calibration of stations was falling behind the constructional programme for new stations.[3] The strain on the calibration resources of No. 60 Group became acute during the spring of 1941, and by May 1941 the calibration position had deteriorated. The Scientific Adviser on Telecommunications, Mr. R. A. Watson Watt, pointed out to the R.D.F. Chain Committee that notwithstanding increases in personnel, apparatus and aircraft for the calibration of C.H. stations the position was far from satisfactory.[4] He instanced three particular cases of inefficient calibration and commented that during March, April and May of 1941 it had been necessary to comment very adversely on eleven sets of calibration results. He summarised the causes of inefficiency as—

(*a*) use of low-grade labour in calibrating parties ;

(*b*) lack of supervision by H.Q. No. 60 Group and Wings ;

(*c*) ever-recurring unserviceability of aircraft ;

(*d*) unsuitable methods of calibration ;

(*e*) slackness and irresponsibility of some calibrating parties.

[1] Air Ministry File S.42719, Encls. 55A and 60A. [2] *Ibid.*, Encl. 64B.

[3] Air Ministry File S.B. 11888, Encl. 26B.

[4] A.H.B./IIE/7/1, R.D.F. Chain Committee, Minutes of Meetings, May/June 1941, Encl. 7A.

He pressed for the appointment of a technically qualified officer to visit all parties while at work and that expert instruction be given to calibration parties, who should not be allowed to introduce new calibration methods without prior approval of the Research Establishment.

Headquarters, No. 60 Group defended their position with regard to calibration, pointing out that an increase in calibration of 142 per cent. had occurred between autumn 1940 and spring 1941 and that such calibrations had been carried out under the Group authority as accurately and far more speedily than by the previous authority, despite the fact that adequate resources in aircraft, in equipment and in personnel were not available.[1] It must be borne in mind, in fairness to No. 60 Group's effort, that in no sphere of R.D.F. at No. 60 Group or elsewhere, had the art of calibration reached a stage where errors were not made. Headquarters, No. 60 Group, also emphasised how difficult it was to keep a station at its calibrated performance in face of frequent feeder-line trouble,[2] for which a solution had not been found. Much of the calibration trouble centred in the design of the aerial systems.

A further conference to improve the speed and efficiency of the calibration of C.H. stations took place at Headquarters, No. 60 Group, in July 1941, when the Scientific Adviser on Telecommunications, members of his Department, No. 60 Group representatives and two members of Headquarters, Fighter Command Operational Research Section, discussed calibration difficulties.[3] The autogyro was the most successful aircraft for this calibration but no further supply of this aircraft from America was anticipated, so alternative methods of calibration had to be explored. Other types of aircraft were listed for examination for this task and Mr. Watson Watt undertook to set in train, at the Telecommunications Research Establishment, experiments to try calibration with the aid of A.I. Beacons. The establishment, at Headquarters No. 60 Group, of a special checking section of some ten officers was also recommended to improve the efficiency of this calibration work. Towards the end of 1941 comprehensive and detailed instructions for both calibration and test flights for R.D.F. stations were issued by Headquarters, No. 60 Group and by Headquarters, Fighter Command.[4] Examination of these orders gives some impression of the magnitude of the effort, a minimum of fifty hours flying per station. A system of calibration reports on a weekly basis from Headquarters, No 60 Group, was agreed upon to keep all interested authorities informed of progress. By the end of 1941 the calibration programme, though lagging behind immediate requirements, was at last on a sound basis and could be regarded as satisfactory. The only delays at this period were those due to weather and enemy action.

The Home Chain and Identification Friend and Foe (I.F.F.)

The increased range of frequencies covered by R.D.F. since the outbreak of war extended the problem of identification. Originally the twenty-station Chain had worked on frequencies in the 22–30 megacycles per second band and the airborne equipment called the I.F.F. set had responded to this

[1] A.H.B./IIE/7/1, R.D.F. Chain Committee, Minutes of Meetings, May/June 1941, Encl. 9A.

[2] Even insulation defects due to a deposit of copper dust on the insulators caused by the aerial wire rubbing on them in windy weather was sufficient to upset the calibration.

[3] Air Ministry File S.42719, Encl. 102c. [4] *Ibid.*, Encls. 105A and B, 106A and 111A.

frequency band. The Advance C.H. stations which had been rushed into operation in 1940 worked on the 38–52 megacycles per second frequency band and the Army G.L. sets from 54–82 megacycles per second, to which the original Mark I I.F.F. signal did not respond. Accordingly a Mark II I.F.F. set was introduced, the response of which swept through the 22–82 megacycles per second frequency band and thus showed on C.H., A.C.H., and Army G.L. stations. By November 1940 Mark II I.F.F. had been fitted to "a large proportion of bomber and coastal aircraft" and to four hundred fighter aircraft.[1] The C.H.L. stations and the newly developing G.C.I. (Ground Control of Interception) stations worked on a frequency band of 180–210 megacycles per second and so Mark II I.F.F. did not respond for aircraft observed by such stations. Accordingly a set responding to G.L., G.C.I., and C.H.L. station frequencies, known as the Mark IIG, was made for use chiefly in night fighter aircraft, to distinguish them quickly during night interceptions of enemy bombers, and by the end of 1940 had been installed in a few fighter aircraft.

The need for an I.F.F. set with universal responses whatever the ground R.D.F. frequencies in use became apparent, and on 20 November 1940 the Inter-Services R.D.F. Committee agreed to adopt I.F.F. Mark III, a set operating on a separate frequency band which would respond to all types of ground R.D.F. sets as an identification if they were fitted with suitable interrogator/responsers. Separate transmitter and receiver aerial arrays were to be installed for the new I.F.F. displays on the ground stations, and an interrogator and responser had to be fitted at each station. The interrogator was a small transmitter of 1 kilowatt power only and the responser connected to the additional receiver arrays caused the I.F.F. to be shown on the cathode ray tube. The changes in the I.F.F. equipment in aircraft are mentioned here because the ground Home Chain stations were the controlling factor in these requirements. The story of the development of I.F.F. is recounted fully in another volume.

R.D.F. Construction—Failure of the R.D.F. Chain Committee

With the formation of the R.D.F. Chain Committee in January 1941 (described previously in this chapter) it was anticipated that a speeding up in R.D.F. construction would occur. Under its terms of reference the Committee possessed very wide powers; its composition gave representation to all the interested Departments and it was arranged that it should meet weekly to maintain close control on the progressing of the large constructional programmes. All possibilities of accelerating progress on the R.D.F. Chain were to be explored and the preferred means put into practice. The installation programme which it had to examine comprised some fifty C.H. stations, ninety C.H.L. stations and thirty G.C.I. stations. During the six months up to June 1941, the Committee, instead of meeting weekly, had met only on four occasions; it had appointed no sub-committees and heard no evidence from non-members save for a brief statement from No. 60 Group, and made no detailed examination of specific causes of delay. Twenty-one of the C.H. stations were due for completion on a two-frequency basis before July 1940 but none was yet operational on this basis: all were operating on one frequency only though the importance of this second frequency for C.H.

[1] Headquarters, Fighter Command Signals Branch, O.R.B., November 1940.

stations ranked highly as one of the safeguards against enemy jamming. The C.H.L. programme had certainly made better progress but large-scale modifications were still required before the most effective operational working would be attained.

With so many masters to serve in the matter of installation and maintenance of R.D.F. stations, the Air Officer Commanding, Headquarters No. 60 Group, felt the problem getting increasingly difficult and protested for help. The Scientific Adviser on Telecommunications, Mr. R. A. Watson Watt, who, it will be remembered, in December 1940 had drawn the attention of the Secretary of State for Air to the lack of progress at that time in the R.D.F. Chain, returned to the attack with considerable vigour in June 1941, submitting a Note on the R.D.F. Chain Committee drawing attention to its shortcomings.[1] Of the effective co-operation between the Directorate of Works, the Directorate of Communications Development and No. 60 Group which it was hoped this Committee would bring about, he wrote :—

> "None is authorised to give instructions to the other. None is responsible, even on the individual site, for trouble-finding and trouble-clearing. This is pseudo-democracy run mad ; each constituent element is an autocracy ; it has not even a chairman of Soviet. . . . No one of them insisted on having facilities adequate for the programme. Each has with gallant folly attempted the impossible ; accepting responsibility without power ; using junior amateurs where he might have demanded professionals of high status ; knowing the War Cabinet instructions on the priority of R.D.F., yet submitting to conditions which are ludicrously incompatible with that priority. Each has, less gallantly and with greater folly, assured the committee of the substantial perfection of his own contribution (within the limits of his facilities) and emphasised the imperfections of all the other co-equal partners."

The Scientific Adviser on Telecommunications then proceeded to advocate :—

(*a*) That an engineer organiser of high status, who had himself been in charge of a major engineering enterprise, be requested to examine and report on the provision required in the Directorate of Works, the Directorate of Communications Development and No. 60 Group, or in any combination of parts of them, and on the best means of engineering organisation and co-ordination towards speedy execution of the R.D.F. Construction programme.

(*b*) That this investigator be specially requested to consider the means for reducing to a minimum the proportion of experienced radio engineers required in the undertaking.

(*c*) That War Cabinet authority be sought for implementing his recommendations on staffing and co-ordination, without regard to normal service practice, gradings, remuneration and relativities.

(*d*) That the recommended co-ordinating authority be given access to high authority on material and personnel priority.

Finally Mr. Watson Watt recommended that if the proposal (*a*) above were not approved, the authority of the War Cabinet should be sought for a reduction in the priority of the R.D.F. Chain to accord realistically with the limited effort being applied to its completion.

[1] A.H.B./IIE/7/1, R.D.F. Chain Committee, Minutes, Encl. 13A.

This devastating but belated attack on the existing R.D.F. construction co-ordinating organisation by the Scientific Adviser on Telecommunications at last focussed attention on the necessity for immediate action. His suggestion for an examination of the whole problem of speeding up the Home Chain construction programme by an engineer organiser of high status was accepted. The Secretary of State for Air invited Sir Robert Renwick of the County of London Electric Supply Company to exercise a general supervision of the progress of the R.D.F. Chain and to co-ordinate the various interests in order to ensure that all needless delays were avoided.[1] The last meeting of the R.D.F. Chain Committee, its 6th meeting, took place on 18 June 1941. The proceedings were largely formal and the Committee were notified of Sir Robert Renwick's appointment.

The R.D.F. Chain Executive Committee—Formation

Within one week Sir Robert Renwick had made a superficial examination of the R.D.F. construction position.[2] He proposed vesting his authority in a committee comprising himself as chairman, Mr. R. A. Watson Watt, the Director of Radio, and, when necessary, the Director of Communications Development, the Director General of Works and the Air Officer Commanding, No. 60 Group. This committee, termed the R.D.F. Chain Executive Committee, superseded the R.D.F. Chain Committee. Sir Robert Renwick arranged for the employment of certain specialist individuals, some ten in number, who were engineers and progressing experts of great experience.[3] They were quickly given rank appropriate to their work. It was at this time that Air Ministry announced a 20 per cent. establishment cut in all Home Establishments in order to economise in manpower. The Secretary of State for Air ruled that this cut would not apply to No. 60 Group but that its establishment would be increased to what was required to enable the Group to carry out its commitments. In view of the enormous expansion of the Chain and also a large G.C.I. station programme it was necessary to economise on the installation effort to the greatest degree. Air Staff therefore decided not to continue with the provision of the third and fourth frequencies at the east coast C.H. stations.[4] Three sub-committees were formed to advise the Chain Executive Committee. These were the C.H. Working Sub-Committee, the C.H.L./G.C.I. Working Sub-Committee and the Ground Modifications Sub-Committee.[5] With these sub-committees providing the impetus in their respective specialised portions of the Chain, the R.D.F. Executive Committee remained effective as the driving force behind R.D.F. construction throughout the subsequent development of the Home Chain. At last an organisation had emerged capable of coping with the very difficult programme.

R.D.F. and the Battle of the Atlantic

Mr. Churchill, in his capacity as Minister of Defence, issued a Directive to the Chiefs of Staff on 6 March 1941.[6] In it he stated : " In view of various German statements we must assume the Battle of the Atlantic has begun. The next four months should enable us to defeat the attempt to strangle our food supplies and our connection with the United States. For this purpose

[1] A.H.B./IIE/74/2, R.D.F. Construction—Under-Secretary of State for Air's Committee, Encl. 36A.

[2] A.H.B./IIE/75, R.D.F. Chain Executive Committee, Minutes and Papers, Encl. 1A.

[3] *Ibid.*, Encl. 3A. [4] Air Ministry File S.41234, Part II, Minute 104.

[5] Air Ministry Files S.10379 and S.10380.

[6] Chief of Air Staff Folder No. 637, " Battle of the Atlantic."

we must take the offensive against the U-boat and the *Focke-Wulf* wherever we can and whenever we can . . ." The Prime Minister went on to give the highest priority to all efforts to provide improved defensive coverage for shipping. In the view of the Inspector General of the Royal Air Force, the German *Focke-Wulf* aircraft was to be regarded as a greater menace to our convoys at that time than the U-boat.[1] In addition, intelligence information led to the belief that the Germans were transferring some 200 to 250 long-range bombers (*Ju. 88* and *He. 111*) from night bombing of this country to the attack on our shipping in the Atlantic.[2] Our shipping had been harassed by U-boats throughout the war, but the addition of a heavy air attack on the convoys increased the seriousness of the threat. Although the major counters to these tactics were an increase of armament of our convoys, the increasing use of our own aircraft to provide defensive cover, and attacks on the *Focke-Wulf* and the U-boat at their bases, R.D.F. had a part to play in giving greater cover to the convoys nearing our shores.

The problem was largely one for the C.H.L. Chain. As a short-term measure the improvement of aerial systems and the fitting of a new valve (V.T.98) to replace the old V.T.58 valve, were put in hand immediately.[3] The V.T.98 valve gave C.H.L. stations an increase of four times the V.T.58 power and of 1·4 times the old range. A priority for the C.H.L. stations covering our Western Approaches was given and instructions were issued to fit Plan Position Indicators (P.P.I.) and power turning gear for the aerials. This would inevitably take longer, being dependent on the supply of the equipment direct from production.[4] The efficiency of the new C.H. stations in the South-West and West was also to be improved as speedily as possible. The whole short-term R.D.F. programme to assist in the implementation of the Prime Minister's directive involved :—[5]

(*a*) Installation of 12 new C.H.L. stations.

(*b*) Modifications to 17 existing C.H.L. stations.

(*c*) Speeding up of work of installation or modification of 32 C.H. stations.

The orders of priority were based on careful operational study of requirements made by the Air Officer Commanding-in-Chief, Fighter Command, in relation to the R.D.F. contribution to the Battle of the Atlantic.

Simultaneously with the extension of R.D.F. cover on our south-west and west coasts in Northern Ireland, there was a big extension in the number of airfields in Northern Ireland and the Hebrides.[6] The Prime Minister sent a message to the Chief of the Air Staff from Chequers on 1 March 1941 giving absolute priority to this work. The combined effect of this policy was to increase the effective area over the North Atlantic sea route where long-range fighter cover could be given to convoys. The entire region where *Focke-Wulf* aircraft could operate, from our western ports out through the Northern Atlantic route, was thus protected except for certain regions directly west of Ireland. With characteristic thoroughness, Mr. Churchill wanted a further extension of R.D.F. cover. On 21 March in a minute (Serial No. M.331/1) to the Secretary of State for Air on the subject of the destruction of *Focke-Wulf* aircraft he wrote : "If we could employ R.D.F. methods to find their positions and to

[1] C.A.S. Folder No. 637, I.G. Report No. 145.

[2] War Cabinet Chiefs of Staff Committee, C.O.S. (41) 130 of 3 March 1941.

[3] Air Ministry File C.S. 8143, Encl. 6A, and O.R.S./4/1/2, Encl. 62A.

[4] Air Ministry File C.S. 8143, Encls. 7A, 8B, 9A.

[5] This programme is given in detail at Appendix No. 9. Also in Air Ministry File S.41234, Part II, Encls. 103A-C.

[6] C.A.S. Folder No. 637, "Battle of the Atlantic."

direct long-range fighters or ship-borne aircraft to the attack we ought to be able to inflict serious casualties." The Prime Minister recommended R.D.F. stations on isolated islands in the Atlantic such as Tory Island and Rockall, and on Lough Erne. As R.D.F. ground stations have their maximum value when part of a chain, and as the sites suggested were very inaccessible from the Works Services aspect, the Secretary of State for Air, in his reply, said he thought the most promising line of approach was the provision of R.D.F. ships to control either their own catapult aircraft or long-range shore based fighters. Such ships, fitted with Naval R.D.F. sets giving a range of 30 miles, were already available but investigations were being carried out to fit them with C.H.L. equipment which would increase their range to 50 miles for aircraft flying at 2,500 feet. The provision of ship-borne aircraft was embarked upon almost immediately. The Merchant Ship Fighter Unit was formed at Speke in No. 9 Group for the training and supply of pilots and catapulting of Hurricane aircraft. These were carried on ships known as escort carriers, fitted with R.D.F., and could be employed against enemy aircraft when a convoy had passed beyond the range of shore-based fighter aircraft and R.D.F. cover.[1]

These measures all contributed to the opening phases of the Battle of the Atlantic. In May 1941 we lost 57 ships during the month, whereas 22 were lost during August. In the latter month, indeed, imports continued to come in at a rate of nearly one million tons a week.[2] There was no complacency because of this early success in combating the enemy's attempt to cut our supply lines from America. To increase the range of R.D.F. cover over the Northern Atlantic sea route, C.H.L. sites were selected by R.D.F. reconnaissance parties during December 1941 on the Faroe Islands and Iceland.[3] The provision of these stations, giving cover to the Denmark Straits, and an improvement in the R.D.F. facilities in the Orkneys and Shetlands during 1942 completed the programme of R.D.F. ground stations employed in support of the Battle of the Atlantic. Although we were to face a resurgence of the U-boat menace later, we had, by the end of the summer of 1941, checked it temporarily. In this important success, the ground R.D.F. stations had played a small but not insignificant part.

The development of the Home Chain during 1941, dealt with in this chapter, may be regarded as the most difficult year in the story of R.D.F. during the War. During 1940, there was some tolerance for minor weaknesses which had shown up in this raid reporting system. This may have been due to the relative novelty of R.D.F. warning and the incomplete state of the Chain, but the toleration for shortcomings in the system did not extend into 1941. Those responsible for its development were its most severe critics; there was no complacency. Criticism invariably produced action and out of it the organisation for control, construction, and development of the Chain was overhauled. Alongside this reorganisation of control, there had been equivalent technical progress, not only with regard to the actual equipment but also in the handling and filtering of R.D.F. information. The training of personnel to man the Chain was at last commensurate with requirements and R.D.F. equipment production was, in the main, satisfactory. All these were the outcome of the year 1941 which may be regarded as the turbulent and decisive year in the Home Chain story. By the end of 1941 the effort was proportioned to the size of the R.D.F. undertaking, and was in keeping with the War Cabinet priority allotted.

[1] C.A.S. Folder No. 637.
[2] Air Ministry File C.27924/45.
[3] Air Ministry File S.14124, Part I, Encl. 5A.

CHAPTER 12

R.D.F. IN THE MIDDLE EAST COMMAND, JULY 1940 – FEBRUARY 1943

When Italy declared war in July 1940 the Middle East Command—always important because of its position in relation to our sea communications with the East, became of even greater consequence, having a common front with the enemy in the Western Desert. The defence of the Suez Canal and the Egyptian Delta area was of great importance. This area, together with Palestine, formed a base against enemy hopes of moving eastwards towards the oilfields of Iraq and Iran. The compact nature of the Delta area had suggested a parallelism with the defensive methods used in the United Kingdom, and plans were already in existence for an Egyptian Chain of R.D.F. stations. Four mobile stations were already in operation at El Dhaba, Aboukir, Port Said, and Ikingi Mariut, near Alexandria. This chapter deals with the development of R.D.F. cover and its operational performance in the Middle East Command from the entry of Italy into the war until the defeat of the Axis forces at El Alamein and the advance of well over a thousand miles into Tunisia.

Increase of R.D.F. Cover—Middle East Command

Royal Air Force Headquarters, Middle East, was fully aware of the urgent need to strengthen the R.D.F. facilities of the Command. Urgent signals were sent to Air Ministry during July 1940 requesting additional R.D.F. equipment to be sent out on highest priority.[1] The Mediterranean Fleet anchorages at Alexandria and Haifa gave additional emphasis to the urgent requirement of adequate R.D.F. cover. Alexandria had some measure of R.D.F. early warning from the four Mobile Radio Units operating on the Egyptian coast. There were urgent representations from the Admiralty for protection for the Palestine area, Haifa in particular.[2]

Partly as a result of the various requests for assistance and also in implementation of Air Staff policy, the Assistant Chief of Air Staff (Radio), Sir Philip Joubert, ordered that the following R.D.F. sets were to be despatched with utmost speed, with a request that he should be kept informed of the progress of this programme :—[3]

- (*a*) One M.B.2 Transportable Radio Unit for Haifa to arrive by 14 August 1940.
- (*b*) Four M.B.2 Mobile Radio Units for the Middle East to arrive by 31 August 1940.
- (*c*) One C.O.L. station for Aden, for Bir Fukum.
- (*d*) One C.O.L. station for Egypt, for Alexandria.
- (*e*) One C.O.L. station for Malta, for Valetta.

At least six month's supply of spares was to be sent with each unit. Thirty-two sets of I.F.F., Mark II, for use in aircraft in the Middle East, were also to be sent and eight sets of A.S.V.—R.D.F. used in aircraft against surface vessels —were included for use in Sunderland flying boats. Special high-speed transport was to take the accompanying party, including R.D.F. staff officers, experienced installation officers and technical personnel.

[1] Air Ministry File S.5734, Encl. 44A. [2] *Ibid.*, Encl. 53A.

[3] *Ibid.*, Encl. 47A. The nomenclature of the various types of R.D.F. station for use overseas, together with their purpose and range, is given in Appendix No. 10.

R.D.F. Low Cover in the Middle East Command

No date for the supply of the C.O.L. stations due for despatch could be fixed, as a fully tropicalised C.O.L. equipment had not yet been prototyped. Although the function of the C.O.L. station overseas was exactly the same as that of a C.H.L. station at home, namely the observation of low-flying enemy aircraft, the radio components of the C.H.L. stations in production at home would only stand up to temperate climates. Experiments on the tropicalisation of the C.H.L. station (thus converting it to a C.O.L. station) had been carried out at the Royal Aircraft Establishment, Farnborough.[1] Tropical-type condensers were introduced, internal wiring was modified, and a cooling system of air blowing was used to prevent formation of hot pockets of air inside the set which might cause consequent breakdown of the components. Six C.H.L. sets were partially modified and made ready for despatch in the hope that they would give satisfactory results temporarily until the fully-modified sets were available.[2] The C.O.L. stations were to be placed on sites at least 200 feet high, and there was a scheme afoot for designing C.O.L. aerial arrays on towers for use on flat terrain, but this was not yet practical due to the difficulties in evolving aerial turning gear. Of these six C.O.L. stations, two were to be sent to Aden for use at Bir Fukum and Ras Marshag, one to Haifa for Mount Carmel, and three to Malta for Dingli, Fort Ta Silch and Fort Madelena.

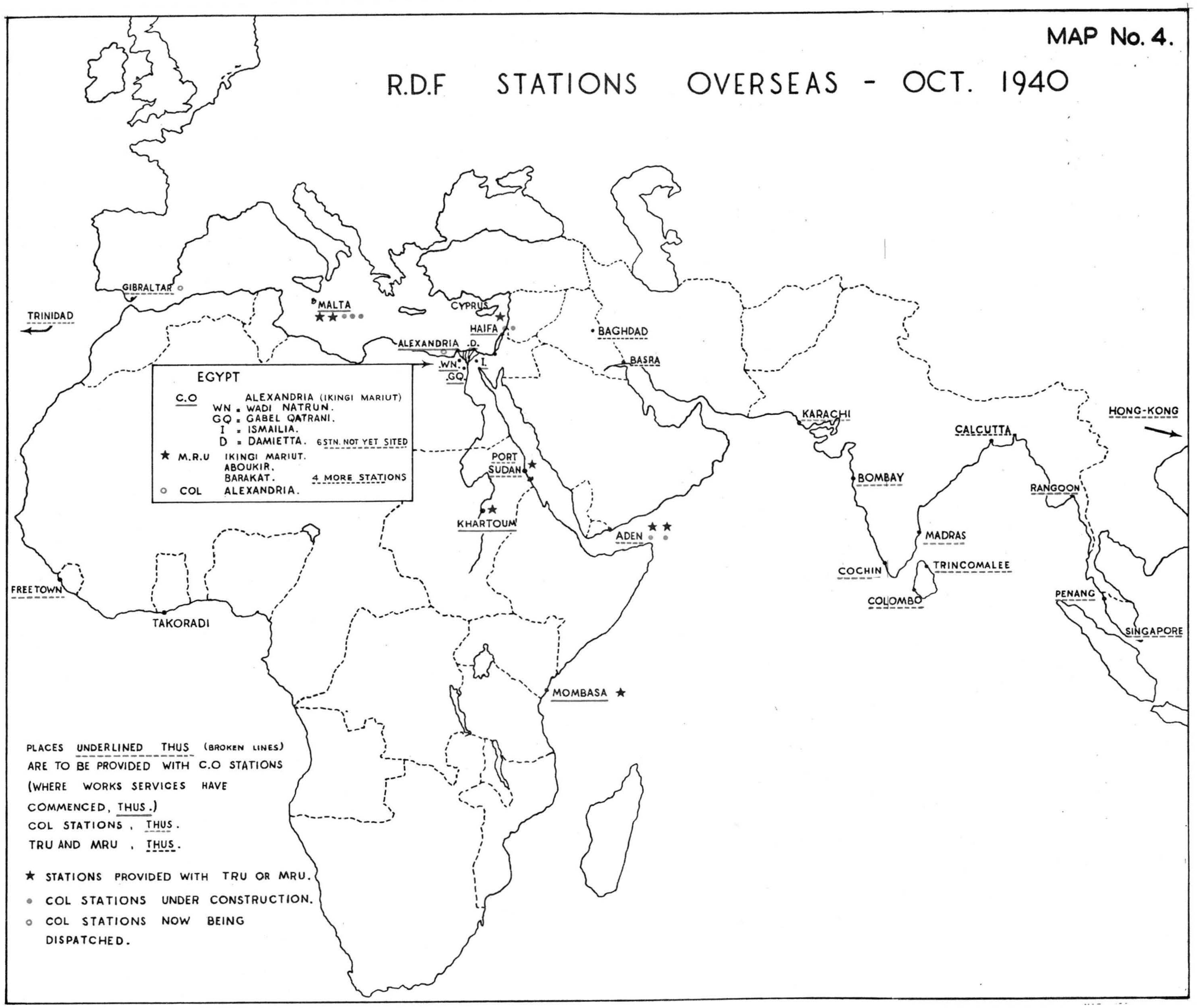
The general policy agreed by Air Ministry was that each C.O. station should be provided with complementary C.O.L. stations. An all-round looking C.O. station required the backing of three C.O.L. stations on an average, in order to give both high and low R.D.F. cover adequately throughout the full 360°.[3] It was for this reason that Malta required three C.O.L. stations as soon as possible.

R.D.F. Stations Planned for Middle East Command—August 1940

The Middle East Command covered a vast area at that time—approximately twice that of the United States of America. In order to present a clearer picture of the progress made in R.D.F. planning within the Command its territories must be considered under geographical sub-divisions :—

(a) *Egypt and the Sudan.*—Permanent installations had been approved by Air Ministry in the form of C.O. stations for Ikingi Mariut, Damietta, Wadi Natrun, a site 25 miles South-West of Cairo, and a site south of Ismailia, to be supplemented by C.O.L. stations at Alexandria and Port Said.[4] An M.B.1 station was earmarked for the defence of Mersa Matruh, to be sited within the defended area on security grounds. Although C.O. stations had been allocated provisionally for both Khartoum and Port Sudan, it was decided that in the case of the latter site a C.O. station would be unlikely to give good results owing to the proximity of the Red Sea Hills, which rise to 7,000 feet. It was therefore recommended that a C.O.L. station with 200-foot towers should be placed on the north side of the harbour where it would have the additional advantage of giving warning of approaching shipping. As little inland cover would be available, it was considered essential to have observer screens in the vicinity.

[1] Air Ministry File S.55153, Encl. 278B.
[2] Air Ministry File S.5734, Encl. 53A.
[3] *Ibid.*, Encl. 105A.
[4] *See* Map No. 4 for locations.


MAP No. 4.
R.D.F STATIONS OVERSEAS - OCT. 1940
GIBRALTAR
TRINIDAD
MALTA
CYPRUS
HAIFA
ALEXANDRIA
D.
WN
GQ
I.
BAGHDAD
BASRA
EGYPT
C.O ALEXANDRIA (IKINGI MARIUT)
WN = WADI NATRUN.
GQ = GABEL QATRANI.
I = ISMAILIA.
D = DAMIETTA. 6 STN. NOT YET SITED
★ M.R.U IKINGI MARIUT.
ABOUKIR.
BARAKAT. 4 MORE STATIONS
○ COL ALEXANDRIA.
PORT SUDAN
KHARTOUM
ADEN
KARACHI
CALCUTTA
HONG-KONG
BOMBAY
RANGOON
MADRAS
COCHIN
TRINCOMALEE
COLOMBO
PENANG
SINGAPORE
FREETOWN
TAKORADI
MOMBASA
PLACES UNDERLINED THUS (BROKEN LINES)
ARE TO BE PROVIDED WITH C.O STATIONS
(WHERE WORKS SERVICES HAVE
COMMENCED, THUS.)
COL STATIONS, THUS.
TRU AND MRU, THUS.
★ STATIONS PROVIDED WITH TRU OR MRU.
● COL STATIONS UNDER CONSTRUCTION.
○ COL STATIONS NOW BEING
DISPATCHED.

(*b*) *Palestine.*—Subsequent to the allocation of a C.O. station for Haifa, a site had been chosen on Mount Carmel. This would have given good ranges and an all-round coverage but would not have been suitable for determining heights. Since Air Defence for Haifa was now under consideration, it was decided that height indication was essential and therefore the C.O. station should be resited on the flat ground to the south of Mount Carmel. As R.D.F. vision would thus be limited to an arc of 180°–360° it was recommended that a C.O.L. station should also be erected on Mount Carmel to provide satisfactory warning along the coast northwards.

(*c*) *Iraq.*—A plan for two MB stations at Basra and Abadan had been submitted to the Air Officer Commanding-in-Chief, Iraq. One station was to provide accurate air information during the last 30 miles of the approach of enemy aircraft and the second station was to fill the gap in the observer post layout, which was caused by the swampy nature of the country. An MB set was also proposed for Khan Bani Saad, about 30 miles from Baghdad, but the Kirkuk and Mosul areas were considered unsuitable for R.D.F.

(*d*) *Aden.*—The non-standard station in operation at Aman Khal in Aden was proving very unreliable. The equipment, which it will be recalled was rushed out just before the outbreak of war, was make-shift and non-tropically finished and replacements were needed urgently. The plan for a C.O. station was changed to two C.O.L. stations and an observer screen, as it was considered that these would give more satisfactory results in view of the nature of the terrain.

(*e*) *East Africa.*—Tentative proposals were made concerning a C.O. station for Mombasa. It was feared that permanent echoes from the coastal hills might prove too great an obstacle and a C.O.L. station might give better results due to its narrow beam. It was recommended that a reconnaissance party should be sent to inspect the area, and if in the meantime an emergency arose, there would be no serious difficulty in setting up an MB station to the north, with an associated observer screen for immediate early warning of the approach of aircraft. Flight Lieutenant J. F. Atherton, a scientific officer well versed in the siting of R.D.F. stations at home and overseas, eventually made a survey of the surrounding country and in his report suggested that a C.O. station should be sited at the disused Bamburi aerodrome, 40–50 feet above sea-level, with two C.O.L. stations, one at Nyali estate to give cover north-east—south—south-west, and the other at Kilifi, 38 miles north of Mombasa.[1] It is interesting to note that the South African Army were providing elementary home-made R.D.F. in this area, giving a range of some 35 miles but with no reliable height estimation for aircraft flying at normal heights.[2]

(*f*) *Malta.*—Although the R.D.F. cover for Malta was more advanced than in any other part of the Command, having two transportable Radio Units, Nos. 241 and 242 T.R.U., giving continuous cover for 24 hours, and with the work on the permanent C.O. station well in hand, the low cover was inadequate and three C.O.L. stations were to be erected as soon as the equipment could be made available.

[1] Air Ministry File S.5734, Encl. 50A.
[2] *Ibid.*, Encl. 51A.

Delay in Implementing Plans for R.D.F. Cover in the Middle East

The R.D.F. Chain for Egypt had been planned originally before the end of 1939. Before an efficient air raid warning system could be developed there, the installation programme had to be completed. This was held up due to the non-arrival of equipment from the United Kingdom. In a letter dated 3 August 1940, to the Deputy Director of Signals, Air Ministry, Group Captain W. E. G. Mann, Chief Signals Officer, Middle East Command, expressed the gravest concern over the delay in the receipt of equipment from the date of its despatch.[1] He feared that R.D.F. and radio communications generally might collapse altogether unless equipment arrived forthwith and, in his opinion, the Air Ministry plan to complete the main R.D.F. chain layout in Egypt by December 1940 was impossible. There was no sign of equipment arriving, and shipment of towers and masts was not possible for at least four months. Part of this delay was due to the long route of the convoys via South Africa. He considered that it was fair to estimate that the organisation would not be functioning for at least another year and that even this was an optimistic guess.

It was difficult to attach blame to any particular person or section for the disorganisation and delay in carrying out overseas commitments. Official comment decreed that R.D.F. reinforcements would be sent "as soon as adequate supplies were available." The time-lag seemed to occur between the proposed date of despatch and the actual date of arrival, and could be anything up to several months. Lack of supervision probably accounted for minor set-backs, for example, the T.R.U. for Haifa was sent deficient of any power supply, as the Navy found it impossible to accommodate two Lister generators. The two C.O.L. stations for Malta and the Mobile Radio Unit for Khartoum were delayed due to shipping breakdown and the personnel were conveyed separately from their equipment, either arriving months ahead as in the case of the personnel for Aden's Transportable Radio Unit No. 304 or becoming lost in transit as did the Officers of this unit.[2] In addition, it was not always possible for a large convoy to stop in order to disembark one R.D.F. set. Every effort was being made to improve this state of affairs, but the United Kingdom at that time was being subjected to the strong enemy air attacks during the Battle of Britain and was making urgent preparations to counter possible invasion, so it could hardly be expected that a rapid improvement in the supply position of R.D.F. equipment for overseas would occur.

The Threat of Vichy French Attack in West Africa and Syria

The attitude of the Vichy Government in France towards Britain was an unknown factor in September 1940. There was every indication that this Government was pro-German. Their forces flanked ours in West Africa and Syria and were therefore a potential threat, not only in themselves alone, for the French colonies had to be regarded as possible enemy bases. Although West Africa did not come under the Middle East Command, being controlled direct from Air Ministry at this time, it is included here because the policy for its defence is so closely allied to our grand strategy for the Middle East generally.

[1] Air Ministry File S.5734, Encl. 58A.
[2] *Ibid.*, Encls. 73B, 88A and 119A. Also File S.1056.

West Africa.—French planes had been sighted over Freetown and Bathurst and the general situation in this area was giving rise to some anxiety over the lack of R.D.F. cover. Pressure of work and heavy responsibilities elsewhere had absorbed the attentions of the few radar experts engaged in siting and installation and no one could be spared for the reconnaissance of the West African sites.[1] Appeals had been made to Air Ministry for four more R.D.F. technical officers and three assistants to be sent out to the Middle East by the most rapid means possible, and these had been promised for the end of September 1940. Meanwhile it was found necessary for an officer, who was being invalided home, to travel via Freetown in order to make a report upon the site there. It was considered difficult country due to its mountainous surroundings and would probably need a combination of C.O., C.O.L. and T.R.U. or M.R.U. stations to ensure all-round cover.

An R.D.F. reconnaissance of the Freetown area, carried out during October 1940, led to the following scheme being drawn up :—[2]

(*a*) Immediate cover was to be provided by two M.R.U.s or T.R.U.s, together with three C.O.L. sets for the detection of low-flying aircraft and ships.

(*b*) Final cover was to be provided by two C.O. stations giving warning and height measurement over 360 degrees, together with the above three C.O.L. stations.

(*c*) An Operations Room was to be provided to utilise the information of aircraft and ship movements obtained from R.D.F. stations and enable counter-measures to be taken.

Further south, on the West African Gold Coast, Takoradi was becoming a port of considerable importance in view of its position as a base for the assembly and delivery of aircraft to the Middle East via the Sudan.[3] This Air Reinforcement Route port required an adequate air raid warning system. Consequently a survey was made during September 1940 in order to investigate the possibility of providing R.D.F. cover and to site the necessary stations. The hilly nature of the district severely restricted the choice of the C.O. station sites, particularly as all-round height measurement was required, whilst the low height of the hills made it necessary for C.O.L. stations to be erected on as high gantries as possible. As a result of this survey the following scheme for R.D.F. provision was proposed :—

(*a*) One T.R.U. and one C.O.L. station for immediate cover.

(*b*) One C.O. station, together with the above C.O.L. station, for final all-round detection and height measurement.

(*c*) An additional C.O.L. station on a 200-foot gantry, when this type of station had been developed.

There were no A.A. or coastal defence guns at Takoradi and the defence would rest solely with fighter aircraft operating from the new airfield north-west of the town. It was therefore considered that a very simple form of plotting table was necessary, to be installed in the Receiving Block of the C.O. station until the arrival of other defences made a more complicated system necessary.

[1] Air Ministry File S.5734, Encls. 83A, 85A, 87A.

[2] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder " R.D.F. Overseas," March 1938–March 1942, Encl. 78A.

[3] Air Ministry File S.6691, Encl. 11A.

Syria.—The defence of the Syrian border was of much importance. It was decided that if two more C.H.L./C.O.L. stations could be made available, one should be placed on the low site east of Mount Carmel, and one should be kept in reserve.[1] Approval was given for these to be despatched in November 1940.

Amended Policy for R.D.F. Overseas, October 1940

The full implications of the threat of the Vichy French territories and the Italian colonies as bases for enemy offensives were quickly realised after the fall of France. Japan, though neutral, was so pro-German that it was necessary to give special attention to the supply of R.D.F. equipment to India and the Far East. The acute shortage of R.D.F. equipment and trained personnel to man it called for frequent reviews of the priority of installation at the various overseas sites already selected. The Inter-Service Committee on R.D.F., in a memorandum to the agenda of its fourteenth meeting on 3 October 1940, had to make further amendments to the order of priority of C.O. stations.[2] Takoradi was added to the list as a result of recommendations of the Port Defence Committee but it was considered that a T.R.U. or a C.O.L. station would suffice for the time being. The amended list was as follows :—

Inter-Service Revised Priority List

1. Alexandria (Ikingi Mariut).	12. Kilindini (Mombasa).
2. Damietta.	13. Khartoum.
3. Gebel Qatrani.	14. Port Sudan.
4. Wadi Natrun.	15. Singapore.
5. Ismailia.	16. Takoradi.
6. 6th Egyptian station.	17. Trinidad.
7. Malta.	18. Hong Kong.
8. Aden.	19. Trincomalee.
9. Freetown.	20. Rangoon.
10. Gibraltar.	21. Colombo.
11. Haifa.	22. Penang.

Although Works Services had not yet been commenced at Stations 6–10 despite the fact that Stations 11, 12 and 13 were well under way, it was decided that Stations 6–10 should retain their present order in view of their importance.

The urgent need for C.O.L. aerial arrays on towers was discussed and a request made to the Director of Communications Development that research on this equipment should be speeded up considerably as good low coverage was lacking in the low-lying coastal areas of Egypt.[3] The type of C.O.L. set in use gave a very poor performance if erected on a 40-foot site such as El Sab Fort, Aboukir.

Nine C.O. stations, five for Egypt and the remaining four for Haifa, Khartoum, Port Sudan and Mombasa, were scheduled to be completed within the next six months. In the interim it was intended that R.D.F. cover should be improved within Middle East Command by an increase in the number of mobile R.D.F. stations.[4] Four M.B.2 stations were in the process of being despatched from the United Kingdom to Mersa Matruh, Aden, Mombasa and Khartoum. Four more M.B.2 mobile stations and three C.O.L. stations were

[1] Air Ministry File S.5734, Encls. 93A, 95A.
[2] A.H.B./IIE/68, Minutes of Inter-Service Committee on R.D.F.
[3] Air Ministry File S.5734, Encl. 74A.
[4] *Ibid.*, Encl. 103A.

in the course of preparation and were to be ready for despatch by the end of November. Building had already commenced to house the C.O.L. stations at Malta, Haifa and Aden.

Meanwhile the islands in the Eastern Mediterranean were not being overlooked. Middle East Headquarters was proposing to carry out an R.D.F. reconnaissance of Cyprus with a view to placing a mobile station on the south-west part of the island, in order to obtain better early warning of Italian air attacks from the Dodecanese islands. Mobile equipment was also being considered for Crete.

Review of R.D.F. in the Middle East Command—October 1940

From the Inter-Service R.D.F. priority list for R.D.F. stations, in which Middle East Command took absolute priority, and from the flow of mobile R.D.F. equipment to this theatre straight from production in the United Kingdom, it can be seen that there was every indication of a great increase in the R.D.F. facilities within the Command. It is difficult, within this welter of proposals and policy, to appreciate the actual R.D.F. cover available at that time without recapitulation.[1] Installed in buildings as a preliminary provision for the fixed C.O. stations, the equipment of which was not anticipated to be available before May 1941, there were mobile sets at :—

	Type.
(*a*) Alexandria (Ikingi Mariut)	M.B. 1.
(*b*) Aden	M.B. 1.
(*c*) Malta	Two M.B. 1.
(*d*) Haifa	M.B. 2.

In addition, fully mobile equipment in vehicles was in operation at :—

(*e*) Ikingi Mariut (supplementary to the original M.B. 1 in order to give 24 hours daily operation)	M.B. 1a.
(*f*) El Dhaba	M.B. 1a.
(*g*) Aboukir	M.B. 1a.
(*h*) Port Sudan	M.B. 1a.

With so few stations in such a vast territory it was inevitable that from the operational view point the outlook was very parochial. Each area under R.D.F. cover was relatively small and was run according to the views of the local commander. Controlled interception, either by Sector controlling or directly from R.D.F. stations, was little practiced. Too much reliance on R.D.F. cover, which was necessarily limited by the paucity of equipment, might indeed have been unwise. In some cases recourse was had to patrolling as the safer method.[2]

Operations Rooms, as in use in the United Kingdom, did not exist and the question of mobility for operations in the Western Desert at first proved a stumbling block to any permanent organisation. Filtering of R.D.F. information could not be compared with the system in use at home, as the plots of the Middle East stations rarely overlapped, making it impossible to obtain range cuts. A Filter Room was in operation at No. 256 Wing Headquarters in Egypt, but it was regarded more as an Information Centre. Communications were difficult and insecure so that complicated codes were in use, and consequently there was an appreciable time-lag on information. Height estimations

[1] Locations and details of R.D.F. stations operating and under construction overseas in October 1940 are given in Appendix No. 11 and Map No. 4.

[2] Air Ministry File S.5734, Encl. 101c.

from the R.D.F. stations were both rare and inaccurate and the Controllers were untrained and inexperienced. The maximum of R.D.F. information was not being obtained from the stations themselves as many of the R.D.F. operators being posted overseas were poorly trained—despite the fact that they had been given a refresher course before they embarked from England. A scheme of local training had to be evolved in the Middle East. Thus the stinted time allotment for basic training in the U.K., designed to speed up the manning of operational stations, failed to achieve its aim and, furthermore, loaded Headquarters, Middle East, with a big commitment which it was not designed to accept.

The Formation of a Separate Radio Branch at Headquarters, Middle East

The establishment for Headquarters, Middle East, had been increased to provide for a Wing Commander to act in an advisory capacity on R.D.F. to the Air Officer Commanding-in-Chief.[1] Wing Commander J. A. Tester was appointed to this post and immediately commenced a vigorous drive to improve the R.D.F. facilities. For the first year of the war all R.D.F. matters came within the province of the Signals Branch in the Middle East. Owing to the growth of the R.D.F. organisation, the special nature of this work, and the rapid expansion which was envisaged with the impending flow of equipment from Britain, it was considered essential to establish a completely separate Radio Branch—though this move was not accomplished without opposition and was without official approval of the Air Ministry. Once convinced of the advantages of such an arrangement, the Chief Signals Officer himself gave weight to this argument, and the Radio Branch came into being in October 1940—in good time to face the heavy programme of R.D.F. expansion in the Middle East.[2]

Establishment of a Branch of D.C.D. in the Middle East

A branch of the Directorate of Communications Development, Air Ministry, was established in the Middle East, in December 1940, attached to the Radio Branch at Headquarters. It was to deal purely with technical matters and in particular with the supply of spares which was causing great concern.[3] It was anticipated that this addition of experienced D.C.D. technicians to the Headquarters would lead to greater co-ordination in the development of R.D.F. facilities in the Middle East. This was certainly borne out in practice when the Middle East D.C.D. staff were working in conjunction with the Radio Installation and Maintenance Unit; the portable R.D.F. pack sets and the increased mobility of the C.O.L. stations resulted from this co-operation during 1941 and were subsequently used with success on operations.

Formation of the Radio Installation and Maintenance Unit (R.I.M.U.)

Following on the re-organisation of the Radio Branch in the Middle East, a Radio Installation and Maintenance Unit was formed on 14 December 1940.[4] With an establishment of 13 officers and 99 airmen (reduced to two officers and 15 airmen on its formation) its object was the installation of A.M.E. Stations and maintenance of R.D.F. equipment (both airborne and ground) in the

[1] Air Ministry File S.5734, Encl. 101c.
[2] Headquarters, Middle East, O.R.B., 10 October 1940.
[3] Air Ministry File S.44211, Encl. 105A, Headquarters, Middle East, File S.50530/R (now A.H.B./IIE/188/13), and Air Ministry File S.5734, Encl. 153A.
[4] No. 1 R.I.M.U. O.R.B., 14 December 1940.

Middle East Command. Its first concern, however, became the collecting and sorting out of missing technical equipment. Supplies had been arriving from the United Kingdom unchecked and badly labelled, so that parts were lost and mislaid. Cases had been known of equipment being unloaded at the wrong ports. With the acute shortage of every type of technical apparatus in this theatre, it was vital that wastage through such causes should be eradicated as soon as possible.

Personnel were arriving to man the A.M.E. Stations—many of which were still in transit. It was therefore suggested that the R.I.M.U. could be utilised as a pool for these surplus operators and it soon became a reception depot.[1] Here the men were reformed into units as the equipment became available. Many of them still had several months to wait before they were sent out to an operational site, but at least there was some sort of attempt by the R.I.M.U. to organise the flow of man-power. It was also under the aegis of this unit that a school was set up to train the airmen, newly arrived from the United Kingdom, on the mobile and transportable types of equipment they would be using. Some idea of local conditions was given to impress upon the men the need for a change in mental outlook from their previous experience in the relative comfort of Home Chain stations.

War Cabinet's Concern over Greece

On 1 November 1940 the Secretary of State for Air, who was visiting the Middle East at that time, sent a signal to the Prime Minister emphasising the imperative need for reinforcement in that area.[2] The Air Officer Commanding-in-Chief, Headquarters, Middle East, had informed the Secretary of State for Air that, in the event of serious military operations developing, the Royal Air Force was not in a position to give the Army any really effective help. Although up to that time the Italian bombing had been singularly ineffective, there was a real danger of heavy attacks becoming imminent over the crowded cities. The Secretary of State for Air paid tribute to the brilliant tactical skill of the small groups of Fighters and Bombers in operations against the Italians, but pointed out that the weakness of the Royal Air Force in the Middle East would become a major issue which might have the gravest consequence.

Between October and November 1940 the defence of the Middle East became a subject for discussion at several meetings of the War Cabinet Defence Committee, particularly with regard to affording assistance to Greece.[3] On 17 October 1940 the Committee requested the Air Staff to review the position of R.D.F. in the Middle East and on 5 November 1940 a report was approved containing proposals for establishing a fleet refuelling base in Suda Bay and advanced landing grounds in Crete.[4] A scale of reinforcements needed to carry out this scheme was outlined, and included R.D.F. equipment. On 6 November 1940 the Air Staff were again invited to examine the possibilities of providing R.D.F. equipment for Crete at the earliest possible moment. Although extremely short of supplies, Headquarters Middle East, was preparing a plan for operating R.D.F. at Athens and in Crete, using sets now existing in the Middle East plus those which it was hoped would be sent in the Greek reinforcements convoy if space in the ships could be made available.

