ENGINEERING RADAR IN THE SECOND WORLD WAR

A New Zealand Perspective

Edward. H. (Ned) Hitchcock

Bio:

Born and brought up in Christchurch, Ned started his Engineering Degree at Canterbury in 1937. His second year was marked by Munich ("*Peace in our time*"), and the third year by declaration of war ("*Where Britain goes we go*"). In 1940 came the German breakthrough, Dunkirk, and the fall of France - and final examinations.

Early next year he was selected to join an RNZAF group, chosen as already having suitable training and experience suitable for secret work overseas. In June in the camp before embarkation, he heard Lord Beaverbrook reveal the existence of the secret defence "**Radiolocation**" and call on the Empire to provide trained recruits to "**man the Chain**". In September his degree was conferred "*in absentia*": the absence due to being on a troopship in mid-Atlantic en-route to the UK.