[1] No. 1 R.I.M.U. O.R.B., 12 January 1941. [2] Air Ministry File S.5734, Encl. 108A.
[3] Confidential Annex to D.O. (40), 39th Meeting of the War Cabinet Defence Committee.
[4] Chiefs of Staff Papers, C.O.S. (40) 352, revised copy of C.O.S. (40) 903 of 11 November 1940, and C.O.S. (40) 26th Meeting (Operations).

Practical Aid for Greece from Headquarters, Middle East

A siting party was sent immediately to Greece and Crete and instructions were issued to divert M.R.U. No. 221, which had arrived by this time for installation at Khartoum.[1] Reinforcements in the shape of one Hurricane Squadron, two Wellington Squadrons and two Mobile R.D.F. Units were promised by Air Ministry as replacements for any forces sent to Greece from the Middle East. In the light of future developments, the reinforcements thus allocated seem somewhat inadequate, but it must be remembered that our industrial effort at home had by no means reached its peak and there were many demands on the small amount of equipment and transport available.

In view of the immediate urgency, it was decided to transfer the M.R.U. No. 252 from its operational site at Sidi Barakat to either Port Said or Crete and to replace it by a C.O.L. station as the site was particularly suited for this type of equipment.[2] A number of C.O.L. stations had finally reached the Middle East and were about to be despatched to Aden, supplemented by an M.R.U. and full crew. A suggestion was made to recall this latter equipment, for use at Khartoum and to dispense with the idea of a C.O. station at Aden until further research had been carried out on a new type of aerial array.[3] The question of a siting reconnaissance for Cyprus was still outstanding and as soon as this could be arranged an M.R.U. station was to be erected on the island and was to report information straight to Haifa.

Siting Difficulties Encountered in Crete

By the middle of December 1940 the Admiralty were making anxious enquiries as to the existence of R.D.F. in Suda Bay. The reply received from the reconnaissance party in Crete was not, on the whole, very reassuring.[4] M.R.U. No. 252 had been placed temporarily at Aroni on the north side of Suda Bay, its final location to be Maleme; and a second M.R.U. was expected for use at Heraklion. There were very few possible sites in the area and out of these there was no site really suitable for an M.R.U. or a C.O.L. station. They were either too low or surrounded by hills which would cause large permanent echoes, and all suffered from extreme difficulty of access. Complete protection of Suda Bay was therefore impossible, and short-range warning only could be given. There were no suitable R.D.F. sites on the western end of the Island, but an efficient observer system was in operation. It was pointed out that even in the event of fighter aircraft being available, interception would be very unlikely with the type of R.D.F. gear then in use.

Development of a Small Portable R.D.F. Set in the Middle East

The Mobile Radio Units (M.R.U.s) were mobile only in the sense that they could be moved from one site to another on their appropriate motor transport. The degree of mobility of such stations during a campaign was really insufficient, as they took some four days to erect. In addition, on difficult terrain such as the mountainous regions in Greece and Crete, where the roads were particularly bad, many suitable sites were inaccessible to the heavy motor transport of these M.R.U.s. Finally, when a suitable site had been selected and the M.R.U. was set up there, no cover was given against low-flying enemy aircraft.

[1] Air Ministry File S.5734, Encl. 115A.
[2] *Ibid.*, Encl. 112A.
[3] *Ibid.*, Encls. 117A and 118A.
[4] *Ibid.*, Encls. 132A and 138A.

These disadvantages of the M.R.U.s under campaign conditions stimulated the Radio Branch at Middle East Headquarters to develop a small portable R.D.F. set, quite independently of any technical developments at home.[1] This equipment consisted of an aircraft A.S.V. set used on the ground with a locally-designed aerial system. In its preliminary stage it gave ranges of 18 miles on an aircraft flying at 2,000 feet and 24 miles at 6,000 feet using an effective aerial height of only 15 feet. The whole equipment was designed for mule transport in the event of good motor roads not being available. By March 1941 two such sets were in use in Crete as satellite stations to the Mobile Radio Units in order to give adequate low cover. Sited on hills, they were surprisingly successful, giving 25-mile ranges on low-flying aircraft. Plans of the design of these sets were sent back to the United Kingdom to be prototyped for general production. Subsequently the first models of this equipment produced at home were unsuccessful, having inadequate range, though ultimately this apparatus was developed into the satisfactory Type 6 Station.

The Axis Bid for Supremacy in the Central Mediterranean

Towards the end of 1940 the enemy decided to make an effort to establish supremacy in the Central Mediterranean. During January 1941 German aircraft arrived in Sicily and began to operate against Malta and our Mediterranean convoys in support of increased enemy submarine activity.[2] Serious toll was taken of Naval convoys and the passage of shipping through the Western Mediterranean from Gibraltar was so dangerous that it became obvious that the Admiralty would be unable to ship any further R.D.F. equipment direct from the United Kingdom to Malta.

Appreciation of R.D.F. Cover in Malta

To safeguard their lines of communications from Italy to North Africa, the enemy undertook a steady aerial offensive against Malta. Radio-location could play a decisive role in the defence of such a compact target as that which Malta presented to enemy aircraft operating from Sicilian airfields. In order to appreciate the R.D.F. cover available in Malta it is necessary to recapitulate briefly the facilities which had been installed there. Until December 1940 the Island was protected solely by Transportable Radio Units Nos. 241 and 242 at Fort Dingli, working alternately throughout each 24-hours period and receiving some assistance from one G.L. set which came on the air when tracks were picked up by these A.M.E. Stations.[3] The object of the G.L. set was to cover that area within the permanent echoes of the A.M.E. Stations. Although sited within 3,000 yards of each other T.R.U.s Nos. 241 and 242 had slight but important differences in performance resulting in varying gaps in the R.D.F. screen. Enemy formations flying at approximately 20,000 ft. were normally detected at 65–75 miles. On No. 241 T.R.U. these raids faded between 35–28 miles but this caused no serious operational drawback. On No. 242, however, the fading area was between 50–39 miles, a most inconvenient distance since it

[1] Air Ministry File S.5734, Encl. 182A.
The M.R.U. had a very unwieldy establishment of "specialist" personnel involving equally unwieldy impedimenta. The Middle East Command developed the policy of having the minimum number of men, each trained to do almost all field jobs—driving, cooking, defence, and operating—for the manning of its improved small portable R.D.F. That, as much as the facilities offered by the new stations, accounted for their remarkable mobility.
[2] *Ibid.*, Encl. 114A, and A.H.B./IIE/70, D.D. Ops. (Overseas) Folder "R.D.F. Overseas", Encl. 63A.
[3] Air Ministry File S.47124, Encl. 131A.

covered the period during which fighters had to be flown off if interceptions were to be made. The addition of another receiving aerial to No. 242 T.R.U. did much to fill up this gap.

The first C.O.L. station became operational to provide low cover at Fort Ta Silch on 28 December 1940, followed by a second on 19 January 1941 at Fort Maddalena, while the third station commenced testing and calibration in February at Fort Dingli. Although these stations were able to plot aircraft at their extreme range (approximately 70 miles), the operational height of the enemy aircraft had been such that they had so far provided only a little extra coverage over Nos. 241 and 242 Transportable Radio Units.

Until mid-January 1941, when the *Luftwaffe* arrived in Sicily, the Italian daylight raids usually consisted of formations of bombers escorted by fighter aircraft and flying at an average height of 20,000 feet.[1] Similarly, reconnaissances were carried out by formations of fighter aircraft and no difficulty was experienced in detecting any of these raids. Single aircraft rarely approached the Island by day. Night raids usually consisted of single aircraft or a succession of single aircraft flying at approximately 10,000 feet. These were normally detected at about 40–50 miles, and were followed in by R.D.F. observation with some, but not serious fading.

With the arrival of the Germans, tactics underwent a noticeable change. Frequent reconnaissances were made by single high-flying aircraft (usually *JU.88*) and these were seldom picked up beyond 25 miles and, on two or three occasions, were only detected when within visual range of the Island. Fighter interception was impossible. On one occasion a *JU.88* slipped through the R.D.F. defence and caused casualties and damage before any alarm could be given. As a result of this attack the Army provided a 24-hour watch with a G.L. set in order to give warning of aircraft which evaded the R.D.F. screen.

At the beginning of February 1941, Wing Commander Tester, Chief Radio Officer from Headquarters Middle East, visited Malta at the request of the Air Officer Commanding, who was seriously perturbed at the number of single aircraft attacking the Island undetected.[2] Several technical faults were found in the newly-erected stations, and the chief trouble in the operation of the stations was found to be the method of sweeping of the C.O.L. stations, so that if the T.R.U. did not pick up a raid there was a great danger of its getting close to the island without being seen at all. A better method of sweep was instituted and Filter Room personnel were instructed in the handling of the stations.

The Filter Room was in a cellar some 500 yards from the Operations Room which was situated in the War Headquarters in Valetta. No Filter Officers were available and the duty was carried out by two A.M.E. Station Commanders, who were thus prevented from supervising their own R.D.F. stations. There was a great deal of activity. In thirty-four normal days about 20,000 plots were received in the Filter Room, the large majority of these being hostile tracks. The need for trained Filter Officers was great, as the Filter Room had insufficient experience to control the reporting of the stations.[3]

An analysis of the station records showed on the whole that the entire air defence system operated with remarkable efficiency. The Controller's task was made more difficult by the lack of height information and I.F.F. but this was

[1] Air Ministry File S.47124, Encl. 110A.
[2] A.H.B./IIE/70, D.D.Ops. (Overseas) Folder, Encl. 72B.
[3] Report on F/O. Findlay's visit to Malta—attached to Air Ministry File S.47124.

mitigated by the smallness of the target area and the low number of friendly aircraft.[1] It was felt that it was highly desirable to have a second "floodlight" station (as opposed to the "searchlight" C.O.L. type) preferably with height-finding. This provision was most urgent consequent upon the undetected raids and the need for height reading. In view of the shortage of R.D.F. gear overseas at that time, the idea of splitting T.R.U. Nos. 241 and 242 into separate stations operating simultaneously was considered. An R.D.F. expert from Stanmore Operational Research Station attributed the non-detection of the single aircraft to their great height, as a similar phenomenon was giving rise to anxiety on the Home Chain.[2]

Various solutions were put forward to the problem of increased R.D.F. cover for Malta but it was finally decided to abandon the idea of a C.O. station at Rabat and to substitute a T.R.U., probably at the north end of the Island, to provide cover over the Island itself.[3] A fourth C.O.L. station would also be required to fill the gap caused by permanent echoes from the island of Gozo.[4]

During the early part of 1941, Headquarters, Middle East was finding it almost impossible to provide sufficient cover for their own territory against increased attacks from German aircraft, but it was arranged that M.R.U. No. 218 should be transferred to Malta from Lakoni in Mombasa.[5] It was also intended to improve the performance of the existing T.R.U.s on Malta which were using M.B.1 transmitters giving a very low power output of 30 kilowatts, by shipping out the latest type of M.B.2 transmitter which would give 200 kilowatts.[6] This new equipment unfortunately was a total loss due to enemy action on the high seas. No more equipment could be sent direct to Malta from England except for small stores, which might be sent by aircraft or submarine.

Suggestion that R.D.F. Equipment for Malta should be supplied direct from the Middle East

Once again Headquarters, Middle East were approached and requested to furnish the hard-pressed Island with two M.R.U.s, complete with height-finding gear, from their own scanty stocks. This brought forth a justifiable protest from the Middle East who considered it unreasonable that they should be expected to supply material to Malta which already possessed five stations in a small area whereas the Middle East had very few more to distribute over a far more extensive coverage.[7] Light German attacks were becoming more frequent on the Suez Canal and in order to contend with these, the non-standard R.D.F. gear which had originally been stationed at Ikingi Mariut and which had latterly been sent to Mersa Matruh, was now withdrawn and removed to Port Said. The only height-finding equipment was the new M.R.U. at Ikingi Mariut, but this had not yet been calibrated and was not therefore operational. It was considered by the Middle East staff officers that in view of the extended commitments of the Western Desert and the threat to the Canal zone, provision of cover for Egypt should have highest priority. Great disappointment was expressed at the non-materialisation of the promised additional Mobile Radio Units, on the early arrival of which all plans for R.D.F. in Egypt had been based.

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[1] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 72B.
[2] Air Ministry File S.50541/R.D.F., Encl. 130A.
[3] Inter-Service R.D.F. Committee, Minutes of 21st Meeting.
[4] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 83A.
[5] *Ibid.*, Encl. 75A, and Air Ministry File S.47124, Encl. 114A.
[6] *Ibid.*, Encl. 141A.
[7] Air Ministry File S.5734, Encl. 145A.

On receipt of this protest at Air Ministry, an attempt was made to expedite the shipment of six Mobile Radio Units awaiting despatch to Egypt and it was agreed for the time being to drop the plan for adding to the present R.D.F. equipment in Malta.[1] Replacement parts had been sent to Malta by air but the Wellington aircraft was lost en route. A duplicate set of parts was despatched and their safe arrival ensured that all three C.O.L. stations located on the island would soon be fully operational again.

The Deputy Air Officer Commanding-in-Chief, Middle East Command, Air Vice-Marshal Tedder, had personally asked Air Marshal Sir Philip Joubert, the Assistant Chief of Air Staff (Radio) at Air Ministry, that the policy for additional equipment for Malta might be reconsidered. In his reply Sir Philip Joubert assured Air Vice-Marshal Tedder that every effort was being made to expedite and despatch further R.D.F. reinforcements to the Middle East, including an early diversion of all the Freetown R.D.F. stations.[2]

By the end of February 1941 Mobile Radio Unit No. 265 and Transportable Radio Unit No. 244 had arrived in Freetown and the personnel for the C.O.L. Stations Nos. 13 and 14 had also reached their destination, though all their R.D.F. equipment had been lost at sea due to enemy action.[3] The reinforcement of the Middle East was so urgent that T.R.U. No. 244 was sent immediately to Headquarters, Middle East, and M.R.U. No. 265 and the crews of the C.O.L. stations were to follow as soon as possible. This removal of the Units from Freetown was an interim measure only. Actually the flow of R.D.F. stations from the United Kingdom was improving.[4] At the beginning of March 1941 some ten Radio Units were en route for the Middle East theatre and an early improvement in the R.D.F. cover could be anticipated.[5]

Initial Policy for G.C.I. Stations in the Middle East

As the German Forces moved into the Balkans and also advanced in the Western Desert during the early part of 1941, there was every reason to anticipate that their bombing attacks would become more intensive and sustained on important targets in the Middle East. Certain areas, vital to our war effort there, were particularly liable to attack as they were situated on the North African coast and provided excellent targets for night bombing. At home the development of Ground Control of Interception (G.C.I.) R.D.F. stations was resulting in a considerable improvement in the night defences. It was thought essential that G.C.I. units should be provided within the shortest possible time for the Middle East. The areas which were considered to have priority were selected as :—[6]

	No. of G.C.I. Sets
Malta	1
Alexandria (and Aboukir)	1
Suez Canal Area	2
Suda Bay	1
Piraeus	1
Tobruk	1
Benghazi	1

[1] Air Ministry File S.5734, Encl. 151A.
[2] *Ibid.*, Encl. 178A and A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 170A.
[3] *Ibid.*, Encls. 168A and 183A.
[4] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 170A.
[5] A summary of the R.D.F. position in Middle East Command, including details of the Mobile Radio Units and C.O.L. stations en route from the United Kingdom, is given in Appendix No. 12.
[6] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 70A.

There was every indication that the warfare in the Middle East would be of a fluid nature. The ebb and flow of the war might bring other important places within range, or the war might recede from the above-mentioned areas. It was therefore recommended that the G.C.I. stations to be supplied should be mobile or transportable and that at least four sets should be held in reserve. In view of the demands of the rapidly-expanding G.C.I. " carpet " at home, it was not anticipated that G.C.I. equipment would be available for the Middle East before September 1941.

Operational Performance of R.D.F. Early Warning during the Campaigns of 1941

Greece

It will be recalled that No. 221 Mobile Radio Unit had been diverted to Greece on 17 November 1940. A siting party had selected a location at Araxos near Point Pappas in the Royal Hellenic Naval area of Patras, some 120 miles due West of Athens, on the west coast of the Peloponnese Peninsula.[1] The M.R.U. had considerable difficulty in reaching the site owing to the poor condition of the roads. It was nearly a month before the R.D.F. station became operational under the appalling conditions of rain and mud which prevailed.

Although one R.D.F. station could not possibly give adequate early warning cover for a theatre of operations of the size of Greece, the performance of No. 221 M.R.U. was very good. Its line-of-shoot was directed towards Southern Italy and it gave good warning of the approach of enemy aircraft from the Southern Italian and Sicilian airfields. Enemy aircraft were frequently observed up to a range of 170 miles. The station told its plots to the Greek Air Defence Centre at Athens by land-line, with stand-by W/T facilities to the Centre and the Headquarters of the British Air Forces in Greece. Some confusion was caused at the Air Defence Centre in Athens, raids there being duplicated on the plotting table because our R.D.F. information was usually about 20 minutes ahead of the Greek observer system of visual detection of raids. Throughout January 1941 the plotting system at the Air Defence Centre was most ineffective—often due to the absence of English-speaking plotters. During February a considerable improvement was effected, airmen from No. 221 M.R.U. taking over plotter's duties at the Air Defence Centre itself.

It had been intended to move No. 251 M.R.U. from the Sudan to Larissa, about 150 miles North of Athens, to give cover against the approach of German aircraft from Bulgaria, but events moved too rapidly.[2] The German break-through began early in April 1941 so really adequate R.D.F. cover was never supplied to our forces operating there.

On 13 April No. 221 M.R.U. at Araxos received orders to close down and move to Massawa airfield.[3] Personal instructions were sent from the Air Officer Commanding-in-Chief, Middle East, to Air Vice-Marshal J. H. D'Albiac, Air Officer Commanding British Air Forces in Greece, that he was to make quite sure that no R.D.F. equipment fell into enemy hands.[4] A warning order to No. 221 M.R.U. to prepare for a move to Crete was issued, but later cancelled

[1] No. 221 A.M.E.S., O.R.B., 26 December 1940.
[2] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 75A.
[3] No. 221 A.M.E.S., O.R.B., April 1941.
[4] British Air Forces in Greece, March–April 1941, O.R.B., D.O. letter of 18 April 1941.

to avoid any suggestion to the Greeks that the Royal Air Force was evacuating. Some two days later the R.D.F. equipment only of the unit was thoroughly destroyed by hand owing to the lack of suitable shipping for its evacuation.[1]

Without technical equipment, the morale of the R.D.F. personnel, high throughout the whole of their stay in Greece, showed to even greater advantage during the last disastrous days of the campaign. On 21 April two junior N.C.O.s manning Lewis Guns in the open shot down an enemy aircraft from some twenty which were straffing the airfield at Eleusis. Under continued bombardment from the air, the R.D.F. unit took to the hills, destroying the remainder of their equipment and all documents. A week later they were evacuated without casualties by sea to Egypt in five small groups, each in different vessels.[2]

It would be futile to claim that Royal Air Force R.D.F. made any really useful contribution to the campaign in Greece, yet the single unit which operated there did so successfully, and the personnel showed a devotion to duty at all times which augured well for future campaigns.

Crete

Reference has already been made to the intention of providing R.D.F. cover for Crete. No. 252 Mobile Radio Unit landed in Crete on 18 December 1940. A location had been selected in advance near Maleme, but this site was completely unapproachable due to the bad state of the roads, which were partially destroyed by the heavy rains. The unit was therefore installed temporarily at Aroni, on a ridge of land North of Suda Bay.[3] A three-way looking aerial array was erected in the absence of specific instructions as to line-of-shoot on this temporary site. The plots were passed to a nearby Gun Operations Room by land-line shared with a G.L. set operated by the Army.[4] All other communications were by W/T. The site could not be regarded as a good one; permanent echoes were rather bad. However, this site was considered by the Officer Commanding No. 252 M.R.U. to be far superior to that proposed at Maleme and he submitted a report elucidating the advantages and pointing out that Aroni had been the original site selected by the R.D.F. reconnaissance party.[5] Headquarters, Middle East were adamant, however, and ordered the unit to proceed to Maleme immediately the weather and adequate defences permitted. The site selected at Xamondochi, on the spur of foot-hills due South of Maleme and only 3 miles from our airfield there, gave the best possible cover on lines of approach of enemy aircraft for both the Naval anchorage at Suda Bay and our airfield. On 15 January 1941 the Mobile Radio Unit moved to its new site. Its plots were passed to the Operations Room at Canae, where an elementary form of filtering took place.[6] The ranges obtained were satisfactory, except for cover against low-flying aircraft. Fairly heavy raids were experienced and plotted successfully, but the information had little value as the Fighter defences were inadequate.

During March the R.D.F. cover on Crete was increased by the arrival of No. 220 Mobile Radio Unit and two R.D.F. pack-sets suitable for mule transport. The M.R.U. became operational at Heraklion on the northern coast of central Crete while the pack-sets were situated on hills on Cape

[1] Headquarters, Middle East File S.50503/221/R.D.F., Encl. 41D.
[2] No. 221 A.M.E.S., O.R.B., 27 April 1941.
[3] No. 252 A.M.E.S., O.R.B., Appendix "I."
[4] *Ibid.*, Appendix "K."
[5] *Ibid.*, Appendix "E."
[6] *Ibid.*, Appendix "M."

Drepanos. These pack-sets were modified aircraft A.S.V. sets used with a suitable aerial system. They were very successful in providing low cover, giving ranges of up to 35 miles.

At the termination of the hostilities in Greece at the end of April, the Germans did not give any respite to our forces, beginning an all-out attack on Crete before we had time to improve the defences there. On 14 May 1941 a message was received by the Mobile Radio Units warning them that a large-scale attack on Crete was anticipated, including landings by enemy parachute troops, the probable date being 19 May.[1] Very heavy bombing raids were being experienced in the areas of both Mobile Radio Units and the plotting results of the stations were excellent but almost useless, because the A.A. fire was gradually being reduced to only a feeble response under heavy bombing and machine-gunning attacks and our Fighter defences were practically negligible at that time.

Troop-carrying aircraft and parachutists landed on 20 May and Maleme airfield fell to the enemy the following day. No. 252 M.R.U. site became an isolated outpost—augmented by a few Royal Air Force personnel, stragglers from Maleme airfield. No instructions were received from either Air Force or Military authorities and the R.D.F. station seems to have been very much an orphan in a particularly violent storm. Fresh enemy landings were made nearby, so steps were taken to smash technical equipment and burn all documents, but the blowing up of the receiver and transmitter vans was left until a bombing attack would camouflage the explosions.[2] This occurred in a matter of hours: a heavy air attack on the Station began by more than fifty enemy aircraft, mainly *Stukas* with *Me. 109* escort and high-level bombers. The bombing was extremely accurate, gun-posts and apparatus were destroyed. The Officer Commanding, the Officer i/c Defence and one airman were wounded but the Administrative Officer managed to collect the remnants of the dispersed personnel and they took the road South towards Suya—the dust from the dive-bombing enabling them to escape under the protection of the dust-clouds. After ten days of privation they reached Sphakia. In view of their condition, instead of rejoining troops a further three hours' march away, they were taken off on board a destroyer on 29 May and transported to Alexandria. The unit had lost sixteen personnel killed and missing, including the wounded Commanding Officer, who was subsequently reported as a prisoner of war.

Meanwhile No. 220 M.R.U. at Heraklion were suffering a similar attack. The station was heavily dive-bombed and machine-gunned throughout 20 May, and in the evening enemy paratroops were dropped, entirely surrounding the compound.[3] Operations ceased, all personnel stood-to on guard, and the documents and all technical apparatus except the W/T set were destroyed to avoid possible capture by surprise night attack. The following morning a W/T message was sent to the Royal Air Force Headquarters in Heraklion that the unit, which was located outside the defended area of the town, was attempting to rejoin the main force inside the perimeter.

En route, there were several skirmishes with the enemy in which German prisoners were captured and two of the unit's personnel were killed. Eventually the defended perimeter of Heraklion, which included the aerodrome and

[1] Nos. 220 and 252 A.M.E.S., O.R.Bs., May 1941.
[2] No. 252 A.M.E.S., O.R.B., 20/21 May 1941.
[3] No. 220 A.M.E.S., O.R.B., 20 May 1941.

harbour, was reached. Here, the unit together with some Army stragglers, were heavily mortared by our own defenders—no notice being taken of the uniform as the enemy were using British uniforms as well.[1] After a brief but uncomfortable time sandwiched between the enemy and our own forces, they were allowed to enter the perimeter defences. Evacuation on H.M.T. "Orion" followed. This ship was heavily bombed and another eight of the R.D.F. personnel were killed.

By the end of the operations in Crete the R.D.F. units had not only proved themselves technically, but their high morale had also demonstrated itself in their ability as fighting men in their own defence when pressed by the enemy. Nevertheless Greece and Crete clearly demonstrated certain principles :—

(*a*) That a single R.D.F. station very rarely produced sufficient results to justify its being there. The R.D.F. stations of that time were seldom satisfactory unless part of a system or chain of stations giving a complete pattern of early warning cover for the area concerned. The exception to this was later realised to be a specialist station which did not necessarily need to provide all-round cover and which was used by a specially trained Fighter Controller. Even then a warning system was often necessary as well.

(*b*) That an observer corps was incapable of producing sufficient information for accurate interception, and that the time-lag on the information was such as to confuse other information unless it were all being filtered by skilled filterers. The outstanding value of an observer system was for identification.

(*c*) That R.D.F. information was usually valueless unless supported by the full machinery of defence, namely, fighter aircraft, guns, searchlights, operations rooms and filter rooms.

Western Desert, December 1940–May 1941

Concurrently with the operations in Greece and Crete there was considerable activity in the Western Desert. On 9 December a British offensive was launched from near Sidi Barrani in Egypt leading to a victorious advance against the Italian forces as far as Agedabia in Libya.

R.D.F. was employed to give early warning of the approach of hostile aircraft, but because of the low degree of mobility which our equipment possessed at that time it was the practice never to deploy R.D.F. units in very forward positions. Although all Mobile Radio Units were adequately briefed on the destruction of their equipment to prevent it from falling into enemy hands, unnecessary risks could not be taken.[2] Security was not the only factor to consider in this respect : the marked insufficiency of R.D.F. apparatus within the Middle East Command at that time precluded the adoption of any policy which would unnecessarily jeopardise the equipment.

The role of R.D.F. during these operations was to give cover to the lines of communication, dumping areas and coastal supply convoys. Immediately following the path of the advance in December, Nos. 216 and 235 Mobile Radio Units were moved up from the R.D.F. Reserve at Aboukir to Sollum and Sidi Omar (S.W. of Sollum) respectively.[3] As the advance of the ground forces

[1] Narrator's interview with Flight Lieutenant J. N. K. Whitford, Commanding Officer of No. 220 A.M.E.S.

[2] Narrator's interview with Group Captain J. A. Tester, Chief Radio Officer, Headquarters, Middle East.

[3] Nos. 216 and 235 A.M.E.S., O.R.B., January 1941.

continued, so the Mobile Radio Units leap-frogged forward. By the end of January No. 235 M.R.U. was operational at Tobruk and No. 216 M.R.U. had moved forward to Acronia, some 20 miles west of Tobruk. This latter unit changed its site to Benghazi two weeks later. By this date, 11 February 1941, our ground forces had reached the limit of their advance.

Tobruk and Benghazi were the main ports of the supply for our forces in Libya. Because of a dearth of transport suitable for desert operations, the sea route for supplies was extremely important. The enemy realised this and there was considerable aerial activity over these two ports—particularly in the case of Benghazi, which was subjected to sustained enemy bombing attacks during March. The plotting of the Mobile Radio Units was satisfactory, within the limits of their equipment. Their information was passed to No. 258 Fighter Wing for advance warning and interception purposes.

During this period of our success in Libya, enemy raids were anticipated in the Delta area and it was expected that the Suez Canal would be subjected to heavy bombing. The number of Mobile Radio Units available in the Middle East Command during the spring of 1941 was insufficient to meet all commitments. No. 204 M.R.U., which was located at El D'aba in the temporary coastal R.D.F. chain, was therefore moved back to Damietta to support the C.O. station at Ikingi Mariut and No. 219 M.R.U. at Port Said.[1] The R.D.F. policy at that time can be summarised as :—

(*a*) Early warning R.D.F. cover for the base area of the Delta and Suez against heavy bomber attacks.

(*b*) The best R.D.F. cover possible for the forward areas, against fighter-bomber and medium bomber attacks on our lines of communication and ports.

The deficiencies in R.D.F. cover were between the forward areas in Libya and the base area of the Delta—due entirely to the shortage of sufficient Mobile Radio Units to cover the extended coastline.

Before there was time to consolidate the ground gained in Libya and surmount the transport problems of our elongated lines of communication, the enemy counter-offensive commenced on 30 March 1941. The German *Afrika Corps* came into action for the first time in the desert and within four days we had to evacuate Benghazi and withdraw to Halfaya, just inside the Egyptian border, leaving forces in Tobruk. No. 216 M.R.U. appears to have been overlooked in the general retreat and withdrew when dangerously near being taken by surprise by the enemy. When the front was stabilised again at Halfaya, No. 216 M.R.U. became operational again at Mersa Matruh on 22 April, plotting to No. 204 Group Operations Control.[2]

In Tobruk, under a siege which subsequently lasted some nine months, No. 235 M.R.U. remained behind to provide R.D.F. early warning for the garrison. Its function became of much greater value than that of local cover, however, for in this location it was viewing across the enemy lines of communication and was thus able to report all enemy aircraft movements between their rear and forward areas. This information was passed in a simple code by W/T to our desert Fighter Wing Operations Control.

[1] Headquarters, Middle East, Radio Branch, O.R.B.
[2] No. 216 A.M.E.S., O.R.B., April 1941.

Strategic Moves in the Middle East during the Summer of 1941

By the end of May our positions in the Middle East appeared somewhat precarious. The enemy had overrun the Balkans and captured Crete, and we had been pushed back in the Western Desert. During the latter part of April trouble had broken out in Iraq, fermented by German agents, and action had to be taken with very weak forces to consolidate our flank. For some time too before the fall of Crete the question of Syria had occupied the attention of the Commanders-in-Chief, Middle East. So long as the Vichy French officials were in power in Syria there was a grave danger of the Germans establishing air bases there from which they could attack Palestine, the Suez Canal, the lines of communication and oil supplies from Iraq and Iran. Cyprus, between Syria and Crete, would also be endangered if the enemy entered Syria; nor could a German advance into Syria through Turkey be ruled out.

The operations which followed to clear the flanks, against Iraq (April/May) and Syria (June/July), and the occupation of Iran in conjunction with our Russian allies, did much to ease our position. From the point of view of R.D.F. early warning, however, some of these territories required adequate defences and thus further calls were made on the Middle East Command's slender resources of R.D.F. equipment—fortunately being steadily reinforced at this time from the United Kingdom.

R.D.F. Position in Palestine

There were three operational R.D.F. stations in Haifa by June 1941, No. 236 Transportable Radio Unit at Mount Carmel and two C.O.L. stations for low cover, No. 503 C.O.L. at Stella Maris and No. 508 at Nesher.[1] The T.R.U. at Mount Carmel was not giving complete satisfaction, due largely to lack of spares, and No. 503 C.O.L. was mainly preoccupied with the Filter Room which was located on its site. This was not a complete Filter Room, but a temporary affair acting as a buffer stage between the A.M.E. Stations and the Air Report Centre at Haifa from which severe leakage of information had from time to time occurred.[2]

There was no overlapping of stations so that all that was necessary in the way of filtering was some smoothing out of tracks, a little co-ordination of information and mainly concealment of A.M.E.S. performance and limitations from the Air Report Centre. The greatest threat to A.M.E. Stations in Haifa came from "fifth column" activities by people living in houses adjacent to the sites.[3] At that time the Filter Room was manned by a skeleton staff picked from R.D.F. officers and operators but when the second C.O.L. station became operational and the C.O. station was installed, these men were to be withdrawn to carry on with their legitimate jobs.

Haifa was eventually to become the control for the whole of Palestine, and with the completion of the chain up the Palestine coast and the formation of a defensive triangle including Cyprus, Beirut and Haifa, the Filter Room would reach full performance and had therefore to be given establishment as such. With the removal of the "back door" threat from the Syrian frontier, C.O.L. No. 508 became unnecessary and its removal to the Suez Canal area was contemplated. The buildings, however, were left intact in case a reversion to former conditions became necessary.

[1] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 88A.

[2] Air Ministry File S.50541, Encl. 4A and 18A.

[3] *Ibid.*, Encl. 11A.

R.D.F. Position in Cyprus

The security of Syria, control of the Eastern Mediterranean, and the defence of the Egyptian Delta, Suez and Palestine from air attack were all intimately dependent upon the holding of Cyprus. The original provision of R.D.F. cover on the island was by No. 218 Mobile Radio Unit, which left Mombasa for Cyprus during April 1941. It was July before this station was operational, plotting to the Fighter Operations Room at Nicosia from its site at Myrton.[1] By this time planning included three M.R.U.s and three C.O.L. stations for the island as the minimum requirement for all-round cover. Aerodromes were either in existence or were under construction at Nicosia, Limassol, Larnaca and Paphos, each with satellites, and a dry-weather landing ground existed near Famagusta.[2] H.Q. No. 259 Wing was at Nicosia, and the only port was Famagusta. These then were the targets to be covered, and since the direction of attack could not be anticipated under the existing conditions—and these might possibly change at any moment—there was no alternative but to complete all-round high and low R.D.F. cover.

It was not until September 1941 that a second Mobile Unit, No. 255 M.R.U., arrived in Cyprus. After setting up on the wrong site and reporting to the Fighter Operations Room at Nicosia, it was moved to the correct site during November.[3] Unfortunately the R.D.F. receiver vehicle was completely gutted by fire just as the unit became operational again, so the station was out of action and it was four months before the unit began to take any active part in the defences of the island.

R.D.F. for Syria, following the Campaign

The only radio commitment in Syria, consequent on the Allied occupation of the country was the defence of Beirut. This was the main port and was to be defended eventually by a Fighter Sector there with full facilities. The airfields to be used were Ryak, Beirut itself, and possibly one or more satellites. A building had been selected on the edge of the town for Air Headquarters and an Operations Room. One M.R.U. and one C.O.L. station had been allocated but not yet sited. This provision was not of high priority and it was probable that the equipment would not be installed before November 1941.[4]

In the meantime, guard was kept by H.M.S. " Coventry " and two G/L sets working in their proper capacity with the guns. A suggestion had been made in June 1941 to move C.O.L. No. 508 from Aden into Syria, but having suffered losses in the past, Headquarters, Middle East were loath to place any non-mobile station outside the areas of the Delta, Suez Canal and Palestine.[5] In this respect every effort was being made to mobilise C.O.L. stations so that they could be used in other areas as well as M.R.U.s. There was still a great shortage of equipment and an even greater shortage of technical staff as the installation programme was under way. It was stressed that the use of an A.M.E. Station solely as an air raid warning was a great waste of valuable equipment. An A.M.E.S. system should, if possible, never exist without the whole machinery of fighter defence behind it. This not only included aircraft but also Sector Operations Rooms, Groups, and all the incidentals such as good R/T for Fighter Control.

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[1] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 88A.
[2] Air Ministry File S.49984, Encl. 9A. [3] No. 255 A.M.E.S., O.R.B., September 1941.
[4] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 88A.
[5] Air Ministry File S.50541/R.D.F., Encl. 18A.

Possible Requirement of R.D.F. for Turkey

Between the Allied positions in Syria and the enemy in Greece, neutral Turkey acted as a buffer. There was considerable diplomatic pressure from the German side on the Turks at that time and it was considered more than a possibility that the Germans would invade Turkey later in 1941, when their supply position in the Balkans would have improved. In the event of such a German invasion, Britain was pledged to go to the assistance of Turkey. While Turkey was still neutral, however, nothing could be done openly in the way of preparations for our forces to take part in her defence. Since R.D.F. ground stations would be necessary in event of a German attack on Turkey, it was decided that the terrain should be examined covertly with a view to selecting the best possible sites for Mobile Radio Units.

During April and May 1941 Flight Lieutenant S. N. Smith of the Directorate of Communications Development, an R.D.F. siting expert, was attached to the British Embassy at Istanboul as a civilian.[1] Working under considerable difficulties, as the Turks suspected all foreigners, Flight Lieutenant Smith managed to cover all potentially-important regions of both European and Asiatic Turkey and selected locations for Mobile Radio Units. Fortunately, the enemy did not attack Turkey, otherwise Headquarters, Middle East would have been in a bad position to supply the number of Mobile Radio Units required to give adequate R.D.F. cover to this large area.

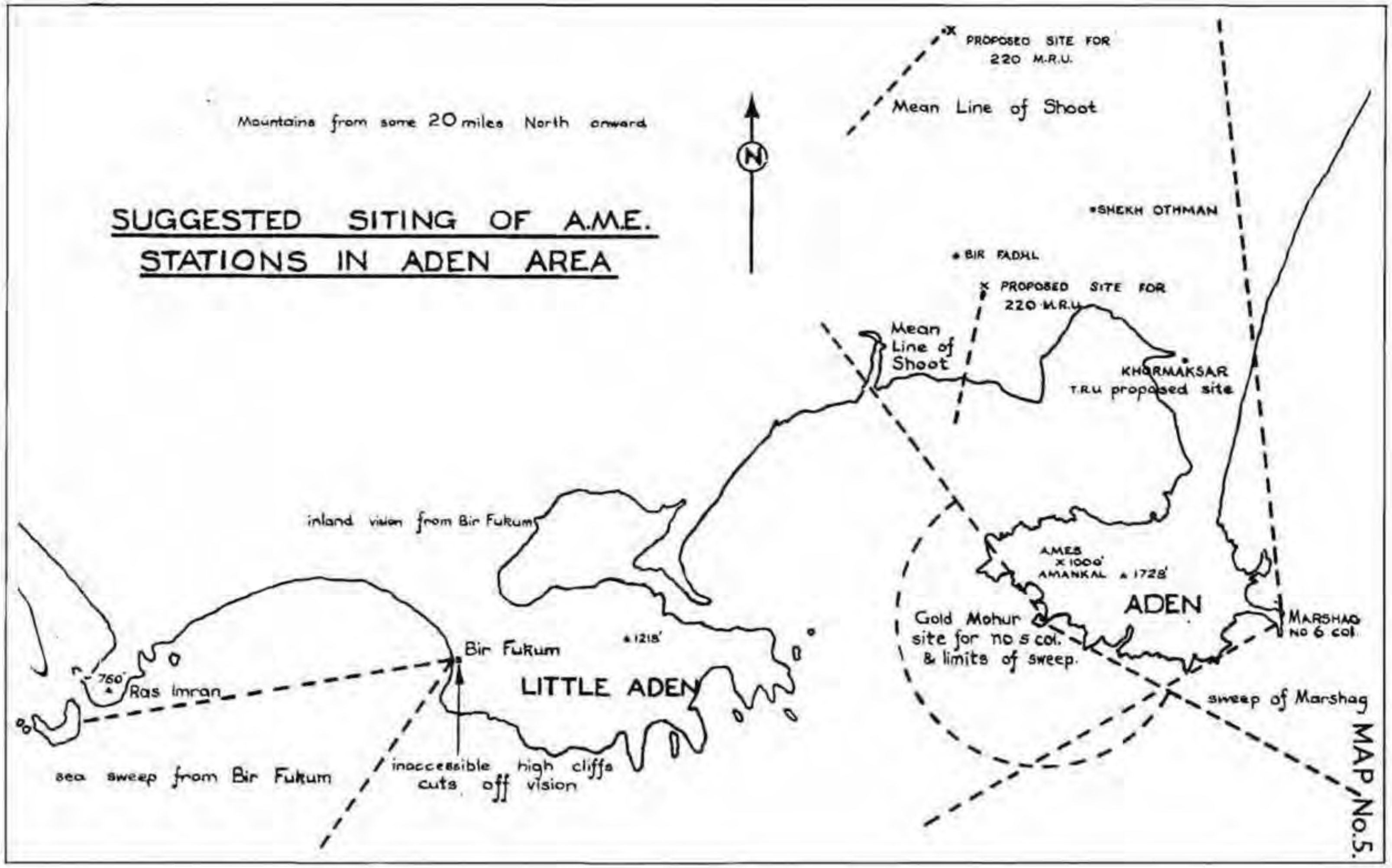
R.D.F. Provision for Iraq

By the late summer of 1941 we had developed a large erection depot in Basrah to handle a high proportion of the American war output destined for the Middle East and Russia. Through this port also, the major part of the requirements of the land and air forces in Iraq were to pass. In addition, the oil output from the Abadan area was vital to the maintenance of our Naval, Army and Air Forces in the Middle East. The threat in this area was expected to come from a German drive through Northern Iraq and Syria or Iran. The original survey of Iraq had been carried out while the military situation was still troublesome and a complete land survey was not possible. An aerial reconnaissance was carried out and land parties visited Basrah, Shaibah, Baghdad and Habbaniya.[2] Later, in August 1941, a complete survey was made possible and it was decided that cover against high and low-flying attacks could be obtained by placing one M.R.U. at Shaibah, and one M.R.U. with two C.O.L. stations on the banks of the Shatt-el-Arab, thus affording warning for Shaibah and Basrah up to the maximum range of the M.R.U.s, with the C.O.L. stations providing fairly good range-cutting for accurate positioning in the event of interception being carried out. The Shatt-el-Arab area would be covered then from high and low-flying attacks, including the dropping of mines. To receive the R.D.F. information, an Operations Room was to be formed at Basrah or Shaibah but no H.F. D/F stations were to be available for Iraq for four to six months, so once again it looked as though R.D.F. would be used simply as an air-raid warning.

The stations on the banks of the Shatt-el-Arab were to be built on brick mounds to keep clear of the swamps. There was no telephone equipment available, and working conditions were expected to be extremely difficult—but

[1] Narrator's interview with Flight Lieutenant S. N. Smith of D.C.D., M.A.P.

[2] Air Ministry File S.49983, Encl. 11A.


SUGGESTED SITING OF A.M.E.
STATIONS IN ADEN AREA
Mountains from some 20 miles North onward
N
PROPOSED SITE FOR
220 M.R.U.
Mean Line of Shoot
SHEKH OTHMAN
BIR FADHL
PROPOSED SITE FOR
220 M.R.U.
Mean
Line of
Shoot
KHORMAKSAR
T.R.U proposed site
inland vision from Bir Fukum
AMES
x 1000'
AMANKAL ▲ 1728'
ADEN
Gold Mohur
site for no 5 col.
& limits of sweep.
MARSHAG
NO 6 col
▲ 1218'
Bir Fukum
750'
Ras Imran
LITTLE ADEN
sweep of Marshag
sea sweep from Bir Fukum
inaccessible high cliffs
cuts off vision
MAP No.5.

in the words of the Chief of Air Staff, " Inconvenience must be disregarded ".[1] Before the rain season came, the Air Officer Commanding-in-Chief, Iraq, pointed out that these units were liable to become isolated by the floods and requested that they should be resited. A suggestion was made that the men might live in barges and be provisioned by water. Eventually No. 256 M.R.U., which had been sited at Banadir on its arrival from India during October 1941, had to be moved and was temporarily located at Shaibah, where No. 264 M.R.U. had just arrived during October 1941.

Proposals for R.D.F. Cover in Iran

After the occupation of Iran by Allied forces, the possible directions from which light-scale attacks by long-range enemy aircraft were most likely to come were either from Crete, Rhodes or Greece, or from the north of Iran, following a German break-through on the Russian Caucasus front. Although air attack on Iran was a difficult proposition for the enemy, the potential targets were of great importance to the Allies—being principally the Anglo-Iranian Oil Company's oil-fields, refineries, and pumping stations, and the ports and shipping in the Persian Gulf.

Though Iran is much nearer to India than to Headquarters, Middle East, the latter was made responsible for the survey and provision of R.D.F. cover for the oil-fields. This responsibility was communicated to Headquarters, Middle East, in a Chiefs of Staff signal.[2] The area covered approximately 9,000 square miles. Fortunately the potential targets divided into three regions, namely, the refineries at Abadan in the south-west, the oil-fields in the north, and the Persian Gulf up to the Oman peninsula. The employment of three M.R.U.s to give early warning in these areas was envisaged, but the units could not be provided from Middle East resources during 1941 in view of the more urgent requirements in Egypt.[3]

Attempts to develop satisfactory R.D.F. Cover for Aden

It will be recalled that developments were proceeding very slowly at Aden in the provision of adequate R.D.F. cover. One Mobile Radio Unit and two C.O.L. stations planned for Aden had arrived at Headquarters, Middle East, on 21 October 1940. Air Headquarters, Aden did not agree to the sites selected for these stations and approved by Air Ministry, and much correspondence followed on this subject.[4] Meanwhile, Headquarters, Middle East, as the R.A.F. Command responsible for Aden, sent the Mobile Radio Unit to Greece instead. The dispute on the sites for the C.O.L. stations continued.

Although it would be out of context and beyond the scope of this chapter to embark at this juncture on a full description of the many delays which occurred at Aden, there are many lessons to be learned from these details.[5] Some of the factors which contributed to this failure to provide satisfactory R.D.F. early warning within a reasonable period of time were :—

(*a*) The remoteness of the superior Royal Air Force Command. Headquarters, Middle East, were approximately 1,500 miles from Aden.

(*b*) The very difficult nature of the terrain at Aden precluded perfect R.D.F. siting.

[1] Air Ministry File S.50124, Encls. 2A and 4A.
[2] Air Ministry File S.49984, Encl. 13A. [3] *Ibid.*, Encl. 20A.
[4] Air Ministry File M.S.50530/R, Encls. 16A and 23A.
[5] Narrator's comment. An appreciation of the attempts to provide R.D.F. cover for Aden is given in Appendix No. 13. Map No. 5 also refers.

(c) Climatic difficulties, chiefly excessive humidity and the consequent super-refraction, prevented C.O.L. stations and personnel from functioning near to their normal standards.

(d) By far the most important factor was the failure of higher authority to appoint a well-informed technical officer at Aden with power to act according to local conditions. The triangular correspondence between Air Ministry, Air Headquarters, Middle East, and Air Headquarters, Aden, caused much delay and lacked decisiveness.

Build-Up of R.D.F. Equipment in the Middle East, May–November 1941

Throughout 1941 the supply of R.D.F. equipment to the Middle East steadily increased. At the same time the defence commitments within the Command had also increased, so there was still a serious lag between demand and supply. This position was appreciated at Air Ministry and a decision was taken during May 1941 that the highest possible order of priority should be accorded to the shipment of R.D.F. equipment to the Middle East.[1] It is hard to appreciate that by the autumn of 1941 there were already forty-five R.D.F. units operational in the Middle East.[2] Constant references to the shortage of equipment and the huge area over which the Mobile Radio Units were deployed tend to give the false impression that the R.D.F. effort within the Command was inadequate. Actually excellent progress was being made, and the home output of R.D.F. units for the Middle East was really large at that time—some fifty more A.M.E. stations were already in transit or awaiting despatch to the Middle East.[3]

For the Delta night defences the G.C.I. equipment which had been allocated was urgently awaited. The authorities at home were fully aware of this requirement. In a draft minute to the Prime Minister, the Vice-Chief of the Air Staff intimated that three G.C.I. sets were to arrive in the Middle East by mid-September.[4] In addition, improved R.D.F. equipment for height-finding was being prepared and shipped as early as possible, as the height-finding apparatus on the existing R.D.F. stations in the Middle East was not fully satisfactory. From the point of view of successful interceptions of hostile aircraft, accurate height-finding was even more essential than really accurate positioning, so the new equipment was expected to produce a big improvement in our defences.

Improvements in R.D.F. Cover in Egypt

Re-organisation of Filter Rooms in the Middle East

Several attempts had been made to improve the value of the available R.D.F. information by establishing an adequate Filter Room organisation in Egypt. It will be recalled that the first filtering of R.D.F. information had been attempted at Headquarters, No. 256 Wing at Mex, Alexandria, but this had been little more than an information centre, formed (as a result of a general conference) as the place at which W/T plotting from the R.D.F. stations was to be received.[5] At first the filter organisation worked in temporary quarters in the Air Defence Centre. The Filter Room there had too large a roof span

[1] Inter-Service Committee on R.D.F., Minutes of 21st Meeting, item 7, para. (a).

[2] Appendix No. 14 gives the locations of all R.D.F. stations in the Middle East, November 1941.

[3] The A.M.E. stations in transit or awaiting despatch from the United Kingdom in November 1941 are listed in Appendix No. 14.

[4] Chief of Air Staff Folder 719.

[5] No. 256 Wing, O.R.B., 22 May 1940.

to enable it to be covered with any form of protection—leading to some trouble with the Egyptian operators who objected to the lack of safe accommodation in this temporary building. However, by the end of January 1941 a special annexe to the buildings had been constructed and fitted as a complete Filter Room.

During January, too, a filter organisation was developed at No. 250 Wing at Ismailia for the defence of the Suez Canal.[1] The two Filter Rooms at Nos. 250 and 256 Wings functioned separately though only 130 miles apart because of the bad communications, No. 250 Wing being concerned with the Fighter defence of the Suez and No. 256 Wing the defence of the Delta (later handed over to No. 252 Wing). The efficiency of the Filter Room crews was low during the early part of 1941—due largely to the lack of training. However, the arrival of Senior Filter Officers improved the organisation considerably; a Filter School was started, regular practice exercises were introduced, and morale and discipline gradually became better.

Operations Room Fighter Control Officers

R.D.F. information is of most value if the Sector Controllers are really experienced in its use. The only experienced Operations Room Officers at that time were in the United Kingdom, so a demand was made in May 1941 to Fighter Command for twenty Sector Controllers to be sent to the Middle East before the end of the month.[2] This came as a great shock to Fighter Command, already some forty-seven Controllers short on their own establishment, with the prospect that when the home G.C.I. " carpet " developed fully they would be approximately one-hundred Controllers short. Fighter Command were anxious to do all they could, however, for the overseas commitments and arrangements were made to supply nine Sector Control Officers for the Delta area and four Wing Controllers needed for the Western Desert.

Extended Egyptian Chain of R.D.F. Stations

By November some twenty-five R.D.F. stations were in operation in Egypt giving R.D.F. cover against high-flying hostile aircraft.[3] The coastal chain was fairly satisfactory, but the Suez Canal defences were still in an extremely embryo state—the low cover for the canal area being negligible.[4] The chief difficulty here was that of suitable locations for C.O.L. stations. The terrain was really difficult for R.D.F. early warning of an adequate nature and this gave considerable worry. No real solution was forthcoming, though the Command Chief Radio Officer gave much attention to this matter.[5] Even a most lavish scale of deployment of R.D.F. equipment in the Suez Canal area failed to overcome the difficulties of the terrain. Why the Germans never put in a serious attack with a large heavy bomber force remains a mystery: only eight attacks were experienced, though at times there was a mass of valuable shipping as a target—as instanced when the " Queen Mary," " Queen Elizabeth," the " Georgic " and many others were all in the Suez roads together, yet only the " Georgic " was damaged in a light attack.

[1] Headquarters, Middle East, O.R.B., 5 January 1941.
[2] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 79B.
[3] The locations of these stations are given in Appendix No. 14.
[4] Air Ministry File S.4422, Encl. 64A.
[5] Narrator's interview with Group Captain J. A. Tester, Chief Radio Officer, Headquarters, Middle East.

As a means of improving the R.D.F. information available from individual R.D.F. stations, in England it had been found necessary to introduce Officer Supervisors on every watch at C.H. stations. Their supervision and the increase in efficiency of the radio operators under them due to their constant operational training had been most effective.[1] It was becoming apparent that similar provision must be made for the Middle East. A number of Radio Operators were therefore trained as Supervisors at home, posted to the Middle East and used as Supervisor-Instructors on R.D.F. stations in Egypt as required by the Chief Radio Officer, during the latter part of 1941.

By November 1941 the R.D.F. system had been improved considerably throughout each link in the system. The number of stations had been increased, the efficiency of the individual stations improved, the filter organisation developed, and Controllers experienced in the use of R.D.F. information were in charge of base area Sectors and desert Wings.

The "Crusader" Operations in the Western Desert[2]

Preparations.—The development of the defensive R.D.F. cover for the Delta and Suez regions was not allowed to take priority over R.D.F. requirements for the ultimate military major project of operations in the Western Desert. By November 1941, three R.D.F. pack-sets, suitable for mule or camel transport in the absence of motor transport, had been made up from aircraft A.S.V. sets, and a further five were nearing completion. These sets had been so successful in the operations in Crete that considerable attention was devoted to their production for desert operations. This had repercussions on the progress made in increasing the mobility of other types of R.D.F. equipment.[3] Only one C.O.L. station was produced in mobile form during the period June-November 1941 ; this was No. 510 C.O.L. Unit.

The R.D.F. pack-sets operated by Nos. 610 and 602 A.M.E.S. were sent forward to give R.D.F. cover to advanced landing grounds.[4] As this was an innovation untried in previous desert operations, a wireless observer screen, also reporting back to Wing Operations, was thrown round the Advanced Landing Ground Area. The Air Officer Commanding, Air Headquarters, Western Desert, was notified that the portable R.D.F. sets provided might be of little use and that it was clearly better to make all plans assuming no R.D.F. cover in the forward desert area.[5]

It will be recalled that there were three Mobile Radio Units located on the coast, situated at :—[6]

(*a*) *Mersa Matruh* (No. 216 A.M.E.S.).—This R.D.F. station covered the fighter base area, the important dumping area at Charing Cross and Matruh itself.

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[1] Air Ministry File S.44501, Encl. 202A.

[2] "Crusader" was the code name given to operations in the Western Desert from 18 November 1941–20 January 1942. Its aim was to destroy the enemy's armoured forces in Cyrenaica and thus pave the way for an invasion of Tripolitania.

[3] Narrator's interview with Group Captain J. A. Tester, Chief Radio Officer, Headquarters, Middle East.

[4] A.H.B./IIJ6/7/3, "Notes on Fighter Wing Organisation and Control—Crusader Operations," 17 January 1942, p. 6.

[5] Headquarters, Middle East Radio Branch O.R.B., 5 November 1941.

[6] A.H.B./IIJ1/12, R.A.F. Middle East Ops. Records, "R.A.F. Operations in the Western Desert and Eastern Mediterranean, November 1941–May 1942," and Headquarters, Middle East, Radio Branch, O.R.B., 14 September 1941.

(b) *Sidi Barrani* (No. 263 A.M.E.S.).—No. 263 A.M.E.S., located here, had evacuated the site on 14 September 1941 under enemy pressure but became operational again some ten days later on the same site. It gave good R.D.F. cover to the forward area where our troops were disposed, and behind which forward dumps were being built.

(c) *Tobruk* (No. 235 A.M.E.S.).—This R.D.F. station was in a unique position across the enemy's lines of communication and was able to report by W/T the movements of enemy aircraft far behind the German lines.

These stations were reporting to No. 258 and No. 262 Fighter Wings, and to nearby Army Gun Operations Rooms. Immediately prior to "Crusader" campaign these R.D.F. units had effectively pin-pointed all enemy advanced landing grounds by observations on enemy aircraft movement and their disappearances on landing.[1]

Before the "Crusader" operations commenced it was thought that the R.D.F. contribution could only be effective in providing protection to our lines of communication and dumping areas—chiefly from the enemy aircraft operating from airfields in Crete.[2]

R.D.F. during the "Crusader" Operation

The ground offensive began at dawn on 18 November 1941 and was very successful at first. Some anxious days were spent prior to the raising of the siege of Tobruk on 9 December, during the enemy's armoured counter-attack which caused temporary disorganisation behind our fluid front. Eventually the enemy armour retreated and Benghazi was recaptured on 24 December. The "Crusader" offensive ended some 150 miles beyond Benghazi, at El Agheila, on 20 January 1942.

As our troops cleared the coastal ports of Cyrenaica, Mobile Radio Units were moved forward to give R.D.F. cover. No. 263 M.R.U. was moved from Sidi Barrani to Derna on Christmas Day, 1941.[3] Some idea of the lack of real mobility in the Mobile Radio Units for the war of rapid movement in the desert may be gained from the fact that this unit was not operational at Derna until 13 January 1942—eighteen days to dismantle the station, move 250 miles and set up again, though the move was carried out quite efficiently.

No. 220 M.R.U. moved up about the same time from their location at Abu Haggag, east of Mersa Matruh, to Benghazi.[4] Thus in January 1942 there was R.D.F. cover at Mersah Matruh, Sollum, Tobruk, Derna and Benghazi, so that the Cyrenaican and Libyan Desert coast-lines were provided with early warning and our lines of communication were reasonably covered. Of these locations, Benghazi and Tobruk were the most important as supply ports. In addition, for the first time in Western Desert operations, low R.D.F. cover became available. Nos. 516 and 520 C.O.L. Units had recently arrived from England and were set up at Mersa Matruh and Tobruk respectively.[5]

The plotting of the Mobile Radio Units was of a good standard but the use to which the available information was put was at times most discouraging. According to a report by the Chief Radio Officer, this was having an adverse

[1] No. 263 A.M.E.S., O.R.B., 14 October 1941.
[2] A.H.B./IIJ6/7/3—Crusader Ops.
[3] No. 263 A.M.E.S., O.R.B., December 1941.
[4] No. 220 A.M.E.S., O.R.B., January 1942.
[5] Headquarters, Middle East, Radio Branch Appendices.

effect on the morale of the R.D.F. operating personnel who realised that few interceptions were attempted as a result of their efforts.[1] The Fighter Wing Operations Controllers at this time were mostly untrained in the use of R.D.F. information. Every effort was made to simplify the R.D.F. information before presenting it to the Controller and to standardise rather than minimise the timelag which occurred during the plotting of tracks. For this reason, where two R.D.F. stations existed in one area, an effort was made to weld them together as an information unit; thus information from a C.O.L. station was passed to the nearby M.R.U. where an elementary filtering process was carried out to present the finished article in the way of a track to the Controller.

Meanwhile, in the Western Desert itself in the region of our advanced landing grounds, the two portable A.S.V. sets being operated by Nos. 601 and 602 A.M.E.S. were not a success.[2] The ranges obtained were inadequate for satisfactory early warning and the sets were returned as being useless during December 1941. On investigation however it was found they had been operating on flat sites in the desert and obviously no adequate ranges could be expected under these conditions. It was decided to check the performance of the sets themselves, so they were resited with the M.R.U. at Mersa Matruh —where they produced ranges of 30 and 40 miles on aircraft of unknown height and an aircraft flying at only 500 feet was observed up to 20 miles range. These results proved there was nothing wrong with the equipment if properly sited.

To replace A.S.V. sets, No. 510 C.O.L. station was moved forward during December 1941. It will be remembered that this C.O.L. unit had been made fully mobile during the previous preparatory period for operations in the Western Desert. It was used well forward to try it out in co-operation with our fighter aircraft. Advanced area commanders were impressed with its performance. It had very quickly two "flamers" to its credit in addition to the provision of satisfactory early warning.[3] The results obtained initially with No. 510 C.O.L. station were so good that in January the Command Radio Officer, Wing Commander J. A. Tester, took command of the station personally with the intention of controlling fighter aircraft directly from the site of the C.O.L. station.[4] No. 522 C.O.L. Unit took over from No. 510 C.O.L. Unit at Benghazi and the latter station was pushed forward to a site just behind the limit of the advance of our ground forces at El Agheila. Before R.D.F.-controlled fighter operations were possible, evacuation orders were received. A German attack was anticipated. Premature evacuation orders were received by No. 510 C.O.L. station (being given and rescinded several times) but on the 21 January 1942 the anticipated German attack commenced.

The Royal Air Force had supremacy in the air over the front at this time, and morale was very high. The weight of the German armoured attack was however so great that our ground forces could not hold the enemy—there was no alternative but to withdraw.

The Retreat to Gazala—R.D.F. Unit Movements (21 January–14 February 1942)

The rapidity with which the enemy had re-organised and launched their counter-offensive was surprising. As a result, the withdrawal of the R.D.F units was somewhat chaotic. No. 510 C.O.L. Unit was ordered back to Msus

[1] Headquarters, Middle East, Radio Branch Appendices, Appendix "A," 1 February 1942.
[2] Headquarters, Middle East, File S.50503/220/R.D.F., Encl. 89A.
[3] Headquarters, Middle East, Radio Branch O.R.B., December 1941.
[4] No. 510 A.M.E.S., O.R.B., December 1941–January 1942.

on 21 January, but in view of petrol shortage and unserviceable transport the unit took the shorter route to Benghazi. On arrival at No. 522 C.O.L. site, the two Commanding Officers of these R.D.F. units attended a conference at the local Army Headquarters, where they were warned that the Army could offer them no special support in the event of an evacuation.[1]

No. 522 C.O.L. Unit received orders to move eastwards immediately towards Tobruk on 24 January and joined No. 263 M.R.U. at Derna the following day, having to burn their receiver mast which was beyond repair as a result of the rough journey. Meanwhile No. 510 C.O.L. Unit also received orders to evacuate from Benghazi but was stopped on the road and told to return—only to find its former site ablaze. Several hours later a further order came to retreat to Gazala and the convoy set off, towing the receiver vehicle. After many miles were covered, one more attempt was made to return to Benghazi. By this time the German break-through was well advanced and the unit was turned back, eventually reaching Gazala on 29 January, and becoming operational the following day.

When the two C.O.L. stations left Benghazi, No. 220 M.R.U. was still there, unserviceable as it had previously lost its transmitter and receiver aerial towers in a violent storm. Receiving evacuation orders late on 24 January, the unit was on the road in one and half hours—only to meet No. 510 C.O.L. on its way back to Benghazi.[2] No. 220 M.R.U. was also ordered back to their site at Benghazi, but after half an hour there, the unit was instructed to move again.

At Derna, No. 263 M.R.U. had a similar but more prolonged experience. From 24-29 January, the personnel spent most of their time dismantling and re-erecting their station. Contradictory signals were received, some favouring a move forward ; others a retreat to Tobruk. To quote the Officer Commanding this unit " At this time orders to advance and retreat were coming so fast the A.M.E. stations were passing each other in opposite directions on the road."[3] It was a very surprised No. 510 C.O.L. Unit advancing on Benghazi that met No. 263 M.R.U. retreating to El Adem. Fortunately, the Chief Radio Officer of H.Q., R.A.F., M.E., was right forward at that time and hurried back to Benghazi and then to Derna, evacuating the units which were still there and turning back other units moving the wrong way.

Eventually all the units reached their retired positions safely despite the confusion. No. 522 C.O.L. departed from Derna and, after a refit at the Radio Installation and Maintenance Unit, were sent to El Dhaba to give low R.D.F. cover over the Delta area as a warning against sea landings which might be carried out by the Axis forces. The locations of the R.D.F. units employed in desert operations, after the retreat of the ground forces to Gazala, were :—

No. 220 M.R.U.	Abu Haggag.
No. 235 M.R.U.	Tobruk.
No. 257 M.R.U.	El Dhaba.
No. 263 M.R.U.	El Adem.
No. 510 C.O.L.	Gazala.
No. 516 C.O.L.	Mersa Matruh.
No. 520 C.O.L.	Tobruk.
No. 522 C.O.L.	El Dhaba.

[1] Nos. 510 and 522 A.M.E.S., O.R.B.s, January 1942.
[2] No. 220 A.M.E.S., O.R.B., January 1942.
[3] No. 263 A.M.E.S., O.R.B., January 1942.

First Successful Mobile R.D.F. Day-Fighter Control Post

On 2 February No. 510 A.M.E.S., the mobile C.O.L. station, was moved back from Gazala to Gambut, a position between Tobruk and Bardia, giving cover to our airfields in the El Adem area. Some four days later, before the line had stabilised fully in front of Gazala, the unit was moved forward again to near Gazala, in advance of our most forward airfields. Four armoured cars and a detachment of Bofors guns were provided for the station's defence in this exposed position.[1] The location proved extremely favourable ; looking across the Gulf of Bomba at the main enemy airfields around Derna. The C.O.L. station was able to call our fighter aircraft directly through nearby forward Operations R/T vehicles. On 14 February a directly controlled operation was arranged against enemy aircraft attacking our front line positions and twenty enemy aircraft were shot down. During the first week of operations under this R.D.F. Forward Control sixty-four enemy aircraft were claimed as destroyed for the loss of only four of ours.

One factor which contributed to the success of these operations was that a reasonably accurate method of estimating heights had been devised from theoretical considerations by one of the unit's own operators. This was very successful and led to satisfactory flying heights being given to our pilots before the interceptions were attempted—a very big advantage in air fighting.[2] The Germans were completely surprised and did not realise we were using R.D.F. for direct ground control. Knowing from their losses that we had some new and effective form of control, they attempted unavailingly to weaken it by jamming ground-to-air R/T communications.

This was the first successful use of forward R.D.F. control of day fighter aircraft in support of ground forces, a method which subsequently played a big part in the operation of fighter aircraft during the remainder of the War, and the forerunner of the more efficient Forward Fighter Director Posts used later in Italy and the North-West European operations.

First Use of G.C.I. Equipment in the Western Desert

Towards the end of 1941 the G.C.I. equipment planned for the Middle East Command began to arrive as complete units from the United Kingdom. Although the first of these units were naturally allocated to the more important task of the night defence of the Delta and Suez Zones, one G.C.I. unit, No. 833 A.M.E.S., was moved into the Western Desert on 21 February 1942.[3] It was the intention not only to provide the ground control of interception at night but also to exploit to the full the possibilities of day interception of the enemy under this R.D.F. control. At that time such a control appeared likely to be of great use both by day and night in intercepting the many Axis raids on Tobruk and Gambut.[4]

The unit was sited some fifty miles behind the front line at a location East of Tobruk in the El Adem area, where our important fighter airfields were situated. There was considerable delay before the G.C.I. station was functioning, due largely to the tardiness with which aircraft were provided for calibration flights. It was six weeks after arrival on site before the unit was fully operational.[5]

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[1] No. 510 A.M.E.S., O.R.B., February 1942.

[2] Narrator's interview with Group Captain J. A. Tester, Chief Radio Officer, Headquarters, Middle East.

[3] No. 833 A.M.E.S., O.R.B., 19 February 1942.

[4] *Ibid.*, 5 April 1942.

[5] *Ibid.*, 13 April 1942.

The results obtained were disappointing during the two months in which this ground control was used. Many interceptions were attempted but the number of " kills " was negligible. The technical equipment worked well so it is difficult to account for the lack of success. Although the lack of experience of both pilots and controllers probably had some effect, a major cause of inefficiency, which could have been avoided, was the radio operators themselves.[1] The majority of the operators sent out with this unit had no experience on G.C.I. When the unit had arrived in the Middle East from the United Kingdom it had been absorbed in the R.D.F. reserve pool. On re-posting from the pool to the Western Desert, an entirely new set of Radio Operators and Mechanics, very few of whom had ever seen G.C.I. apparatus, were placed on the strength of this unit.

A second G.C.I. unit, No. 845 A.M.E.S., was brought up as far as Abu Haggag, but the absence of night fighter aircraft in this area for most of the period of operations rendered its presence almost useless. Hostile aircraft appeared with great regularity, almost nightly whether or not there was a moon, and many opportunities of night interception were lost.[2] This first deployment of G.C.I. units in the Western Desert was far from impressive. In view of the efficiency of the technical equipment, this must be interpreted as being due to faulty organisation.

Reorganisation of Responsibility for R.D.F. Matters in the Middle East Command

Since October 1940 R.D.F. had been constituted as a separate Branch from Signals in the Middle East. This was contrary to Air Ministry policy in 1941, so Air Marshal Tedder, Air Officer Commanding, Headquarters, Middle East, gave instructions in December 1941 that R.D.F. should be brought under the control of the Command Chief Signals Officer.[3] This merging of the two Branches took place gradually during the spring of 1942, hence there was no lack of continuity in the development of R.D.F. facilities within the Command.

Under this re-establishment there was an interchange of information between Signals and Radio Officers in the Cairo area by means of lectures and friendly discussions. Radio Staffs were established at the Headquarters of subordinate Commands, and every effort was made to encourage Signals Officers to become conversant with R.D.F. work and Radio Officers to acquire a knowledge of Royal Air Force Signals procedure and practice.[4] By this merging of R.D.F. into the Signals Branch it was felt that a more competent entity was being produced than the former method with each Branch working separately.

Malta and the Battle for Supplies

With the stabilisation of our lines at Gazala, there was a lull in active ground operations though there was considerable aerial activity. Both sides were engrossed in the building up of supplies in the Western Desert in order to resume the offensive. From the German point of view, supremacy in the Central Mediterranean was essential for the safety of their supply convoys. Malta was our base for offensive action against enemy shipping in this region and had also been used successfully as a base for our bombers operating against the Axis

[1] No. 833 A.M.E.S., O.R.B., 14 April 1942. [2] No. 845 A.M.E.S., O.R.B., May 1942.
[3] Air Ministry File M.S.50124, Encl. 9B.
[4] Headquarters, Middle East, O.R.B., Signals Appendices.

principal supply ports of Naples and Tripoli. It was therefore to be expected that the enemy would again attempt to neutralise this serious threat to the striking power of their forces in Libya.

During December 1941 the Germans transferred a large force of some 400 aircraft to Sicily, under the command of Field Marshal Kesselring, consisting largely of units formerly engaged on the Russian front. Towards the end of December enemy raids of increasing intensity commenced on the Island, evidently intended to neutralise it as an air and naval base by destroying all essential installations.[1] These attacks reached their peak in April 1942, attaining a weight far greater than anything the Island had ever previously experienced. In addition, the enemy sea and air blockade of the approaches to Malta was so effective that it was impossible for our supply convoys to reach the Island. It was virtually cut off, except for meagre air and submarine supplies, throughout this period.

R.D.F. during the Siege of Malta (January–May 1942)

It had been the aim of Air Ministry to build up Malta's R.D.F. stations to give complete cover round the coastline and also over the Island itself by means of a G.C.I. station. At this time R.D.F. cover was provided by :—[2]

Type of Station	*Location*	*Remarks*
C.O. station ..	Fort Dingli ..	Formed from No. 242 M.R.U. with new M.B.2 Transmitter and R.F.7 Receiver. Old mobile equipment used as standby. Now constituted an Advance C.O. station.
No. 501 C.O.L.	Fort Ta Silch ..	These three C.O.L. stations were giving all-round low cover.
No. 502 C.O.L.	Fort Magdalena..	
No. 504 C.O.L.	Fort Dingli ..	
No. 314 T.R.U.	Kaura Point ..	Used in conjunction with the C.O. station.
No. 841 G.C.I.	Gudia	—

Notes.—(*a*) A fourth C.O.L. station, No. 521 C.O.L., was located on the island of Gozo, north-west of Malta. Installation work progressed during this period but the unit was recalled to Malta on 29 April 1942 on the eve of becoming operational, it having been decided that Gozo could not be adequately defended.

(*b*) No. 241 M.R.U., which had been operational with No. 242 M.R.U. at Fort Dingli, had its personnel merged with the latter unit operating the C.O. station for a time.[3] Eventually a site was selected for No. 241 M.R.U. at Ghar Lapsi giving cover to the south and west approaches to Malta against possible raids from Tripolitania. The work of installation was hampered by enemy raids so that the station did not become operational until May 1942.

[1] Headquarters, Mediterranean O.R.B., Appendix "A," Extract from Air Ministry Weekly Intelligence Summary No. 158, para. 126.
[2] These locations were obtained from the O.R.B.s of relevant R.D.F. Units.
[3] Nos. 241 and 242 A.M.E.S., O.R.B.

Theoretically one C.O. station and three C.O.L. stations were sufficient to give adequate high and low R.D.F. cover, all reporting to the Filter Room at Valetta. In practice, due largely to the lack of ideal sites, the R.D.F. cover was not perfect. The addition of No. 314 T.R.U. had provided a useful asset in arranging day-fighter interceptions, as the C.O. station could keep track on our fighter aircraft while the T.R.U. concentrated on the hostile tracks.

When the enemy aircraft took off from Sicilian airfields and climbed to their operational height before setting course for Malta, the R.D.F. early warning given by the stations was excellent.[1] There was ample time to "scramble" our fighter aircraft for interceptions to be made. The enemy soon developed the tactics they had used from France against England, of taking off and climbing to their operational height en route. Since the distance of Malta from their Sicilian bases was only a little over sixty miles, by the time the enemy aircraft were observed by R.D.F. the warning was too short to enable our defending fighters to reach their operational height for successful interceptions.

By February 1942 under the increasing scale of enemy attacks against our airfields, our shortage of fighter aircraft, spare parts, and civilian labour for emergency repairs, proper use of the available R.D.F. information for interception purposes could not be carried out. In effect, the R.D.F. system was little more than a long-range air raid warning system.

The Germans adopted a system of standing fighter patrols over the Island. These were assisted by the installation of highly efficient enemy R.D.F. in Sicily. The latter passed movements of our fighter aircraft to their patrols, which were then able to swoop down on our outnumbered defending aircraft, who were at a great disadvantage against these surprise tactics.[2]

After the experience in Crete, a sea and airborne invasion of Malta could not be ruled out during the period of the siege. During 1941 the C.O.L. stations had kept a watch on all shipping and in July of that year No. 504 had given warning of an attack by twenty Italian E-boats on the Grand Harbour. As a result of the station's plots the element of surprise was lost to the enemy and the coastal defences destroyed practically the entire attacking force.[3] This shipping watch was maintained throughout the months of siege.

Despite the concentrated air bombardment, which during the heaviest periods in March and April 1942 averaged 200 enemy sorties per 24 hours, there were few R.D.F. casualties.[4] The maintenance of damaged reporting land-lines was heavy but the stations themselves received no major hits, despite the many bombs in their vicinity. One R.D.F. officer, three N.C.O.s and two airmen were killed by the explosion of the bombs on a crashed enemy *Ju. 87* aircraft they were attempting to salvage.[5]

In common with all forces on the Island, the R.D.F. personnel were very short of food. During these months, January to April 1942, the operators were kept watching at high pressure night and day. Mental strain and general fatigue began to tell on the R.D.F. personnel by April and, saving their physical strength for their duty hours, all personnel stopped taking any form of exercise ;

[1] Headquarters, Middle East, O.R.B.
[2] Headquarters, Mediterranean O.R.B., February 1942, para. 3.
[3] No. 504 A.M.E.S., O.R.B., July 1941.
[4] Air Ministry Weekly Intelligence Summary No. 158, May 1942.
[5] No. 501 A.M.E.S., O.R.B., 1 April 1942.

many of the men never went outside their camps for months.[1] Even so, morale remained good and the devotion to duty of R.D.F. personnel was very high during these hardest days.

Large deliveries of Spitfire aircraft to the Island on 7 May 1942 brought about a temporary increase in the enemy attacks, but these were however of shorter duration. The Island was now in a better position to fight back. One particularly interesting application of R.D.F. in Malta at this time was the use of the G.C.I. station, No. 841, near Gudia, for day interception of very high-flying enemy aircraft.[2] Successful " kills " were achieved on these raiders using a night-interception technique during the day.

Towards the end of May 1942 the enemy's attacks on Malta had died down. Malta had withstood the weight of German bombardment successfully. The R.D.F. stations had contributed considerably to the defence of the Island by their efficient early warning. The smallness of our fighter force on Malta had made it impossible to use the available R.D.F. information to the full but the successful interceptions achieved had taken toll of the enemy air forces—this major effort had been accompanied by heavy losses in their aircraft.

Although the tide of the air battle was turned by the defenders in May, June and July, the siege was still tightening. Two gallant attempts had been made to relieve the Island by convoys during June 1942, but both had proved unsuccessful. In August 1942 a large convoy had planned to sail from England through the Straits of Gibraltar. It was a desperate bid and only four ships out of 13 got through to the Grand Harbour. Finally, a convoy, which sailed from Egypt on 15 November 1942 raised the siege of the Island when its reserve stocks were practically finished.

From July 1942 the enemy began an intensive radio jamming campaign directed against the Malta R.D.F. stations with the intention of disrupting the night fighter defences.[3] This interference increased in intensity until the end of August. It was then noticed that the jamming was not synchronised with the enemy's raids. This was later ascribed to disagreement between the German scientists and Air Staff ; a state of affairs probably arising from Malta's policy of scrambling fighter aircraft during raids despite the fact that the jamming prevented correct height reading and thus the chance of effective interceptions. Anti-jamming devices were developed and constructed by the personnel of the C.O. station at Fort Dingli to combat this interference.[4] They were highly successful and were later issued to all stations on the Island. With the day fighter strength greatly increased, and the enemy superiority in numbers dwindling, the policy of forward interception was inaugurated, and although unable entirely to ward off a heavy offensive, proved itself as it had done in the Battle of Britain.

The Retreat in the Western Desert to El Alamein (25 May–8 July 1942)

Meanwhile the battle for supplies for the ground forces in the Western Desert, involved as it had been with the siege of Malta, had ended by May 1942. On 26 May 1942 the Germans launched their opening attack in the campaign popularly termed " The Battle of Egypt " with an assault on our line at Gazala.

[1] No. 242 A.M.E.S., O.R.B., April 1942. [2] Headquarters, Malta O.R.B., May 1942.
[3] Narrator's interview with Wing Commander N. Goodman, Chief Signals Officer, Air Headquarters, Malta. [4] No. 242 A.M.E.S., O.R.B.

When the Axis ground offensive commenced, although the ground forces could not hold the weight of the enemy attack, the Royal Air Force held supremacy in the air. Their rôle was therefore to inflict as many losses as possible on the enemy and fight a delaying action in support of our retreat. In common with this aggressive air policy, the R.D.F. stations along the East Cyrenaican and Egyptian coasts were left operational until the last possible moment before the capture of their locations by the enemy, so that the fighter aircraft and fighter bombers had the maximum of information on which to make successful interceptions.

It is beyond the scope of this work to deal with the many adventures of the individual R.D.F. units in these circumstances. They all continued to pass plots until the last possible moment and then moved back in leap-frog manner.[1] One station passed 744 plots in seven hours by W/T and did not leave until its position was immediately threatened by the enemy—a typical indication of the morale of the R.D.F. personnel at that time. Not all stations were able to remove their equipment in time. The M.R.U. and C.O.L. at Tobruk had to destroy all their equipment before the enemy captured the port on 21 June. Twenty of the R.D.F. personnel escaped by sea, eventually reaching the M.R.U. at Mersa Matruh, where they were re-equipped.[2] At this latter station some four days later, emergency evacuation had to be carried out, blowing up the aerial masts and firing the buildings before leaving on the long road back to Cairo for overhaul at the Radio Installation and Maintenance Unit.

The mobile C.O.L. stations were very successful in bringing about effective fighter interceptions as our forces fell back to their El Alamein positions. No. 510 C.O.L. Unit, after being cut off by enemy tanks and infantry, was given an escort of fifteen Valentine tanks and was able to continue plotting.[3] Precautionary destruction of all secret documents and correspondence was carried out because of the unit's very forward position. Although the station was subjected to strafing, bombing and shelling it was able to render useful assistance to our aircraft in the mauling of the Axis air forces. When the unit eventually retired on 26 June 1942 the number of enemy aircraft claimed as shot down as a result of interceptions brought about by this unit's operation was ninety-six.

Altogether the performance of the R.D.F. units in retreat was quite in keeping with the aggressive Royal Air Force ascendency over the enemy air forces at this time in the Western Desert. There could be little doubt that when the moment arrived for our ground forces to launch their counter-offensive, the experience and technical efficiency of the mobile R.D.F. units would be adequate to meet all calls upon them.

While the front line was static at El Alamein the enemy were only about 80 miles from Alexandria. A full dispersal of those R.D.F. units not immediately required for operations in the Western Desert was undertaken to extend the Mediterranean Coastal screen to give early warning of enemy aircraft threatening Suez. Enemy bombers had adopted an approach from the East, flying down through Palestine and across Sinai.

[1] Air Headquarters, Middle East O.R.B., Signals Branch Appendices, and Nos. 216, 220, 235, 257, 263, 510, 516, 522, and 526 A.M.E.S., O.R.B.s, 25 May–8 July 1942.
[2] No. 216 A.M.E.S., O.R.B., 23 June 1942.
[3] No. 510 A.M.E.S., O.R.B., 29 May 1942.

R.D.F. Defence of the Delta and Suez (July–October 1942)

Because of the proximity of the enemy to Cairo, heavy bomber raids over the Delta area and the Suez Canal zone were anticipated. Fortunately, in addition to the eleven R.D.F. stations giving early warning there were also nine G.C.I. stations now operational,[1] the first having commenced operations during February 1942. The combination of the R.D.F. early warning, and the G.C.I. stations' control of our A.I. equipped night-fighter aircraft gave good reason for optimism that any attempt by the enemy on mass raids over Egypt would result in heavy losses to their bomber forces, with perhaps the possible exception of an attack on Suez from the East. By this time the G.C.I. stations had nearly six months' experience. According to the Chief Signals Officer, Headquarters, Middle East, they had really "found their feet."[2] Their performances compared very favourably with those which obtained at home, and the only cause for concern was the inadequacy of the supply of replacement spare parts—for which urgent requests had been made to the United Kingdom. For some inexplicable reason, however, despite the advantageous position of the Axis forces at the time, there were no really heavy raids on the Delta and Suez. The R.D.F. stations were kept busy by the raids which occurred, but were never called upon to play a major role in defence.

Emphasis was placed on the provision of good cover for the Naval Base of the Mediterranean Fleet at Alexandria, special precautions being taken against low-flying aircraft and shipping.[3] Two C.O.L. units using CD/CHL aerial arrays (as used at home on our coastal defence CH/CHL Triple Service Stations) and three of the portable modified A.S.V. sets, which also provided excellent all-round low cover, were all sited in the vicinity of Alexandria. One Naval Type 271 R.D.F. set was also operated to sweep the approaches to the harbour. The Fleet anchorages had thus excellent R.D.F. cover not only against high and low-flying aircraft but all against enemy E-Boats and one-man submarines.

R.D.F. Preparations for an Offensive in the Western Desert (July–October 1942)

Following the retreat of our ground forces to El Alamein there was a period of great activity at the Radio Installation and Maintenance Unit near Cairo.[4] Those R.D.F. units which had been evacuated from the Western Desert required overhauls and in some cases, re-kitting. New A.M.E. Stations were also arriving from the United Kingdom, including a really mobile R.D.F. station termed the Light Warning set (L.W.S.). This latter equipment was capable of erection in under one hour, housed in a tent on a collapsible metal framework. It was readily transportable in one three-ton lorry and was considered ideal for giving R.D.F. early warning to Advanced Landing Grounds.

Previous campaigns in the Western Desert had given ample experience in the use of R.D.F. in highly mobile operations. All R.D.F. motor transport was overhauled and existing technical gear was "cleaned up" with a view to increasing its mobility. There were occasions when early warning by R.D.F. equipment might be required before it was possible to reach an Advanced Landing Ground by motor transport. In keeping with the policy of manning such Advanced Landing Grounds by personnel and equipment flown in by air,

[1] *See* Appendix No. 15 for the location of the early warning R.D.F. stations and the G.C.I. stations at this time.

[2] Headquarters, Middle East File S.54205/Signals, and Headquarters, Middle East O.R.B.

[3] Report on Alexandria Area low-flying cover by Flight Lieutenant S. N. Smith of D.C.D., M.A.P. (Narrator's interview).

[4] R.I. and M.U., Egypt O.R.B., August/September 1942.

two L.W.S. and crew were prepared, suitable for air-lift in either Bombay or Hudson aircraft.[1] The crews were specially trained in the use of their equipment and were capable of becoming operational in under 45 minutes.

The Mobile Radio Units in the forward areas along the coast usually had to *plot* by W/T to their appropriate Filter Centre. The W/T plotting code was revised and simplified, track numbering and identification procedure by the Filter Room was altered, and the standard Middle East grid map was adopted. Every effort was made to improve the efficiency of the R.D.F. raid reporting system.

Early in October 1942 there were ample R.D.F. units to support the coming land offensive. Light Warning sets were already deployed covering our Advanced Landing Grounds and mobile C.O.L. stations were in the forward areas being used for day fighter control purposes. A programme had been drawn up for the role of R.D.F. stations in the forthcoming advance ; this was explained to the commanding officers of the various mobile R.D.F. units concerned at a conference held on 18 October 1942 at Advanced Air Headquarters, Western Desert.[2]

The R.D.F. plan for the campaign was based on the technique which had been developed in the Middle East in the previous advance and retreat in the Western Desert. Briefly this was to be :—

(*a*) Forward area early warning from Light Warning Sets, and the control of fighter aircraft by mobile C.O.L. stations in the tactical area.

(*b*) As the ground forces advanced, there was to be an extension of the R.D.F. cover along the African coast by the siting of mobile R.D.F. units at intervals. G.C.I. units and additional C.O.L. stations were also to move forward from those held in reserve, to give good defensive cover and night fighter control over important ports which were to be captured.

This scheme involved more than the mobile R.D.F. units already under the Western Desert Command ;[3] a further five Mobile Radio Units, three C.O.L. units and two G.C.I. units were to be moved up as reinforcements from the reserve R.D.F. pool. This made a total of fifteen R.D.F. stations envisaged as required for employment in our impending advance. This was, of course, a ridiculously small number viewed by home standards but to the Western Desert Air Force it was luxury.

The Advance from El Alamein to Algeria (October 1942–February 1943)

The British offensive opened on the evening of 23 October at El Alamein. After hard fighting there were signs of an enemy withdrawal by 3 November. As the momentum of our advance developed the enemy was unable to mass for more than momentary stands and our pursuit continued, its speed being limited mainly by the rate with which our supplies could be brought up.

In the air the Royal Air Force held an almost complete mastery of the Axis air forces. The employment of R.D.F. units both in early warning and fighter interceptions was by now quite stereotyped and there are several references in relevant documents to the appreciations by our Fighter Control Officers of the

[1] Air Headquarters, Middle East O.R.B., Signals Appendices.
[2] No. 220 A.M.E.S., O.R.B., 20 October 1942.
[3] These Units were No. 220 M.R.U. and Nos. 510, 515, 522 and 526 C.O.L. stations.

accuracy of the R.D.F. information supplied by the mobile C.O.L. stations.[1] These stations, employed in forward areas, were frequently given direct control of tactical aircraft far beyond the enemy's lines. Nos. 510 and 522 C.O.L. Units, the two most experienced mobile stations in this type of work, continued to enhance the high reputation they had established in the Western Desert earlier in the year.

With so many R.D.F. units involved in this campaign, to deal with their movements individually in this vast theatre of operations would obscure their real contribution to the campaign. Even in terms of the appropriate dates it is hard to appreciate the speed of our advance. Nevertheless, some impression can be gained from the movement of No. 515 C.O.L. Unit, which travelled 740 miles under rough desert conditions in only seven and a half days during November. As had been foreseen during the preparations for this offensive, it was not always possible for the R.D.F. stations using motor transport to keep up with the speed of the advance. The airborne L.W.S. early warning station was therefore used on 18 December, when it was transported to the Marble Arch landing ground by air.[2] The standard attained by its specially trained R.D.F. crew was excellent—they were able to set up the station and give R.D.F. cover to the landing ground within three-quarters of an hour.

By 23 January 1943 the British ground forces entered Tripoli—nearly 1,500 miles of North African coastline had fallen into our hands since the Battle of El Alamein had started. During February this was increased, but the enemy made a stand at the " Mareth Line " in Algeria. Along this coastline both M.R.U.s and C.O.L. stations were installed rapidly to give cover against both high- and low-level enemy attacks on our elongated lines of communication.[3]

The only major R.D.F. problem at that time was the maintenance of the many stations operating in this Chain. The available stock of spare parts in the Middle East was too low to permit each unit to hold adequate spare parts to cover all possible technical breakdowns. Replacement spare parts were, therefore, held at the Radio Installation and Maintenance Unit at Tura.[4] The front was 1,500 miles away at that time, and the air transport position was extremely bad—the Air Freight Centre at Heliopolis claimed that each day they were receiving twice as much equipment as they could carry. The roads along the coast were in very poor condition and the distance so great that supplying the Chain by road was a very slow procedure. The most forward R.D.F. units supplied by the R.I. and M.U. were actually nearer to London than the Delta, so it was necessary to split the R.I. and M.U. and send a forward R.I. and M.U. detachment with adequate stores and technicians to function in Tunisia. This provided an effective solution to the acute stores and servicing problems.

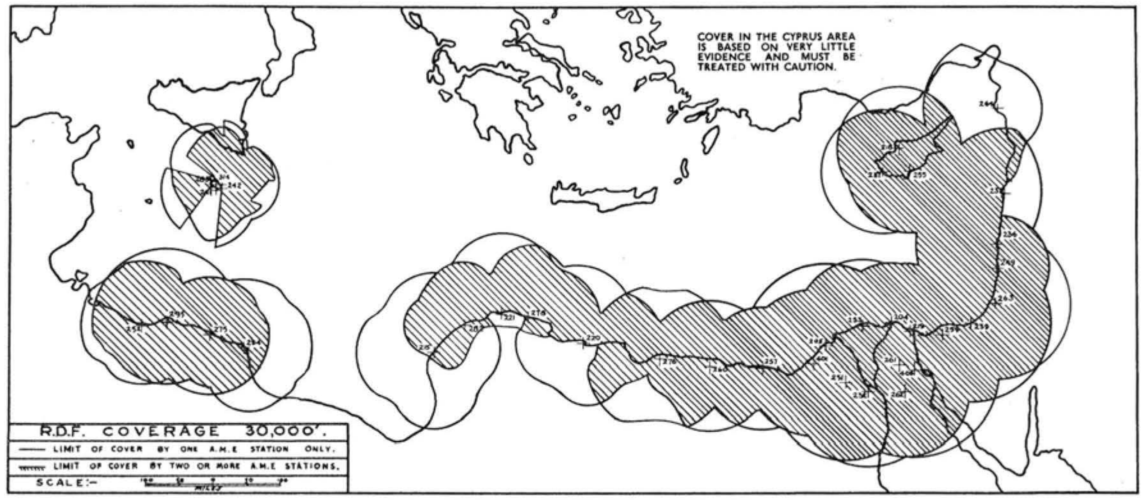
This chapter ends on the flood-tide of our successes in Egypt, Cyrenaica, Libya and Tripolitania. In its adaptability to the very mobile warfare of this theatre of operations, the R.D.F. early warning system had functioned very successfully. It is appreciated that details have been omitted from this narrative of the development of static R.D.F. cover in such localities as East

[1] Nos. 510 and 522 A.M.E.S., O.R.B., December 1942–February 1943.
[2] Air Headquarters, Middle East O.R.B., Signals Appendices, 18 December 1942.
[3] Diagrams of the high and low R.D.F. cover available and the number of R.D.F. units involved at this time are given in Map No. 6.
[4] R.I. and M.U., O.R.B., 28 February 1943.

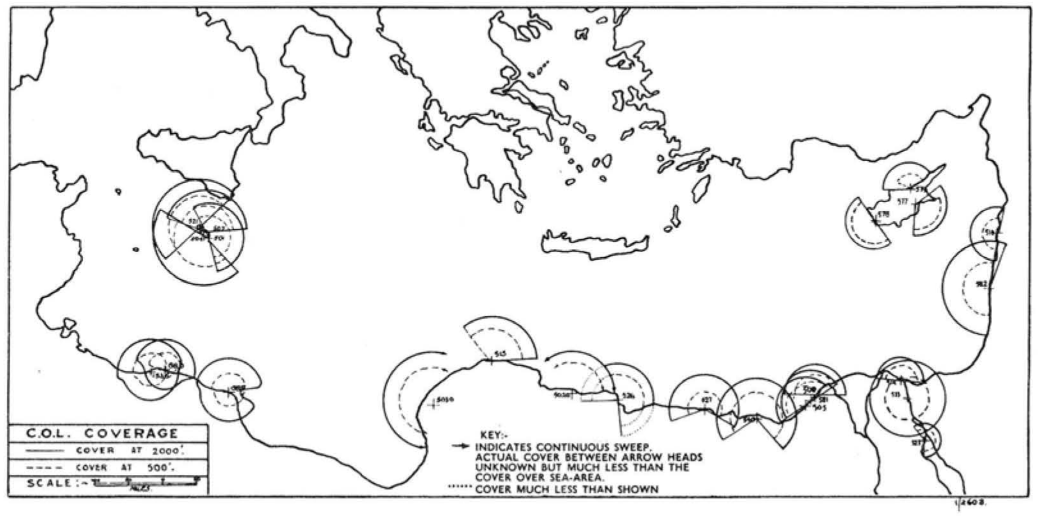
MAP No. 6.

MARCH, 1943
R.D.F. COVER IN CENTRAL AND EASTERN MEDITERRANEAN UNDER H.Q. MIDDLE EAST, AFTER THE FINAL ADVANCE FROM EL ALAMEIN.

(.1.) HIGH COVER BY C.O. STATIONS, T.R.U., AND M.R.U..



(.2.) LOW COVER BY C.O.L. STATIONS.



A.H.B.I. MAP No. 160.

and West Africa, under the aegis of the Middle East Command but remote from the major operations against the enemy. Rather has attention been focussed throughout this chapter chiefly on the support offered by ground R.D.F. stations to the various military campaign requirements in the Middle East.

With the Axis forces driven back into Tunisia, the operational importance of the Middle East Command declined. The American and British landings in North-West Africa on 8 November 1942, following the victory of El Alamein, swung the centre of operations towards the Western and Central Mediterranean. By the end of January 1943 the newly-forming Mediterranean Air Command was taking over the major direction of operations, embracing the subordinate Commands of the Allied Air Forces in North-West Africa, the R.A.F. in the Middle East and the Royal Air Force in Malta.

The part played by R.D.F. ground stations in the subsequent final defeat of the enemy in North Africa is dealt with later in this volume.[1]

[1] The relevant chapters are :—

Chapter 17—" R.D.F. Raid Reporting in the Invasion of North-West Africa (Operation Torch)."

Chapter 18—" Ground R.D.F. in the Final Phases of the Tunisian Campaign (January-May 1943)."

CHAPTER 13

R.D.F. RAID REPORTING IN THE FAR EAST, JULY 1940 – MAY 1942

This chapter includes the period before our declaration of war on the Japanese on 8 December 1941, following their attack on Pearl Harbour, and ends with the peak of the Japanese military successes in the British theatre of operations —the fall of Mandalay, 1 May 1942. The narrative therefore covers our attempts to build up an early warning raid reporting system at strategic points in the Far East, followed by details of the R.D.F. units during the short campaign culminating in the collapse of our forces.

The most vital factor controlling the slow development of R.D.F. cover in the Far East was the general shortage of R.D.F. equipment during the period under consideration, and the even more important demands of the Home Chain and Middle East requirements. These production difficulties at home were emphasised still more by the fact that R.D.F. apparatus for the Far East had to be fully tropicalised—the components in the normal Home Chain equipment would not stand up to the rigours of the climate in the Far East, and research into adequate tropicalisation was making slow progress in the United Kingdom.

The location of R.D.F. stations in the Far East was coloured largely by factors of general policy of the War Cabinet. Of these, the basic principle which exercised most influence was that R.D.F. had a useful contribution to make only when used in conjunction with the active defences of fighter aircraft and A.A. guns. In order to appreciate the lack of progress in R.D.F. provision in the Far East during the first year of the War it is necessary to recapitulate briefly[1] the early history of the organisation there.

Early History of R.D.F. Organisation in the Far East

Before 1941 no more than a superficial consideration had been given to the possibility of erecting R.D.F. stations in the Far East. The only work that had been done was a brief survey made in 1938 when all-round looking C.O. Type stations were recommended for Hong Kong, Singapore, Penang, Rangoon, Trincomalee and Colombo, but no sites were chosen except in the case of Singapore.[2] It will be remembered that in April 1939 the Air Officer Commanding, Far East, Air Vice-Marshal A. W. Tedder, had asked for the erection of at least one single R.D.F. station near Singapore as soon as possible, but due to the lack of R.D.F. supplies, no equipment was available when war broke out in Europe.[3]

A provisional programme of one MB2 transmitter and MB1a receiver to arrive in Singapore by April 1940 and a C.H.L. set in May 1940 was agreed upon by the Port Defence Committee in January 1940. In June 1940 no siting reconnaissance had yet been carried out and it was proposed to send F/Lt. Atherton, who had done such work in the Middle East, to make a survey of both Singapore and Burma as soon as possible.[4] A month later Air Marshal

[1] Full details of the early plans for R.D.F. cover in the Far East are given in Chapters 5 and 8 of this volume.

[2] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 80A.

[3] Air Ministry File S.44211, Encls. 26A and B.

[4] A.H.B./IIE/68, Minutes of the Inter-Service Committee on R.D.F., 11th Meeting.

Sir Philip Joubert, Assistant Chief of Air Staff (Radio), in a letter to the Director of Communications Development, pointed out that the problem of defended ports abroad was of low priority, and east of Suez could be regarded mainly as a C.H.L. commitment. There were, however, two exceptions to this :—

(*a*) the probability that both Rangoon and Singapore, owing to the danger of Japanese air attack from land bases, might require full C.O. equipment.

(*b*) the mobile defence of the North-West Frontier.

By August 1940 the Governor of Burma was still in ignorance on the subject of R.D.F. The siting expert, F/Lt. Atherton, had travelled no farther than India. There was still great insistence on the urgency for R.D.F. installation in Singapore, but the minimum needs of the ports in the war zones had to be satisfied first.[1]

In October 1940 the 14th Inter-Service R.D.F. Committee meeting decided that the Directorate of Communications Development must make available the necessary personnel to make a survey of Singapore and Burma.[2] In November 1940 the question of R.D.F. for overseas was on the agenda of the 15th Meeting of the Inter-Service R.D.F. Committee but was postponed for discussion until the 17th Meeting in March 1941. It noted however that some equipment was intended for despatch in the near future to Singapore. Thus it was not until toward the end of the year, following the appointment of Air Chief Marshal Sir Robert Brooke-Popham as Commander-in-Chief, Far East, that the Air Ministry finally arranged for the despatch of R.D.F. equipment to that theatre. In addition a Chief Radio Officer and Radio staff officers were to be added to the establishment of Air Headquarters, Far East, including Directorate of Communications Development scientific representatives.[3] A Radio Installation and Maintenance Unit was to be formed in Singapore and initially one M.R.U., one T.R.U., and two C.O.L. stations were to be sent.

Re-allocation of Priorities for Installing C.O. Stations

On the agenda for the 17th Meeting of the Inter-Service R.D.F. Committee held on 18 March 1941, a proposal was made to amend the order of priority for C.O. stations which had been agreed at the 14th Meeting.[4] This new policy affected stations in the Far East mainly, and involved the following changes :—

Old Order.	*Revised Order.*
Hong Kong.	Penang.
Trincomalee.	Rangoon.
Rangoon.	Hong Kong.
Colombo.	Trincomalee.
Penang.	Colombo.

This was the decision agreed upon at War Cabinet level but local conditions produced differing opinions. Following discussions between the Commander-in-Chief, Far East, and the newly-formed Radio Branch there, a

[1] A.H.B./IIE/68, giving the 9th Meeting of the Ports Defence Committee, 23 August 1940.
[2] *Ibid.*, Inter-Service Committee on R.D.F., Minutes of 14th and 15th Meetings.
[3] Air Ministry Files S.4422, Encl. 1A, and S.52465, Encl. 55A.
[4] This order of priority was indicated in Chapter 12. The new policy is shown in A.H.B./IIE/68, 17th Meeting, Item 5 (*b*). Map No. 4 refers.

policy was formulated giving first priority to the provision of R.D.F. cover for Singapore, particularly against attack over the sea from the north-east and providing for the expansion of R.D.F. cover along the eastern coast of Malaya, to be followed by a station at Penang and subsequent cover down the western coast of Malaya.[1] R.D.F. cover for Hong Kong was not considered justifiable, nor was the provision of R.D.F. for Ceylon necessary at this time. Rangoon and the oil-fields of Burma were deemed to be low priority and the possibility of providing cover for Manila and the Netherlands East Indies was thought to be neither desirable nor politically possible at this stage. Fighter aircraft were not available in the Far East and both wireless and telephone communications were rudimentary in the extreme. Thus the all-important accessories to perfect R.D.F. functioning were non-existent and the recurring trouble of the Middle East of single R.D.F. stations acting purely as air raid warnings was even more difficult to overcome in this partially uncivilised and impenetrable territory.

Erection of R.D.F. Stations in the Far East

The first site chosen was for a Mobile Radio Unit, to be situated on the south-east side of Singapore Island at Tanah Merah Besar, close to Changi. M.R.U. No. 250 was erected there shortly after its arrival in Singapore during March 1941.[2] It was a sea-shore site and the station had a one-way looking aerial array with a line-of-shoot of 067° covering an approach from the sea, giving good height measurements over an arc 020° to 160°.

T.R.U. No. 243, which had arrived with M.R.U. No. 250, was next erected with considerable delay on the part of the Directorate of Works at Mersing, a sea-shore site on the east coast of Malaya about 100 miles from Singapore.[3] The station, with a line-of-shoot of 045°, gave comparatively good heights but its performance in the ranges of 40 to 50 miles was poor owing to the presence of large permanent echoes from the 2,000-foot island of Pulau Tioman, which lay practically on the line-of-shoot of the station.

The next two A.M.E. stations to arrive in the Far East were C.O.L.s Nos. 511 and 512 in April 1941, and although they were sited immediately, Works Services were not completed until December 1941.[4] It was a marked characteristic of the Far East theatre, that the whole of the R.D.F. programme was consistently held up by the extreme slowness of the Directorate of Works.[5] Provision of hutted buildings for C.O.L. stations took at least six times the time required for similar work in the United Kingdom, apart from which the huts were badly built and seldom completed. Part of the reason for this slowness was undoubtedly the extreme peace-time financial control which the Ministry Auditors appeared to exert over the Chief Engineer.

C.O.L. stations Nos. 511 and 512 were sited in Johore, No. 511 at Bukit Chunang, on the extreme south-east tip of Johore overlooking the sea, with a clear sweep from 010° to 260° over the sea and further round to 290° to cover Singapore Island and south-west Johore. No. 512 was sited on the corresponding south-west tip of Johore at Tanjong Kupang.

[1] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 80A.
[2] No. 250 A.M.E.S., O.R.B.
[3] No. 243 A.M.E.S., O.R.B.
[4] Nos. 511 and 512 A.M.E.S., O.R.B., April 1941.
[5] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 80A.

Additional Cover for Singapore

In early May 1941, Air Vice-Marshal Pulford became Air Officer Commanding Headquarters, Far East. He immediately appreciated the fact that Singapore was virtually undefended from attack overland and insisted that at least one R.D.F. station should be sited to give some attempt at providing cover against overland attack. During the month two further C.O.L. sets had arrived in the Far East and one of these, No. 518 A.M.E.S., was therefore placed at Kota Tinggi, halfway between Singapore and Mersing.[1] This site, 550 feet above sea level, had a reasonably good sweep over broken country, but was almost blind in the sector 270° to 000° due to a range of mountains some 2,000 feet high. After a survey of Burma had been carried out, No. 517 A.M.E.S., the second C.O.L. set, was sent to a site alongside the airfield at Moulmein in South Burma.

Cancellation of the C.O. Station Programme

In May 1941, with the Home Chain passing through the transition stage from " Intermediate " to " Final " form and the Middle East needing replacements of equipment lost in Crete and Greece together with reinforcements to consolidate our position on all flanks, it was finally decided that the C.O. Type stations must be abandoned at Aden, Gibraltar, Freetown, Takoradi, Kilindini, Penang, Rangoon, Hong Kong, Singapore, Trincomalee and Trinidad.[2] The construction of a C.O. station was necessarily a long-term programme, and in view of the fact that a Transportable Radio Unit, using MB2 equipment and 105 feet transportable aerial masts might be regarded as giving an adequate performance, they were to be substituted for the proposed C.O. stations on the sites mentioned above, with variations in the type of towers as might be dictated by local conditions and the substitution, subject to availability of equipment, of the RF7 receiver for the RM3B. An added advantage of a Transportable Radio Unit was the fact that it could be erected in temporary buildings in from three to four weeks, and a further consideration influencing this drastic step in R.D.F. policy was the lack of trained personnel to undertake the necessarily elaborate installation work in the construction of a full C.O. station.

Production of R.D.F. Equipment in Australia

With the threat of a hostile Japan always in mind, satisfactory R.D.F. cover for Australia became essential. It was hoped that the Australian authorities might be able to meet their own R.D.F. requirements. Up to date, May 1941, they had approximately fifty C.D. sets in production which they hoped would be completed by the end of 1941.[3] Twenty of these would then become available for use outside Australia. In general, Australian production was limited to low-power sets using a very small type of valve and they were engaged in making A.S.V. as well as C.D. equipment, but neither was to British pattern.[4] Crews and wood for masts were also required from Australian sources, in fact the Inter-Services R.D.F. Committee would only sanction a Transportable Radio Unit for Rangoon on the understanding that the crew personnel could be obtained from Australia and the masts made locally in the Far East.[5]

[1] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 80A, and Air Ministry File S.4422, Encl. 67A

[2] Air Ministry File S.44211, Encl. 111A.

[3] Inter-Service Committee on R.D.F., Minutes of 20th Meeting, para. 11.

[4] *Ibid.*, 21st Meeting, Item 7, para. (*f*).

[5] Air Ministry File S.44211, Encl. 110A.

Increased Demands for R.D.F. Equipment for the Far East

Although a much more remote problem at the time, the Far East presented a more formidable task for R.D.F. provision than the Middle East, in that far greater stretches of coast-line had to be adequately covered, often encroaching on uncivilised and hostile territory, spreading over a far wider area than had ever before been envisaged in R.D.F. organisation. In July 1941 Air Headquarters, Far East, submitted an estimate of the ground R.D.F. station requirements that they considered essential for safeguarding the area with which the Command was concerned, namely, Malaya and Burma.[1] This estimate was based on two surveys that had been carried out by R.D.F. experts and far exceeded any original plans made in the past.[2] This change in policy was the direct outcome of a scheme for strengthening the entire air defence of Malaya and Burma and included the construction and equipping of both fighter and bomber airfields. The scale of equipment considered necessary was as follows :—

T.R.U.s	*M.R.U.s*	*C.O.L.s*
23	7	32

The R.D.F. Policy Sub-Committee agreed that this demand should be met and anticipated that all such equipments would have been shipped by April 1942.

R.D.F. Provision for the Netherlands Indies

In September 1941 a letter was received from the Royal Netherlands Navy Department concerning the establishment of an R.D.F. organisation in the Netherlands Indies as soon as possible. The strategical position of the Netherlands Indies made this question not only one of mutual interest, but also, in view of the political situation in the Pacific, one of great urgency.[3] Sourabaya Bay was the first strategic point to come under consideration, the Dutch Naval Base, major Air Base and centre of industry forming a vulnerable target for high and low-flying attack from the Java Sea, the region north of Java and Madoera, or from an easterly direction north of Bali and Java and south of Madoera. Cover from surface shipping attacks from these areas would also be required. The War Cabinet concurred with the idea that R.D.F. should be provided to the Netherlands but stated that the equipment must come from the Far East Pool, to be released to the Dutch after the Commander-in-Chief was satisfied that his more urgent commitments had been fulfilled, as it was impossible to create extra supplies for this purpose.[4]

R.D.F. Policy for India—Emergency Action

Having regard to the urgent requirements at home and the even more pressing commitments for the Middle East Command during May 1941 the provision of R.D.F. equipment for India was postponed first until the beginning of 1942 and later to an indefinite date. Owing to the highly secret nature of R.D.F., it was considered inadvisable to train Indian personnel in operational details.[5] By August 1941, however, the increasing Japanese threat to India

[1] War Cabinet R.D.F. Policy Sub-Committee, 7th Meeting, R.D.F. (41), Annex 11.

[2] The survey of Burma and the Radio Branch report on R.D.F. cover in Malaya are given in Appendices Nos. 16 and 17.

[3] War Cabinet R.D.F. Policy Sub-Committee, 7th Meeting, Appendix to papers.

[4] *Ibid.*, R.D.F. (41) 7th Meeting, para. 6, sub-paras. (i) and (ii).

[5] Inter-Service Committee on R.D.F., Agenda for 21st Meeting, Item 7, para. (*b*), and Air Ministry File S.49984.

could no longer be ignored; it was felt that India should have priority of equipment over Aden and that provision should be made for R.D.F. sets for Calcutta and Madras from those becoming immediately available.

Scarcity of trained crews presented a particularly acute problem and to relieve the even greater pressure that Indian demands would create on the shortage of manpower from the home country, it was agreed at the second meeting of the War Cabinet R.D.F. Policy Sub-Committee that Indian personnel generally should be accepted and trained to operate the earlier types of R.D.F. equipment.[1]

Disclosure of R.D.F. Information to Russia

Prompted no doubt by the signing of the Anglo-Soviet Pact in July 1941, the same R.D.F. Policy Sub-Committee also decided that the Russian authorities should be given technical details to the extent of those given to India. It was believed that the Russians already possessed a fairly comprehensive knowledge of R.D.F. and if this equipment fell into the hands of the Germans through a Russian collapse it was not now of such a secret nature that it would harm the Allied cause. No information however was to be given on up-to-date equipment such as I.F.F. other than Mark II, G.C.I., G.L., Mark II, S.L.C., A.I., A.S.V. or anti-jamming equipment for C.H. stations.

To meet unforeseen requirements a reserve pool of ten M.R.U.s had been held in the United Kingdom, but to substantiate the technical knowledge imparted to the Russians and to assist in their training facilities, three of these sets were released to Russia, despite overwhelming demands from the Middle East and requests for M.R.U.s from the Royal Navy to afford R.D.F. control at certain Naval Air Stations for the training of fighter aircraft in air interception.[2] By this time all existing demands for M.R.U.s had been met. This left a deficiency of eleven sets and no reserve—the latter being considered vitally important to meet the almost unpredictable requests of future operations, or additional demands from Russia or other Allies. It was therefore arranged to place an immediate order for eighteen more M.R.U.s for overseas use.

Difficulties Encountered in Effecting an Efficient R.D.F. Organisation in the Far East

By mid-summer 1941 three things became apparent in the light of experience. The first was that telecommunications in Malaya were the major limiting factor in any expansion of R.D.F. cover; the second was that Seletar airfield, which was already overcrowded, had insufficient accommodation to absorb the expanding Radio Installation and Maintenance Unit, and the third was that the parent unit system of administration of A.M.E. Stations (No. 151 M.U. had been the parent unit for all A.M.E. Stations in the Far East) was a failure.[3]

The problem of communications was tackled from two sides. On the long-term basis arrangements were initiated for the provision of trunk tie-lines from each area in which A.M.E. Stations were to be erected, to their respective Filter Rooms; and inter-linking by lines between the two Filter Rooms. Provision was also to be made in each area for the A.M.E. Stations to plot direct to the Fighter Operations Room at the local aerodrome. In view of

[1] War Cabinet R.D.F. Policy Sub-Committee (41), 2nd Meeting, para. (4).
[2] *Ibid.*, 7th Meeting, para. 8 and Annex III.
[3] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 80A.

the delay, however, which was anticipated in the provision of these circuits (at least eighteen months for the equipment to be obtained from the United States) and the fact that the slow rate of working of the Directorate of Works had necessarily entailed considerable misemployment of radio mechanics, it was decided to tackle the communications problem from a second side. This was the provision of V.H.F. R/T links for ground-to-ground working. Air Ministry had informed Headquarters, Far East, that no V.H.F. R/T would be available for shipment to their Command before June 1942; and as H.F. R/T and W/T were almost useless for the ranges required in the Far East (where electric storms are the normal state of the atmosphere) it was decided to concentrate on locally-made V.H.F. R/T links. The task was given to the Officer Commanding No. 518 C.O.L. Station and he and his crew were installed in the top flat of the Cathay skyscraper in Singapore. There they produced a highly successful V.H.F. R/T transmitter and receiver from locally obtained components. The essence of the design was simplicity itself and links were finally installed between the Cathay and all existing A.M.E. Stations. Whereever these links were installed, communications never failed right up to the time of the withdrawal or the demolition of the stations concerned.

The second main problem of keeping pace with the expansion of the Radio Installation and Maintenance Unit was settled by moving the unit to a new site at Ponggol, three miles East of Seletar. Making it responsible for the administration of the A.M.E. Stations disposed of the third problem. It became, in effect, a South Malaya Radio Wing.

Expansion of the Air Reporting System in Malaya, August 1941–December 1941

By August 1941 the R.D.F. plan for Malaya was fairly well crystallised. Siting had been carried out throughout Malaya, Burma and Trincomalee and two stations, M.R.U. No. 250 at Tanah Merah Besar and T.R.U. No. 243 at Mersing, were operational, plotting to a Filter Room situated temporarily at Katong.[1] Towards the end of August 1941 the expansion of the R.D.F. programme in Malaya began and stations which had been requested from Air Ministry started to arrive. No. 575 (C.D./C.H.L.), No. 306 and No. 370 (A.C.O.s) and two C.D./C.H.L. stations provided by the War Office were in the Far East before September 1941.

To implement the R.D.F. cover and fill in the numerous gaps in the information which were unavoidable in a country so unsuited to the use of R.D.F. equipment, it was found necessary to bring the Observer Corps up to date. In August 1941 the responsibility for the organisation and training of the air watching scheme was transferred from the General Officer Commanding, Malaya, to the Air Officer Commanding, Far East.[2] This organisation consisted of 171 Observer Posts and six Observer Centres to be supplemented by fifty further posts and an additional centre. The method of manning these posts by Service personnel and local police was considered unsuitable for conditions of active warfare and Air Vice-Marshal Pulford set about reorganising the Corps to run on similar lines to those on which the Royal Observer Corps was run at home.

The period from September to December 1941 was marked chiefly by continual difficulties over the Works Services for A.M.E. stations. Sometimes the hold-up lay in the fact that it was necessary to erect a station in an Unfederated Malay

[1] A.H.B./IIE/202, Far East Operational Reports.
[2] Air Headquarters, Far East O.R.B., August 1941.

State and this required prior sanction from the ruler of the state, which usually took some time to obtain—especially in the case of Johore. More often it was just the administrative machinery that was not used to or designed for working with any great speed. This difficulty became so onerous that eventually Air Vice-Marshal Pulford found it necessary to attach three officers, who had had Works experience in civil life, to the Radio Branch as Works Liaison Officers for the sole purpose of hastening the Works Services of A.M.E. stations. The fruits of their labours very shortly became visible, and it was largely due to their efforts that Nos. 511, 512 and 518 A.M.E.S. became operational at the beginning of December 1941.

R.D.F. Provision for Hong Kong

Although Hong Kong had been one of the earliest ports selected for R.D.F. provision, namely, one C.O. type station, this was contrary to War Cabinet policy as it was realised that the island could not be defended for any length of time. At the C.H.L. Planning Sub-Committee meeting held in April 1941 no provision was made for a C.O.L. station as no fighter aircraft were being despatched to Hong Kong and it was considered inadvisable to instal any important equipment which might have to be destroyed to avoid capture.[1] In August 1941, the War Cabinet R.D.F. Policy Sub-Committee went so far as to note that no operational requirements now existed for R.D.F. at Hong Kong and that the only likely account on which equipment might be desirable would be for the purpose of stiffening morale.[2] Despite the somewhat gloomy view taken by higher authority, however, a siting party visited Hong Kong in November 1941, also making a preliminary survey of Manila and the more important parts of the Philippine Islands.

Before any R.D.F. equipment arrived in Hong Kong, Japan opened hostilities without any formal declaration of war and Hong Kong received surprise aerial attacks on 7 December 1941, the same date as Pearl Harbour. Only eighteen days after the outbreak of war with Japan, Hong Kong was captured by the Japanese, our position there being virtually untenable. The original War Cabinet decision not to risk R.D.F. equipment without adequate defence thereby proved to be correct.

The Position of R.D.F. in the Far East at the Outbreak of War with Japan

The outbreak of the war with Japan on 7 December 1941 found the following A.M.E. stations[3] operational in the Far East :—

(*a*) No. 243 T.R.U. operational at Mersing.

(*b*) No. 250 M.R.U. operational at Tanah Merah Besar.

(*c*) No. 511 C.O.L. operational at Bukit Chunang.

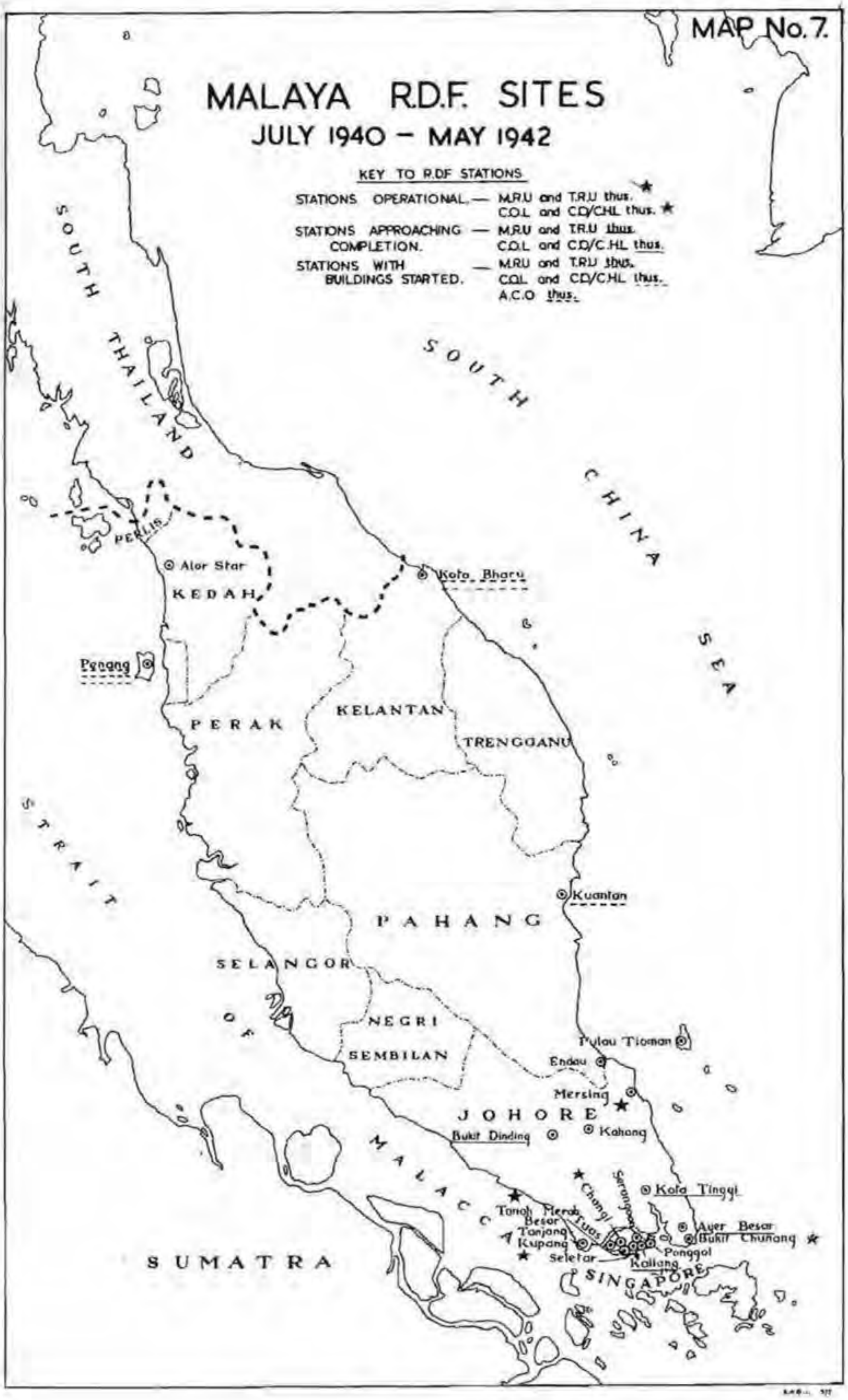
(*d*) No. 512 C.O.L. operational at Tanjong Kupang.

No. 518 C.O.L. at Kota Tinggi was approaching completion and works services were well advanced for No. 575 C.D./C.H.L. to be erected at Bukit Dinding in the middle of Malaya, west of Mersing: for No. 307 T.R.U. at Kahang,

[1] War Cabinet Paper W.P. (40) 302, " Report by Chiefs of Staff on the Situation in the Far East in event of Japanese aggression," 5 August 1940 ; and A.H.B./IIE/67, C.H.L. Planning Sub-Committee of the Inter-Services R.D.F. Committee, Interim Report, 24 April 1941, para. 22.

[2] War Cabinet R.D.F. Policy Sub-Committee (41), 3rd Meeting, para. 6, and A.H.B./IIE/70, Encl. 80A.

[3] The locations of both proposed and actual R.D.F. sites at the outbreak of war with Japan are shown on Map. No. 7.


MAP No. 7.
MALAYA R.D.F. SITES
JULY 1940 — MAY 1942
KEY TO R.DF STATIONS
STATIONS OPERATIONAL. — M.R.U and T.R.U thus.
C.O.L and CD/CHL thus.
STATIONS APPROACHING COMPLETION. — M.R.U and T.R.U thus.
C.O.L and C.D/C.HL thus.
STATIONS WITH BUILDINGS STARTED. — M.R.U and T.R.U thus.
C.O.L and CD/CHL thus.
A.C.O thus.
SOUTH THAILAND
SOUTH CHINA SEA
PERLIS
Alor Star
KEDAH
Kota Bharu
Penang
PERAK
KELANTAN
TRENGGANU
STRAIT OF MALACCA
Kuantan
PAHANG
SELANGOR
NEGRI SEMBILAN
Pulau Tioman
Endau
Mersing
JOHORE
Bukit Dinding
Kahang
Kota Tinggi
Changi
Serangoon
Tanah Merah Besar
Tanjong Kupang
Tuas
Seletar
Kallang
Ponggol
Ayer Besar
Bukit Chunang
SINGAPORE
SUMATRA

two miles from No. 575 and for No. 306 T.R.U. at Ayer Besar, about a mile from No. 511.[1] Building had also been started on two M.R.U.s and one C.O.L. station at Penang; on one T.R.U. and one C.O.L. station at Kota Bharu and on one A.C.O. station at Kuantan. Three of the four operational stations were plotting by V.H.F. R/T links from the Cathay to the Filter Room at Katong, and the fourth, No. 243 T.R.U., was plotting by telephone when it was serviceable (which was not very often) and by W/T when it was not. Six M.R.U.s, fourteen C.O.L. stations, eight C.D./C.H.L. stations and six more T.R.U.s were also allocated to the Far East pool, but were diverted after the collapse of the entire Malayan front.[2]

Operations During the Malayan Campaign

The first raid on Singapore occurred in the early hours of the morning of 8 December. It was first picked up by No. 243 A.M.E.S. at approximately 0320 hours at a range of 75 miles on the line-of-shoot, flying south. About ten minutes later No. 250 A.M.E.S. started plotting this raid, and it was given a filtered height of 18,000 feet.[3] Almost immediately afterwards, No. 511 A.M.E.S. started plotting it, followed by No. 512, No. 243 in the meantime losing it. By this time some 35 minutes had passed and the raid was 30 miles off the south-east tip of Johore and due east of it. The raid next turned west. An auditory plot was passed on it about ten minutes later by No. 511 who reported that it consisted of a large formation flying high. It continued flying due west, plotted by Nos. 250 and 512 A.M.E.S. until directly over Singapore when bombs were dropped, the first to fall being a stick across Seletar aerodrome, 55 minutes after the first plot had been passed by No. 243 A.M.E.S. The air raid sirens had not been sounded nor had any aircraft taken off. The station personnel were for the most part still in bed. The raid was again picked up by the R.D.F. stations on its way out and was plotted due north from Singapore, passing inland at Mersing to a range of 110 miles in the direction of Saigon.

No. 518 A.M.E.S. went on the air at Kota Tinggi during the third week of December 1941.[4] During the first two weeks after the outbreak of war the Japanese raided Singapore by night, and they usually flew high. They were flying from Saigon, and this gave the R.D.F. stations then operational excellent opportunities for good tracking which they used to full advantage.

Emphasis was, however, being laid by Air Vice-Marshal Pulford on the necessity for providing more and better R.D.F. cover for the overland approaches to Singapore ; he considered that the provision of this cover was essential in view of the fact that the Japanese then had possession of the airfields at Alor Star and Kota Bharu. The buildings for No. 575 CD/CHL at Bukit Dinging and No. 307 T.R.U. at Kahang were practically completed. Both these sites were approximately 70 miles north of Singapore and, although technically both very poor, were the best obtainable in this very difficult country.[5] A new site was also chosen at Serangoon on the north side of

[1] Air Ministry File S.4422, Encl. 49A, and A.H.B./IIE/70, D.D. Ops (Overseas) Folder, Encl. 80A.
[2] A.H.B./IIE/70, Encl. 93A.
[3] A.H.B./IIJ/50/4, Operations Room Narrative, Air Headquarters, Far East, 8 December 1941, 0408 hours.
[4] No. 518 A.M.E.S. (C.O.L.), O.R.B., December 1941.
[5] A.H.B./IIJ/50/4, Ops. Room Narrative, A.H.Q., F.E.

Singapore Island for an A.C.O. station to be equipped with 125-foot towers. These towers, however, were never completed beyond the 50-foot level and No. 307 T.R.U. was rushed on the air at this site late in January 1942, using a very simple type of improvised aerial.

On 15 January 1942 the Officer Commanding, No. 243 T.R.U. at Mersing, reported that the position was becoming undefendable following the Japanese landing at Endau, 20 miles to the north of the station. The enemy were infiltrating south and the Australian forces, who had been holding Mersing, withdrew.[1] No. 243 T.R.U. was finally given orders to withdraw, which they did under extreme difficulties. Out of the fifty-eight airmen on the station only nineteen were not suffering from malaria. Throughout the withdrawal the unit was consistently bombed and machine-gunned from a low level and transport, as usual, was inadequate. Despite these obstacles the Officer Commanding removed his transmitter, receiver, both masts and aerial arrays and reached Singapore with them undamaged. He unfortunately was unable to remove the electrical power generators and one mast base and although a volunteer party essayed to salvage these the following night, the attempt was unsuccessful except for the salvaging of a large number of generator accessories.

No. 243 A.M.E.S. was then converted from a T.R.U. into an M.R.U. by the Radio and Installation Maintenance Unit and went on the air at its new site at Tuas on the west coast of Singapore Island on the 29 January 1942, fourteen days after its withdrawal from Mersing. No. 243 M.R.U., at this new site, now gave high-flying cover over the approach to Singapore down the Malacca Straits and the mainland of Malaya. The Japanese by this time were in possession of all the airfields in the north of Malaya and were using them to base their aircraft for attacks on Singapore.

Between 20 and 29 January 1942 it became necessary to withdraw Nos. 511, 512 and 518 C.O.L.s from Bukit Chunang, Tanjong Kupang and Kota Tinggi respectively. This equipment, with that of No. 575 CD/CHL and one of the Army CD/CHL.s, was taken to the R.I.M.U., overhauled, carefully packed and put on the S.S. *Loch Ranza* for Sumatra and Java. During this period, however, all evacuee shipping was being subjected to heavy bombardment and although various distress signals were received throughout the long days, lack of sufficient fighter aircraft made any air cover impossible. On 6 February a message was received reporting the loss of the S.S. *Loch Ranza* and instructions were immediately given for the ship to be salvaged or else blown up as it carried 1,000 tons of R.D.F. equipment aboard.[2] In the general chaos neither plan was implemented. The crews of these stations, however, fared better and with 70 per cent. of the personnel of the R.I.M.U. and the remainder of the Radio Branch of the Headquarters, they left Singapore for Java on the evening of the 6 February 1942, reaching Batavia without casualties.

The position in Singapore was then as follows :—

(*a*) No. 250 M.R.U. was still operational at Tanah Merah Besar, giving a reasonably good performance both in heights and ranges. The military tieline to the Filter Room was not particularly satisfactory but the V.H.F. reporting system never gave any trouble.

[1] A.H.B./IIJ/50/4, Ops. Room Narrative, A.H.Q., F.E., 20 January 1942, and A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 80A.
[2] *Ibid.*, 6 February 1942.

(*b*) A CD/CHL station was operational about half a mile from No. 250 M.R.U., having been erected on the top of the water-tower of Changi Gaol—and appropriately named "A.M.E.S. Calaboose." This station was manned by the Army and told plots by means of a tie-line and field telephone to No. 250 M.R.U. Its performance was not up to standard, as it had only recently been erected under extreme technical difficulties and the receiver required an almost complete rebuild in its power supply circuits.

(*c*) No. 243 M.R.U. was operational at Tuas on the west coast of Singapore Island, having been removed from Mersing. Its performance was highly commendable considering its lightning transformation from a T.R.U. to an M.R.U. and its first plot was at a range of 110 miles. Ranges of 120 miles were frequently passed on high-flying enemy aircraft presumably based on Butterworth or Alor Star airfields. Unfortunately it was not calibrated for height or D/F as the enemy were only four miles away (on the one time site of No. 512 A.M.E.S.) when the station was erected.

(*d*) No. 307 A.C.O. station was operational at Serangoon half a mile to the north of the R.I.M.U. at Ponggol. The aerial arrays were a simple type, formerly used on a G.M. set,[1] and mounted on the 50-foot high stubs of the half-erected 125-foot towers previously intended for the station. Erection of these towers had been going on for some time with relays of Malabri riggers working throughout the hours of daylight, but as supplies had to be obtained locally the wood was green, which necessitated burning out practically all the prebored holes before the bolts would fit, making it an extremely slow process.

The "Radio R/T Unit," as it was termed, was doing excellent work in its elevated position in the top flat of the Cathay Skyscraper. A series of R/T sets working on 100 megacycles per second frequency were manned, receiving the reports from the various A.M.E. Stations; the receivers were monitored by R/T operators who had fortunately been sent out under the incorrect title of Radio Operators, and the output of the receivers was fed through a telephone switchboard to the tie-lines linking the building with the Filter Room. Duplex operation was provided, and operators and plotters invariably preferred to plot by means of this system, since it was louder and clearer than the telephonic communications available in Malaya. Results were excellent and more than justified the expenditure of men and materials that had been put into building the system up, not the least of the difficulties being the hard and tedious task of requisitioning the flat in question.

The remaining personnel of the R.I.M.U. stayed at Ponggol, their chief concern being the completion of the modification of C.O.L. receivers to make them work under tropical conditions and, having accomplished this, to send them complete with non-technical gear to the main party of the R.I.M.U. for erection in Java and Sumatra.[2] Part of the unit's small stock of spares which had been retained in Singapore were held at the Cathay Skyscraper to provide an "immediate maintenance party" run by a few selected Radio Mechanics

[1] *See* Appendix No. 10 for details of this type of R.D.F. equipment.
[2] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 80A.

equipped with a Ford van and two Ford Mercury cars. The other equally vital job of the skeleton R.I.M.U. was attempting to obtain information of impending changes in the Army dispositions. These were liable to take place without any warning whatsoever leaving the A.M.E. stations in the unenviable position of being in front of the front line. On 9 February No. 243 M.R.U. found itself in such a position and finally, receiving orders for an immediate withdrawal, got out just in time to evade the enemy, but having to leave masts and aerial arrays behind.

By that time, the Japanese had advanced on the north side of the Island past the Naval Base, towards Seletar and the R.I.M.U. site at Ponggol was threatened. All stocks were therefore moved to a building on the south-east side of the Island by the following day, and No. 243 A.M.E.S., this now highly-seasoned traveller, once more began to bed down under the protection of the R.I.M.U. site. Work went on throughout the night on the re-erection of spare masts and technical equipment.

R.D.F. Units during the Fall of Singapore

On 11 February 1942 instructions were received for personnel of all A.M.E. stations and R.I.M.U. to be detailed into two parties, armed and unarmed, issued with four days' rations and, in the event of a withdrawal becoming necessary, the unarmed party was to move first, followed by the armed party, each man taking the bare minimum of personal kit.[1] The destination in the event of a move was Alexandra Evacuation Camp. Kallang airfield was under shell-fire and was being denied to the enemy. The Fighter Operations Room was being destroyed and the personnel withdrawn, thus leaving the Gun Operations Room the only recipient of the Filter Room information.

By that time there were only two surviving Observer Posts. These were wired to tell directly into Filter Room, and the R.I.M.U. were instructed to form further posts. At midday on 11 February 1942, No. 307 A.M.E.S. reported that the local Army authorities gave them one hour to get out. This was confirmed five minutes later by the Gun Operations Room and instructions were accordingly given for the station to be destroyed in the order (*a*) technical spares, (*b*) non-technical equipment, (*c*) technical equipment, (*d*) telephone equipment, but the V.H.F. R/T equipment was to be removed intact. The next move was a suggestion for a fourth possible alternative site for No. 243 A.M.E.S. on Bukit Brown, but a siting officer driving up to A.H.Q., Sime Road, to make a reconnaissance of the proposed spot was met by a warm but distinctly hostile reception from a machine gun. Communications were cut intermittently with Air Headquarters and news came through that the evacuation centre at Alexandra Camp was in enemy hands. A Group Captain from Air Headquarters visited Filter Room to enquire the whereabouts of the personnel from Air Headquarters, as he had been detailed to embark with the remaining troops but the ship had been rushed by armed deserters.

On 12 February the situation in the Changi area had become highly dangerous and No. 250 M.R.U. was instructed to remove its transmitter reflectors in order to give an improved performance to the South from which direction the heaviest raids were emanating. In the event of a withdrawal the Officer Commanding was warned to save his receiver aerial arrays at all cost, as they could be erected rapidly on telegraph poles, and the deserted Fighter Operations

[1] A.H.B./IIE/70, Encl. 80A.

building was selected as the best spot for the station's next move as the line to Filter Room was still intact. The CD/CHL " Calaboose " was to remain operational until it had to be destroyed.

During the afternoon many reports were received of heavy enemy troop movements in the West but no confirmation could be obtained from the Gun Operations Room and the local Brigadier could not be contacted. By the evening of 12 February 1942 instructions finally came through from the Army for the withdrawal or destruction of all secret equipment in the Changi area as the Japanese had landed in force at Loyang. By this time the crews of No. 250 M.R.U. and CD/CHL " Calaboose " had arrived at the R.I.M.U., both sets of equipment having been destroyed for fear of them falling into enemy hands on the road. These men were then told to report to the Filter Room in company with the personnel from a nearby Observer Post and the crews of No. 307 and No. 243 M.R.U., the latter complaining bitterly that they had just become operational on their new site. At 2130 hours the Air Officer Commanding instructed the Senior Radio Officer to meet him at Fort Canning and in conference with the local Army Commander it was decided that No. 243 M.R.U., which had maintained all its technical equipment, should be re-erected on Fort Canning as soon as possible.

The following morning at daybreak No. 243 M.R.U. moved to Fort Canning and once more made preparations to go on the air. The Air Officer Commanding again contacted the Senior Radio Officer and informed him that shipping accommodation had been found for 152 radio personnel in S.S. *Tien Kwong* and S.S. *Kuala*. The crews of No. 250, 307 A.M.E.S. and the remainder of the R.I.M.U. were detailed to embark from Laburnum Pier in Telok Ayer Basin between 1500 and 1700 hours. Great care was to be taken to avoid observation, no kit or bedding was to be carried, only arms and rations sufficient for four days, and the last mile of the journey was to be made on foot in groups of not more than ten men. The crew of the Filter Room were to be handed over to the Gun Operations Room and the Radio R/T Unit was to join the Army signals. No. 243 M.R.U. was to continue with its preparations for becoming operational.

At 1400 hours word was received from the Army that they were withdrawing and that the enemy were a mile away. Steps were taken to destroy the Filter Room and later instructions were received to destroy the V.H/F R/T equipment and have the personnel embarked. The Senior Radio Officer contacted the Air Officer Commanding who considered that it was hardly worthwhile waiting for No. 243 M.R.U. to become operational but that he would not give the word for its destruction unless the Army authorities agreed, promising to ring the Senior Radio Officer back. Telephone lines were cut, however, and an hour and a half later, on contacting the Senior Army Officer, the Senior Radio Officer was told that Singapore would fall before the R.D.F. station could become operational and he was therefore advised to destroy the equipment and get the crew embarked. Singapore was taken by the Japanese two days later on 15 February 1942.

At 2000 hours the Senior Radio Officer, Officers and Airmen of No. 243 M.R.U. arrived at the docks only to find they were not allowed entry unless they had passes. After some difficulty the Senior Radio Officer argued his way in and located the Air Officer Commanding in a motor launch in company with an Admiral who issued a pass for the crew of No. 243 M.R.U. to enter the basin and embark on the S.S. *Chukwong* and S.S. *Tenggarch*. Some time later the demolition party of No. 243 A.M.E.S. arrived and embarked on the S.S. *Tanjong Pinang*. Shelling of the Telok Ayer Basin from a battery in the direction of Changi took place. Explosions were very heavy and shelling continued throughout the night. All the dock area was burning furiously, particularly the coal dumps and the oil tanks on the Dutch Islands. S.S. *Tanjong Pinang* moved outside the basin and went aground.

S.S. *Chukwongi*, in which the Senior Radio Officer had embarked, was subjected to heavy bombing during the morning of 14 February 1942. Despite the zigzag course she adopted she was finally hit in the engine-room and the forward hold killing thirty men, and while she lay with her engines unserviceable and a heavy list to starboard, three enemy aircraft returned and scored another direct hit on the forward hold and one on the port side amidships, causing twelve more fatal casualties. S.S. *Tenggaroh* and the S.S. *Tanjong Pinang* hove to to pick up survivors and the Senior Radio Officer once again joined the demolition party of No. 243 M.R.U. They continued their journey up the Inderagiri River on the East side of central Sumatra, reaching Padang on 20 February, only to find that Royal Air Force personnel from the local airfields were awaiting evacuation. At Ayer Moeloek they were joined by nine airmen of the Filter Room and Radio R/T Unit personnel who reported that they thought they were the only Royal Air Force survivors from the S.S. *Chang Tei*, in which those two units had embarked. They had reached the coast in a boat, taking it in turns to be towed behind her as she was overloaded, some personnel having been in the water for 25 hours.

On 1 March 1942 the Senior Radio Officer and a party of radio personnel now numbering twenty-eight embarked in two naval craft which had put into Padang for oil, en route to Ceylon. Four airmen, ex-Nos. 250 and 307 A.M.E.S., had arrived at Padang stating that the S.S. *Tien Kwong* had been sunk. The Senior Radio Officer was most anxious that he should return to Sawahloento to check that no more radio personnel had arrived in Sumatra but he was refused permission. On 9 March the party finally found a home on the racecourse in Colombo, and three more airmen, ex-No. 307 A.M.E.S., joined them with the information that a number of officers and airmen previously believed killed or drowned were in fact alive at Ayer Moeloek in Sumatra.

Meanwhile the main party of the R.I.M.U. and Radio Branch of Air Headquarters had not fared so well. On arriving in Java on 7 February 1942 they found there was no organised R.D.F. defence of the Island.[1] The sole aircraft attack warning system was a Dutch air observer post organisation which reported in R/T clear communication to a combined Gun and Fighter Operations Room about 12-foot square, situated 3 miles out of Batavia.

Although most of the R.D.F. equipment evacuated from Singapore had been lost in the S.S. *Loch Ranza*, it was found that three Army G.L. sets and six excellently packed and complete M.R.U.s from the Royal Air Force Station, Kidbrooke, England, were stored in the Batavian transit camp. It was immediately decided to provide R.D.F. cover against Japanese air attack for Batavia initially with two M.R.U.s and later to cover Sourabaya from the mainland and from the island of Madoera. The exact locations for these

[1] A.H.B./IIJ/53/10, Malayan Report Section File M.R.S. 2019 in Directorate of Staff Training Folder titled " Signals Matters—Malaya."

stations would be decided by the findings of a siting party. A decision was also made to set up a new Filter Room in Batavia on the lines of Headquarters Fighter Command and to place the two M.R.U.s within the Batavia defence zone. Suitable sites were found and installation began at once. The Dutch supplied and erected 95-foot aerial towers with ladders and platforms made of bamboo, temporary buildings and telephone lines.

On 20 February 1942 orders were received to install the three Army G.L. sets on the West coast of Java to provide a better and earlier warning system than the existing observer corps. As this area was outside the Batavia defence zone the Dutch authorities were approached to determine how much warning of attack from the sea these sites might expect. Dutch Army Headquarters guaranteed 48 hours warning.

To the East, four G.L. sets with extended range had been left behind by the Americans and these were manned by Royal Air Force personnel to give cover over Sourabaya. The Army G.L. sets became operational on 25 February 1942. Two days later notification was received of an expected Japanese invasion and the G.L. stations were told to pull out. Two hours later the order was rescinded as the warning had proved to be a false alarm and the stations resumed operations. The following day the T.R.U. at Tengarang began plotting on a tie line to the new Filter Room and although uncalibrated it seemed to give good D/F and range. The time taken to bring the T.R.U. and Filter Room into working order from scratch was ten days.

That night information of a pending invasion was again received and this time it was no false alarm. The promised 48 hours warning had not been given and the shore stations were immediately called in to Headquarters. A Royal Air Force pilot officer was intercepted and killed while trying to evacuate his G.L. set. A driver of a lorry and transmitter trailer was stopped by the Japanese firing a shell at close range. The projectile cleared the cab of the lorry and exploded in the trailer. The driver was surrounded and ordered at pistol point to back the trailer down a 30-foot bank into a wet Padi field. When this had been completed a Japanese officer got in alongside the driver and again with revolver drawn, told him to proceed across a narrow bridge which lay ahead guarded by the Dutch. The driver accelerated, but half way over the bridge he locked the lorry sharply into the parapet where it blocked the whole road and then dived into the river. He swam to the opposite bank, warned the Dutch and the bridge was blown up.

The Japanese advance was so rapid that on the morning of 1 March 1942 Batavia was expected to fall within 48 hours. Orders were given for all secret equipment to be destroyed and for a general withdrawal of the R.D.F. personnel to Tjilitjab to be available for evacuation by sea. The several convoys met at the appointed rendezvous but found that evacuation was impossible and on 4 March 1942 all parties were ordered to return to Poerwokerto to surrender arms and ammunition in capitulation. Personnel travelled back by train and were ambushed by a force of Japanese who had wheeled westwards to cut the railway line. Casualties were not high but the wounded who were unable to walk were bayoneted by the Japanese.

Full casualty lists of R.D.F. unit personnel were ultimately compiled from statements of survivors. Two officers and twenty-nine airmen reached Ceylon out of the forty officers and five hundred airmen who manned the R.D.F. organisation in the Far East.

R.D.F. in the Burma Campaign

The Japanese were not only pressing south into the islands of the East Indies at this time. When the R.D.F. units were driven from Malaya, Burma was also being subjected to air attacks to soften up the ground defences preparatory to an attack by the Japanese Army. No. 517 A.M.E.S. C.O.L. station at Moulmein was putting up an excellent performance against heavy enemy air raids.[1] The station was installed on the top floor of the chemical laboratory of the Rangoon University. This site had been chosen after an exhaustive search of the neighbourhood. Three partly-built R.D.F. sites existed, two at Syriam, 10 miles south of Rangoon and one 18 miles to the north, but labour and supplies problems were becoming acute and the University site was practically ideal from the technical point of view as it was 700 feet above sea-level and the R.D.F. aerials were therefore clear of nearby trees and obstacles. Speed in erection and calibration had been essential as Japanese air raids were frequent, and the station personnel were congratulated by the Air Officer Commanding on the rapid manner in which they had become operational. The unit was in operation continuously, using the municipal electrical mains supply for power, and plots were passed to a temporary underground Sector Operations Room at Mingaladon airfield, pending the opening of the new Group Operations Room near No. 221 Group Headquarters.

Enemy activity was fairly heavy and several interceptions were confirmed, the Controller indicating that the R.D.F. plots were far more accurate than the Observer Post information. During the beginning of February several experiments were carried out under increasingly difficult circumstances with modified aerial systems, and ranges were improved. The situation in Burma however deteriorated, and No. 517 C.O.L. was warned to formulate some sort of evacuation scheme. Two were prepared, one covering the destruction of the equipment and evacuation of personnel at the last moment and the second one provided for the withdrawal of equipment. One of the difficulties of the latter was the risk of the equipment being intercepted on the road, as the enemy was advancing slowly down the main Mandalay–Rangoon road and it was possible they would reach the Prome Junction 20 miles north of Rangoon before the heavily-laden convoy.

On 21 February 1942 the Observer Corps ceased functioning at 1800 hours. The Chief Operations Officer was doubtful as to whether a C.O.L. station could carry on alone as it was expecting too much to ask that type of station to observe over 360° with no long-distance warning, especially as raids were coming in simultaneously from different directions. The following day the enemy carried out heavy daylight raids but failed to break through. By this time No. 517 A.M.E.S. had all its available gear packed on lorries and Group had given instructions that the station was to remain operational as long as there were any of our fighter aircraft operating from Mingaladon ; when the last aircraft had left, No. 517 A.M.E.S. was to blow up the equipment and leave by the " most suitable means." The equipment was working extremely well and there was plenty of work to be done but the administrative difficulties were almost insuperable. The ration organisation had broken down and only odd items of food were issued, medical arrangements had failed completely and the entire night was spent searching for a doctor for a sick airman. Most of the Army key-men had left the city, the City Fire Brigade, Civil Defence and Police

[1] No. 517 A.M.E.S., O.R.B., January/March 1942.

had gone, the telephones were cut and 1,500 convicts and 200 native mental cases had been let loose in the city. Looting was general and many fires were raging, including 4,000 " Lease and Lend " lorries on fire at the docks. The Adjutant of No. 517 A.M.E.S. investigated the possibilities of escape up river by boat should the road become completely blocked.

Air raids continued all through the night, and on 23 February the unit was told to stand by at half an hour's notice under the first evacuation scheme. Operations continued, and on 24 February 1942 the air attacks increased. The Japanese were now definitely trying stronger tactics to smash Mingaladon by drawing off our fighter aircraft to the West after approaching South of the city, while the really heavy raids approached from due East. This state of affairs continued for three days, reports of an outbreak of cholera adding to the general disorder. Thirty enemy aircraft were destroyed over Rangoon and Moulmein but attacks became even heavier. On the evening of 26 February 1942 the Officer Commanding No. 517 C.O.L. was called to a conference with the Air Officer Commanding at No. 221 Group and given instructions to evacuate under the second scheme, although the time limit for reaching the Prome–Mandalay Road Junction was 22 hours instead of the original 48 hours. Work was immediately started on dismantling the R.D.F. station and, working through the night, the convoy was ready to leave Rangoon at 0705 hours the next morning. It consisted of sixteen vehicles, one of which contained Burmese and Indian Army guards.

The party arrived at Magwe on 28 February 1942 and were instructed to hand over to the Army Guard for evacuation to India by air, after destroying their equipment. On the following day, however, the policy was again changed and it was decided to keep the unit at Magwe pending the arrival of our fighter aircraft. It was imperative that the unit should become operational as soon as possible, so instead of applying to the Works Directorate for technical buildings, it was considered that far less time would be taken in building coachwork bodies on to the vehicles, thus providing ultimate mobility for the whole unit.[1] On 3 March 1942 the technical lorries were run in to the Burma Oil Company workshop and four days later the now-mobile C.O.L. unit moved to its site at Yenangyaung, three miles north of the Khodoung Chaung, 11 miles north of Magwe, where it was possible to get off the road into the desert scrub for camouflage—a remarkable feat of technical skill, improvisation, and co-operation between a small unit of men.

During the next two weeks the unit changed its site five times. No trouble was spared to give the best performance possible under the most exacting conditions. On 22 March 1942 the unit packed up and left for Yenangyaung on its way to Lashio, but was stopped and told to return as aircraft reinforcements were expected at Magwe. Ten days were spent waiting for Royal Air Force personnel to return to the airfield, the time being put to good use in overhauling the equipment and, as the local Army Signals Section could not be located, the unit set to work to lay their own telephone lines. These were placed as far away from the town as possible, for the enemy had a habit of burning built-up areas to destroy communications.

In the absence of instructions from any higher authority a drain under the main road was selected as an Operations Room, being the only protected, ready-built shelter within suitable distance of our aircraft dispersal points. Again taking matters into their own hands, the unit moved to Magwe and set

[1] No. 517 A.M.E.S., O.R.B., March 1942.

up within two miles north of the airfield. Two days later they were once again on the road to Lashio. The receiver vehicle sustained damage and repairs were delayed due to heavy air raids. Eventually the unit, still intact, arrived at Maymyo only to find there was no accommodation available. The surrounding terrain was almost impossible country for R.D.F. operations, consisting as it did of mountain ranges running from north to south and separated by river valleys roughly two miles wide. Several days were spent in an exhaustive search for a suitable site, not only from a technical point of view but from the point of view of accommodation for the crews, as the rains of the monsoon had started. To build housing was out of the question as the Works Services labour had deserted, and the type of rough shelter used by the occupying Chinese Sixth Army was primitive to a degree. The equipment was eventually set up near a private bungalow loaned by the Burma Oil Corporation and became operational on 17 April 1942. The site was poor and there was no means of obtaining test flights as there were no aircraft at Lashio airfield. The food situation became increasingly serious. No Service rations were available and supplies of certain articles from local sources were non-existent.

The Japanese army in the meantime were making two new drives northwards, one from the Southern Shan States towards Haipaw, and the other up the Salween.[1] This situation required careful watching in view of the unit's valuable equipment, as the convoy on evacuation would have to return to Lashio by a difficult road before it could reach the main North road, and might easily be cut off by advancing enemy troops. On 24 April 1942 W/T signals were intercepted from the N.C.O. in charge of a portable R.D.F. set sited in the Lashio basin that they were surrounded by enemy forces and no Allied troops were in the vicinity. The following day the Officer Commanding, No. 517 C.O.L., drove into Lashio to review the position and wirelessed the unit to pack up and withdraw immediately.

Great hardships and privation were endured on the journey towards the Chinese border. Personnel slept in the vehicles and food supplies were reduced to a ration of oatmeal per man. On arrival at Wanting on the border, the town was so badly jammed with refugees and Chinese military traffic that the unit took the law into its own hands and crossed over into Chinese territory—a fortuitous decision, as Royal Air Force units who did not take such a serious view of the situation remained and had to leave Burma the next day in a hurry without their equipment.

In these circumstances, accompanied by four vehicles of the portable unit (W6B2), No. 517 A.M.E.S. set out on its hazardous 600 miles journey to Chengtu. Many adventures befell them on the way, food was terribly scarce and roads in parts were non-existent. At one stage the party were halted by overhanging rock on a narrow path which ran high above the river. The tops of the built-up lorries had to be lopped off and jettisoned into the river and the rock blasted and hammered away before the convoy could force its way through. For three weeks during the worst of the monsoon season they travelled non-stop and reached Chungking, having been diverted from Chengtu, on 23 May 1942. Here they found that the surrounding terrain was even more disappointing from an R.D.F. point of view than the Lashio area had been. The whole point of diverting No. 517 A.M.E.S. from Chengtu lay in the fact that the Chinese Air Force were not worried about long-range warning as this

[1] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 80A.

was provided by the Chinese Observer system but required merely close-range ground control for Fighter interception. This changed the whole situation as it was considered impossible to obtain all-round coverage without C.O.L. No. 517 being sited on a peak in the mountain range. After some discussion it was decided that W6B2, the portable unit brought out of Burma, should be brought to Chungking and installed on a mountain peak (which would be a relatively easy task for the lighter equipment) and No. 517 C.O.L. unit should make for Chengtu.[1]

Arriving at Chengtu, the unit found the usual difficulty of lack of accommodation, shortage of food and difficulty in obtaining supplies for reconditioning of equipment. It is significant that the unit reached Chengtu on 29 May 1942, but by the beginning of July 1942 the station was still not sited. The ground was not so difficult as previous locations from the technical point of view but food, accommodation, rate of exchange, clothing, etc., formed a major problem—as did the suspicious attitude of the Chinese Air Force towards something they did not quite understand. By 11 July 1942 it was pretty obvious to the unit that the Chinese Air Force were not going out of their way to be helpful. The only method left to stimulate them into full co-operation was to provoke the local Chinese Air Force authorities into witnessing a practical demonstration of the R.D.F. equipment and then see if "results" would produce a more favourable attitude.

By this time the spares position was acute. The unit had not received any further supplies since the initial meagre issue in July 1941. The receiver cathode ray tube eventually gave out and it was proposed to convert the monitoring cathode ray tube from the transmitter into use for the receiver, as it seemed hardly likely that spares would be forthcoming. On top of these major difficulties, the Headquarters Unit, Royal Air Force in China, attempted to incorporate the unit as part of Headquarters—which was vastly irritating, considering the hardships with which the unit already had to contend. The long journey was beginning to tell on the technical condition of the equipment and breakdown followed breakdown. Practically all the diesel oil that had been brought from Burma was used up and still none was forthcoming as promised by the Chinese. Periodical rains saturated everything and no cover could be found for the equipment. Most trying of all to bear was the thought that but for the unsatisfactory technical position the unit might have proceeded to the fighting front to assist the United States Army Air Corps.

There was no co-operation from the Chinese Air Force, and in the city itself there were several hostile incidents against the lorries belonging to the unit. Repeatedly the Officer Commanding asked for prior notice of aircraft flights in order to bring the unit on the air and check its performance, but no advance information was ever given. Finally on 13 August 1942, after a great deal of persuasion and diplomacy, a test flight took place and two officials of the Chinese Air Force were invited to witness the results. The flight actually failed in its specific purpose, *i.e.*, to obtain suitable data for the station, as its course was decidedly erratic, varying from 20 to 60 degrees off the agreed bearing. Nevertheless it at least impressed the two Chinese officials to such a degree that they were finally convinced of the strange powers of this equipment and of the mutual benefit that might be derived from closer co-operation between A.M.E.S. No. 517 and the Chinese Air Force.

[1] No. 517 A.M.E.S., O.R.B.

Unfortunately the Chinese Air Force was controlled by three co-equal generals and the only suitable site for the unit happened to come under the jurisdiction of the least friendly of the three. After many delays and setbacks, inevitable in a country prone to dealing with all matters in a leisurely manner, it was finally arranged to train Chinese personnel in both Operators' and Mechanics' duties. Lectures and practical instruction were started on 11 January 1943, and on 28 April 1943 the equipment of C.O.L. No. 517 was handed over in its entirety to the Chinese Air Force.

R.D.F. Position in the Far East at the Beginning of 1942

The seriousness of the situation in the Far East was fully appreciated in the United Kingdom. Despite the welter of R.D.F. requirements for Home, Allied, Dominion and Middle East theatres, plans were made to send additional R.D.F. units to the Far East as soon as possible in support of fighter aircraft then being diverted there.[1] The full benefits of R.D.F. planning occasioned by the entry of the Japanese into the war had not been reaped so far in the Far East. The disastrous Malayan campaign had ended before many of the R.D.F. units intended for its support had arrived in the theatre of operations. Eight R.D.F. units were already en route by sea and fifteen more were expected to follow by the end of January 1942. The first step was therefore to re-allocate these in attempts to contain the Japanese within the already-existing land and sea fronts.

Emergency Defensive R.D.F. Measures against further Japanese Aggression

With the collapse of Hong Kong, Singapore, the Andaman Islands and Mandalay, all between 25 December 1941 and 1 May 1942, Air Headquarters, Far East, ceased to exist and Air Headquarters, India, took over command. The few R.D.F. personnel who had managed to escape the Malayan debacle were withdrawn to India and units and equipment in transit were diverted where they could be saved, and sent to India and Ceylon.

Allocations were hastily made for supplying R.D.F. as quickly as possible to the remaining bulwarks against further Japanese expansion. By the late spring of 1942 the situation could be summarised as follows :—[2]

India.—On the 1 March 1942, one M.R.U. was at last in transit for Calcutta. Three A.C.O.s, four M.R.U./T.R.U.s, eight C.O.L.s and two G.C.I.s had been allocated and were awaiting despatch for dispersal in India.

Ceylon.—Two CD/CHL.s were on site in Trincomalee at Chapel Hill and Kodipotumalai Hill and five M.R.U./T.R.U.s, six C.O.L.s and one G.C.I. were in transit with a further G.C.I. having been allocated. Three of these sets had been diverted from the Middle East.

Australia.—Two CD/CHL.s for Port Darwin and Sydney were in transit accompanied by five C.O.L.s to form the nucleus of an Australian pool. Two A.C.O.s, six C.O.L.s and a G.C.I. were allocated and were awaiting despatch.

New Zealand.—Two A.C.O.s were on their way to New Zealand and five C.O.L.s were allocated and awaiting despatch.

[1] A.H.B./IIJ/50/24/5, "R.D.F.—Far East (including Anzac)" D. of Ops. (Overseas) F.O.S. Folder G.D.S., Encl. 48A.

[2] A.H.B./IIE/70, D.D. Ops (Overseas) Folder, Encl. 99A.

There were many lessons to be learned from the failure to resist the Japanese attack on Burma and Malaya—and particularly the loss of the key-port of the Far East, Singapore, on the defence of which considerable expenditure had occurred. As far as the R.D.F. raid reporting organisation was concerned, perhaps the chief lesson to be pressed home was that although the individual R.D.F. units and the Maintenance Unit locally had functioned extremely well under the most adverse conditions, Singapore was so far away from the supply bases in the United Kingdom that it had largely to depend in wartime on its own local resources.[1] These should have been backed up by technical information and drawings sent from the United Kingdom and by extensive provision of workshop facilities, skilled tradesmen, mechanical transport and wide local purchase powers. Much could have been accomplished locally if these facilities had been available. In their absence, and more particularly while rigid contract procedure was demanded in dealing with local sources of supply, the stranglehold was such that little or no effective progress could be made. It is interesting to conjecture whether the situation would have been any easier if Malaya had been administered from Australia during the initial phase of the war.

The serious setback of the Japanese successes in the Far East, coming as they did when the Germans were at the peak of their territorial gains in Europe and the Middle East, clearly indicated that the road back for the Allied forces in the Far East was to be a hard one. From the R.D.F. point of view a build-up of mobile units and equipment, all to be shipped over more than ten thousand miles from the United Kingdom, was the first essential. These units were necessary not only to strengthen the existing defensive raid reporting systems but also to prepare for the day when our forces would assail the areas then occupied by the enemy. The story of this build-up under what became South East Asia Command (S.E.A.C.) is written in a later chapter of this volume.

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[1] R.I. and M.U., Seletar O.R.B., December 1941.

CHAPTER 14

ENEMY COUNTER-MEASURES AGAINST THE HOME CHAIN R.D.F. RAID REPORTING SYSTEM

During the first year of the War the enemy had been slow to realise the value to home defences of the R.D.F. Chain, although during August 1940 an attempt had been made by direct bombing attacks to strike a blow at the South coast R.D.F. stations.[1] Subsequent interrogation of high-ranking officers of the *Luftwaffe* showed that the enemy held the opinion that R.D.F. stations were considered difficult targets to damage effectively by direct attack, especially in face of the opposition of Fighter Command.[2]

Nevertheless, direct attacks continued on a much-reduced scale. More than forty-seven such incidents were reported during the years 1942–1943, directed either in whole or in part against the R.D.F. stations; three of these attacks were made on Swingate (Dover) by shell-fire across the English Channel, and this station received more attention from the enemy than any other in the R.D.F. Chain.[3] The aerial attacks were mainly concentrated on the East and South-East coasts, with a few on the South coast. One fatality was sustained at Bawdsey C.H. Station, but on the whole very little damage was done to technical installations and no station was put out of action as a result. More than eight enemy aircraft taking part in these raids were destroyed. Operations were carried out as usual through even the heaviest attacks.

The alternative method which the enemy might employ of indirectly attacking the Home Chain had not been overlooked, namely, by attempting to render R.D.F. raid reporting impossible by the use of jamming transmissions on the frequency bands within which the R.D.F. stations functioned. Such a method, if successful, would have masked the observation of enemy aircraft on the cathode ray tube itself by blanketing the "echoes" of the aircraft in some curve or pulses sweeping across the face of the tube. Fortunately the possibility of enemy jamming had been foreseen as far back as 1935 and considerable research and development had been done, with the result that the R.D.F. stations were not unprepared. An account of the preparatory work appears at Appendix 18.

Spasmodic attempts had been made by the enemy to jam R.D.F. transmissions during the Battle of Britain and had been continued along experimental lines throughout the 1941 period. Jamming before February 1942 was probably largely experimental on the enemy's part, as the periods of interference were very intermittent and the jamming rarely intense. Nevertheless, it is necessary to consider the earlier forms of jamming employed by the enemy in order to appreciate the degree of success achieved by his radio counter-measures.

Frequency Modulated Continuous Wave Jamming

The jamming first employed in 1940–1941 against the C.H. stations was Frequency Modulated Continuous Wave (F.M.C.W.)—a continuous wave the frequency of which was not fixed but varied rapidly between definite limits.

[1] An account of these attacks is given in Chapter 10.
[2] These interrogations are described from the R.D.F. viewpoint in Chapter 10.
[3] Headquarters, No. 60 Group, O.R.B.

For instance to jam an R.D.F. station working on a frequency of 26·6 megacycles per second the enemy transmission varied between about 26·2 to 27 megacycles per second about 200 times per second. On the cathode ray tube of the C.H. station, part of the trace was displaced into an inverted bell-shaped curve which moved along the trace from end to end, the " bell " on occasions reaching saturation.[1] When the selectivity of the C.H. station receiver was increased, the bandwidth of the receiver, *i.e.*, the range of frequencies to which it was sensitive, was correspondingly reduced, and for that purpose a switch was provided on the set which would automatically tune the receiver to either wide, medium or narrow bandwidth. When the receiver bandwidth was reduced, the width of the " bell " was correspondingly reduced, generally covering a distance of approximately 20 miles on the tube time-base when narrow bandwidth was employed. Scientific observers were sent to the R.D.F. stations at Great Bromley, Canewdon and Dover to make observations on this jamming. By the end of 1940 all C.H. stations from Worth Matravers to West Beckham were experiencing regular F.M.C.W. from enemy jamming stations located in the Boulogne and Calais areas, and from Holland.[2]

C.H. stations were equipped with several devices designed to modify the effects of accidental interference and jamming, and these devices were as a rule effective either by cutting out the offending signal or minimising its effects so that operations were possible in at least a modified form. The chief palliative was the Intermediate Frequency Rejector Unit (I.F.R.U.) which was fitted in pairs to all C.H. receivers and which, used separately or together, was capable of cutting out a small frequency band. This was very effective if the interfering signal came within its range. The Intermediate Frequency Rejector Unit could not, however, completely reduce the effects of F.M.C.W. as it was only capable of dealing with one small frequency band at a time, whereas the jamming was sweeping continuously through a whole range of C.H. station frequencies. C.H.L. receivers were not at that time fitted with I.F.R.U.s though later in April 1942 a version for C.H.L. stations was proposed and a prototype model was available on 24 June 1942.[3]

In addition to the I.F.R.U.s and the Anti-Clutter Gain Control (referred to in App. 59), C.H. stations were provided with special anti-jamming cathode ray tubes which had a long afterglow screen. This remained luminous for some time after the electron beam had moved off, thus enabling responses to be plotted through a heavy interfering signal. C.H. stations were also provided with a set of coloured filters to be placed in front of the tube and these were a considerable help in minimising interference, by separating the afterglow from the instantaneous trace on the tube. For instance, a yellow filter placed over the blue instantaneous trace on the tube would allow the afterglow to appear, but very little of the instantaneous trace. Aircraft echoes remained luminous on the screen for some seconds and so could be seen, but the jamming signal appearing on the instantaneous trace would be cut out or at any rate considerably reduced. Operators on the R.D.F. stations soon became used to F.M.C.W. jamming and skilled, experienced operators were generally able to plot very satisfactorily through it. At first, then, the enemy's attempts at jamming had a " nuisance " value only.

[1] Headquarters, No. 60 Group File 60G/S.742/Sigs., November 1940.
[2] Air Ministry File S.44413, Encl. 42B.
[3] Headquarters, No. 60 Group File 60G/50/11/1/Ops., Encl. 70A.

"Railings" Jamming

A new and far more troublesome form of jamming had been first seen at the C.H. station, Great Bromley, in the autumn of 1940, though at the time it was not considered as such but was thought to be some form of accidental interference.[1] After an interval, however, it appeared at several South coast R.D.F. stations in May and June 1941. This was called "railings" from its appearance on the tube, which consisted of a series of close pulses of equal amplitude sweeping across the whole time base. The pulses were about 5 megacycles per second wide with a recurrence frequency of 50 kilocycles per second and were not locked to the time-base or mains. The amplitude, though constant across the trace at any one moment, varied suddenly from time to time, from saturation to something very small.[2] It was possible to plot through this jamming with the aid of an afterglow tube but its great drawback was that it tended to mask I.F.F. responses. On the C.H. stations the I.F.R.U. was ineffective for this form of jamming, though its effects were largely alleviated by the use of a wide bandwidth to give the narrowest possible interfering pulse, and a wide transmitter pulse to give larger responses. The C.H.L. stations had no remedy against "railings" and in consequence their operations suffered more than those of the C.H. stations from this type of jamming.

Initial Organisation for the Investigation of Enemy Jamming

On 3 October 1940 Air Ministry Research Establishment suggested the formation of a specialised body of experts to deal with the whole question of jamming, and this work was therefore undertaken by scientists of the Telecommunications Research Establishment.[3] A mobile jamming van, in charge of a scientific officer, was prepared so that it could be rushed immediately to areas where jamming was being experienced. By the middle of November 1940, however, most of the jamming ceased temporarily. When it began again in March 1941 the mobile van was already installed at Stoke Holy Cross R.D.F. Station in Norfolk, where it investigated jamming signals coming from the Dutch coast. The van was moved to the C.H. station at Dunkirk on 11 January 1942 and did valuable work in investigating jamming whilst it was still in progress, as a result of information passed to it by stations affected.

Before the investigation into this jamming was complete the enemy resorted to its employment on a scale never before experienced. This was in his attempt to cover that most important operational incident of February 1942—the escape of the enemy warships *Scharnhorst, Gneisenau* and *Prinz Eugen* through the English Channel from the French port of Brest. During the war, secrecy restrictions precluded a full public disclosure of the details of this event, leading to a popular rumour that the R.D.F. system had failed. It is therefore expedient to consider this incident in relation to effect of jamming on the efficiency of the Home Chain at that time.

The Home Chain and the Escape of the Enemy Warships "Scharnhorst," "Gneisenau" and "Prinz Eugen"

It will be recalled that the *Scharnhorst* and *Gneisenau* had been cooped up at Brest from March 1941, being joined in May of the same year by the *Prinz Eugen* after the sinking of her consort, the *Bismarck*. During this time the

[1] Air Ministry File S.44413, Encl. 77B.
[2] Headquarters, No. 60 Group, File 60G/S.742/Sigs.
[3] Air Ministry File S.44413, Encls. 59A, 84A and 114B.

battle cruisers had been bombed repeatedly and heavily by the Royal Air Force, and though damage was inflicted, none of the ships was destroyed. Early in 1942 a reconnaissance aircraft revealed that the three ships were apparently again seaworthy and reports indicated that they were preparing to leave the port for Germany, where they would be in a safer and more distant harbourage.[1]

This in fact they did on the night of 11 February 1942, slipping out of harbour about 2200 hours and escaping detection at the time through the unfortunate breakdown of the A.S.V. equipment on the aircraft patrolling the area. This aircraft had been forced to return to base pending the despatch of a relief, and it was during this short interval that the ships actually left Brest. By bold tactics the ships succeeded in passing up the English Channel and getting through the narrow waters of the Strait of Dover, despite R.D.F. observation, before being engaged in action by British forces, and finally they reached port in Germany.

It was not until 1230 hours on 12 February that contact was made with the enemy. The story of the pursuit and the battle which ensued, in which both the Royal Navy and the Royal Air Force played a gallant part, is not one for this chapter, but is dealt with fully elsewhere in the Naval accounts of the engagement and in Royal Air Force operational narratives.

Enemy Attempts to Blind our R.D.F. Stations by Jamming

The outstanding features of the day, as far as the R.D.F. stations were concerned, was the use by the enemy of measures designed to jam the stations.[2] Deliberate jamming by the enemy was no new thing, and had been used in a crude form on occasions to mask offensive aerial action by the enemy, but this was the first occasion on which all stations in a certain area were deliberately jammed for any length of time. Enemy jamming on 12 February lasted from approximately 0930 to 1930 hours and affected to a lesser or greater degree all types of R.D.F. stations except those working on the higher frequencies of 600 and 3,000 megacycles per second. Frequency-Modulated Continuous Wave Jamming was employed by the enemy, and was of a more severe type than had previously been experienced, being particularly severe against C.H.L. stations.

Jamming of Home Chain Stations

With the exception of Newchurch C.H. Station, the operating efficiency of the C.H. stations generally was not greatly impaired. Stations between North Foreland and Beachy Head were jammed on two bands about 1 megacycle per second wide on approximately 22·6 and 26·8 megacycles per second. Newchurch was singled out for particular attention by the enemy and had a special jammer working on 27·7 megacycles per second. The interference here was sufficiently severe to cause the station to become non-effective between 1200 hours and 1930 hours, although it did operate eventually to some extent at a much reduced efficiency by detuning the C.H. station receiver.[3] At a meeting held in Air Ministry on 23 February, when the whole question of the jamming of R.D.F. stations on 12 February was considered, it was decided that the existing anti-jamming facilities on a C.H. station were sufficient to

[1] A.H.B./IIK/18/7, Battle Summary No. 11, "The Passage of the *Scharnhorst, Gneisenau* and *Prinz Eugen* through the English Channel, 12 February 1942," C.B. 3081 (7).
[2] A.H.B./IIK/7, "Evidence and Report of the Board of Enquiry."
[3] No. 75 Wing, O.R.B., 12 February 1942.

deal with the crude type of jamming and the low power employed on this occasion by the enemy, although it was stressed that if the enemy improved the type and extent of jamming in future the relief afforded by existing measures would be less.[1]

Jamming of C.H.L. Stations

The C.H.L. stations were affected in a varying degree from Bawdsey to Beachy Head by jamming on a frequency band of 190–210 megacycles per second using 1 microsecond pulses at a repetition rate of 150 kilocycles per second, fully amplitude-modulated at 100 megacycles per second. Swingate C.H.L. Station was completely blotted out, as were the C.D./C.H.L. stations between Foreness and Beachy Head, whilst the C.H.L. stations between these two points could not plot along the French coast within fifteen miles of Cap Gris Nez. The pulses were lengthened to 3 microseconds by the narrow band radio-frequency amplifier of the C.H.L. receiver equipment and this affected both the Range and the Plan Position Indicator cathode ray tubes. Naval Type 271 stations, working on the 3,000 megacycles per second frequency, were unaffected. In most cases the jamming began intermittently around 0930 hours, varying in intensity from a very slight disturbance to saturation point, but it was not until about 1000 hours that it became really serious and continuous.

R.D.F. Information on the Enemy Ships and Escorting Aircraft

Despite the care with which the Germans had prepared their jamming programme, the enemy force did not go unobserved by our R.D.F. stations. The first recorded plots on enemy activity came from the C.H.L. station at Beachy Head at 0824 hours, when it began plotting on hostile aircraft off the French coast. A report to this effect, with a statement that the aircraft did not seem to be moving very much but were circling all the time, was made to Filter Room at Headquarters, Fighter Command immediately, via the C.H. station at Pevensey, as the C.H.L. station itself did not then possess a direct telephone tie-line to the Filter Room. These plots were at a bearing which, when worked out later, showed them to have been the umbrella of enemy aircraft over the battleships.

Interference at this station began at 0920 though it was able to pass a few further plots on the same aircraft. Later it appeared to the Radio Operator observing at the cathode ray tube that there was a shipping response associated with the aircraft, and at 1014 and 1016 hours respectively two plots were passed from two different responses, reported as being three ships each, at ranges of 44 and 46 miles. Instructions were given for these shipping plots to be passed to the Naval Plotting Room at Dover at 1014 hours, but unfortunately due to trouble on the telephone line this could not be done. The information was, however, passed by another telephone line to the corresponding Plotting Room at Portsmouth at 1019 hours with a request that it be passed on by them to Dover. At the same time it was reported via Pevensey C.H. Station to the Filter Room that six vessels were at that spot. Dover Naval authorities were eventually contacted by Beachy Head C.H.L. Station at 1040 hours and a repetition of the same shipping plots was passed.

Up to the time—1014 hours—when the shipping responses were seen, the interference had been slight, but from then on it became much more severe and

[1] Air Ministry File S.6412, Encl. 99A.

continuous until the cathode ray tube was completely blotted out, further plotting being impossible. The shipping responses were on the tube for approximately five minutes. Pevensey were informed at 1016 hours that the interference was Frequency-Modulated Continuous Wave and was now permanent and were requested to pass this information to Filter Room.

The R.D.F. station at Bembridge later plotted several hostile aircraft at a range from them of 120 miles, the tracks being plotted for 190 miles, and Fairlight R.D.F. Station also plotted hostile formations of aircraft in the Channel 15 miles west of Le Touquet, just before these stations experienced interference.[1] From 1015 hours Fairlight Station reported great activity in the Channel and hostile aircraft were plotted continuously till after 1140 hours. Thirty-two tracks were plotted by the station in this period, despite heavy interference.

Capel, Type 271, Station picked up a track at 1054 hours at a range of 35 nautical miles (40 land miles) which was plotted for two hours and fifty minutes to a range of 52 land miles, this being claimed as a record range on surface craft for a station of this type. The track was estimated as consisting of 20 plus surface craft.

At 1045 hours Fairlight, Type 271, Station observed a plot 27 miles S.W. of Cap Gris Nez. No details as to size and number of vessels could at first be made out, but as it was a very long-range plot and the first indication from any source of shipping in that area which he had then received, the Air Staff Officer attached to Vice-Admiral, Dover, " wisely warned " both No. 16 Group of Coastal Command and No. 11 Fighter Group, in addition to impressing on the latter the necessity for another " Jim Crow " report.[2] " Jim Crows " were reconnaissance aircraft from Fighter Command sent out to investigate specific areas or targets about which further or confirmatory information was required. These reconnaissances had a rigidly observed rule which ensured that absolute wireless silence was kept in the air, so that any reports had to be made verbally immediately the aircraft landed on return to base. At 1105 hours the " Jim Crow " report was received by Vice-Admiral Ramsay at Dover, which stated that the long-range shipping plot consisted of from twenty-five to thirty vessels, small destroyers or sloops, with E- or R-boats, in two groups, one of the latter appearing to be making smoke. No mention was made of the three battle cruisers by name.

In the meantime, Group Captain Beamish and Wing Commander Boyd, the Officer Commanding and second-in-command respectively of Kenley (Fighter) Royal Air Force Station had, in the course of an offensive fighter sweep south of Boulogne unconnected with shipping reconnaissance, attacked two *Messerschmitt* aircraft, and in the pursuit which followed they found themselves flying immediately over the German ships, which they recognised. In accordance with the rule for observing wireless silence, Group Captain Beamish returned at once to his base, landing at 1109 hours. His report was immediately transmitted through No. 11 Group to Fighter Command and to all other authorities concerned. This message was the first really definite indication that the three battleships were actually in the Channel, and consequent on this information all possible steps were taken by all three Services to make contact with the enemy forces.

[1] No. 75 Wing, O.R.B., 12 February 1942.
[2] A.H.B./IIK/18/7, Battle Summary No. 11, pp. 8 and 9.

Investigation by the Board of Enquiry

A full enquiry into the whole circumstances of the escape of the three battleships was undertaken by a Board of Enquiry under the chairmanship of the Hon. Mr. Justice Bucknill.[1] In its report it was confirmed that the R.D.F. plots had clearly indicated aircraft circling in a small area and later, indications of shipping had appeared. The R.D.F. stations had functioned satisfactorily despite the enemy jamming. The significance of the plots was not recognised immediately as such plots were common in the area concerned—the Germans had intentionally carried out exercises over Brittany for several days. No particular significance would normally have been attached to these plots as they were outside the area of day-to-day fighter interceptions. Had these plots been investigated, however, as soon as their character came under suspicion, it was possible that the enemy warships would have been sighted an appreciable time earlier than they were.

Besides the R.D.F. plots, another indication that something unusual was afoot was the intense jamming by the enemy of the R.D.F. Chain. The significance of this jamming was missed initially because the Germans employed it intermittently at first and the R.D.F. stations reported it as " interference." It was only after the first hour that action was taken by the Filter Room staff, the " interference " reported then being recognised as deliberate jamming.

German Impressions of the Success of Jamming

A few days prior to the passage of the warships through the Channel, Dr. Scholz, a civilian employee of the *Reichpost Zentrole* in charge of radio counter-measures, was specially brought from Berlin to supervise this first big operation of their whole jamming chain against British R.D.F. ground stations. The R.D.F. cover of the C.H. and C.H.L. stations had been carefully plotted by the enemy and it was ascertained that the ships would come within their range as they passed off Fécamp, where they were scheduled to be at 10 a.m. At that hour every available jammer was switched on. The fact that the battleships passed through unscathed was, in the opinion of Dr. Scholz when interrogated, the best proof of the effectiveness of German counter-measures. He was not aware that we had either decimetre or centimetre R.D.F. in operation at this time.

Summary of the Part played by R.D.F. Stations during the Escape

For full details of the Royal Air Force activities in the belated attempts to stop the German force escaping, the reader will have recourse to the findings of the Board of Enquiry which investigated the whole episode. From the Signals viewpoint, it is apparent that the R.D.F. stations themselves could not have done more in the circumstances to enable earlier detection to have been made. The jamming experienced undoubtedly hampered operations considerably, but valuable information was given by the Chain stations in spite of this disability. It is doubtful whether much earlier warning could have been given of the ships themselves, as they were at very long range from the stations and their protective aircraft " umbrella " circled over them as low as possible in order to escape detection by R.D.F. Every station in the area appeared to have passed promptly all the information it possibly could. No blame could be attached to the R.D.F. stations—they had functioned well, despite the most effective jamming

[1] A.H.B./IIK/7, " Evidence and Report of the Board of Enquiry," Finding and Summary from p. 5.

the Germans had yet produced. The main trouble appears to have been a lack of liaison and the failure of the Inter-Service organisation, in that insufficient use of the information available was made at the time, and insufficient attention was paid to the fact that steadily-increasing interference was being reported by so many stations. It did not appear to be realised immediately that the trouble had a much deeper significance than mere spasmodic interference and that it was, in fact, deliberate jamming by the enemy designed to mask important operations.

The whole episode must be regarded as a triumph for the German organisation, and to some degree it ventilated what had always been a defect in our use of the Home Chain system—namely, that maximum advantage was not always taken of the R.D.F. information available. There is no doubt that the incident provided adequate stimulus for the eradication of minor defects in the organisation and improvement in inter-Service liaison.

Emergency Alternative Higher Frequency Equipment for use to Counter Jamming

Subsequent scientific investigation of the jamming experienced during the escape of the enemy battleships through the English Channel showed that the principal jammer stations used on this occasions by the enemy were in a chain along the whole French Channel coast.[1] There was every reason to anticipate an increase in jamming activity to mask enemy operations. Accordingly at a meeting held at Air Ministry on 23 February 1942 to discuss proposals for counteracting jamming of R.D.F. stations it was decided to install emergency R.D.F. equipment working on higher frequencies at the more important C.H.L. stations, only to be brought into use when jamming rendered the 200 megacycles per second frequency band stations unserviceable.[2] The higher frequency band selected was 500–600 megacycles per second. This was the German R.D.F. frequency band, so there was less likelihood that the enemy would resort to jamming on this band.

On 29 April 1942, three mobile Type 11 sets on the new waveband, and using vertically polarised waves, were installed at Beachy Head, Swingate and North Foreland.[3] By the end of 1942 three more were established at Foreness, Ventnor and Truleigh Hill. The Type 11 sets, however, provided for plan position location only and a comparable equipment was therefore needed (with the same anti-jamming properties as the Type 11) which could be used for height determination. Consequently a decision was made to produce a 500–600 megacycles per second frequency-band equipment (Decimetre Height or D.M.H.) for use with the Type 11, Mark II, set, which would be designed to work over the same variable frequency band as the Type 11 equipment, namely 500–600 megacycles per second. The purpose of having variable frequency equipment was to enable station technical officers to change the frequency of operation of the station (according to pre-arranged spot-frequencies) in order to attempt to avoid the jamming.[4]

Reorganisation of Jamming Investigations

Until July 1942 the work of investigating jamming and of testing counter-measures had been one part only of the many duties undertaken by the research staff at Telecommunications Research Establishment, but the volume of work increased so much that it was decided a larger staff for this special purpose was

[1] A.H.B./IIE/209, Air Ministry Signals Branch Folder R.C.M./141, Encls. 2A and 7A.
[2] Air Ministry File S.6412, Encl. 99A. [3] Air Ministry File C.S. 16601, Encl. 19A.
[4] Headquarters, A.D.G.B. S.30806, 18 September 1942.

essential if adequate control was to be maintained over the investigation of jamming and the testing of anti-jamming measures. Accordingly a special unit known as "Central J. Watch" was established on 4 July 1942, with a specially trained staff under the command of a Squadron Leader. It was stationed at Telecommunications Research Establishment but came under the operational control of Headquarters No. 60 Group. Later, special sub-sections were stationed at the C.H. stations of Ringstead, Dunkirk (later moved to Dover Hill) and Stoke Holy Cross, each being responsible for special investigations into jamming at the R.D.F. Stations in their area. These sub-sections covered all the areas where enemy jamming had been experienced ; stations in other districts would if necessary report direct to Central J. Watch.[1] R.D.F. stations had very strict instructions to report all cases of jamming or suspected jamming immediately to the nearest J. Watch giving all details possible. Telephoned reports in accordance with a pre-arranged code were made, using a "Priority One" call if an open telephone line had to be used.[2] These telephoned reports were followed up the same or next day by written detailed reports to Central J. Watch, giving additional details and accompanied where possible by sketches or photographs. In this way J. Watch knew the moment the enemy started jamming and were generally able to observe its effects for themselves by tuning their specially devised sets to the frequencies of the stations affected, and so were able to co-ordinate results reported by the various stations. Stations also reported immediately to Filter Room whenever interference was experienced, whether this was accidental, suspected, or of proved enemy origin.

In addition to collecting all possible information on jamming, collating measures designed to combat it, and doing research into further methods of anti-jamming, J. Watch were responsible for training operators at R.D.F. stations to recognise and overcome enemy jamming. This was done by means of lectures and demonstrations, and the training proved very valuable.

In December 1942 it was decided that an anti-jamming unit would be formed in No. 80 (Signals) Wing, the Royal Air Force formation in charge of radio counter-measures against the enemy, and accordingly the functions of J. Watch were transferred from Telecommunications Research Establishment and No. 60 Group to No. 80 Wing on 5 February 1943.[3] In order to provide mobile jamming units for ultimate employment in the Allied Expeditionary Air Forces, four J. Watch Units at No. 80 Wing were disbanded on 15 May 1944, all surplus personnel being transferred to No. 60 Group. This Headquarters thus resumed its old responsibility for the investigation of enemy jamming of the Home Chain. The J. Watch static stations in No. 60 Group were finally closed on 1 January 1945, with just a nucleus maintained at No. 60 Group, equipped with a mobile van available for analysis should the need arise.

Jamming during 1942 and 1943

The increased enemy aerial activity in the spring of 1942 brought a return of jamming, more particularly affecting the C.H.L. stations. This was generally F.M.C.W. on the C.H. stations and a mixture of F.M.C.W., "railings," and other pulsed transmissions on the C.H.L. stations. On 18 and 19 March all

[1] Headquarters, No. 60 Group, O.R.B.

[2] The highest G.P.O. priority for Service purposes at this time—tantamount to having a telephone line cleared and made available for the call immediately.

[3] Air Ministry File C.S. 6412, Encl. 193A, and No. 60 Group O.R.B.

C.H.L. stations between Walton and Beachy Head were fairly heavily jammed though operations were still possible.[1] This continued intermittently until June 1942, when, from the 21st of the month, jamming again became very heavy, from Hopton in Norfolk round to Ringstead in Hampshire, being particularly heavy in the area round the Strait of Dover. Here it was sufficiently serious to render a number of stations non-operational for some two hours. The C.H. stations were affected to a lesser degree than the C.H.L. stations; in some cases G.C.I. (Ground Controlled Interception) stations were also affected. This jamming corresponded with enemy attacks made during moonlight nights on Southampton (21/22 June), Birmingham (24/25), Norwich (26/27) and Weston-super-Mare (27/28/29). The jamming continued from July to about November, again the C.H.L. stations suffering most.[2]

The jamming interference generally came on at night and nearly always coincided with a period of heavy enemy bomber activity, although sometimes it appeared that the enemy was using it to mask our own offensive bombing operations. Whitstable C.H.L. station experienced very heavy enemy jamming between 1648 hours on 31 October and 0245 hours on 1 November during which period there was considerable enemy activity around Canterbury and district. A fighter-bomber raid in the late afternoon was followed by two bomber raids at night, about twenty-six enemy aircraft being involved in the latter raids.

The onset of winter brought a welcome relief from the enemy's jamming activities, but it again came into operation on 17 January 1943, with the obvious intention of covering an attack on London.[3] This was the enemy's first night of intensive raiding for nearly six months, with the exception of the Canterbury raids of 31 October/1 November 1942, and was a reprisal for a heavy British raid the previous night on Berlin.[4] About seventy-five long-range bombers, flying in two waves, set out to attack London, whilst another fifteen or so laid mines in the Thames Estuary; about thirty aircraft succeeded in getting through to the capital and eight enemy aircraft were destroyed. On this occasion the C.H. stations were not badly affected, except for Swingate. This was operational on its "Buried Reserve" equipment, which lacked anti-jamming devices, and raid reporting operations were in consequence much hindered. The C.H.L. stations, however, from Walton to Bembridge were much more seriously jammed, the effects increasing around the Strait of Dover area. Generally, stations working on 200 megacycles per second frequency band were completely blotted out when looking in the Calais-Boulogne area. G.C.I. stations nearest the Continent were not seriously jammed, but their operations were restricted. Swingate C.H. Station was also seriously jammed again on the next day, and during this period, between 1955 and 2030 hours, the station itself was attacked by six enemy aircraft dropping incendiaries and H.E. bombs. Two Army personnel were injured by an explosive incendiary bomb.

Types of Jamming Employed

All types of station were jammed with the sole exception of those working on decimetre or centimetre waves. C.H. stations were mostly jammed by F.M.C.W., although "railings" was used in the early part of 1942. Later other forms of pulsed transmission were tried by the enemy. One of these

[1] No. 60 Group and No. 75 Wing, O.R.B.s.
[2] Headquarters, Fighter Command, O.R.B.
[3] Air Ministry File S.6412, Encl. 190A.
[4] Headquarters, Fighter Command, O.R.B., Intelligence Summary No. 376.

was called " Road Drill " (from its sound when monitored in the loud-speaker) and it came into use in April 1942, gradually replacing "railings."[1] Its appearance on the cathode ray tube was of evenly-spaced pulses spread right across the time base. The signals persisted for 4 milliseconds in every 20 milliseconds and then slowly drifted off the time-base. Another form was known as " Spaced Pulses." Of these, " railings " was by far the most troublesome. After November 1942 most pulse transmissions ceased against the C.H. stations and only F.M.C.W. was used.

On the 157–236 megacycles per second frequency band (covering Mark III I.F.F., A.I., A.S.V., C.H.L., G.C.I., Light Warning and Oboe installations) other types of modulation were used, in addition to the jamming experienced by the C.H. stations. The signals usually contained low frequency and high frequency amplitude modulations—frequency modulation often being present also. During a typical jamming period on this frequency band some twelve to fifteen enemy transmitters were active, the calculated number available in the Calais-Boulogne area being about twenty-four. The transmissions were either horizontally or vertically polarised.

Some C.H.L. stations had special modifications to the receivers installed which permitted improvement to the I.F.R.U., although it was noted in some instances that the relief afforded by the wider bandwidth of the new Intermediate Frequency Unit was partially annulled by a reduction in signal/noise ratio. This was overcome at Beachy Head C.H.L. Station by fitting both units to the receiver with a change-over switch, so that wide bandwidth could be brought into use. C.H.L. stations were being issued as rapidly as possible with anti-jamming cathode ray tubes and filters, and variable bandwidth devices were gradually being installed in the equipment. The new C.H.L. station I.F.R.U.s were being gradually fitted from the spring of 1943.

Much time and thought was devoted in 1943 to anti-jamming measures for the C.H.L./G.C.I. stations, but the full results of this policy were not seen till the following year. The main measures tested were Pulse Width Discriminators and a Rejector Unit, Type 7. Experimental equipment was installed at Sandwich, Swingate and North Foreland Stations, giving satisfactory results. From the summer of 1943 the C.H.L. stations, which had previously worked on a uniform frequency of 200 megacycles per second, were staggered on the two frequencies 200 and 193 megacycles per second for the whole of the Southern area of England between Bempton and Kete.[2] It was thought that by this means the enemy would have to double his transmitters if he wished effectively to jam all C.H.L. stations at the same time.

" Window " Jamming

A form of jamming had been developed by the British as a counter-measure against German radar stations and was known by the code name " Window."[3] It consisted of thin strips of metallised paper, cut to the wavelengths of the radar stations, and dropped from aircraft. These paper strips gave a response on a cathode ray tube much like that of aircraft and proved very confusing, giving an appearance of several hundred aircraft. Amidst this confusion the tracks of the real aircraft were often able to escape detection. This form of counter-measure was first used by us with great success on 23 July 1943.

[1] No. 75 Wing, O.R.B., and Air Ministry File C.S. 15041, Encl. 73A.
[2] Air Ministry File S.3522, Encl. 24A.
[3] Volume VII gives a full account of " Window."

Not unnaturally, the enemy soon reciprocated with this method of producing spurious " echoes," and his first attack with " Window " jamming was made on 7 October 1943.[1] It caused slight confusion at first, but was quickly recognised and operators were able to plot through it successfully. Fortunately, operators had been warned to look out for this type of jamming, so that they were prepared when it finally came. There was no known form of anti-jamming device to combat it, but skilful and experienced operators were soon able to plot successfully through it. The chief disadvantage was that it made the counting of aircraft difficult and estimations of raid strengths were often unreliable in consequence. It is certainly true to say that at this time our efforts at jamming by " Window " caused far more trouble to the enemy than his caused to us. Nevertheless, it must be appreciated that the success of the Home Chain in continuing operations in face of " Window " was partly due to the fact that the enemy did not lay " Window " with any degree of skill during these attacks. Had he made a real effort, operations of both control and raid reporting stations would have been greatly reduced. Within No. 60 Group it was felt that " Window " remained a most serious menace to the ground search R.D.F. system—an opinion which was to prove extremely accurate in the light of subsequent operations.[2]

Final Enemy Policy against Early Warning R.D.F. Stations

During the last year of the War the Germans maintained their policy of countermeasures against early warning metric R.D.F. by using ground jammers against our C.H. and C.H.L. stations during their bomber operations. They experimented with jammers in special aircraft, but decided that these were not so effective as the ground jammers, because the frequencies on which R.D.F. Chain stations worked had to be constantly monitored and adjustments made to their transmitters to " follow " our stations : the airborne jammers were therefore abandoned.[3]

The newer higher frequency Chain stations (decimetre and centimetre stations) working on the " beam " principle, had very narrow beams, so it was impossible to jam them effectively. Even up to the end of the war the enemy were experimenting vigorously in an attempt to improve their jamming technique.

Although the enemy jamming proved effective on occasions against C.H.L. stations and partially effective against the C.H. stations, it was never capable of crippling the Home Chain completely. The original Air Ministry decision, taken in February 1942, to increase the number of frequencies in use and expand the decimetre and centimetre chain proved the most useful counter to enemy jamming efforts. Alternative frequency working of stations, together with the invulnerability of the centimetre " beam " stations against jamming meant that the early warning system could survive the enemy's attacks. Technically the Germans were never permitted to establish an appreciable lead over us in this jamming, though their efforts involved us in much inconvenience, research, and expense.

[1] The Germans used the code name " Duppel " for " Window," a word with a similar pronunciation to the German word " dipol " (dipole), indicating the function of the metal strips.

[2] This was borne out during the operations in Italy during the early part of 1944. Details of this are given in Chapter 21, " Ground Search Radar in the Mediterranean Campaign, September 1943–May 1945," in this volume.

[3] A.D.I.(K) Report No. 380, 1945, para. 49.

CHAPTER 15

THE DEVELOPMENT OF LOW-LEVEL R.D.F. COVER AFTER 1941—C.H.L. STATIONS AND CENTIMETRIC WAVELENGTH OPERATIONS

By the beginning of 1942 there were many indications that despite the undoubted strength of the Axis forces, the opposition was stiffening considerably. During January 1942 the United Nations' Anti-Axis Pact had been signed in Washington by twenty-six nations. Only one year previously, Britain and her Empire had stood alone and our Island had borne the entire weight of aerial attack from the undivided forces of the *Luftwaffe*. Now, in 1942, the German Air Force was heavily involved on the Russian front and in the Middle East. As a direct consequence of this geographical dissipation of effort, the scale of the German aerial offensive against this country fell. The weight of bombs dropped on Britain during the entire year of 1942 was roughly only equivalent to one month's bombing during the intensive 1940–1941 winter *blitz*.

Based on a superficial examination of the weight of bombs dropped and the numbers of enemy aircraft involved, it would appear that the R.D.F. Home Chain had fulfilled its major task before 1942. Nothing could be further from the truth. The enemy made every effort to obtain a higher return from this reduced bomb tonnage—the raids were much more accurate and effective. In an attempt to achieve this, German pilots adopted tactics calculated to evade observation by R.D.F. The method which had given them most success in 1941 had been to approach our coast, flying very low. The Home Chain during 1941 had been unable to give adequate cover against such wave-hopping raiders, though it will be recalled that developments were in progress to counter this weakness in the raid-reporting system.[1]

The principal methods adopted may be summarised as :—

(*a*) An improvement in the C.H.L. Chain of stations, involving technical improvements, standardisation, and the completion of the Triple Service C.D./C.H.L. Chain.

(*b*) The adaptation of C.H.L. stations on high towers in an attempt to increase the range of detection on very low-flying aircraft.

(*c*) By far the most important method—the development of a chain of centimetric R.D.F. stations.

Although this narrative is concerned largely with the aircraft raid-reporting system, these low-cover R.D.F. stations also had the important role of surface-watching, giving information on the movements of enemy shipping in the English Channel and, very often, useful navigational information on the movement of our own shipping. Both the aircraft raid-reporting and surface-watching roles of these stations are therefore dealt with in this chapter.

The C.H.L. Stations

At the beginning of 1942 there were sixty-nine C.H.L. stations in operational use around the coast of the British Isles, forty-four having hand-rotated aerial systems and the remainder being automatically power-turned.[2] A further thirty-six C.H.L. stations were planned to complete the low R.D.F. cover, and of these twenty-two were commissioned during the 1942–1943 period.[3]

[1] Chapter 11 of this volume discussed the measure taken to counter the low-flying raiders.
[2] Air Ministry File C.S. 8143/II, Encl. 21A.
[3] No. 60 Group, O.R.B. The locations of the C.H.L. stations constructed during 1942 and 1943 are given in Appendix No. 19.

It will be recalled that many of the earlier C.H.L. stations had been constructed during the special " crash " programmes of 1940 and 1941. There had been a lack of standardisation about these stations. Three programmes involving major modifications to equipment were in progress at the end of 1941, and these alterations, completed early in 1942, were to bring the older stations up to the latest type as far as technical efficiency was concerned, and also to standardise the equipment.[1] The modifications comprised chiefly :—

(*a*) The conversion of the older C.H.L. transmitters to the latest type (T.3056), giving both increased power and range.

(*b*) The conversion of the separate transmitter and receiver aerial systems to a single common aerial array for both the transmitter and receiver.

(*c*) The improvement of the aerial rotating systems. The aerial framework and rotating mechanism had given some trouble and attempts were being made to increase aerial rotation speeds—a step considered to be essential for C.H.L. stations used for both normal raid reporting and for interception purposes.

C.H.L. Stations and Surface Reporting

Within the limitations of their range, the C.H.L. stations gave valuable information on surface craft, both hostile and friendly, to the Naval authorities. These shipping plots were passed directly to Naval Plot (or Control Room) and not to the Royal Air Force Filter Room. Some impression of the contribution made by the C.H.L. stations in this work may be gained from a letter, dated 31 March 1942, from the Flag Officer-in-Charge at Liverpool to the Secretary of the Admiralty, in which it was stated :—[2]

> " Six C.H.L. stations are directly connected by telephone to Liverpool Plot, reporting half-hourly day and night. In the past two months the efficiency of surface craft plotting has improved to a very high standard from all C.H.L. stations and great keenness and interest are shown by the R.A.F. operators.
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> " The value of C.H.L. information has been clearly indicated and in the past month, during which haze or foggy weather in the Irish Sea has persisted, navigational assistance has been given to no less than twelve convoys, outward and inward bound, and on three occasions it was possible that disasters were prevented by issuing warnings to the escorts.
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> " Confidence in the Liverpool Plot on the part of the Commanding Officers of the Liverpool Local Escort Vessels has been established, and it has not been unusual for several requests to be made for positions during night passages rounding the Chicken Rock and making the North Channel.
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> " During the week ending March 28th, phenomenal ranges were obtained ; in one case Prestatyn plotted a convoy at a range of 60 miles and was able to give an accurate number of ships at that range. All stations have rendered valuable assistance."

Although C.H.L. stations on the west coast were able to offer so much useful assistance to the Naval authorities, similar stations in the south-east of England were not always able to give the very full information required by the Navy. In this area the almost incessant aircraft activity kept the C.H.L. stations

[1] Air Ministry File C.S. 8143/II, Encl. 20A. [2] Air Ministry File S.3864/II, Encl. 160B.

fully occupied and it was often impossible to do full justice to the different types of information required by the Royal Air Force and the Royal Navy. However, the C.D./C.H.L. stations recently erected were taking over the Triple Service function from the C.H.L. stations in these vital areas. In addition the development of the centimetre equipment had progressed very favourably. Three Type 271 centimetre installations in the Army R.D.F. Chain together with the C.D./C.H.L. stations were able to take full responsibility for surface shipping in the Dover Naval Command by March 1942. It was laid down that, in future, reference by the Naval authorities to Royal Air Force C.H.L. stations was only to be made in the event of emergency, though these stations might be required occasionally to check the presence of I.F.F. on responses picked up by the centimetre equipments.[1]

C.H.L. Stations and Controlled Interception

Where hostile aerial activity was frequent over our South and East coasts there was an increasing demand made upon the C.H.L. stations for use in the controlled interception of enemy aircraft. With the increased speed of revolution of the continuous rotation of the aerial system instead of the older method of manually rotating or "sweeping," very accurate continuous tracking of aircraft could be carried out. In consequence, some C.H.L. stations were used very successfully for interception purposes, and ceased to form part of the normal raid reporting chain. This aspect of their activity is dealt with more fully elsewhere in this history.[2]

C.H.L. Stations on High Towers

One method of obtaining adequate warning of the approach of wave-hopping aircraft which was being explored was the use of C.H.L. stations on high towers, and towards the end of 1941 a decision had been taken to erect C.H.L. equipment on a 200-foot tower at Humberston as a prototype.[3] If this station proved successful, plans existed for further tower stations at West Beckham, Drone Hill, Happisburgh, Hopton, Dunwich, Cresswell and Bamburgh—all at sites selected because of the incidence of very low-flying raids in their areas.

The prototype C.H.L. (T) station at Humberston was operational during December 1941. A provisional report issued at the end of the year stated that it had been on the air since 10 December 1941. Activity since then had been slight and the assessment of very low-flying cover provided was not easy in consequence. The longest range then plotted over the sea was 143 miles. A theoretical performance chart then drawn gave the following pick-up ranges :—[4]

500 feet	32 miles.
1,000 feet	45 miles.
2,000 feet	60 miles.
4,000 feet	77 miles.
10,000 feet	110 miles.

These figures were, however, thought to be on the conservative side as the only information so far obtained was on limited activity, although some confirmation of these values was obtained by plots on a convoy at 30 miles and a pick-up

[1] Air Ministry File S.3864/II, Encl. 140A.
[2] Volume V, Part 3.
[3] Air Ministry File S.4039, Encl. 30A.
[4] *Ibid.*, Encl. 52B.

of 60 miles on an incoming bomber flying at 3,000 feet. Operations were rather erratic at first, but this was probably due to inexperience on the part of the operators, as later it was found that direction-finding was as good as, if not better than, that of other C.H.L. stations in the area. Direction-finding was found to be accurate at all bearings up to 60 miles. Test runs had not up to then been possible owing to prolonged unfavourable weather conditions.

Headquarters, No. 60 Group, summarised the findings to date at Humberston by stating that it did not appear possible to provide the ideal operational requirements under the high windage conditions which were likely to be experienced with power-turned C.H.L. stations on towers.[1] It was considered, however, that the additional coverage obtained by the extra 200 feet outweighed any limitations and that if power-turning gear could be operated in wind speeds up to 65 miles an hour, and if the rate of sweep could be controllable from 2 to 6 revolutions per minute under normal conditions, then erection of similar installations should proceed.

The desirability of being able to switch over instantaneously from the tower aerial on the new equipment to the ordinary 20-foot gantry aerial on the old equipment as a form of gap-filling became a subject of discussion. Fighter Command, in a letter to Air Ministry dated 28 January 1942, stated that though rapid switching facilities would be an attractive proposition, the primary operational role of the tower stations should not be allowed to suffer for the purpose of providing additional high-flying cover.[2] It was feared that this might be the case if the operator was able to switch rapidly from one aerial system to the other, owing to the danger of missing low-flying aircraft when using the gantry aerials. It was, in consequence, recommended that rapid switching facilities should not be provided on any tower station and that the gantry aerials should be regarded only as a reserve for the tower aerial array.

A complication arose in February 1942 regarding the erection of these towers, as it was thought that they might prove an obstruction to our own aircraft flying in the vicinity. In consequence, work was held up on five stations (Bamburgh, Cresswell, Hopton, Happisburgh and Dunwich).[3] The matter was referred for decision to the Deputy Chief of Air Staff, who ruled that these towers were necessary in order to give adequate warning of the approach of low-flying raiders, and that the operational necessity outweighed the possible risk of collision. Authority was therefore given on 4 March 1942 for the work to be implemented, subject to the provision of adequate safeguards, such as obstruction and warning lights on the masts.

Work therefore continued on the building of these towers and on the installation of their aerial arrays. The first to come into operation was Cresswell, commissioned in November 1942. Hopton and Happisburgh became operational the following month, and finally Bamburgh and Dunwich came on the air in April 1943.[4] Headquarters, 60 Group, commented in their monthly report that the new aerial array at Hopton gave very promising operational results, whilst Dunwich reported that their tower array gave them increased ranges on shipping tracks; this was confirmed by Happisburgh, who also reported increased ranges on aircraft.

[1] Air Ministry File S 4039, Encl. 50A.
[2] Headquarters, Fighter Command, File F.C/S.20424, Encl. 71A.
[3] Air Ministry File S.4039, Encl. 90A.
[4] No. 60 Group and Nos. 73 and 74 Wing, O.R.B.s.

Project abandoned on C.H. Cantilever Towers

Work on the station at West Beckham, where it had been intended to mount a C.H.L. station on a cantilever of one of the C.H. station steel towers, was suspended in November 1942 and the project abandoned. It was considered that the need for this station was no longer justified in view of the fact that

(*a*) Tower stations were being erected nearby at Hopton and Happisburgh.

(*b*) The use was impending of pre-amplifiers which would give a marked improvement on low-flying aircraft performances on existing stations.

(*c*) Installation was projected of a high-power 10-centimetre equipment at Hopton, and

(*d*) It had now become urgent, owing to the increasing calls for R.D.F. cover at home and overseas, to conserve operational manpower, installation effort and technical gear.

Work was for similar reasons suspended in December 1942 on the tower installation at Drone Hill C.H. Station. It was also considered undesirable to erect further ordinary C.H.L. (200 megacycles per second) stations owing to the jamming then being experienced from enemy sources, and the development of more efficient ultra-high frequency equipment.[1]

Termination of C.H.L. on High Towers Policy

Some criticism of the performance of the station at Happisburgh was made in April 1942, and consequently investigations into the performance of this and all other C.H.L. tower stations were made in the next few months. However, in a report made in February 1944, No. 60 Group Headquarters reported that their investigations carried out over a period of several months showed that the performance of the tower stations was well up to standard.[2] In all cases the results of test flights showed that adequate low cover was obtainable. It was recommended that no further research be undertaken into the performance of these stations in view of the fact that the high-power 10-centimetre chain was now coming into operation and these stations would be able to pick up any aircraft which might possibly escape detection by the C.H.L. tower stations.

The programme for C.H.L. on high towers was developed as an operational requirement, namely, to counter the very low-flying raider. It was expensive in installation and research man-hours. Subsequently the decision to erect further stations on the steel towers of C.H. stations had to be abandoned because the 10-centimetre R.D.F. equipment gave a better performance on a more economical basis. The C.H.L. on towers programme must be regarded as another example of a technique which became obsolescent as a result of progress in research. It was essential to make adequate provision against possibilities, some of which inevitably proved unnecessary in the long run. The C.H.L. (T) type of station was abandoned because the ultra-high frequency R.D.F. equipment supplanted some of its functions and it was thought at the time that it gave much superior results for considerably less outlay.

The Triple-Service C.D./C.H.L. Stations

Although the original scheme[3] for the C.D./C.H.L. Triple Service Stations was intended to be complete for our South and South-East coasts by the spring of 1941, and later to be extended all round the coastline, there had been considerable delay in implementing this project. The twelve stations, for the construction of which the Army had been responsible, were very much behind

[1] Air Ministry File S.4039, Encl. 140A and 141A. [2] *Ibid.*, Encl. 151A.

[3] The original scheme is illustrated by Map No. 3 and described in Chapter 11.

schedule. Unforeseen difficulties, not only technical but also such considerations as the provision of reporting telephone lines, approach roads and living accommodation, had prevented the inclusion of these stations in the full Royal Air Force reporting and operational system.

On 21 January 1942, however, the first Army station fulfilling the functions of a C.H.L. station was taken over by the Royal Air Force and became immediately operational. This was Bard Hill in North Norfolk, and it was followed at the beginning of April by The Needles (Isle of Wight), Goldsborough (near Whitby), Westcliff (Portland) and Bolt Tail (Salcombe, S. Devon). Three more came into operation in the following month: Marsden (South Shields), Oxwich (Gower Peninsula) and The Jacka (near Falmouth)), and by 31 May the remaining stations—Crannoch Hill (Elgin), Westburn (Aberdeen), The Law (Carnoustie, Angus) and Black Head (County Antrim)—of the original C.D./C.H.L. chain were operational. Thus a thin chain of stations, the nucleus of the final Triple Service Chain envisaged for the future, was complete, covering the South and East coasts of England and Scotland from The Jacka in Cornwall to Crannoch Hill in Banffshire, with one station to cover the approaches to Belfast Lough.

Though these stations were in use, much remained to be done before maximum efficiency was obtained, but it was felt that the need for maintaining a constant watch on shipping was so urgent that the stations should work with the apparatus already available; further improvements and modifications were to be made by No. 60 Group as opportunity arose.

The stations were operated by Royal Air Force operators from No. 60 Group, with a normal crew establishment as for a C.H.L. station, and in addition four Naval and four Army observers (ratings and other ranks—one each per watch) whose duties were to man the Naval and Army reporting lines respectively, and to pass to their appropriate Operations Rooms all relevant information. Shipping plots were generally reported at quarter-hourly intervals, although more frequently if the occasion warranted it.

The Development of Centimetre Equipment

The chief technical development during 1942 was in the field of very high frequencies, which led to an increasing use of equipment working on a 3,000 megacycles per second frequency (10 centimetres wavelength). The great advantages of centimetre stations were that they could be used equally effectively for the detection of surface objects and for the detection of the very low-flying hostile aircraft. Great advances were made in the period under review in this chapter by the setting-up and consolidation of a chain of centimetre stations—known as the C.H.E.L. Chain (Chain Home Extra Low)—used jointly by all three Services for surface watching and the detection of the very low-flying raider.

One other advantage of ultra-high frequency equipment, and an additional reason for hastening its development and production, was that as it employed a very fine beam it was very difficult to jam.[1] In common with other equipments, it was liable to jamming when "looking" in the direction of a jamming station, but this would only have an effect on, at worst, an arc of 10°. Jamming by the enemy had by this time become so troublesome to C.H. and especially C.H.L. stations that the installation of centimetre sets became imperative to ensure adequate R.D.F. cover at all times and in all conditions.

[1] Air Ministry File C.S. 16660/R.D.F.1, Encl. 48A.

From 1941 onwards the possibilities of applying the Naval Type 271 R.D.F. equipment to the problem of the efficient detection of the very low-flying raider were being explored ; its value in the detection of surface craft was already apparent.[1] This set worked on the ultra-high frequency band of the order of 3,000 megacycles per second and, employing the new magnetron valve, had a power of 7 kilowatts.[2] During the late summer of 1941 the Low Cover and Surface Planning Sub-Committee of the Inter-Service R.D.F. Committee had noted the advantages of the Type 271 equipment as :—[3]

(*a*) The detection of very small craft at long range. This was possible with an apparently greater consistency than was obtainable with C.H.L. equipment.

(*b*) Owing to its very narrow beam it could probe those areas which presented a clutter of permanent echoes on the C.H.L. display, and

(*c*) Its ultra-high frequency beam had a low-angle coverage on very low sites.

This last factor was of great importance as this was the only real weakness in the Home Chain raid reporting system at the time. In December 1941 authority was given for the development of the Type 271 set to meet the requirements of the Royal Air Force, and the first experimental equipment was installed at Ventnor in February 1942.[4]

The first experimental installation was modified to common aerial working, using a ten-foot parabolic reflector on the rotating aerial system, and a Plan Position Indicator was incorporated for the observer. First operational tests indicated that the cover obtained against very low-flying aircraft and surface craft was good.[5] Further tests were carried out in the spring of 1942 and comparisons between a mobile Naval 271 set at Selsey Bill, on a site approximately 30 feet above sea-level, and the modified set at Ventnor, 780 feet above sea-level, led to the conclusion that for the successful use of the Type 271 as an aircraft tracking device, continuous rotation of aerials and the use of a Plan Position Indicator were essential. It was thought that little or no advantage would be obtained by the installation of this equipment at a high-sited C.H.L. station, but that considerable advantages might accrue with regard to the tracking of very low-flying aircraft and surface craft, if the set were installed at a C.H.L. station on low ground.[6]

Additional tests and developments were carried out, bearing these considerations in mind, and using higher-powered equipment. The experiments at Ventnor showed that with the Type 271 set then in use, aircraft at flying heights of 200 to 50 feet could be tracked to approximately 30 miles, with a faint response on occasion to 45 miles. As an instance of the success of this set, on 23 May 1943 it detected aircraft at a range of 34½ miles, which were identified one minute later as hostile.[7] A 15-minute warning was given between first pick-up and landfall. The raid turned out to be twenty enemy aircraft, flying at 50 feet. Fighter aircraft were unsuccessful in interception, but A.A. defences destroyed two of the raiders.

[1] This is described in Chapter 11.
[2] The magnetron valve advantages are discussed in Appendix No. 8.
[3] Air Ministry File S.8696, Encl. 16A.
[4] Air Ministry File C.S. 17288, Part 1, Encl. 8A.
[5] Air Ministry File C.S. 12138, Encl. 1A.
[6] Air Ministry File C.S. 17288/1, Encl. 20B.
[7] Air Ministry File C.S. 19224/1, Encl. 11A.

Transfer of Army Surface-Watching Stations to the Royal Air Force

The ultra-high frequency Naval Type 271 stations were giving better results on shipping than the C.H.L. stations. A scheme was therefore formulated in March 1942, whereby Army and Royal Navy C.D. No. 1, Marks IV–VI stations (using Naval Type 271, later modified to the high power Type 277 equipments) were to be installed on Royal Air Force C.H. or C.H.L. station compounds for surface-craft detection.[1] A further plan was devised in July 1942, whereby No. 60 Group was eventually to take over all Army surface-watching stations in the early warning Chain. This latter scheme embraced the former, but was a long-term policy measure, whereas the first plan was being implemented by the summer of 1942. When operational, the C.D. No. 1, Marks IV–VI stations were to take over surface-watching functions from the C.H.L. stations to which they were attached, these then being used only for stand-by purposes.

Siting and installation for the various stations were to be the joint undertaking of the Royal Navy, Army and Royal Air Force, each Service being responsible for certain specific sites. The Royal Air Force was to take on charge immediately all stations on existing Air Force sites, and eventually those manned by the Army. Crews were to be drawn from all three Services.

The scheme whereby all Army surface-watching stations were to be transferred to No. 60 Group was planned to take place in two stages. First, No. 60 Group was to be responsible for the maintenance of each station's equipment by a certain date, manning and administration remaining the responsibility of the Army or Royal Navy. Second, No. 60 Group was to take over complete responsibility for each station.

The three Services had each utilised differing nomenclatures for their equipment. This was a possible source of confusion when considering the various stations from the Triple Service aspect. Accordingly, on 25 August 1942, a summary of the various types of equipment was made by the War Office and confirmed by No. 60 Group.[2] This introduced a revised nomenclature for the equipments which was to be used by all three Services.

The programme at that date laid down a total of sixty-three coastal defence stations using centimetre equipment already installed or envisaged, covering between them the coastline of Great Britain and Northern Ireland. Sixteen of the stations were to be in existing C.H. or C.H.L. compounds, seven in C.D./C.H.L. (Triple Service) compounds, eight on C.D./C.H.L. (Dual-Service, Army/R.A.F.) sites, eight on existing C.H.L. stations, five on Naval stations in the Triple Service area and the remainder were to be on new sites remote from any existing R.D.F. stations. Of these sixty-three stations, installations were at that time complete on sixteen, and work in progress at several more.[3]

Operational Control of Triple Service Surface-Watching Stations

A meeting was held at the Admiralty on 27 August 1942, between their representatives and those of the War Office and Home Forces, to discuss the operational control of the R.D.F. Surface Chain. It was agreed that the Admiralty should assume operational control of altogether one-hundred and three stations, either in being or planned, and including all those stations

[1] Air Ministry File C.S. 12788, Encl. 92B.

[2] The Summary and Revised Nomenclature are given in Appendix No. 21. (Reference, Air Ministry File C.S. 12788, Encls. 71A and 92A.)

[3] *See* Appendix No. 20 for list of Air and Surface-Watching Stations at 31 December 1942.

mentioned in the previous paragraph.[1] The transfer was to be made area by area, as arranged between the Admiralty and Headquarters, Home Forces, subject to the following conditions :—

(a) The transfer was to take place when the stations had been taken over by the Royal Air Force for manning and maintenance.

(b) The Admiralty undertook to supply to Army Plots the information necessary to meet their requirements and to ensure that stations continued normal sweep during operations.

(c) The stations should operate solely for surface-watching over their allotted arcs of sweep. An additional set would be provided if stations were required to concentrate on individual targets for Naval purposes. (This set was not actually provided before 1944.)

The first eleven stations were taken over by the Royal Air Force by December 1942, followed by three more in May 1943. By December 1943 practically all surface-watching stations had been taken over for manning and maintenance by the Royal Air Force, operational control being exercised by the Navy.[2] A few stations, however, were retained solely by the Navy for their own particular needs, maintenance only being provided by the Royal Air Force, and these stations did not come into the normal reporting system of the Royal Air Force.

Value of Centimetre Equipment against the Low-Flying Raider

Added impetus to the more speedy adoption of ultra-high frequency R.D.F. equipment by the Royal Air Force was provided by the Air Officer Commanding-in-Chief, Fighter Command, who in September 1942 referred to the numerous attacks being made by the enemy on coastal targets in the South of England by very low-flying aircraft, frequently *Focke-Wolf 190* fighter-bombers, which came in at sea-level.[3] He stated that the existing C.H.L. stations on the South Coast, in spite of the fact that they were mostly high-sited, seemed quite incapable of providing adequate warning of such attacks. It did not seem to him that technical adjustment or improvement in operators' skill would make any substantial improvement in the detection of these aircraft, and other measures would be necessary.

As a solution, the Air Officer Commanding suggested the provision of 10-centimetre sets, similar to the Naval Type 271 sets but higher-powered, in all areas where very low-level attacks were likely to be made by the enemy, and as an instance he stated that a suitable equipment on trial at Great Orme's Head (the N.T. 273 medium-power 70-kilowatt equipment) had shown that an aircraft flying at 50 feet could be detected at approximately 35 miles.

Unfortunately, Plan Position Indicators were still unavailable in any quantity, and this lack meant that owing to the very narrow beam-width of 10-centimetre equipment the rate of sweep was so reduced that the arc over which efficient detection could be reasonably guaranteed was not likely to be more than 60°. The result of this would be that at any particular C.H.L. site at least two high-powered 10-centimetre equipments would be required in order to ensure that the coverage provided by this apparatus would be superior to that of the C.H.L. stations equipped with Plan Position Indicators (P.P.I.). The provision of a

[1] Air Ministry File C.S. 16640, Encl. 1A.
[2] Air Ministry Files S.12138/I, Encl. 112A, and S.16640, Encl. 15A.
[3] *Ibid.*, Encl. 36A.

suitable P.P.I. for use with 10-centimetre equipment was a matter of great urgency, but pending this development Fighter Command recommended that all C.H.L. stations between Land's End and The Wash be provided with two high-power 10-centimetre sets, to be reduced to one per site when effective P.P.I.s became available.

Difficulties of design made it impossible for this recommendation to be implemented in full, but developments were hastened on an Admiralty set, Type 273, Mark V, which it was hoped would help meet the need for low-flying cover. This set was undergoing tests at Ventnor and Great Orme's Head and was an improvement on the Type 271 set in so far as it was specifically designed to provide cover for aircraft and was not merely an adaptation of a surface-watching instrument.[1] As it was an Admiralty design, however, it was not anticipated that production would be available in quantity for the Royal Air Force before June 1943.

In order to give the Service operational experience with 10-centimetre equipment for aircraft cover, A.D.R.D.E.[2] was making the technical equipment for three C.H.E.L. stations for installation at Beachy Head, Happisburgh and Deerness (Orkney), these three sites being of high, low and medium altitude respectively. The equipment was similar to the experimental high-power set already in operation at Ventnor (known locally as the H.P.T.) comprising a ten-foot paraboloid reflector aerial system mounted on an Army type gantry over one-third of a standard Nissen hut, the latter being the Operations Room. The equipment was to be provided with a high-power 500-kilowatt magnetron valve, with both P.P.I. and range tube displays, and seemed to be the most satisfactory set yet designed for its purpose.

Reporting of Very Low-Flying Aircraft by Surface-Watching Stations on the South Coast

In order to give every assistance to Fighter Command Operations Rooms in the early reporting of very low-flying aircraft, the Radio Board recommended on 27 October 1942 that certain surface-watching stations should operate primarily for this purpose over their allotted arcs of sweep, but aircraft information observed by them should be relayed through C.H.L. stations to operational Filter Rooms and Sector and Gun Operations Rooms, providing that this did not interfere with the surface reporting function of the station.[3] If a station was required to concentrate on individual targets for Naval purposes (as, for instance, at Capel) then an additional set of equipment would be provided.

The Air Officer Commanding-in-Chief, Fighter Command, recommended that as a temporary measure these stations should be allotted a primary rôle of watching for aircraft during daylight hours and a secondary rôle of sweeping once in 15 minutes for surface watching. He further recommended that as many centimetre stations as possible should immediately be brought into action in the South of England and that P.P.I. displays should be provided at the earliest possible moment. As a consequence, Headquarters, Fighter Command issued orders on 18 February 1943 to Headquarters, No. 60 Group, repeated for information to the Admiralty and War Office (who later confirmed them to their own stations) that all ultra-high frequency stations on the South

[1] Air Ministry File C.S. 12138, Encl. 37A.
[2] (Army) Air Defence Research and Development Establishment.
[3] Air Ministry File C.S. 12138/R.D.F., Encls. 1A and 35A.

Coast should treat the detection of low-flying aircraft as a first priority. Naval and Army plotting rooms were to retain operational control and the right to order the full arc to be swept if and when considered necessary. Aircraft so detected were to be tracked and reported continuously to Royal Air Force Filter Rooms and Sector Operations Rooms through the associated C.H.L. telephone lines.

Provision of Further Cover against Low-Flying Aircraft

Instructions were given in February 1943 for the installation of eight special R.D.F. equipments in addition to already existing stations, their sole purpose being the detection of very low-flying aircraft. These sets were to be of the Type 273, Mark V, Admiralty pattern and six were, in fact, in operation by the end of March 1943, so great was the urgency of this requirement in view of the enemy's tactics to evade our early warning R.D.F.[1]

On 28 February 1943 the Director-General of Signals wrote to the Air Officer Commanding-in-Chief, Fighter Command, stating the action taken to provide special R.D.F. cover on the South Coast for the detection of low-flying raiders.[2] The Admiralty agreed to put temporarily at the disposal of the Royal Air Force three Naval Type 273 Mark V stations, to be sited on existing C.H. or C.H.L. stations at the discretion of the Royal Air Force, and in addition they promised that any information on very low-flying aircraft obtained by them at their new station at Capel (then undergoing test) should be placed at Air Ministry's disposal. Both the Admiralty and the War Office agreed that all Coast Defence Mark IV stations from Dengie to Start Point should be used primarily for aircraft detection during daylight. In the meantime the Telecommunications Research Establishment and the Admiralty Signals Establishment were pressing on with the development of suitable P.P.I. displays and power turning gear for the Type 273 stations. Two centimetre height (C.M.H.) Mark I stations which had been intended for use by the Admiralty in Orkney were also diverted instead to the South Coast to help to strengthen existing R.D.F. defences.

The ultra-high frequency R.D.F. technique was the only really successful method of obtaining early warning against the very low-flying raider, and so by April 1943 further low cover was provided using Royal Air Force Stations, Types 13, Mark I, and 14. The Type 13, Mark I station was the Air Force nomenclature for the Centimetre Height Set, originally designed for height-finding on C.H.L. stations. This equipment had proved rather unsatisfactory in performance and so was relegated to the rôle of watching for very low-flying aircraft. The Type 14 station, ultimately to replace all stations Type 13, Mark I, was the Naval Type 277 set. Installation details were as follows :—

(a) *Stations, Type 13, Mark I,* were provided at North Foreland, Kingsweir Beer Head and Fairlight. A note is made in the Operations Record Book of Headquarters, No. 75 Wing in No. 60 Group to the effect that the very low-flying cover was considerably improved by the addition of the two sets at North Foreland and Fairlight. The latter became operational on 18 April 1943, and five days later it was reported that the station had been able to keep continuous track of a raid flying at zero feet in mid-Channel at about 20 to 30 miles from the station.

[1] Air Ministry File C.S. 12138, Encls. 59A, 72A and 87A.

[2] *Ibid.*, Encl. 74A.

(*b*) *Stations, Type 14* were designed for the dual rôle of the detection of low-flying raiders during daylight hours and for detection of surface craft at long range during the night. Production of the Type 13, Mark I equipment had ceased in 1943 and it was intended that these should be replaced by Type 14 sets. The first Type 14 equipment was installed at Capel for the Royal Navy and during the spring of 1943 further stations, in mobile form, became operational at Beachy Head, Ventnor, Start Point and The Verne. It was anticipated that further equipment of this type, when available, would be installed on other south coast stations.

Operational Performance of Type 13 Mark I and Type 14 Equipment

The German practice of approaching our shores flying just above the sea to avoid detection by R.D.F. had initially achieved a high degree of success, but the new ultra-high frequency equipment could detect the approach of these wave-hopping raiders. The length of the warning was short, but gave sufficient time to permit interceptions to be made and also to warn anti-aircraft gun defences in the area likely to be attacked. The following specific instances give a picture of the effectiveness of the warning obtainable from Types 13, Mark I, and 14 stations :—[1]

(*a*) During an attack on Hastings on 23 May 1943, Fairlight T.13, Mark I station picked up a low-flying raider at 30-mile range, giving a warning period from pick-up to landfall of 11½ minutes. Four Typhoon aircraft intercepted and destroyed one *F.W.190*.

(*b*) On 25 May 1943, Beachy Head Type 14 station detected a formation of aircraft at a range of 22½ miles, with a warning period of 8 minutes (though only 3½ minutes warning after Filter Room gave a hostile identification). Five enemy aircraft were destroyed by A.A. guns and two by fighter aircraft.

(*c*) On the same day twelve *F.W.190s* set course for Folkestone and were picked up by Capel Type 14 station at a range of 18 miles. Immediate hostile identification followed and seven patrolling Spitfires sighted the formation and destroyed five raiders.

(*d*) On 30 May, Beer Head Type 14 equipment detected a formation at 26 miles range, and Kingsweir C.H.L. saw it only at 9 miles range. Nineteen miles of filter track were passed to Exeter Operations Room. The Air Raid Warning was given five minutes after the first plot, but unfortunately bombs were dropped on Torquay at the same moment, causing twenty-one fatalities. Thirty-two of our aircraft were airborne, including Typhoons which took off three minutes after the first plot. One enemy aircraft was destroyed by fighter aircraft and three were shot down by the A.A. defences around Torquay.

With a range of detection which may be seen from the above examples as between 20 and 30 miles the time factor for actioning such plots was of great importance. Every effort, therefore, had to be made to avoid any delay in both Filter and Operations Rooms.

Installation of High-Power Centimetre Equipment

To provide further cover in the Triple Service Chain, and in particular to counter the low-flying enemy aircraft which were making repeated raids along the East Anglian coast, it was decided in May 1943 to install high power

[1] Air Ministry File C.S. 19224, Part 1, Encl. 11A.

equipments on towers at six existing R.D.F. stations.[1] These stations were to be of the C.D. No. 1 Mark VI** (Tower) type, mounted on 200-foot towers using a high-power equipment known as the Naval Type 277—a high-powered version of the Type 271. The apparatus was to be installed in half-Nissen huts at the base of the towers, and 9-inch Plan Position Indicator tubes were ordered. The need for this low cover was so great that the project was awarded the highest priority. Rapid progress was made, and the first station, Hopton, became operational on 23 June 1943, followed two days later by Trimingham. Thorpeness and Winterton came on the air in July, Bard Hill in August, and Benacre on 13 September.

A further twelve Naval Type 277 stations were approved and a meeting was called at Air Ministry on 10 July 1943, to discuss their installation. Some discussion had already taken place on the desirability of installing the transmitter at the top of the tower, as at Hopton, or at the base, as in the case of Trimingham. Comparative tests carried out in July proved inconclusive. The meeting decided to carry out tests over a period of some months, and if later it was agreed that the performance of stations using a transmitter at the tower base was equal to that where it was mounted on top of the tower, then modifications could be carried out. Transmitting equipment was to be installed on top of the towers at Bard Hill, Bempton, Dimlington, Skendleby, Thorpeness, Beer Head, Hopton, Start Point, Winterton, Dengie and the Naval station at The Verne. Transmitter equipment at the base of the towers was scheduled for Benacre, Bamburgh, Cresswell, North Foreland, Pen Olver, Rosehearty and Trimingham. The reason for this was that the first batch of stations listed was equipped with Army towers and lifts ; the second batch built with Royal Air Force towers, was not so equipped ; and lifts were essential if the constant maintenance required by this gear was to be regularly carried out by the station mechanics.

A decision was taken in August 1943 to extend low-flying cover on the East coasts of Scotland and England by installing C.D. No. 1 Mark VI** stations on the 200-foot cantilevers of C.H. station steel towers.[2] The stations were Douglas Wood, Drone Hill, Dunkirk, Bawdsey and Danby Beacon, which were to be operated in the dual capacity of air and surface watching, and Great Bromley, to be used for aircraft detection only. Difficulties arose in November 1943 over the erection of the ten centimetre high-power sets on the C.H. towers at Douglas Wood, Drone Hill and Danby Beacon. Originally, it had been hoped that when operational they would render redundant the original C.D. stations in the area, but it was now decided that better inshore cover was provided by the existing stations at Lamberton Moor, Saltburn and The Law, so that no economy would be effected. Work was therefore held up pending a decision as to their suitability.

During late 1943 further extensions were planned to the chain of centimetre high-powered static stations, some for long-range surface watching only, the majority for air and surface-watching, as the need for detection of very low-flying aircraft still persisted. Types 277 and 277A equipment was to be installed using either a 200-foot wooden tower, or a 200-foot cantilever of the C.H. stations, or a 20-foot gantry aerial system on the higher-sited stations.[3] It was hoped to obtain a continuous rotation rate of at least four revolutions per minute.

[1] Air Ministry File C.S. 12788/I, Encls. 123A and 149A.
[2] Air Ministry File S.12138/II, Encl. 3A.
[3] Air Ministry File C.S. 12138/II, Encls. 25A and 46A.

A summary of the C.D. No. 1, Marks VI* and VI** stations at the end of October 1943, revealed a programme of forty stations. Thirteen were operational at this date and good progress was being made on a further fourteen stations, which were due for completion by the New Year. Thirteen of the stations were high-powered on Army 200-foot towers, but the remainder were high- or low-powered and mounted on truncated towers, on gantries or in "Gibson Boxes."[1] The area covered was from the Moray Firth southwards to Pembrokeshire, with one station at Greystone in Ulster and another, Deerness, covering Scapa Flow.

Filter Room Instructions for Plotting on Low-Flying Aircraft

In an endeavour to hasten identification at Filter Rooms and to ensure immediate priority for any tracks suspected of being hostile, Fighter Command issued an Operational Procedure Instruction on 31 March 1943, which laid down that plots from R.D.F. surface watching stations (known as "K" stations) and from stations, Type 13, Mark I (Centimetre Height) and Type 14 (Naval Type 277) should be told immediately via the associated C.H. or C.H.L. station and given priority on the telephone line.[2] All such plots were to be prefixed with the letter "K" and were to take precedence over all others. Special display plaques were provided for use in the Filter Room so that Filter Officers and Controllers could see immediately which plots were from these stations. In addition, as each plot was passed the plotter was to call the attention of the Sector Controller to it by saying "K" Plot in a loud voice as soon as the information was received and displayed on the table. Controllers were instructed to treat all "K" plots as potential hostile tracks and to take appropriate action without delay.

It was realised that Stations, Type 14, would help materially in plotting our own fighter patrols, but the continuous tracking of friendly patrols could not be achieved at this time, and so it was inevitable that a number of the "K" plots passed would prove to be friendly aircraft, with numerous false alarms arising in consequence. Nevertheless, this fact was not to be allowed to delay intercepting action, as "K" plots might often be the only indication of attack before such action was actually in progress. Priority was given for providing these stations with adequate telephone facilities for reporting direct to all Operations Rooms concerned.[3]

Possibility of Low-Flying Raids at Night

A new factor had to be taken into consideration with the lengthening nights of the autumn of 1943—the possibility of the enemy sending over very low-flying aircraft by night as well as by day. This possibility was first envisaged in a letter dated 8 October 1943 by the Air Officer, Commanding-in-Chief, Fighter Command, to the Under-Secretary of State for Air. In this he stated that events had proved that there was a serious danger of hostile aircraft approaching this country by night at very low levels, particularly during moonlight periods, thereby evading detection by the normal R.D.F. reporting Chain.[4] If these raiders were to be detected it was essential that full use should be made of the anti-low-flying C.H.E.L. Chain (Chain, Home Extra-low) by night as well as by day, and for that purpose it was necessary that stations should be permitted to maintain a continuous rate of sweep so that no area should be left uncovered for even a short period of time.

[1] "Gibson Boxes" were small wooden transportable cabins.

[2] Headquarters, Fighter Command File F.C./S.27004/Ops. 2 dated 31 March 1942, and Air Ministry File C.S. 12138, Encl. 89A.

[3] Air Ministry File C.S. 12138/II, Encl. 56A.

[4] *Ibid.*, Encl. 32A.

The Naval requirements from C.H.E.L. stations included the plotting of hostile surface craft, the accurate and detailed plotting of friendly shipping, the conduct of sea strikes, and, in collaboration with the Royal Air Force, the conduct of air/sea strikes. For all these purposes the current Naval practice was to stop sweep every time an observation was to be made in order to take plots of surface craft from the range tube, using the range and bearing method of plotting. If adequate air cover was to be provided while surface craft were being plotted, it was necessary that a constant rate of sweep should be maintained and all plots read from a Plan Position Indicator tube. The Admiralty reviewed the position of their stations in view of Fighter Command's statements, and stated that the policy then in operation for High-Power Dual-Purpose Radar Stations, Type 14, was, in general, that stations watched for low-flying aircraft by day under Royal Air Force tactical control, and for surface craft by night under Naval control.[1] This made possible the development of two operational systems—the Royal Air Force method whereby stations swept continuously and read plots from a P.P.I. tube, and the Naval system where continuous rotation and P.P.I. readings were only adopted until it was necessary that concentration should be made upon specific targets. If continuous sweeping could be generally accepted, a great advance would be possible, because all distinctions in the tactical control of stations would disappear, and stations would sweep continuously and report whatever was seen to the correct quarter. A very considerable economy of high-power stations and crews would result with consequent simplification of the chain and of maintenance. Trials were, therefore, instituted by the Admiralty to decide whether the system of continuous sweep could meet all or any of the Navy's requirements. These trials were carried out in November at Hopton and Beachy Head.

The Army Commander-in-Chief, Home Forces, considered, after studying the results of these trials, that the dual-service use of high-power centimetre radar stations employing continuous aerial rotation with P.P.I. presentation (and a separate tube for surface watching) would be acceptable for all Army purposes, subject to certain safeguards when particular information on any target was required by them.[2]

The Admiralty, in consequence of the foregoing trials, agreed at the end of 1943 to the policy of continuous sweep, with the following provisos :—[3]

(a) That the local Naval Plotting Rooms should have power to interrupt the continuous sweep for counting or estimating size for a period not exceeding 20 seconds in any two minutes. Further, that this period might occasionally have to be extended, particularly at night, during the course of an action, or other special circumstances at the direction of the Flag Officer controlling the Operation. It could be accepted that these occasional protracted periods would only be ordered with the greatest discretion by the Flag Officers concerned and full arc sweeps would be interposed whenever the state of the action permitted. This requirement necessitated that adequate " inching " control should be fitted in the continuous sweep gear, so that the sweep could if necessary be stopped momentarily to investigate any particular response.

[1] Air Ministry File C.S. 12138/II, Encl. 47A.
[2] Air Ministry File C.S. 12138/II, Encl. 68A and 70A. [3] *Ibid.*, Encl. 85A.

(*b*) That each high-power radar station concerned should be fitted with a second P.P.I. tube, the range tube being flanked on either side by the Surface Watching and aircraft detecting P.P.I. tubes.

The whole matter was discussed at a meeting of the Radar Board in January 1944, and agreement was expressed with the Admiralty's proposals, with a recommendation that they should be adopted subject to further review should this prove necessary in the light of operational experience.[1] Consideration was also given to the proposals for providing extra P.P.I. tubes and facilities for reading I.F.F., and Air Ministry gave instructions to all parties concerned to implement this policy at the earliest possible moment.[2]

By the end of 1943, the counter to the enemy very low-flying attacks could be said to be operating successfully. The centimetre station had proved to be the answer to this problem which had faced our defences since 1941. The Home Chain ultra-high frequency stations could give cover both by night and day against the very low-flying raider. Out of the original Admiralty proposal, considered at the 16th meeting of the Inter-Service Committee on R.D.F. during January 1941 for a common C.H.L. Chain for all three Services, had now been developed an ultra-high frequency R.D.F. Chain with the original C.D./C.H.L. stations acting as stand-by equipment. On superficial considerations, three years may appear an unduly long period in which to achieve a satisfactory Coast Defence Chain. It must be appreciated, however, that in addition to the original C.D./C.H.L. Chain, the new ultra-high frequency technique had been adapted to Coast Defence requirements and equipment had been produced and installed.

The Triple Service Chain may be regarded as a triumph of technical liaison between the three Services. It provided adequate R.D.F. cover against the very low-flying enemy aircraft as well as surface-watching and was therefore a valuable adjunct to the C.H. stations—which, however, continued to give the broad picture of enemy activity on to which the reports from the centimetre stations had to be superimposed.

[1] The R.D.F. Board had been inaugurated at a meeting of the Radio Policy Sub-Committee on 27 February 1942, and held its first meeting on 4 March 1942. It became known as the Radar Board on 22 June 1943. Membership consisted of Service representatives from the branch of each of the three Service Ministries responsible for R.D.F. policy in their Service, under the chairmanship of Air Commodore V. H. Tait. Its terms of reference included the co-ordination of inter-Service action with regard to operational requirements, recommendations regarding the development, provision and allocation of R.D.F. equipment for home and overseas, the collection and dissemination of R.D.F. information to the Service Planning Staffs, and co-operation on R.D.F. matters with Dominion and Allied authorities.

[2] Air Ministry File C.S. 12138/II, Encl. 96A.

CHAPTER 16

GENERAL OPERATIONS OF THE HOME CHAIN DURING 1942 AND 1943

Although the heaviest attacks of enemy bombers on this country took place in 1941, and the subsequent years were marked by a decrease in the tonnage of bombs dropped, the decrease in the numbers of enemy aircraft was not accompanied by a corresponding simplification of the pictures presented on the cathode ray tubes of the R.D.F. stations. Bomber Command was steadily increasing the weight of its attacks, and the Home Chain stations plotted all such "friendly" activity, often being able to render valuable assistance for the safety of bomber aircraft and crews.

The period under consideration in this chapter is technically largely one of refinement of R.D.F. equipment in the C.H. stations, and of improvements in the apparatus embodied in the experimental progress of the 1941 period, with few major modifications in design. Methods of plotting and filter interpretation of the R.D.F. information were constantly under consideration because the maximum value was often not derived from the information available. To obtain a general picture of the problems which faced the Chain during 1942 and 1943, it is necessary to review briefly the type of aerial activity, both hostile and friendly, which it was called upon to plot.

Hostile Activity

1942 was notable for the number of attempts by the enemy to retaliate for the increasingly heavy bombing offensive actions undertaken by Bomber Command and later by the United States Army Air Force. There were approximately four classes of enemy raid :—[1]

(*a*) The early "Baedeker" raids on non-industrial targets of 25/26 April and 8/9 May 1942,

(*b*) The later "Baedeker" raids and other attacks which continued onwards from mid-May,

(*c*) Daylight "tip-and-run" raids by very low-flying fighter and fighter-bomber aircraft, and

(*d*) Daylight raids by twin-engined aircraft.

The year 1943 saw developments in the equipment and technical methods used by the *Luftwaffe* in attacks against the United Kingdom. On Hitler's orders an "*Angriffsfuhrer England*" had been appointed to take charge of bombing activities directed against this country. *M.E. 410* light bomber and bomber-reconnaissance aircraft were introduced in the summer, and the *Ju. 188* bomber in the autumn. Single-engined *F.W. 190* fighter-bomber aircraft were used by night as well as by day from April. A lesser tonnage of bombs was dropped than in the previous year, but attempts were made to get a higher return for this tonnage by an improvement in bombing accuracy, and to reduce losses by such tactics as mingling with the stream of returning British bombers, and by the use of faster aircraft.

[1] Headquarters, Fighter Command Intelligence Summaries and No. 60 Group O.R.B.

In the night raids of spring and summer 1943, the more accurate placing of flares and incendiaries by the leading enemy aircraft and the greater care by the Germans in the selection and briefing of their crews, produced a higher " raiding efficiency " than in the last half of 1942. This improvement was not maintained, however, and the enemy's battle casualties were considerable, and higher in proportion than in the previous year. Increasingly heavy casualties were imposed by our defences. By the autumn of 1943 such an ascendancy had been achieved that for the last three months of the year daylight flights over this country by any type of enemy aircraft were a rarity. " Tip-and-run " raids ceased at the end of the first week in June, partly because the enemy aircraft were needed in the Mediterranean, where a critical situation had arisen for the Germans as the result of Allied successes in the Tunisian campaign, and partly because the enemy found his raids too expensive both in men and machines.

Activity by Allied Air Forces, 1942–1943

Until 1942 the Chain had acted almost entirely in a defensive capacity, by giving warning of incoming hostile raids. This function it, of course, continued to fulfil, but in addition was now very much occupied in keeping track of friendly aircraft. Bomber Command's activities began quietly enough at the beginning of 1942, but its attacks became heavier and heavier as time went on. The development of R.D.F. as an offensive weapon, and the fitting of bomber aircraft with " Gee," " Gee-H," " H2S," and other forms of R.D.F. apparatus meant that more aircraft could be sent on raids at increasing range over enemy territory, with a greater accuracy of bombing. Production in this country was getting into its stride, and increasing numbers of aircraft were daily being delivered from the factories. The Royal Air Force training programme provided plenty of trained crews, enough to allow for new crews as well as replacements for casualties which were, unfortunately, mounting rapidly as the number of raids increased. Finally, by the middle of this period there was the valuable assistance of the United States Army Air Force, with its vast reserves of men and aircraft.

Activity gradually increased from 8 March 1942 when the first raid of aircraft using " Gee " was made, three hundred and fifty bombers going to the Ruhr, until 30/31 May 1942 when the " one-thousand bomber " raid directed against Cologne marked a turning point in our campaign. Intense activity at night continued throughout the summer, decreasing about November, when wintry weather brought its additional hazards. Daytime activity throughout the summer continued on an increasing scale, both day raids by bomber aircraft and offensive fighter sweeps keeping the coastal R.D.F. stations at concert pitch. Activity again increased from the spring of 1943. Stations which, early in 1942, thought themselves busy when one-hundred or more bomber tracks were plotted, were now regarding raids of five-hundred or six-hundred aircraft at a time as commonplace.

All this meant very considerable work for the Home Chain, particularly on the East and South-East coasts. Accurate tracks had to be maintained on the mass formations as they crossed the coast on the outward journey, with a constant watch for enemy fighter aircraft coming out to intercept them. Very careful watch had to be kept as our aircraft returned to base at varying times throughout the night and early daylight hours ; constant vigil had to be maintained for stragglers, for damaged aircraft unable to reach their home airfields and so returning by unexpected routes, and for aircraft in distress. Typical instances of the Home Chain co-operation with the Air/Sea Rescue services worthy of mention were :—

(a) On 4 June 1943, at 0329 hours, a returning bomber crashed in the sea ; a fade plot on the track given by a C.H.L. station marked the exact position. The station plotted four fighter aircraft guarding the spot for six hours until at 1010 hours the Rescue launch picked up all six of the crew. The associated centimetre station at the same time passed plots which were believed to be the dinghy and wreckage from the bomber.

(b) On 4 August 1943 St. Margarets, Type 14, R.D.F. equipment was the first station to pick up a response, later found to be a dinghy. Directed by plots from the station, a Walrus aircraft and twelve escorting fighter aircraft went to the rescue, and saved all the crew.

The C.H. Stations

The C.H. stations, which had proved their value during 1940–1941, were again the backbone of the raid reporting system throughout the period under review. The major portion of the C.H. station installation programme had already been carried out, and the years 1942–1943 were chiefly a time of consolidation. Twelve new C.H. stations were, however, completed in this period, filling gaps in coverage in the more remote parts of the British Isles, chiefly in Northern Ireland and North and West Scotland.[1] C.H. cover was now complete and adequate around the whole coastline of Great Britain and Northern Ireland. In addition, "Buried Reserve" equipments became operational and a "Remote Reserve" site was completed at St. Lawrence. An Intermediate C.H. station was commissioned at Broad Bay, near Stornoway, and two C.H.B. stations in the Western Isles of Scotland. These latter were stations using C.H.L. equipment plus a method of height-finding. They fulfilled the normal functions of C.H. stations but were placed in locations where siting difficulties made a full C.H. station impracticable. The great advantage of the C.H. stations was that they gave at all times a fairly complete picture of practically all aerial activity in their neighbourhood, the only real drawback being that very low-flying aircraft were beyond their scope. The C.H.L., centimetre, and G.C.I. stations all gave increasingly valuable help to our defences, but this was of a more specialised nature and only of full value when seen against the background picture depicted by the C.H. stations.

The extension of the C.H. Chain around the whole coastline, together with improved equipment and the provision to the majority of stations of adequate reserve equipment for use during maintenance and breakdown periods meant that Filter Rooms were always able to get a general idea of the activity in their area. C.H. stations again proved their worth particularly during periods of enemy jamming. Although they were often themselves affected, the enemy's attention appeared primarily to be directed towards the higher frequencies of the C.H.L. stations, which were sometimes rendered almost unserviceable. It was only rarely that C.H.L. and C.H. stations were jammed so intensively at the same time that adequate information could not be provided from either source.

[1] *See* Appendix No. 19 for all new station locations. These were taken from No. 60 Group, O.R.B.

The East and South-East Coast stations were particularly busy in these days, as here most of the Royal Air Force bomber activity was concentrated. Cathode ray tubes were often saturated with echoes when a heavy formation of bombers was plotted outwards over the sea, and frequently several hundred responses would be seen at a time, making individual tracking impossible and accurate estimation of numbers extremely difficult. After the one-thousand bomber raid on Cologne of 30/31 May 1942 one East Coast station's report read " tube was solid with echoes "—another report described it more enthusiastically as " literally dripping with echoes."[1] An indication of the activity displayed on the tubes is given by High Street's station report, which recorded on 4 August 1943, eight-hundred plus friendly aircraft as being seen at one time ; and on 30/31 of the same month they reported one-thousand aircraft. Despite the large numbers of aircraft seen, stations yet managed to pass readily intelligible information to Filter Room, and maintained a high standard of accuracy. A report dated March 1942 from the Headquarters, No. 75 Wing Operations Log stated that[2] " a fighter sweep and large formations of hostile aircraft were plotted at the same time. The accuracy of the plotting was directly instrumental in enabling Royal Air Force Station, Tangmere fighter aircraft to shoot down eight enemy aircraft without loss. Poling (C.H.) and Truleigh (C.H.L.) R.D.F. Stations saw most of these tracks."

An example of the increased range obtainable with improved equipment, allied to favourable weather conditions, was provided by Stenigot C.H. Station which, on 26 June 1942, plotted a high-flying photographic reconnaissance aircraft all the way to Bremen, a distance of 340 miles.[3]

Technical Improvements to C.H. Stations, 1942–1943

The main technical modifications to C.H. stations during 1942–1943 were concerned with the simplification of operation of the R.D.F. equipment, improved presentation to the Observer and more effective liaison between the Observer-Plotter and the Tracker, all leading to increased accuracy and speed of the R.D.F. information. Outstanding among these developments installed at the more important C.H. stations were :—[4]

(*a*) An improved C.H. station receiver, R.F.8, which included the new Electronic Range Marker (E.R.M.). This latter " electronic pointer " replaced the range marker mechanical coupling between the Observer and Tracker cathode ray tubes on earlier type receivers.

(*b*) A new Console, Mark III, containing major improvements to the Tracker and a much more practical lay-out of the controls of the radio portion of the Console (The Tracker Unit).

(*c*) The Automatic Message Recorder—a device for the teleprinted transcription of R.D.F. information observed at the Station, for the station's official records for onward transmission to the Operational Research Section at Headquarters, Fighter Command.

The decision as to the priority with which C.H. stations were to be fitted with this new equipment was taken by the Chain Executive Sub-Committee on 4 July 1942.[5] The work was well in hand by autumn 1942, but all stations

[1] No. 74 Wing O.R.B. [2] No. 75 Wing O.R.B. [3] No. 73 Wing O.R.B.

[4] The earlier types of range marker and tracker unit were described in Chapter 11.

[5] Air Ministry File C.S. 16358, Encl. 3A. Details of the Receiver R.F.8, the Console, Mark III, and the Automatic Message Recorder are given in Appendix No. 22.

could not be supplied with completely new receivers and consoles. Under the reverse Lease-lend agreement with the United States of America, some of the first new R.F.8 receivers off production were sent direct to America for use on their developing Pacific Coast Chain of R.D.F. stations. In order to avoid any delay occasioned by this diversion of new equipment, the existing R.F.7 receivers on some of the Home Chain stations were converted into R.F.8 design and the necessary modifications made to the existing consoles. During busy periods of enemy or friendly aerial activity the Automatic Message Recorder did not find favour with R.D.F. Operators, who preferred to use manual recording instead. The other C.H. station improvements, however, to the receiver and console did much to ensure the increased operational efficiency of the stations, and so enabled them to deal with the heavy aerial activity which fell to their lot during 1942 and 1943.

General R.D.F. Ground Station Policy for 1942–1943

Towards the end of 1941 Air Ministry reviewed the capabilities of the R.D.F. sets then in use, with a view to planning development and manufacture for the ensuing year. Ten basic sets were then in use by the Royal Air Force, divided into the following groups :—[1]

(*a*) C.H. (Chain Home), M.R.U. (Mobile Radio Units), A.C.H. (Advance Chain Home) and their overseas equivalents. These stations used masts or towers and the goniometer method of direction finding, giving radio " flood-lighting."

(*b*) C.H.L. (Chain Home Low) and G.C.I. (Ground Controlled Interception) stations, using beamed transmission or radio " searchlight " technique.

(*c*) The Naval Type 271 equipment, a beamed transmission using ultra-high frequency and parabolic reflectors.

(*d*) High powered Air-to-Surface Vessel (A.S.V.) equipment which used a beamed transmission adapted for highly mobile ground use.

It was considered that the development of the ultra-high frequency R.D.F. technique should be carried out as an adjunct to the existing C.H. and C.H.L. Chain systems. The former policy had been that the C.H. stations, using a " radio floodlight " technique, were the only satisfactory method of long-range warning and had the advantage of being able to estimate the heights at which aircraft were approaching. In 1940 this conclusion had been quite correct, as comparison of the " floodlight " technique with radio beam or " searchlight " methods had been made between the then existing C.H. and C.H.L. stations. By 1942 the newer centimetre (or ultra-high frequency) equipment gave several advantages, the chief being that it could detect surface objects and, in its specialised form (Type 13, Mark 1), could be used for height-finding by tilting the beam. By the beginning of 1942 there was no doubt that although the C.H. station Chain would continue to give effective long-range early warning on high-flying aircraft, the future development of R.D.F. lay in the perfection of beam systems used in conjunction with the Plan Position Indicator for detection at shorter range, surface watching and the plotting of very low-flying aircraft.

[1] Air Ministry File S.41234/II, Encl. 113B.

Summary of R.D.F. requirements

The Air Ministry appreciation of the requirements of R.D.F. at the beginning of 1942 was summarised in three types of R.D.F. ground equipment only :—[1]

(*a*) The C.H.L./G.C.I. general purpose set, its functions varying according to the type of set and being available in either permanent or hutted/mobile form.

(*b*) A special surface-watch/very-low cover set. This would use ultra-high frequency technique and would be an adjunct to existing stations already sited on high ground, or could be mounted on a tower when high land was unavailable.

(*c*) A very mobile set capable of going in a light vehicle and providing power for its own plant, for emergency use at home and also for providing cover to forces operating in the field in overseas theatres. This simplification of the requirements was to have a considerable influence on the production side. Too often in the past only "Crash" production and installation programmes had enabled reasonably adequate R.D.F. cover to be provided. The shortcomings of the equipment were only found when in operational use. Now the benefits of experience were beginning to show themselves in this standardisation of future requirements.

"Intruder" Aircraft

During 1941, when the enemy night bomber offensive had been at its height, Fighter Command had developed a policy of "intruder aircraft" over enemy airfields. These "intruders" had awaited the return of the enemy bombers and attacked them as they attempted to land. The enemy adopted this method and adapted it to their own requirements during the 1942–43 period when the Royal Air Force bomber offensive was pressed home with increasing vigour. Their "intruder" aircraft flew in with our returning bombers, often escaping detection until they were right over one of our airfields. The first indication of their presence only too often was the arrival of a bomb or machine-gun bullet. Entries such as the following in the operational logbooks of the Chain stations are common.[2]

Stenigot C.H. 23 February 1942.—"Twenty-five bombers went out south of station. Returning bombers picked up at various ranges and were followed by a small number of hostile aircraft flying at same height."

Staxton C.H. 13 March 1942.—"During the evening hostiles came in with returning bombers. Incoming hostiles plotted. Twenty-three responses, seventeen hostiles."

73 *Wing Operations Report.* 12 December 1942.—"Random hostile activity. Enemy aircraft approached as our bombers returned, making identification very difficult."

In the vast majority of cases the problem was not one of non-detection but one of identification. The hostile aircraft were nearly always seen by the R.D.F. stations, but the numbers on the tubes were such that individual tracking of aircraft was impossible, and macroscopic plotting (or area reporting) was adopted instead. In this case a general plot was given of the front and rear edges of a formation, in the case of a C.H. station, with a mean height and an estimation of the numbers in the area. The C.H.L. stations passed plots on the four corners of the area raid. On the Filter Room table a four-cornered

[1] Air Ministry File S.41234/II, Encl. 113B. [2] No. 73 Wing O.R.B.

raid would be shown, with mean heights and estimated numbers, but within this area no individual tracks were filtered. Thus it was not always possible to identify hostile aircraft when their bearing and height were similar to that of the returning bombers and when they appeared in the middle of a formation. The chief contributory cause to lack of, or delay in identification, was the fact that so few of the British bombers showed I.F.F. All bombers were fitted with it, but many crews failed to switch it on when returning home, thus making the tasks of Filter Room and the R.D.F. stations even more difficult. Had all returning bombers shown I.F.F. then the intruder would have been easily spotted and a separate track could have been maintained. Constant complaints were made to this effect by the R.D.F. stations, and some improvement was noted, but the percentage of I.F.F. shown in a raid still remained insufficient.

As it was, it was very difficult in a mass raid to distinguish which particular aircraft were showing I.F.F. The introduction of Mark III I.F.F. ~~made some~~ improvement. When first introduced, this system proved by no means perfect, though providing more information than did the Mark II I.F.F., but constant research undertaken during 1942 to improve its stability and operational use had its effect and was shown by better performance. When single tracks only were on the tube it worked very well, but in a mass raid it was difficult to relate an I.F.F. response to any particular aircraft. The increased recurrence rate of Mark III however did to some extent simplify the R.D.F. Observer's job. Another great advantage was that it could be seen by all types of R.D.F. stations, and when more than one station was seeing a track, Filter Rooms were able to get confirmation of I.F.F. reports, thus assisting them in the difficult task of identification.

An Operations Research Section report reviewing hostile intruder action during 1943, stated that on the average there was one enemy attack per 4·5 friendly bomber nights.[1] Attacks were generally confined to the region of airfields, and the area most affected was to the East of a line Hull/Cambridge/Worthing, East Anglia being particularly affected. The following comments were made :—

(*a*) The operational limitations of tracking by the Radar-Filter Room system were such that recognition and tracking of a small number of hostile aircraft could not be expected in the following conditions :—

- (i) At the time and in the area when " area raid " technique was in operation.
- (ii) When numerous friendly aircraft were going out or coming in over a wide front and when there were more than fifteen tracks in any area 100 kilometres square.

(*b*) Early radar warning of hostile activity might have been given, but continued plotting of the hostile aircraft as far as the coast could not be relied on in the following conditions :—

- (i) When there was moderate or heavy density of friendly activity near the coast (*e.g.*, fighters in the Thames Estuary, or trainers in the Wash area).
- (ii) Whenever tracks near the coast were not coming straight in or out.
- (iii) When there was heavy friendly activity inland.

It must not be thought that the Home Chain failed completely with respect to the detection of these intruders. The job of the Chain was to pass details

[1] O.R.S. (A.D.G.B.) Report No. 13, 3 January 1944, and Air Ministry File C.S. 19224/1 Encl. 98A.

of tracks to Filter Room; the identification of tracks and the use made of such information was the responsibility of Filter Room and Operations Room staffs. The whole trouble was that with heavy activity it was impossible for the Home Chain to pass satisfactory information on separate tracks, and even had they been able to do so, Filter Room would not have been able to deal with them all. The matter was discussed in August 1943 by the Deputy Chief of Air Staff in a report to the Chief of Air Staff. He stated that the failure to obtain adequate warning of these raids was due to faulty identification, which arose from a few hostile aircraft coming in mixed with homecoming bombers.[1] There was no evidence of any deterioration in the performance of the Radar Chain. It was further stated that the problem of identifying a few hostiles among a number of friendlies, and vice versa, had been occupying the attention of both the technical and operational staffs for some years and in neither case did there appear to be hope of finding a complete solution.

General Operational Efficiency of the Home Chain

The enemy raids which adopted a technique designed to avoid observation by our R.D.F. stations, namely, very low-flying attacks and "intruder" operations, had provided the major problems to the Home Chain during the 1942–43 period. Normal enemy activity in night raids between 10,000 and 20,000 feet in height continued on a reduced scale throughout these years, but was usually adequately reported by the C.H. and C.H.L. stations. Although the major R.D.F. effort had been directed against the very low-flying raider, a close watch was kept on the C.H. and C.H.L. Chain with a view to maintaining it at maximum efficiency. Some criticism of the operational efficiency of the Home Chain was made in Fighter Command's Operational Research Section's report dated May 1943, in which it was stated that stations were worse operated than in the Battle of Britain days. This criticism was felt to be unjustified by Headquarters, No. 60 Group, for the following reasons:—[2]

(*a*) At the time the report was written a considerable amount of re-fitting and installation was taking place on the E., S.E. and S.W. coasts, and a number of stations were using reserve channels in consequence.

(*b*) There was a high percentage of inexperienced operators in Numbers 9, 13 and 14 Groups, as these areas had been robbed in order to maintain a high standard in Numbers 10, 11 and 12 Groups, where activity was mainly concentrated.

(*c*) The Home Chain had been much diluted by withdrawal of operators for service on "Gee" and "Oboe" equipment in this country, and for general R.D.F. service overseas.

(*d*) The vastly-increasing numbers of stations meant a corresponding increase in the number of operators. Consequently it was not always possible to maintain the general level of efficiency which obtained in 1940, when operators were far fewer and could be "hand-picked" as a result.

(*e*) The estimation of numbers of aircraft in a formation, of which criticism was made, was very difficult and depended largely on the type of formation used by the enemy. On most offensive operations formations flew tightly packed and it was doubtful if stations could always estimate the number of aircraft accurately in such conditions.

[1] Air Ministry File C.S. 19224/1, Encl. 67A. [2] *Ibid.*, Encl. 3A.

During the Battle of Britain the ratio of enemy tracks to friendly ones was relatively high and there was neither time nor staff to apply a meticulous analysis to station performance. The primary consideration was that of destroying the enemy and this aspect was satisfactory. There was at that time a very urgent need for a picture of aerial activity, however mediocre, and all information was thankfully received.[1] By 1942 the Chain's best performances were regarded as normal, and there was ample time and staff for any discrepancies or mistakes to be noted. The current performance could be compared to the past only when due allowance was made for the changed conditions. Invariably enemy aircraft approached our shores in a manner best calculated to defeat R.D.F. cover. The "50-footer" aircraft and the current trick of flying in to the verge of R.D.F. cover and then climbing to the height of 16,000 feet in six minutes or so were examples of his attempt to escape detection by the Chain.

Sir Robert Watson Watt in August 1943 stated that there was a tendency in Air Staff to use the term "R.D.F. failed to see X," when the facts were that "no filtered track corresponding to X appeared on the table." He was impressed by the number of investigated cases where the records of R.D.F. stations showed that adequate track data was provided but that it was mis-filtered. This accounted, amongst other things, for some of the many failures to deal adequately with low-flying aircraft. Sir Robert did not consider that the proportion of effort directed towards (*a*) improved filter room performance, and (*b*) improved station performance had ever been right, and he stressed the importance of maintaining the closest possible liaison between operating and filtering staffs.[2] Filter Rooms had many difficulties with which to contend and the only method of assisting them directly was in the simplification of the information presented from the Chain stations themselves. This approach was fully exploited by increasing the responsibilities of the supervisors on R.D.F. stations and arranging for closer team work between the C.H., C.H.L. and centimetre stations.

Improvements in Plotting Procedure to Filter Rooms

Directional Plotting.—C.H.L. improvements during 1941 and early 1942 made possible a speed of reporting which was far greater than any plotter at Filter Room could manage. The result was great congestion on the telling line to Filter Room and consequent confusion on the Filter Room table, with a loss of valuable information. In April 1942, therefore, an experiment was tried at Bawdsey in "Directional Plotting."[3] This was a method whereby the C.H.L. stations, instead of passing plots to Filter Room direct from the P.P.I. tube, plotted the tracks on a perspex map in their Operations Room. On every third plot, a filtered position with a direction of travel was passed to Filter Room. C.H.L. plots were so accurate that there was little margin for error in the filtering. Directional Plotting presented a very good picture of the activity and cut down congestion on the telling line. In June 1942, Headquarters, No. 60 Group decided to train all C.H.L. crews in Directional Plotting, and by the end of the year all stations from Beachy Head to Rame Head were reporting by this method. Later this form of plotting became current operational procedure at all C.H.L. stations.

[1] Air Ministry File C.S. 19224/1, Encl. 6A.
[2] *Ibid.*, Encls. 53A and 66A.
[3] No. 60 Group File 60G/51/19/5/Ops.

Combined Directional Plotting.—With three types of stations reporting to Filter Room—C.H., C.H.L. and C.H.E.L. (Chain Home Extra Low—the Centimetre sets)—it was found by the end of 1942 that information was often duplicated. Directional Plotting, so successful on C.H.L. stations, could not be used at a C.H. station, where inaccuracies in bearing made filtered information from the stations unreliable. In January 1942, however, a new conception of plotting based on individual station filtering was suggested, and this eventually came into operation as "Combined Directional Plotting."[1] In this method, stations worked in teams, comprising one C.H. station, its associated C.H.L. station and the attached C.H.E.L. station. Within P.P.I. range (up to 90 miles from the C.H.L. station) all plots were passed by the C.H.L. teller to a Filter Room plotter sitting on the inland side of the Filter Table. A plotter at the C.H. station monitored the C.H.L. filter line and reproduced on a perspex map in the C.H. Operations Room everything passed by the C.H.L. If the C.H.L. station was plotting, then the C.H. station supplied only ancillary information on the same track, such as raid strengths and height, for transmission through the C.H.L. station to the Filter Room. C.H. station plots were only passed on aircraft not within C.H.L. or C.H.E.L. cover. Beyond P.P.I. range, plots were passed to a Filter Room plotter on the sea side of the table, on a line available either to the C.H. or C.H.L. station by throwing a switch. The C.H. station Supervisor was able to act as a co-ordinator of all information, and thus much of the filtering could be done at stations. This Combined Directional Plotting Method cut down the clutter on the Filter Room table and plotters were enabled to plot more easily, as their plaques were always within reach. This method was tested in January 1943 with the Branscombe-Beer Head teams, proving most successful. It was then adopted by Bawdsey, and by May 1943 the No. 11 Group area was covered entirely by C.D.P. units ; by the end of the year the method was in operation along the whole of the South and South-East coasts of England.

Restricted Plotting Area

The Combined Directional Plotting pre-filtered information dispensed with the need for having multiple information on each track. In June 1943 a system of Restricted Plotting Areas was introduced.[2] The Filter Table was divided into small areas (about ten to each table) and each C.D.P. unit was allotted up to about four of these areas. The boundaries were chosen so that each C.D.P. unit reported in the area of its best coverage, and generally not more than three units reported in each area. This allowed for concentrated plotting on tracks within the boundaries, but prevented confusion from long-range plots passed by stations outside the areas, and resulted in an appreciable improvement in the interpretation of R.D.F. information by the Filter Room.

Change in Nomenclature—" Radar "

In order to avoid differences in terminology between the Allies, the name "Radar" (Radio Detection and Ranging) used in the United States of America for radiolocation, was officially adopted instead of "R.D.F." in September 1943.

Radar Preparations Made for Anticipated Attacks by Enemy Long-Range Rockets

Early in 1943 Intelligence reports revealed that the enemy was working on new weapons, believed to be long-range rockets, and preparations were accordingly made so that the Home Chain would be equipped to meet this

[1] No. 60 Group File 60G/51/19/5 Ops.   [2] Headquarters, Fighter Command O.R.B.

menace immediately it came into use. An Inter-Departmental Committee was set up in June 1943, under the chairmanship of Sir Robert Watson Watt, to discuss the possibility of the enemy using rockets to attack this country, and to make recommendations from the radar aspect.[1] In a report dated 12 June 1943 the Committee stated that as the firing points would probably be numerous it was most important that associated range and bearing data on each target should be obtained from individual radar stations. It was thought that this could be obtained, with a probable increase in maximum range for observation and with a subsequent improvement in immunity from jamming, by the installation at selected C.H. stations of an equipment developed at the Telecommunications Research Establishment in 1941 and known as Cathode Ray Direction Finding (C.R.D.F.). The equipment had been used experimentally at Dunkirk in 1942, when it was thought that it might be installed as a reserve equipment in the event of C.H. operations becoming impossible through German jamming, but had never come into general use on the Chain. The Committee felt that it could be of value in obtaining the special information required in rocket data, as it displayed instantaneously, visibly, and in a form suitable for continuous or intermittent automatic photography, range and bearing information for all targets within an angular sector of about 120° in front of the C.H. station.

The Committee therefore recommended that a prototype C.R.D.F. set held at the Telecommunications Research Establishment (T.R.E.) should be installed immediately at the C.H. station at Rye, linked to the Mark III aerial array, and that a second set also at T.R.E. should be sent to Pevensey. Improved models were to be developed and later installed at Poling, Ventnor and Swingate, and to supersede the equipments at Rye and Pevensey. It was further recommended that a second cathode ray tube should be incorporated to give a direct elevation display. Other recommendations from the Committee were the development of photographic recorders, the provision of extra telephone facilities, and the development and production of special recorders to give a range/time display. Instructions were also drawn up for radar operators in the area where bombardment was expected; it was anticipated that London would be the main target, with possibly subsidiary attacks on Portsmouth or Southampton. Two members of the Committee, Mr. A. F. Wilkins of the Operational Research Section at Headquarters, Fighter Command, and Wing Commander Jennings, Operations Officer at Headquarters, No. 60 Group, were detailed to visit all C.H. stations from Swingate to Ventnor (later the area was extended westwards to Branscombe) to initiate immediate discussions of the problem with the technical and operational personnel of the stations.

The "Bodyline" Watch

Although production and installation of the C.R.D.F. equipment was put in hand at once, it was apparent that it could not be operational for some months. It was felt, however, that the enemy might attack before that time, so that some form of special watch from the radar stations should be instituted immediately until such time as the C.R.D.F. equipment was installed. It was decided, therefore, to maintain a special lookout on the normal equipment at the C.H. stations, and this became known as the "Bodyline Watch." The strictest secrecy was maintained at all times; all radar personnel concerned

[1] Air Ministry File, C.M.S. 99/I, Encl. 2A.

at the stations had to sign a certificate of secrecy, and they were screened from posting away from their stations. The normal R.F.8 standby receivers at the C.H. stations were used. Besides the usual C.H. station crew two additional personnel were required, one to man the cathode ray tube and the other to read the range drum. A paper strip was placed over the range scale of the tube, to be marked with a vertical line coincident with the spot should an echo appear. Very accurate range and bearing records were required, and in order that times should be correct, a new system of synchronised time signals were issued from No. 11 Group Filter Room, and each station was issued with two stop-watches.[1] Very close and accurate observation was required of the " Bodyline " crew, as any response seen would necessarily be of very brief duration.

All C.H. stations from Swingate to Branscombe were maintaining a continuous " Bodyline " watch by 31 July 1943. It was then decided to extend the watch to C.H.L. stations in the same area ; although their information was not likely to be as valuable as that anticipated from the C.H. stations, it was yet felt that no chance should be missed of getting all available data. Accordingly the C.H.L. stations were all maintaining the " Bodyline " watch by the beginning of September 1943. At the same time T.R.E. had undertaken to man a suitably equipped trainer for C.R.D.F. and this equipment, followed in September 1943 by a second similar outfit, made a tour of all the relevant stations giving practice to all operators in operational technique. Lectures and discussions were given by the officer-in-charge, and comment and criticism freely invited from the crews. On 8 September 1943 the Assistant Chief of Air Staff (Operations) issued an instruction to the effect that the " Bodyline " watch might be suspended only in the case of (*a*) the period during which a station was receiving training instruction, providing only one station at a time was being trained, and (*b*) during the installation in the Operations Room of the C.R.D.F. equipment.[2] The normal reporting functions of the stations were, of course, unaffected by this order.

C.R.D.F. Equipment

The standby R.F.8 receiver was modified so that two cathode ray tubes appeared in front of the operator and two control knobs. One tube displayed a normal range-time base, with the exception that echoes appeared both above and below the trace.[3] A bright spot appeared on this trace, controlled by the strobe knob, and by its use the appropriate echo could be indicated or strobed. On the second tube a " cursor " line was displayed along a diameter which could be rotated about the centre by means of the azimuth knob. This bearing tube also displayed the signal as a line so that the direction from which the signal was received could be read from a circular scale. When the strobe knob was turned so that an echo on the range tube was brightened a line of light appeared on the azimuth tube, the operator rotated the bearing knob until the cursor line lay in the same direction and the bearing was then read from the position where the bearing scale was cut by the cursor line. With practice, it was possible for the operator to obtain good D/F readings very quickly by this method. The speed of R.D.F. plotting by C.R.D.F. was much higher than that by the standard Home Chain equipment.

[1] Air Ministry File C.M.S. 99/1, Encl. 111A. [2] *Ibid.*, Encl. 100A.
[3] Air Ministry File C.S. 8688, Encl. 10A.

The prototype C.R.D.F. equipment from T.R.E. was installed at Rye in July 1943 and at first was manned only by a special watch. Installation at Swingate and Ventnor followed in September, and the new model at Rye, together with equipments at Poling and Pevensey, followed in October.[1] By 6 December the five stations had been calibrated and were fully operational, and by the end of the month the westward portion of the C.R.D.F. chain—Southbourne, Ringstead and Branscombe was operational too. The Remote Reserve station at St. Lawrence and the I.C.H. station at Dymchurch were found to be unsuitable for C.R.D.F., but they maintained a continuous watch for rocket incidents on the tracker tube of their normal set.[2]

An additional measure adopted to help in the accurate location of firing points was a special electrical high-speed tracker, with a photographic attachment which automatically recorded photographs of the trace on a continuous film. A record was made of range, rate of change of range and time bearing data. Authority was given in July 1943 for installation of this unit—Display Unit, Type 53, or "Oswald," as it was known—at Rye, Pevensey, Swingate, Poling, Ventnor, Southbourne, Ringstead and Branscombe.[3] The equipment was installed at Rye in August 1943, at Swingate on 28 August, at the remainder of the eastern C.R.D.F. chain later in the year.[4] Ringstead, Southbourne and Branscombe were not equipped until early in 1944. Completed film and all available information was to be sent to Operational Research Section at Headquarters, Fighter Command, where a special Computation Unit had been set up to correlate all information received on long-range rockets. At the end of December 1943, four supernumerary technical officers were posted to each "Bodyline" C.H. station, with a primary responsibility towards the maintenance of the photographic equipment and correlation of data obtained from the films.[5] A switchable camera was also fitted to the C.R.D.F. receiver itself, and this was referred to as "Willie." This recorded azimuth, range and time data and had a high rate of film consumption, "Oswald" recording at a much slower rate. The respective rates were 12½ feet per minute and 1·2 inches per minute. In order to economise in film, only "Oswald" operated continuously, "Willie" being brought into operation only upon detection of suspicious signals.[6]

Duties of C.R.D.F. Crews

The members of the crew on a C.R.D.F. station equipped with "Oswald" were four, assisted in the event of incident by the members of the normal reporting watch. The four special crew members were :—[7]

(*a*) Range Strobe Operator,

(*b*) Range Drum Reader and Recorder,

(*c*) Azimuth Cursor Operator,

(*d*) Display Unit Type 53 Operator,

and their duties, briefly, were as follows :—

Range Strobe Operator.—Strobed all new echoes in excess of 30 miles and in the event of an echo exhibiting "Bodyline" characteristics he made the C.R.D.F. camera switch and shouted "Bodyline." He held the strobe to the left hand of the echo, announced ranges and fades, and if the rocket had a "tail," announced and strobed it.

[1] No. 75 Wing, O.R.B.
[2] Air Ministry File C.M.S. 99/2, Encl. 29B.
[3] Air Ministry File C.M.S. 99/1, Encls. 85A, 118A.
[4] Air Ministry File C.M.S. 99/2, Encl. 29B.
[5] *Ibid.*, Encl. 20A.
[6] Air Ministry File C.M.S. 636.
[7] Air Ministry File C.M.S. 99/1, Encl. 150A.

The Azimuth Observer.—Resolved all azimuths presented by the Range Strobe Operator by means of the cursor and in the event of incident called all bearings on it and on all subsequent announcements by the Range Strobe Operator.

The Range Drum and Recorder.—On each announcement of a "Bodyline tail," "range" or "fade," observed and recorded the figures shown on the range drum.

Operator on "Oswald."—Sat observing the high speed tracker tube and on witnessing a characteristic echo shouted "Bodyline" and pressed the camera switch which started the C.R.D.F. photographic recorder.

In the event of incident, the following normal crew members assisted as follows :—

C.H.L. Monitor.—Recorded the time sequence of an incident on the stop-watch.

C.H.L. Liaison Teller.—Was ready to provide a sequence of stop-watches and paper masks for the C.H.L. monitor and advised the C.H.L. that an incident was running.

C.H. Plotter.—Recorded the time of the incident to the nearest minute, recorded maximum signal/noise ratio and maintained accurate record of the sequence of events.

Long Range Teller.—When the Range Strobe or Type 53 Operator called "Bodyline" he warned the Filter Room by saying "Bodyline at . . ." and was additionally responsible for checking the stop-watches against Filter Room time signals.

Duties of the Recorder.—He was responsible for reloading the C.R.D.F. camera after every incident or otherwise as necessary.

Use of Stations, Type 12

In addition to "Bodyline" cover provided by the C.H. and C.H.L. stations, provision was made for mobile stations to be used for similar duties in the event of the C.H. stations being rendered non-operational through enemy jamming.[1] These stations, known as Type 12, were originally devised to use a beam technique, but were specially modified to "floodlight" use. Installation of the Type 12 stations was completed at Ramsgate, Hythe, Highdown Hill, Bexhill and Whitehawk in October 1943.[2] Crews were to be drawn from the neighbouring C.H.L. stations in case of necessity ; all such equipments were not continuously manned. They were maintained instead on a "Care and Maintenance" basis, but were able to be brought into immediate use should enemy jamming render this necessary, on the authority only of the Air Officer Commanding-in-Chief, Fighter Command.

All these preparations were made solely on the basis of intelligence information. There was no precise knowledge on which to build up new radar defences. Everything had been done which could reasonably be expected from intelligent foresight to prepare the Home Chain to meet this anticipated new form of bombardment, if and when it should occur.

[1] Air Ministry File C.M.S. 99/1, Encl. 130B. [2] *Ibid.*, Encl. 150A.

CHAPTER 17

R.D.F. RAID REPORTING IN THE LANDINGS IN NORTH-WEST AFRICA (OPERATION "TORCH")

After the French Government capitulated in July 1940 and the Axis sphere of influence extended in the central and western Mediterranean with the advent of Italy into the War, there were many strategical advantages to be gained by a military operation against French Morocco on the south-western Mediterranean sea-board. The western end of the Mediterranean was the key-point in the British blockade, and the strategic importance of the French North African Colonies in support of the blockade was not lost upon the British Government. In addition, the Chiefs of Staff feared a German advance southward into Spain and there was little prospect of serious Spanish resistance being forthcoming. Above all, there was the incentive of the moral victory which would be won if the French in North Africa could be roused to continue the struggle against the Axis.

With the fear of invasion threatening the United Kingdom and the acute shortage of war materials even at home, it was hardly possible at that time to launch a campaign of the magnitude required for a North African venture unless there was a guarantee of French support. Efforts were therefore made to rouse the French by offering considerable assistance should they decide to re-enter the War. These attempts, initiated in December 1940 by Mr. Churchill, were continued throughout 1941 whenever there were forces to spare or the political situation in Vichy France seemed to offer a chance of the French in North Africa attempting to escape from German domination. With the entry of the United States into the War, the policy of helping the French in North Africa to resume the struggle against the Axis was adopted at the Washington War Conference (December 1941–January 1942) as a combined Anglo-American operation.

Throughout 1942 various proposals for a "Second Front" were made. It was obvious to Chiefs of Staffs that the Allies could not launch a cross-Channel invasion that year, so the proposed help to the French in North Africa, which had been abandoned in March 1942, was revived. This time, however, the Allies were not merely desirous of assisting the French ; they were determined that should the French not come over to their side, Morocco and Algeria would nevertheless be occupied. The Allied forces were then to seize Tunisia as expeditiously as possible. In addition to these basic aims, it was intended to establish a striking force in French Morocco that could ensure the control of the Strait of Gibraltar by moving, if necessary, into Spanish Morocco.

General Plans for Operation "Torch"

The Code Name "Torch" was given to this impending operation and the elements of the earlier plans were revived and revised.[1] There was a considerable period of negotiation between Allied Staffs before the places of assault were decided. Ultimately, on 31 August 1942, after several plans had been drawn up, Oran, Algiers and Casablanca were selected—D-day for the invasion of North Africa being fixed for 8 November 1942. Fresh plans and

[1] Prior to March 1942 planning for an operation against North Africa had been known successively as Operations "Cackle," "Gymnast" and "Super-Gymnast."

instructions had therefore to be compiled and forces embarked in a time-limit of just over two months, a stupendous task for the first large-scale amphibious landing involving British troops to be carried out since Gallipoli in 1915.

After such events as the British occupations of Syria and Madagascar, and the naval actions against the French Fleet at Oran and Mers-El-Kebir, it was thought that the French were more likely to co-operate in North Africa if Operation " Torch " had, externally, an American complexion. It was therefore decided that Oran should be attacked by American Army forces with British naval and Air Force units. Algiers was to be assaulted initially by Americans, to be followed up within the hour by a British force supported by British naval and air units. Casablanca was a wholly American undertaking.

Responsibilities of the Allied Air Forces

The air cover so essential for such an operation was to be divided between the American and British Air Forces. Both forces were given separate rôles and zones of responsibility.[1] The 12th United States Army Air Force, known as the Western Air Command, in an area bounded by the Atlantic coast of Morocco and a line north and south through Cap Tenes in Algeria, was to be responsible after the initial landings for assisting in the subjugation of the French forces if they offered resistance, and subsequently providing air support for the United States Army in the event of the occupation of Spanish Morocco becoming necessary. They were also to build up a force for a later move into Tunisia.

The rôle of the British Royal Air Force, which was called Eastern Air Command, was to—

(*a*) provide air cover and support for the initial assaults ;

(*b*) protect the bases and communications against air attack and, in conjunction with naval forces, against attacks by submarines and surface raiders ;

(*c*) disseminate propaganda by leaflet dropping ;

(*d*) provide air co-operation and support for land operations subsequent to the assault ;

(*e*) provide an offensive air striking force for strategic bombing ;

(*f*) provide protection for Allied shipping convoys.

The initial assaults on Oran and Algiers were to be covered by carrier-borne squadrons of the Fleet Air Arm and that on Casablanca by shipborne aircraft of the United States Navy. To fulfil the rôle allotted to the British Air Forces, shore-based ground units of the Royal Air Force had to be provided for many varying tasks, not the least of these being the ground search R.D.F. units for early warning and the control of fighter aircraft.[2]

The plans as to size and composition of the forces required for the operation were governed almost entirely by the limitations of available shipping. Personnel and material considered to be required for the operation were available in quantities far in excess of the amount of shipping that could be escorted by the Navy in each convoy. This reduction of shipping capacity necessitated drastic cuts being made in the material requirements, and consequently had a considerable effect on the scales of supply of R.D.F. equipments in the initial

[1] Air Ministry File C.26023/45, Report on Operation " Torch " by Sir William Welch, para. 25.
[2] *Ibid.*, Appendix " B."

stages of the operation. When the bids were made for shipping space they were so cut that only 50 per cent. of the necessary vehicles could be taken in the early convoys.

General Plans for Ground R.D.F. in Operation "Torch"

As it was not clear as to whether the assault would meet with resistance or not from the Vichy French military forces in North-west Africa, two plans were originally prepared, but it was finally decided that the plan must be adopted which assumed full opposition by the French. Thus the system of loading based on this assumption had to be carefully worked out and a somewhat slow build-up in the theatre of operations became inevitable.

At the time Operation "Torch" was planned it was still assumed that the only way in which R.D.F. could be used satisfactorily was to group a number of dispersed R.D.F. stations round a central Operations Room, to which they might report, and to repeat this system at various intervals throughout the territory to be covered until they formed a chain basically similar in principle to that functioning in the United Kingdom. This system had proved a great success at home and in Libya, and, given time to become fully operational, might have proved invaluable at Singapore.

It is regrettable that the outstanding success of the improvised mobile C.O.L. stations used as Fighter Directors in the Western Desert by Headquarters, Middle East, could not have been exploited in this landing.[1] Instead of developing a mobile R.D.F. system along Fighter Direction lines which could move with advancing ground forces, and providing for a later build-up of raid reporting stations for the territory occupied when the military position had become stabilised, they continued to make provision for the formation of a static chain to extend the entire length of the Algerian coastline.

For the initial provision of R.D.F. cover to land with the assault forces on D-day, it was planned that Light Warning Sets were to be used. This new equipment had been developed at the Telecommunications Research Establishment (T.R.E.). There had long been a requirement for a portable R.D.F. warning set in the field. It will be recalled that such a need had been apparent in the Middle East in 1941, and that as a temporary expedient a number of pack-sets had been constructed using standard A.S.V. radio parts.[2] The chief drawback with this type of pack-set was its range, 15–20 miles on aircraft at 10,000 feet. Preliminary work had been embarked upon in January 1942, to produce an improved light warning set. The transmitter and aerials were developed at Metropolitan Vickers while T.R.E. had the responsibility for the development of a nine-inch Plan Position Indicator. Designs for the turning gear and aerials were largely taken over by T.R.E. The receiver was the orthodox equipment used in A.S.V. apparatus and the whole unit, working on a frequency of 176 megacycles per second, would pack into one 3-ton lorry and could be erected in a tent in a matter of an hour. The range of this equipment on aircraft at 10,000 feet was about 40 miles. Rough height-finding was possible by the comparison of signals from two Yagi aerials at different heights.

The Light Warning Sets to be available for Operation "Torch" were put together in Air Defence Research and Development Establishment workshops, as the contracts with Metro-Vickers had been delayed and production

[1] Chapter 12 of this volume describes this successful use of mobile C.O.L. stations.

[2] *See* Chapter 12 of this volume.

did not meet the dates demanded. A total of six hand-produced sets were demanded from A.D.R.D.E., some of which were to make their operational début in the North African Landings.

After the Light Warning Sets had landed in the D-day assault, the R.D.F. build-up was to begin with the arrival of C.O.L./G.C.I. mobile stations on D + 4, followed by a steady reinforcement of the territory gained by Allied ground forces of two similar equipments every fortnight.[1] This R.D.F. programme was worked out on the assumption that there would be a fairly slow Army advance due to resistance on the part of the Vichy forces.

Having decided on the general plan of the sequence of R.D.F. equipment to be used during the assault and build-up stages, the detailed plans for the American and British Zones were then evolved. These are described separately under their respective zones in the ensuing paragraphs.

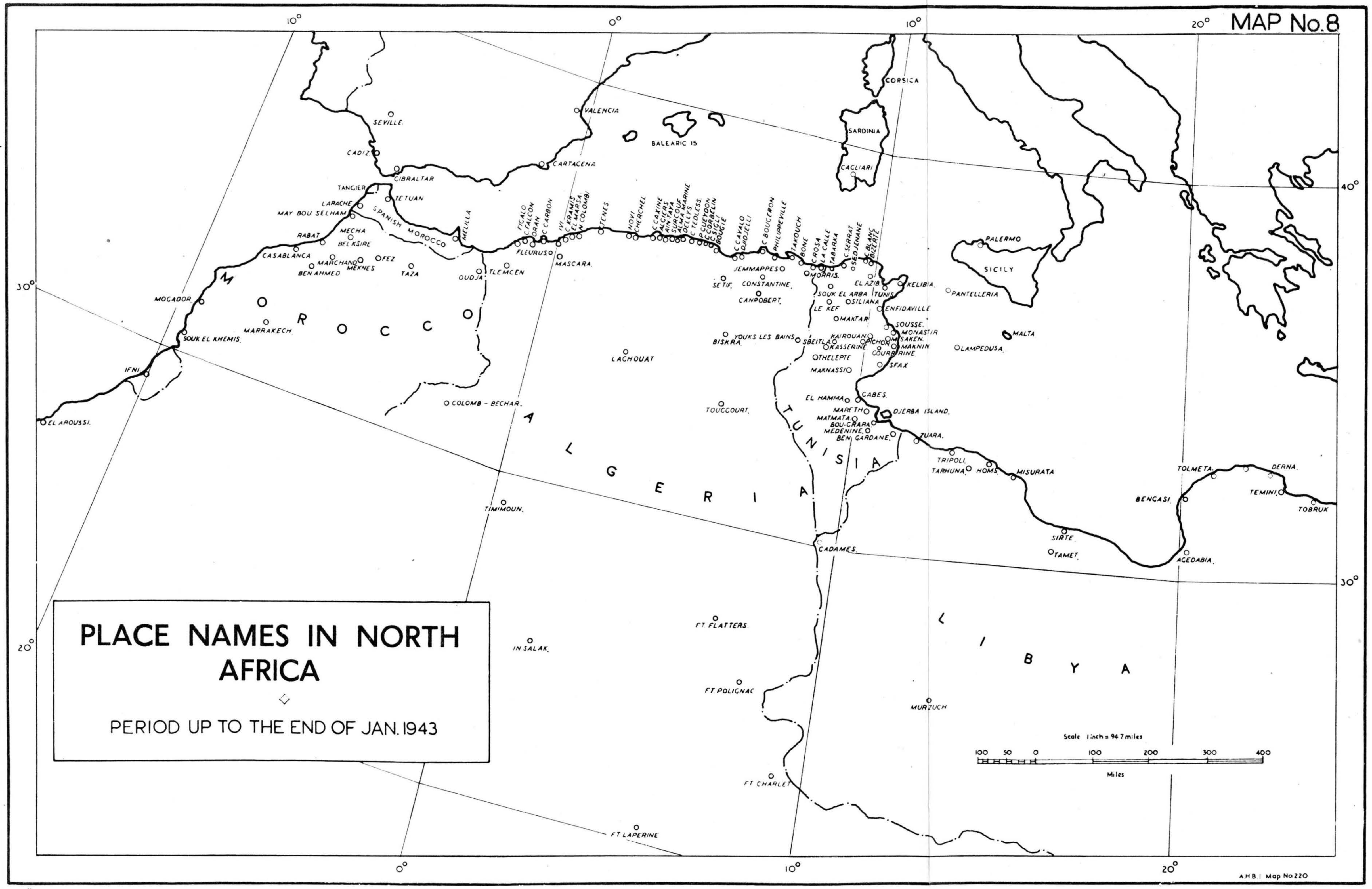
Detailed Ground R.D.F. Plans for the American Zone (Western Air Command)

Planning for the Western Task Force and the Western Naval Task Force, which were to make landings at Casablanca, was done in Washington, and American R.D.F. equipment and personnel were to be used.[2] The remaining planning was carried out in London. One Royal Air Force officer was attached to the American planning staff at Norfolk House, and with a small group of American officers prepared the R.D.F. plans for the Centre Task Force which was responsible for the area from the Spanish Moroccan Border to Cap Tenes.[3] The intention was to provide R.D.F. cover as early as possible in the operation and then to begin a steady build-up of a chain of ground R.D.F. stations.[4]

One Light Warning Station was to be despatched in the Assault Convoy in company with a Wireless Unit, which consisted of a multiple collection of listening-watch receivers and observer units. These were to be followed by four C.O.L./G.C.I. stations in the Follow-up Convoy three days later. On D + 14 a second Wireless Unit was to arrive, and on D + 28 two Mobile Radio Units, similar to those used in the Middle East campaigns, and two more Light Warning Sets were to complete the ground search R.D.F. facilities for Operation " Torch " in the American zone of responsibility. All the sites, except those for the Mobile Radio Units, were chosen by the planning Staff in London with the aid of contour maps and aerial photographs; the maps were rather old and unreliable. Tentative sites only were selected for the M.R.U.s as it was considered that there would be ample time to choose these at leisure as the sets were going in at a later date. The rest of the equipment was to be sited as follows :—

A.M.E.S. No. 890 to act as a C.O.L. Station at Cap Carbon.
A.M.E.S. No. 899 to act as a C.O.L. station at Cap Falcon.
A.M.E.S. No. 8000 to act as a C.O.L. station at Cap Ivi.
A.M.E.S. No. 8001 to act as a C.O.L. station at Cap D'Acra.
A.M.E.S. No. 675 Light Warning Set at Arzeu.
A.M.E.S. No. 6003 Light Warning Set at Cap Tenes.
A.M.E.S. No. 6004 Light Warning Set in reserve.

[1] No. 333 Group, O.R.B., Appendix " D," Signals Instruction.
[2] C.O.S. (43) 98 (0), 4 March 1943—War Cabinet Chiefs of Staff Committee, North Africa Operations, Lessons in Signals Communications, para. 2, sub-para. (g).
[3] Map No. 8 shows locations mentioned in this chapter.
[4] Narrator's interview with Wing Commander J. Swinney, Royal Air Force, R.D.F. Liaison Officer with U.S. Forces for Operation " Torch."


MAP No. 8
PLACE NAMES IN NORTH AFRICA
PERIOD UP TO THE END OF JAN. 1943
MOROCCO
SPANISH MOROCCO
ALGERIA
TUNISIA
LIBYA
SEVILLE
CADIZ
GIBRALTAR
TANGIER
TETUAN
LARACHE
MAY BOU SELHAM
RABAT
CASABLANCA
MECHA BELKSIRE
FEZ
MEKNES
TAZA
MARCHAND
BEN AHMED
MOGADOR
MARRAKECH
SOUK EL KHEMIS
IFNI
EL AROUSSI
MELILLA
OUDJA
TLEMCEN
ORAN
FLEURUS
MASCARA
TENES
VALENCIA
CARTAGENA
BALEARIC IS.
CORSICA
SARDINIA
CAGLIARI
BOUGIE
PHILIPPEVILLE
BONE
LA CALLE
TABARKA
JEMMAPPES
SETIF
CONSTANTINE
CANROBERT
SOUK EL ARBA
SILIANA
LE KEF
MAKTAR
TUNIS
KELIBIA
ENFIDAVILLE
SOUSSE
MONASTIR
KAIROUAN
SBEITLA
KASSERINE
THELEPTE
MAKNASSI
SFAX
GABES
EL HAMMA
MARETH
MATMATA
MEDENINE
BEN GARDANE
DJERBA ISLAND
ZUARA
TRIPOLI
TARHUNA
HOMS
MISURATA
YOUKS LES BAINS
BISKRA
LAGHOUAT
TOUGGOURT
COLOMB - BECHAR
TIMIMOUN
IN SALAK
FT FLATTERS
FT POLIGNAC
FT CHARLET
FT LAPERINE
CADAMES
MURZUCH
PALERMO
SICILY
PANTELLERIA
MALTA
LAMPEDUSA
SIRTE
TAMET
BENGASI
AGEDABIA
TOLMETA
DERNA
TEMINI
TOBRUK
Scale 1 inch = 94.7 miles
Miles
A.H.B.1. Map No 220

The possibility of the Germans entering Spain and establishing bases there had to be borne in mind and provision was made to extend the ground R.D.F. cover to the west with the extra Light Warning Set. If the Germans were to enter Spain early in the operation it would be necessary to divert a C.O.L. station to the west and sites had been chosen in preparation for such a contingency at Cap Milonia and Cap Tarsa.

Detailed Ground R.D.F. Plans in the British Zone (Eastern Air Command)

The most important immediate objective in the assault on Algeria was the airfield at Maison Blanche, four miles south-east of Algiers. A landing was to be made on Surcouf beach. The aim of the forces landed there was to occupy the major airfield of Maison Blanche before dawn on D-day, 8 November 1942, and the two smaller airfields at Sidi Feruch and Blida, so that fighter aircraft could be flown in from Gibraltar at the earliest possible moment.[1] All Royal Air Force assault personnel were to be landed at " Charlie " beach, Surcouf, although several other landings were to be made. Two light mobile R.D.F. sets were to go in with the assault—later R.D.F. supplies would provide the setting up of a coastal chain similar to that operating in Libya.[2]

The Royal Air Force Commander and his staff were to be carried in H.M.S. *Bulolo*, the headquarters ship from which all operations were to be directed. Royal Air Force Signals section was to be a permanent part of the ship's company and was to be in contact with a small advance section of Headquarters, Eastern Air Command, in operation at Gibraltar, which in turn was to be in communication with the United Kingdom during the early stages of the campaign.

A Royal Air Force advance party, consisting of Nos. 322 and 323 Wings together with two Servicing Commandos, two A.A. Flights, four Signals Sections and two Light Warning R.D.F. Sets, were to travel with the Assault Convoy.[3] These units were to be disembarked from the transport ships in which they travelled into landing craft, and then were to follow the assault troops over the beach. Their rôle was to assist five fighter squadrons to operate from Maison Blanche airfield until the arrival of full Wing Operations facilities.

The immediate aim of the Royal Air Force Signals section in the assault was to provide facilities for the control of the aircraft in the Algiers area. To assist in this endeavour the two R.D.F. Light Warning Sets were to broadcast plots by W/T for reception at the airfield and elsewhere as required. A.M.E.S.s Nos. 6000 and 6001 were to take part in the landing.[4] The crews of each unit were to travel separately, that of A.M.E.S. No. 6000 in a United States personnel ship and that of A.M.E.S. No. 6001 in a British personnel ship. The drivers and two vehicles were to travel separately in two British motor transport ships. On landing, the personnel of A.M.E.S. No. 6000 in company with the other parties were to report to the embarkation staff, who in turn were to form units in as large groups as possible and order them to move to Maison Blanche. The exception to this was A.M.E.S. No. 6001, who were to report to the Advanced Headquarters and go into operation in that area as rapidly as possible. In general, it was decided that it was impossible to issue precise

[1] Air Ministry File C.26023/45, para. 54 of report. [2] *Ibid.*, Appendix " B."
[3] No. 333 Group, O.R.B., Appendices, Joint Operation Order for the Assault.
[4] *Ibid.*, Appendix " D."

orders for such an operation, the success of which must depend upon the individual unit officers acting with energy and initiative. Unfortunately there was no accommodation for an R.D.F. officer on the assault craft. Technical N.C.O.s were to be in charge of the Light Warning Sets.

The first units to commence operations were to be No. 2 Force Headquarters and A.M.E.S. No. 6000. These two units were to proceed sufficiently far inland to be clear of the beach and while the Force Headquarters opened W/T and V.H.F. R/T with the Headquarters Ship *Bulolo* on pack sets and Gibraltar on a T1190 transmitter, the Light Warning Set was to start operating and passing plots on enemy or friendly aircraft activity as soon as possible. When the road to Maison Blanche was reported clear by the Army, the two Advanced Landing Ground Sections and A.M.E.S. No. 6001 were to proceed to the airfield. A temporary Operations Room was to be established on arrival and A.M.E.S. No. 6001 was to become operational just adjacent to it, passing in R.D.F. plots on aerial activity by telephone to be provided from the land-line equipment carried by the Advanced Landing Ground Signals Unit, and also by W/T.

R.D.F. Build-up in British Zone up to D + 28—Plans

The first follow-up convoy was planned to arrive at Algiers on D+4. The R.D.F. equipment was to be increased by the following sets :—

A.M.E.S. No. 892 (G.C.I.).
A.M.E.S. No. 893 (G.C.I.).
A.M.E.S. No. 6002 (L.W.S.).

Also planned to be included in the signals facilities on this convoy was a Wireless Unit and a Wireless Observer Unit. These were to supplement the raid reporting organisation by passing plots to a central Operations Room where they would be co-ordinated with the R.D.F. plots. The Wireless Unit obtained its information through listening to enemy W/T and R/T transmissions, and the Wireless Observer Unit by visual methods similar to the Royal Observer Corps in the United Kingdom. By D+4 it was considered, too, that sufficient signals equipment would have been landed to warrant some form of servicing organisation—No. 301 Mobile Signals Servicing Unit was therefore formed to deal with minor repairs and emergency assistance beyond the capacity of the R.D.F. unit mechanics.

The instructions for the deployment of the R.D.F. reinforcements were in general terms. A.M.E.S. No. 892 and W.O.U. No. 87 were to report to the Chief Signals Officer on landing and he was to dispose of them in such a way that the best possible air raid warning system was provided for Algiers. He was then to arrange for A.M.E.S.s Nos. 893 and 6002 to proceed eastwards to provide R.D.F. cover for the advanced ground forces.

The second follow-up convoy was to arrive on D+14. The R.D.F. supply was to be supplemented by two more G.C.I. stations and two Light Warning Sets :—

A.M.E.S. No. 895 (G.C.I.).
A.M.E.S. No. 894 (G.C.I.).
A.M.E.S. No. 6004 (L.W.S.).
A.M.E.S. No. 6006 (L.W.S.).

A further W.O.U., No. 88, and a second M.S.S.U., No. 303, were to accompany this convoy.

The third and final convoy was due to arrive on D+28 and was to bring a further three G.C.I. stations and two Light Warning Sets :—

A.M.E.S. No. 896 (G.C.I.).
A.M.E.S. No. 897 (G.C.I.).
A.M.E.S. No. 898 (G.C.I.).
A.M.E.S. No. 6007 (L.W.S.).
A.M.E.S. No. 6008 (L.W.S.).

Two more M.S.S.U.s, Nos. 302 and 304, making four in all, and a second Wireless Unit, were scheduled to sail with this convoy. Arrangements for the disposal of R.D.F. equipment brought by follow-up convoys were to be made by the Chief Signals Officer to meet the needs of the prevailing situation.

The remaining ground search R.D.F. units were to arrive in Algerian and Tunisian ports by successive follow-up convoys at fortnightly intervals and were to be disposed of in accordance with the military situation obtaining at the time.[1] In the main, this equipment was to consist of G.C.I. stations and Mobile Radio Units, which were to be used to strengthen the R.D.F. coastal chain and extend it to the east. The supply of M.R.U.s was left to a later date as they were cumbersome to move and more appropriate to static and defensive warfare than to front-line movement.

Training of Ground R.D.F. Crews for the Invasion of North-West Africa

The crews for the three Light Warning Sets designed to go in with the assault troops on D-day were picked from the Home Chain R.D.F. stations and sent to the Combined Operations training centre, H.M.S. *Dundonald* in Western Scotland, for Commando training.[2] The crew of each set numbered twelve men with a senior technical N.C.O. in charge : the unit to be completely self-contained with its own R.D.F. and W/T operators, cook and motor transport driver. While at H.M.S. *Dundonald* the men were toughened up by means of physical training, daily Commando assault courses and hard living under field conditions. To complete their technical training as a team of skilled tradesmen it was intended that the Light Warning Sets to be used in Operation " Torch " should be sent up to H.M.S. *Dundonald* as soon as they came off production. This would have given the crews a chance to become fully acquainted with the new equipment before embarking on the invasion. Unfortunately these sets were not ready in time to be sent to the training camp and the first sight their crews had of this new and unfamiliar equipment was at West Kirby Personnel Despatch Centre. Here they were allowed three or four days only in which to practise setting up and taking down the gear. Owing to the rigid nature of the shipping time-table it was impossible to delay the despatch of the equipment in the convoys and therefore no extension of this far too brief technical training period could be allowed.

The training of the C.O.L./G.C.I. crews on the other hand was handled with much greater efficiency. It had been instituted by Headquarters, No. 60 Group, and was carried out at No. 21 Signals Training Unit, Renscombe Down, Swanage. The crews were given a training programme covering practice in assembling and dismantling the technical gear, driving heavy lorries, route

[1] *See* List of the units concerned in Appendix No. 23.
[2] Narrator's interview with Wing Commander Humphreys-Owen, R.D.F. Officer, Eastern Air Command.

marches, lectures and medical instruction. On completion of training at Renscombe Down the units were dispersed to R.D.F. stations in the South of England where they continued their training under operational conditions, living in the field in the neighbourhood of the Home Chain stations. Operators and mechanics often shared watches with the station personnel and in most cases this worked out extremely well. The major complaint was the cancellation of all leave during training, as the time spent at the Personnel Despatch Centre at West Kirby allowed for a maximum of only three days embarkation leave.

On the whole, this training system for the G.C.I. crews gave excellent results; the men were keen and experienced and formed united teams. Good as the training was, however, these crews were trained in raid reporting and control functions purely for defensive operations, and at no time was any suggestion made that the units could or would be used for R.D.F. operations involving Royal Air Force tactical close support to the Army.

Embarkation and Voyage

Between 11 September 1942 and the end of that month, the R.D.F. units for the assault and build-up stages of Operation "Torch" for the Eastern and Centre Task Force were phased into the North-West Personnel Despatch Centres near Liverpool and Glasgow; their technical equipment, fully packed and crated, being despatched separately with unit M.T. vehicles direct to the ports of embarkation.[1] The training period, short though it had been, was at an end. The personnel were embarked at various dates during October on shipping convoys from British ports, the assault forces sailing on 26 October 1942. Then followed the journey to the North African coast, a distance of approximately 1,500 miles, subject to U-boat attacks. The vessels on which the Assault R.D.F. units were shipped completed their slow convoy voyage safely, re-fuelling at Gibraltar, and arrived off their appropriate North African beaches before dawn on 8 November 1942, to await the beginning of the assault.

The Landings in the American Zones of Responsibility

The Western Task Force was to make landings at Casablanca, the Centre Task Force at Oran and Arzeu. The bulk of the American R.D.F. equipment in the assault convoy for the all-American Western Task Force was sunk during the journey from the United States. The American Signals Aircraft Warning Battalion of the mixed British–American Centre Task Force arrived without its equipment.[2] The assault convoy containing Royal Air Force R.D.F. equipment, however, arrived off Arzeu, East of Oran, in the early hours of 8 November 1942.

Before dawn the assault troops started going in and met with only light opposition from the French, which they soon overcame. By the afternoon the first staff officers of the 12th United States Air Force and the Royal Air Force R.D.F. liaison officer went ashore. They were taken within 40 yards of the beaches by landing barges and then left to wade ashore up to their chests in water, presumably to give atmosphere to the proceedings as there was no opposition by this time.[3] Accompanying them were the crew of one C.O.L.

[1] Royal Air Force Station, White Waltham O.R.B., September/October 1942.

[2] C.O.S. (43) 98 (0), 4 March 1943—War Cabinet C.O.S. Committee, North Africa Operations, Lessons in Signals Communications, para. 21, sub-para. (*a*).

[3] Report on Operation "Torch"—"R.D.F. used in the Centre Task Force" by Wing Commander J. Swinney.

unit, one Light Warning Set, and one Wireless unit. By the following morning the personnel had been formed into collective units but the only R.D.F. equipment aboard the ship, the Light Warning Set No. 675, took two more days to bring ashore. Therefore as far as the assault phase was concerned, ground search R.D.F. played no part in the landing at Arzeu. Every effort was made to get A.M.E.S. No. 675 into operation, but several setbacks in the form of an acute lack of spares, the usual teething troubles with newly-designed equipment, and difficulties with power supplies caused considerable delay. The station did not become operational at its appointed site near Arzeu until D + 6, 14 November 1942.

R.D.F. During the Period Immediately Following the Assault

On D + 3 a convoy arrived carrying four G.C.I./C.O.L. stations. Priority had not been given to R.D.F. equipment in the loading of ships and irate R.D.F. unit personnel had to stand by and watch much luggage being unloaded before their technical equipment could be taken off the ships. A.M.E.S.s Nos. 890 and 899 were two of the units in the follow-up convoy. The crew of A.M.E.S. No. 890 had made a wet-shod landing on D-day and were several days getting their R.D.F. equipment unloaded from three separate ships. They moved as soon as possible to their assembly point and found that a road would have to be constructed to their site at Cap Carbon. Heavy rains which turned the ground into a bog added to their difficulties. The morale of the R.D.F. personnel was high however and keen competition arose between the men of this unit and those of A.M.E.S. No. 899, who had docked at Mers el Kebir on 12 November 1942, as to which unit would become operational first. A.M.E.S. No. 890 finally was operational on 18 November 1942, beating A.M.E.S. No. 899 by a day, the latter losing their aerial vehicle in the mountains, which delayed them.[1] The two remaining C.O.L. units in the follow-up convoy, A.M.E.S.s Nos. 8000 and 8001, had similar trouble in collecting their equipment but after much perseverance became operational on 21 and 24 November 1942, at Cap Ivi and Cap d'Acra.[2]

The Filter Room

The provision of Filter Room facilities had been an American responsibility. On setting up this reporting centre for the R.D.F. stations, they found they had not sufficient radio equipment to receive information from all the R.D.F. units, so it was necessary to use some of the equipment and personnel of one of the Wireless Units. A temporary Filter Room was set up in the French Observer Stations Centre at Oran. The filter map had been drawn in London on a piece of white oil-cloth and only had to be pinned on a table. The Plotters and Filter Officers, who were American, were rather slow at first through the lack of experience in the job, but they soon improved. By D + 12 the Filter Room was operating well with four C.O.L. stations, A.M.E.S.s Nos. 890, 899, 8000, and 8001, one Light Warning Set, A.M.E.S. No. 675, and approximately ten Wireless Observer Unit Posts telling into it. On D + 14 the first enemy aircraft was plotted over Oran. The stations' plotting was accurate and as all the equipment was beam type there was no need for filtering, each station's plots lying practically on top of one another.

[1] No. 899 A.M.E.S., O.R.B. [2] Nos. 8000 and 8001, O.R.B.

On D + 28 (6 December) two Mobile Radio Units and two additional Light Warning Sets were brought to Mers el Kebir. A.M.E.S. Nos. 285 and 286, Mobile Radio Units types similar to those used in the Middle East, took some considerable time to amass their equipment and repair the damages they had sustained during the long sea voyage. A.M.E.S. No. 285 finally became operational at the end of February 1943 at La Plage de la Bouliche, a sandy and well-drained site. A.M.E.S. No. 286 had trouble with bad weather, and flooding of their site delayed the erection of the equipment. They came into operation ahead of A.M.E.S. No. 285 on 16 January 1943 at El Marsa.[1]

A.M.E.S. No. 6003, a Light Warning Set, was attached to the 561st A.W. Signals Battalion, 12th Fighter Command, U.S. Army at La Senia airport. They found their equipment to be entirely different from that on which the unit had been trained. In the absence of secret documents, circuit diagrams or technical information of any kind, the erection and installation of the equipment presented a major problem. No wavemeter, an essential accessory with equipment fresh from production, was included but the equipment was put into operation with great difficulty for testing purposes.[2] Motor transport, and tents for sleeping accommodation were insufficient. In many small ways a lack of foresight was shown in the provision of non-technical equipment. Minor examples were the provision of nineteen inkwells for a unit totalling twelve personnel, five hundred duplicator stencils but no duplicator, and even the provision of Air Ministry Orders from 1918 to the current date lost some of its value in the absence of the relevant appendices. The unit moved to Cap Tenes, where the equipment had to be carried the last 150 feet to the site as the rocky nature of the ground precluded transport being driven over it. The personnel were billeted in a near-by lighthouse.

A.M.E.S. No. 6004, the Light Warning Set which had been in reserve, found itself in a sorry plight after landing at Mers el Kebir. No one could give it instructions where to go and no equipment could be found for it. Some days later when its crew were walking disconsolately through the docks they noticed a particularly ragged M.T. vehicle with the canvas torn and sides crushed in. This was A.M.E.S. No. 6004's equipment.[3] With great credit they became operational on 26 December 1942 at Cap Bacchus. Many breakdowns occurred, however, due to the set coming straight from production.

Trouble with the Technical Equipment

Considerable trouble was experienced with the technical components of the ground R.D.F. sets and it became increasingly apparent that a much more careful vetting of the equipment should have taken place before it was despatched in the convoys. The practice of having only one R.D.F. mechanic on the establishment of each unit led to chaotic conditions in the event of his becoming a casualty. Many of the mechanics had been used to relying on a Wing technical section during their previous experience on the Home Chain and consequently were inexperienced in servicing major faults. The lack of a first-rate R.D.F. mechanic on these isolated field units might mean a station becoming non-operational for far too long a period until the Mobile Signals Servicing Unit mechanics had been called in.

[1] Nos. 285 and 286 A.M.E.S., O.R.B. [2] No. 6003 A.M.E.S., O.R.B.
[3] No. 6004 A.M.E.S., O.R.B.

Motor Transport

The Light Warning Sets had one 15-cwt. motor vehicle only, which was quite inadequate to carry technical equipment, tents, domestic equipment and a crew of twelve. As these sets were primarily to be used for the assault phase they needed a high degree of mobility. Under the prevailing conditions in North Africa the personnel and equipment had to be moved alternately.

The C.O.L. stations fared better. They had ten prime movers but only one motor transport driver. This meant that M.T. maintenance could not be carried out efficiently and a total breakdown of any one vehicle caused delay to the entire convoy. Some of the lorries had been damaged in loading and unloading from the sea passage and many of the ancillary parts such as windshields, cabs, lamps, etc., were destroyed completely. Tow-bars for the trailers had been lost in transit,and some vehicles had been deck-loaded during shipment causing electrical leads to ignition systems and wiring to become unserviceable due to corrosion by sea water. Many of the vehicles were old before the operation began, one Wireless Unit Humber Utility Van had already covered 42,000 miles. They were consequently always coming to grief on the rough tracks and roads of the North-West African coast and were not adapted for transport in a tropical climate.

The Landing in Algiers in the British Zone

As originally planned, the airfield at Maison Blanche was occupied on D-day, 8 October 1942. This was mainly due to the fact that there was only temporary opposition from the French and no enemy air attacks on Algiers itself during that period. The assault operations proved a failure, however, as far as Royal Air Force Signals were concerned. The sea conditions at " Charlie " Beach at the time of the assault were a heavy swell and high rising wind, a combination of factors which precluded the landing of the equipment as planned.[1] Many landing craft were wrecked in attempts to beach them. Neither the point-to-point wireless stations nor the R.D.F. Light Warning stations could be landed. This resulted in a serious breakdown in communications and the provision of R.D.F. cover. No news was received of the progress of the operation subsequent to the initial landings until a small Army W/T hand-portable set was brought into operation. This made a link with the beach and the Command Ship H.M.S. *Bulolo*, which was lying off the main beaches to the West of Algiers and out of visual touch with "Charlie" Beach. Communications between Gibraltar and Algiers were conducted entirely through H.M.S. *Bulolo*, as was the early warning of enemy aircraft and fighter control, until these services were established ashore some days later. Officially, hostilities at Algiers ceased at mid-day on D-day and equipment from the assault vessels was brought into the harbour on D + 1, 9 September 1942.

The first of the Light Warning Sets to land, A.M.E.S. No. 6001, was left at the beach-head at Surcouf with the advanced Wing Headquarters while A.M.E.S. No. 6000 followed the Army advance to the airfield at Maison Blanche. Unfortunately they were of little use during this first phase of the landing due to the crew's complete lack of knowledge of their equipment and the slow and disorganised process of unloading the assault equipment. Not only were the packing cases difficult to find, and the case-openers packed inside them, but

[1] Air Ministry File C.26023/45, para. 58 of the report.

when located it was found that, due to the unsupervised packing of the equipment, the components were broken down to far too fine a degree. The aerial systems in particular were separated to the last screw. The crew, inexperienced and untrained on this equipment, found it an almost impossible task to piece their R.D.F. set together in order to get it operational. Consequently the Light Warning Sets which should have been ready to work within an hour of landing were not set up until the following day. This situation might have been alleviated if shipping space could have been found for one R.D.F. officer to accompany the sets during the assault.

Enemy Attacks on Ports and Shipping

On D + 1 no move was made owing to conferences on armistice conditions with the French. Enemy air attacks were made on Algiers and one ship was sunk off Cap Matifou. Twelve enemy aircraft were destroyed however by British fighter aircraft without the aid of any R.D.F. system, this proving to be the first and last time an attack was made on Algiers by day. On the following day information was received that the Axis had made an unopposed landing in Tunisia—small numbers of enemy troops had arrived at Aouina airfield on 9 November 1942, from Sicily. It therefore became all the more imperative to seize the airfields at Djidjelli and Bone to assist in a speedy occupation of Tunisia. After his attack on Algiers the enemy carried out bombing attacks on the ports of Bougie and Bone which were occupied on 11 and 12 November 1942 respectively. These air attacks for the most part were comparatively light, but there were further signs that the enemy was moving material and personnel into Bizerta and Tunis at a rapid rate, the Allied plan of anticipating the Axis in Tunisia thereby being placed in jeopardy.

Enemy air tactics during the early period underwent various changes. They began by attacks on the ports and shipping and then turned to the congested airfields, using *JU.88s* and fighter bomber aircraft in high and low-altitude attacks. Here again the lack of adequate R.D.F. cover was a serious deficiency in the defence system, and until a satisfactory warning system was established, standing aircraft patrols had to be maintained over the ports. Bone airfield in particular was subjected to frequent and heavy attacks while the port itself was raided intermittently. Some damage was sustained by the harbour and ships lying in it but it was never serious enough to prevent its use, vital to the build-up of the First British Army.

By 13 November 1942, the airfields at Algiers, Djidjelli, Blida and Bone were all occupied and squadrons quickly based on them to provide cover against enemy aircraft for convoys proceeding to and from the East, these convoys being the primary line of supply for Allied land forces. The same airfields provided the fighter defence of the ports in their vicinity. The operations of these squadrons were once more handicapped in the early stages by the absence of adequate warnings which only R.D.F. could give, and standing fighter aircraft patrols had to be kept over the convoys and ports, involving heavy flying hours for the limited number of aircraft.

R.D.F. During the Period Immediately Following the Assault

Once started, the advance to the East proved to be even more rapid than had been expected and by D + 9 the leading elements of the ground forces were less than 60 miles from Tunis, and Philippeville and Souk el Arba airfields had been added to Maison Blanche (Algiers), Blida, Djidjelli and Bone.

As a result, there was an acute shortage of all signals equipment. On D + 4 the main follow-up convoy had arrived. This should in theory have materially eased the situation. It was not, however, until 18 November 1942 (D + 10) that the first item of Signals equipment was collected from the ships nor was it until many days later that all the units were complete.[1]

One reason for this inordinate delay was the fact that all R.D.F. equipment had been stowed in the bottoms of ships and thus were the last of the cargo to be off-loaded. But the main cause of the trouble was the state of confusion resultant upon complete lack of organisation at the docks. Equipment was unloaded and then dispersed arbitrarily, not only over a large dock area, but also to various dumps all over Algiers. No attempt was made to ensure that vehicles bearing the same field unit's numbers should be sent to the same dispersal area, and no record was kept of the destination of individual vehicles, which were removed by the nearest man who could drive to whatever destination was favoured by the officer or N.C.O. supervising the unloading. The result was that the only practical way of concentrating a unit was to detail its personnel to wander about the docks and the better-known dispersal dumps, in the hope that from time to time they would come across their own equipment. It meant almost literally inspecting every packing case. No preferential treatment had been given to the highly-secret R.D.F. equipment, and it lay under a welter of barrack and domestic equipment, including mobile laundries and complete office furniture for the Headquarters staff.

Mobile R.D.F. Used in the Follow-up Stages

From 20 November 1942 onwards, the plan of deployment of R.D.F. stations agreed upon at Norfolk House ceased to be followed. This plan had been governed by the lack of shipping space available for R.D.F. in the early convoys and was based on a fairly gradual move forward of our forces eastward from Algiers. In actual fact the Army went straight forward into Tunisia and was only 16 miles from Tunis by the night of 24/25 November. Instead of a number of mobile R.D.F. sets being available to advance with the ground forces, there were only two L.W. Sets, and the promise of a steady but slow supply of C.O.L./G.C.I. stations arriving in fortnightly convoys, two at a time.

So short was the supply of the available equipment, that instead of it being sent to its planned positions to form a chain of stations along the North African coast, the plan was scrapped and the R.D.F. stations were sent wherever the need was greatest. Unfortunately this led to a high degree of chaos and confusion due to the inability of the operational and signals staff to agree on any one site. The R.D.F. stations consequently had a worrying time dashing up and down the countryside in response to contradictory signals. Here again the rigidity of shipping plans had to be adhered to and it was quite impossible to increase the flow of R.D.F. equipment to this theatre.

R.D.F. Units in Action

A.M.E.S. No. 893 arrived in Algiers on 13 November 1942. It took a week for the unit to collect its equipment and proceed en route to Bone.[2] But on 20 November 1942 the enemy made his first attack by night on Algiers. These attacks continued for five nights during the full moon, the maximum number

[1] Report on Operation "Torch" by Air Marshal Sir W. Welsh—(Air Ministry File C.26023) Appendix "B," Signals Instructions. [2] No. 893 A.M.E.S., O.R.B., 13 November 1942.

of aircraft used being about thirty. The R.D.F. warning system had not yet been developed and the only warning of approach of these raids was obtained from Naval R.D.F. on warships in the harbour. These attacks caused despondency amongst the civilian population.[1] A.M.E.S. No. 893, therefore, was turned back and on arrival at Algiers was ordered to proceed to Surcouf. The unit arrived here at 1600 hours on 23 November 1942, and with commendable efficiency and in the minimum of time, became operational at 2000 hours.

In order to carry out controlled interception satisfactorily it was necessary to have the R.D.F. not only on the ground in the form of the G.C.I. station but also in the aircraft, that was the A.I. (Air Interception) apparatus. Air Ministry had decided on security grounds that A.I. equipment was not to be fitted in aircraft flown into the North-West African theatre of war during the early stage of the campaign. This secret aircraft R.D.F. equipment was to come by ship and would consequently take some time to reach Algiers. Attempts to use both Hurricane and Beaufighter aircraft by night without ground control proved abortive, and when A.M.E.S. No. 893 finally became operational, attempts at "cat's eye interception" failed also.

Although these enemy attacks were delivered early in the operation, a Sector Gun Operations Room had already been set up near Maison Blanche. Complete control of the shore guns and fighter aircraft was effected from it except for the fact that there had been no G.C.I. control and the defence of Algiers had therefore to be left to the A.A. guns.[2] The damage caused during these raids to the harbour was negligible but General Eisenhower was concerned at the effect which might be produced on the civilian population. He therefore made urgent representations to the Chiefs of Staff to accelerate the provision of A.I. equipment. A rapid decision was made and a flight of Beaufighter aircraft fitted with A.I. was obtained from the Headquarters Middle East. When they arrived at Maison Blanche it was found that A.M.E.S. No. 893 still had no V.H.F. R/T control, but improvisations were made and on the night of 27/28 November 1942, a flight from No. 87 Squadron, in co-operation with A.M.E.S. No. 893, shot down five enemy aircraft. A greater number of enemy raiders had been anticipated by the Intelligence section, but after the first five leading enemy aircraft had been brought down the remaining enemy bombers evidently withdrew.

This successful operation showed that the German Air Force had not learnt its lesson from the night battle over Britain and its pilots continued to fly into the target at 15,000 feet in procession at five minute intervals. These tactics were perfect for G.C.I. interception. After this success the enemy did not renew his night attacks on Algiers for some weeks. Instead he turned his attention to ports further to the East. A.M.E.S. No. 893 remained at Surcouf for many months, as Maison Blanche was one of the main vulnerable points in the theatre. They made many successful interceptions but the *Luftwaffe* tactics changed and by the time they returned to the attack on Algiers they had adopted the low-flying approach to reduce the effectiveness of the R.D.F. cover.

The original tactics adopted by the enemy in his attacks on the ports were high and low-level bombing of ships at anchor in the bays. He had in the early days, as at Bougie, a measure of success but as it became possible to provide

[1] Air Ministry File C.26023, para. 133 of the report.
[2] *Ibid.*, paras. 135 and 136 of the report.

stronger fighter aircraft patrols, and as the R.D.F. and communications improved, he was forced to change his methods to torpedo-attack of ships in harbour and night attacks—neither of which was highly successful.[1]

The personnel and vehicles of A.M.E.S. No. 892 were disembarked at Algiers on 13 November 1942, but about this date a ship was sunk in Djidjelli harbour and A.M.E.S. No. 892 was ordered to re-embark without prior notice for Djidjelli on 17 November 1942.[2] With so little advance warning given, the minimum of equipment was put on a landing craft to be taken to the port by sea. Great hardships were suffered by the R.D.F. crew, and although most of the technical equipment arrived, none of the domestic articles were included, and indeed were never found. The unit became operational on the dock side to begin with, and suffered heavy bombing attacks which added to the considerable discomfort in which they already existed. Two nights later the unit moved to a second site, setting up as a C.O.L. station plotting to Djidjelli airfield, as suitable G.C.I. sites were practically impossible to find in this locality.

Four enemy aircraft were shot down on 28 November 1942 on the information given by A.M.E.S. No. 892 and several other successful interceptions were brought about later. It did not have such a success as A.M.E.S. No. 893, as Djidjelli airfield was only a small private flying field and could not accommodate fighter aircraft.[3] Once again the same mistake had been made of sending R.D.F. to a port without realising it only has a really useful function when used in close conjunction with fighter aircraft. Occasionally Beaufighter night-fighter aircraft would be flown from Maison Blanche to be controlled by Djidjelli but after the first week or so Djidjelli became of secondary import and it was considered more advisable to control aircraft from Maison Blanche. Later, day fighters based at Philippeville flew patrols over to Djidjelli and A.M.E.S. No. 892 remained on its site to become part of the final coastal chain.

The Light Warning Set A.M.E.S. No. 6002 which arrived with A.M.E.S. No. 892 and 893 was sent to a French airfield inland at Youks le Bains. It was of no actual use there and the airfield was not being attacked—its move was due rather to political representations at a high level. Meanwhile it was decided to resite the Light Warning Set A.M.E.S. No. 6000 on some high ground in the Bois du Boulogne area near Algiers—to give low cover. A.M.E.S. No. 6001 was taken from Surcouf where it had been encamped and was resited at Maison Blanche. A temporary Filter Room was set up in the maintenance buildings belonging to the French civilian airline, *Air France*, which lay adjacent to Maison Blanche airfield.

Start of the Ground Search R.D.F. Build-up for the Coastal Chain

By D + 14, R.D.F. equipment was coming in through the ports fairly steadily, although there were still considerable delays in assembling and moving it forward. A.M.E.S. No. 894 proceeded to Bone and was set up on good flat ground about 15 miles east of the town, becoming operational on 2 December 1943. To a large extent the story of A.M.E.S. No. 893 at Surcouf was repeated. Enemy night attacks on Bone had begun before the G.C.I. convoy arrived there, and despite the fact that most of the crew had only a little G.C.I. experience as the unit had been intended for use as a C.O.L. station, morale and keenness were very high. On the third night of operation, when night fighter aircraft were available for the first time, three enemy aircraft were

[1] Air Ministry File C.26023, paras. 127 and 129.
[2] No. 892 A.M.E.S., O.R.B.
[3] No. 893 A.M.E.S., O.R.B.

shot down.[1] The port of Bone remained a vital target for the *Luftwaffe* throughout the campaign as it was the nerve centre for supplies to the British First Army under General Anderson. Thus A.M.E.S. No. 894 always had plenty to do and the total claims of night fighter aircraft operating under its control from December 1942 to early summer 1943, were approximately seventy enemy aircraft, thirty-four being shot down in the first month of being operational.[2] The toll taken of enemy raiders proved so devastating that the German Air Force abandoned the attacks for some time and never renewed them in force.

A.M.E.S. No. 895 arrived at Algiers on 22 November 1942. There was some disagreement between R.D.F. technical officers and Operations staff officers as to whether it should be sited at Bone or Cap Takouch. Eventually it was agreed that it should remain near Philippeville and it became operational at Herbillon near Cap Takouch on 6 December 1942 as a C.O.L. station. Generally the siting of C.O.L. stations on this terrain proved to be far from easy. There were few roads and the site at Cap Takouch was a typical example of some of the difficulties which had to be overcome. The selected location lay in a lighthouse and although there was a sort of road to the foot of the lighthouse, the site lay a further hundred feet up. Six-wheeled lorries had to be half-dragged, half-driven over hard, rough rock that formed the approach to the lighthouse compound.

Of the two Light Warning Sets that accompanied A.M.E.S. Nos. 894 and 895, one could not find its equipment and the crew were therefore dispersed amongst other stations and the other was put near Cap Gros close to La Calle, about 60 miles east of Bone. This advance position was useful for early warning in conjunction with A.M.E.S. No. 894.

A.M.E.S. No. 896 was on its way to Philippeville, but soon after its arrival a state of emergency arose in Algiers necessitating a C.O.L. station to back up A.M.E.S. No. 893. A.M.E.S. No. 896 was therefore turned back and was finally sited on high ground slightly west of Algiers in the grounds of the observatory at Bouzereah, for a straightforward C.O.L. function, becoming operational on 29 December 1942.[3] The site was only fair, as the R.D.F. view was impeded by permanent echoes on the cathode ray tube for a radius of 10 to 20 miles from the station. The missing Light Warning equipment finally turned up and the station was set up on the highest site in the cork forest, west of Algiers, as an experiment for the resiting of A.M.E.S. No. 896.

At the end of December 1942 Bone was being heavily attacked by air. This port was in range of enemy fighter and fighter-bomber aircraft and it constituted the most forward port available to the Army, so was used to a maximum capacity. The R.D.F. coverage was poor at Bone owing to the configuration of the country, so A.M.E.S.s Nos. 897 and 898 which had arrived at Algiers in early December to supplement the R.D.F. early warning system were sent to Bone.[4] A.M.E.S. No. 897 became operational as a C.O.L. station at Cap Gros in order to extend the advance warning against Bone, and No. 898 set up as a reporting G.C.I. at Souk-el-Khemis on 2 January 1943, just east of Souk-el-Arba. These sites covered a group of makeshift advanced inland airfields, used for the support of the Army, which were being attacked by German fighter-bomber aircraft, necessitating standing fighter patrols being

[1] No. 894 A.M.E.S., O.R.B.
[2] Air Ministry File C.26023, para. 136 of the report.
[3] No. 896 A.M.E.S., O.R.B.
[4] Nos. 897 and 898 A.M.E.S., O.R.B.

kept throughout the hours of daylight. In planning the R.D.F. programme the main object had been to protect ports and shipping. Full appreciation had not been given to the fact that the stations could be used for protecting the airfields. Used in this way, they would give sufficient warning to Allied fighter aircraft to scramble, thereby eliminating the necessity for standing patrols. The Light Warning Set could have been usefully employed for this purpose, but at that time they were being used as gap-fillers for the C.O.L. and G.C.I. stations.

The End of the Initial Race for Tunisia

At the beginning of December 1942 the weather had broken and the period of heavy rains began. The narrow lowlands of the North African coast became a glutinous sea of mud. Thus rainy weather was the worst enemy of all at that time, making it increasingly difficult for the ground forces to advance or withdraw. The Axis forces in Tunisia had been steadily building up by reinforcements brought in across the Sicilian narrows and the enemy resistance became too strong. The British First Army, having advanced nearly 550 miles from Algiers to within 16 miles of Tunis, had to withdraw to a more easily defended position at Medjez el Bab because of the difficult supply problem and the stiffening enemy opposition. The immediate aim in the race for Tunisia had not been achieved and it was impossible to capture the whole of Tunisia by a single stroke.[1] The weather, by bogging down transport and airfields, frustrated Allied plans, and a battle for supplies of both sides began. The Axis forces had the easier supply route of some 100 miles only from Sicily compared with the arduous sea passage of the Allied supply routes, followed by either 500 miles of road or rail, or a sea journey along the North African coast.

Establishment of the North-West African Coastal Chain

The Allies could not hope to resume major operations in the north until the middle of March 1943 when the weather would have improved. Consolidation of the territory occupied included the improvement of the R.D.F. coverage and raid reporting organisation of the coastal chain of stations. By 21 December 1942 the R.D.F. position was as follows :—[2]

A.M.E.S. No. 890 was operational at Cap Carbon.
A.M.E.S. No. 892 was operational at Djidjelli.
A.M.E.S. No. 893 was operational at Surcouf.
A.M.E.S. No. 894 was operational at Bone.
A.M.E.S. No. 895 was operational at Herbillon, Cap Takouch.
A.M.E.S. No. 896 was operational at Algiers, supporting A.M.E.S. No. 893.
A.M.E.S. No. 897 was operational at Cap Gros, Bone.
A.M.E.S. No. 898 was operational at Souk-el-Khemis, Bone.
A.M.E.S. No. 899 was operational at Cap Falcon.
A.M.E.S. No. 8000 was operational at Cap Ivi.
A.M.E.S. No. 8001 was operational at Cap D'Acra.
A.M.E.S. No. 675 was operational at Arzeu.
A.M.E.S. No. 6000 was operational at Bois de Boulogne.
A.M.E.S. No. 6000 was operational at Algiers.
A.M.E.S. No. 6001 was operational at Maison Blanche.
A.M.E.S. No. 6002 was operational at Youks les Bains.

[1] Air Ministry File C.30435/46, Commander-in-Chief's Despatch on North African Campaign, pp. 16/17.
[2] Air Ministry File C.26023, R.D.F. Appendix to the summary of lessons learned in Operation " Torch." These locations are shown on Map No. 8.

From that date R.D.F. units started arriving from the United Kingdom in far greater numbers. They were soon piling up in the base areas, as they were intended for the provision of a chain of stations along the entire Tunisian coast. New G.C.I. stations with power-rotated aerial systems were brought to Algiers, and Mobile Radio Units, which had been sent later as their masts had to be broken down in detail, also began to arrive. Two of the ships in one convoy were torpedoed and some equipment was lost, the R.D.F. personnel fortunately suffering only one casualty.

All the units had great difficulty in amassing their equipment. The ship in which the technical equipment for A.M.E.S. No. 387 was being carried had been forced to return to the United Kingdom on account of bad weather. Several other units had minor parts missing and had to obtain them locally. A.M.E.S. No. 389, despite the fact that it had several vital pieces of equipment missing, claimed to be the first M.R.U. to become operational east of Algiers on 18 January 1943. The following are points of interest relating to the other Mobile Radio Units in this theatre :—

(*a*) The crew of A.M.E.S. No. 372 was embarked on the flagship S.S. *Strathallan*. Throughout the voyage a W/T watch from this unit's personnel was operated and was congratulated on its efficiency by the ship's officers. At 0230 hours on 21 December 1942 the ship was hit by a torpedo when approximately 68 miles out of Oran.[1] The unit was transferred to a destroyer and subsequently disembarked at Algiers on 23 December 1942, becoming operational on 19 January 1943 at Jemmapes near Bone. They were a highly complimented station subsequently, the peak of their success being a track picked up at 90 miles due south on 26 March 1943. This track was plotted across the station and out to a range of 234 miles, making a complete run of 318 miles. It was later verified as a friendly aircraft attacking the docks at Tunis and enemy concentrations at Cap Bon.

(*b*) *A.M.E.S. No.* 318 became operational a month after its disembarkation at a site name Lac des Oiseaux on 25 January 1943.[2] It was on level ground back from the sea on the edge of a 12 miles swamp, backed by mountains.

(*c*) The ship on which the crew of *A.M.E.S. No.* 392 were travelling was torpedoed on 21 December 1942. The unit was disembarked at Oran just before the ship blew up.[3] They re-embarked for Algiers on 23 December 1942 and were operational at Alma Marine, east of Algiers, by 29 January 1943.

(*d*) *A.M.E.S. No.* 388 was put as far east of Bone as possible and slightly inland in the hope of catching enemy aircraft reconnoitring Bone from Bizerta airfields.[4] An objection was made to the site by the Army as it lay next to an ammunition dump, but the objection was over-ruled and the station became operational on 4 February 1943.

(*e*) *A.M.E.S. No.* 387 had to wait six weeks for a further supply of technical equipment as its original load had returned to the United Kingdom and the station consequently did not become operational until the middle of March at Port Gueydon to give advance warning to Bone.[5]

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[1] No. 372 A.M.E.S., O.R.B. [2] No. 381 A.M.E.S., O.R.B. [3] No. 392 A.M.E.S., O.R.B. [4] No. 388 A.M.E.S., O.R.B. [5] No. 387 A.M.E.S., O.R.B.

(*f*) The crew of *A.M.E.S. No.* 226 were aboard H.M.T.P. 15 which was torpedoed on 21 December 1942.[1] The personnel were taken off by a destroyer and landed at Algiers on 23 December except for one corporal who was missing and whose body was later washed up at Djidjelli. On finding their technical equipment, it was discovered that most of the masts were missing. After considerable trouble they obtained spare parts from local sources, but so great was the delay that it was not until 1 April 1943 that the station ultimately became operational at Djidjelli.

Five mobile G.C.I. stations, A.M.E.S.s Nos. 8002–8006, were distributed between Philippeville and Bone, the idea being to site them as far up with the advanced front of the Army as possible.[2] A.M.E.S. No. 8002 did good work as a G.C.I. station at Cap Cavallo reporting in to A.M.E.S. No. 892 at Djidjelli as it had no Filter Room telephone line of its own. Its maximum range on enemy aircraft reached 183 miles. A.M.E.S. No. 8003 gave a creditable performance, located in a vineyard just outside Philippeville, helping to destroy six enemy aircraft in the first six days of being operational from 21 December to 27 December 1942. A.M.E.S. No. 8004 had a spectacular position on the summit of a marble mountain at Col de Bes Best.

A.M.E.S. Nos. 8005 and 8006 were diverted at the request of the American authorities to Tebessa and Biskra to give R.D.F. cover to two of their inland airfields on the edge of the desert. On 14 January 1943 A.M.E.S. No. 8000 was removed from its site at Cap Ivi and rushed to Cazes airfield preparatory to setting up as a G.C.I. for the protection of Casablanca. The setting up of A.M.E.S. No. 8000 at a point 6 miles east of Fedala coincided with the arrival of Mr. Winston Churchill and the President of the United States of America for the Casablanca Conference and the unit was subjected to the visits of numerous high-ranking and important officials.

The Americans had very little R.D.F. of their own and few trained personnel. Their supplies had been depleted considerably by the loss of ships in their assault convoy for the Western Task Force. The Type 270 was an example of the equipment they erected in the Oran and Casablanca areas. It was a heavy static set with two Cathode ray tubes indicating range and bearing only, and worked on a frequency of 106 megacycles per second. These sets had originally been used in Iceland. Experience gained in Operation "Torch" demonstrated the difficulty of preparing in the United States a seasoned and well-equipped air warning system ready for immediate deployment in a very distant theatre of war. The loss of equipment in transit and damage in shipment and landing necessitated considerable replacements and servicing as soon as the units reached dry land. Furthermore, replacement personnel arrived with a very limited amount of practical field experience, precluding their use in an active theatre. It was therefore suggested that the Casablanca area should be used as a location for a training school to be established, combined with an installation and maintenance reception centre.

By 30 January 1943 there were thirty-nine Allied ground search R.D.F. stations operating along more than 1,100 miles of North African coastline from the Casablanca area to Western Tunisia, excluding the relatively small

[1] No. 226 A.M.E.S., O.R.B.

[2] *See* Deployment of R.D.F. Stations, Appendix No. 24. Nos. 8000, 8002–8006 A.M.E.S. O.R.B.s, give these details.

portion of the Spanish-Moroccan sea-board.[1] In spite of all set-backs, the Coastal Chain had made good progress during the twelve weeks since Operation "Torch" had begun.

R.D.F. Lessons Learned in Operation "Torch"

The North-West African coastal R.D.F. chain could be regarded as reasonably adequate at the end of January 1943. Many valuable lessons had been learned by then of the application of R.D.F. to a campaign of this nature. Perhaps the strongest impression created from the R.D.F. and Signals aspect was that in any future similar operation the equipment and crews should sail together in the same vessel, and that as far as possible the equipment should not merely be transportable, but actually mobile, being fitted in a vehicle and adequately waterproofed.[2]

All R.D.F. equipment required skilled setting-up before it could be brought into operation. It was therefore a bad policy to issue untried equipment such as the new Light Warning Sets immediately prior to the voyage from the United Kingdom. The crews required experience on these sets before they could be regarded as adequately trained for such an operation. This situation might have been alleviated to some degree by the presence of an R.D.F. specialist officer, well versed in siting and technical supervision. On future occasions an R.D.F. officer should accompany each equipment in the assault stages and be with the station at all times while it is operational. The officer should be supplied with a light vehicle and it should be equipped with R/T equipment to enable the R.D.F. officer to keep in touch with all stations.[3]

Even had the Light Warning Sets worked immediately, their limitations made it imperative that sufficient long-range equipment of the G.C.I. type should be available at each assault area to cover vital focal points.[4] These would also require V.H.F. R/T ground-to-air facilities with them so that the night defence of the assault areas could be quickly organised in conjunction with A.I. equipped night fighter aircraft. As it was, in Operation "Torch," three Royal Navy ships were lost while attempting to provide this initial R.D.F. local cover.

The G.C.I. stations, though mobile, were very cumbersome, including trailers for aerial systems and power supplies. With the beginning of the rainy season in North West Africa the G.C.I./C.O.L. Units were practically immobilised by the mud. All vehicles should have been prime-movers so that rapid movement to new sites was always possible and never dependent on weather conditions.[5]

In the initial stages, the Army swept rapidly forward leaving a very large and important tract of country behind it; within a very few days of the first landings the area of combat had moved over 300 miles from the landing places. The R.D.F. stations at that time were required to provide cover over ports and airfields behind the battle area. The scale of provision of R.D.F. equipment in the operation was insufficient for any to be spared for Army support in the very forward areas. It was all absorbed for the vital task of building the coastal chain. In addition, practically no inland R.D.F. reporting system could be set up either, giving rise to a need for airfield R.D.F. sets for purely local warning only.

[1] *See* Deployment of operational and non-operational R.D.F. stations in North Africa, Appendix No. 24.

[2] C.O.S. (43) 98 (*o*), 4 March 1943—War Cabinet Chiefs of Staff Committee, North Africa Operations, Lessons in Signals Communications, para. 21, sub-paras. (*c*) and (*e*).

[3] *Ibid.*, para. 21, sub-para. (*d*).

[4] *Ibid*, para. 21, sub-para. (*g*).

[5] *Ibid.*, para. 2, sub-para. (*b*).

Specialist tradesmen, particularly R.D.F. operators, quickly lose efficiency if they do not work regularly. Since the unit equipment was packed and shipped long before the embarkation of the personnel, additional equipment for continuous training should have been made available in the United Kingdom and special measures taken for daily training on board ship, particularly when the voyage was to be of so great a distance as that covered by the invasion troops of Operation "Torch."[1]

A much more thorough maintenance organisation for R.D.F. equipment should have been planned and organised in advance.[2] Spare replacement parts should have been received in the theatre of operation in greater quantities and at a much earlier date. Light Warning Sets should have been furnished with a greater percentage of spare parts to accompany each set as the maintenance organisation could not be expected to function in the early days of the assault.

Finally a plan for the installation, maintenance, and operation of the Air Warning Services should have been made under the control of the Royal Air Force Commander charged with the fighter defence of the area, and an R.D.F. staff officer should have been assigned to work under him. This would have obviated a lot of unnecessary wrangling about the disposition of the stations and enabled the units to settle down quickly and efficiently to the task for which they were intended.[3]

Although there had been deviations from the original R.D.F. plans for Operation "Torch" at the beginning of the operation, occasioned by both the inability to land the Light Warning Sets at the beaches because of the heavy sea, and also the landing of R.D.F. equipment at the unorganised docks, nevertheless, in the main the scheme of building a coastal R.D.F. chain was carried out successfully. By January 1943 this chain was fulfilling its functions, namely, giving R.D.F. warning of enemy air attacks on our coastal convoys, ports and coastal airfields, and G.C.I. cover for night attacks on these important targets. In addition, two G.C.I. units had been spared for the night defence of two inland airfields. The R.D.F. requirement in North Africa had become remarkably similar to the original requirement in the United Kingdom—a coastline had to be covered and certain targets had to have local sets—there was a definite R.D.F. "frontier" following the coast and the stabilised battle-line by January 1943.

The end of the race for Tunis in December 1942, in which the British First Army failed only by the narrowest of margins, saw the end of the first major phase of the North-West African campaign. The junction of General Von Arnim and Field Marshal Rommel's forces, and the approach of the British Eighth Army to the Mareth line fused the two separate theatres of war east and west of Tunisia into one. The Allies therefore re-organised during the latter part of January and February 1943 to achieve a unified command which was to lead to the final defeat of the Axis forces in North Africa.[4] The part played by the Royal Air Force ground search R.D.F. units in the concluding phases of the pincers movement in the culminating stage of the campaign is dealt with in the next chapter.

[1] C.O.S. (43) 98 (*o*), para. 5, sub-para. (*d*). [2] *Ibid.*, para. 21, sub-para. (*j*).
[3] *Ibid.*, para. 21, sub-para. (*k*).
[4] Air Ministry File C.30435/46, Commander-in-Chief's Despatch on North African Campaign, p. 37.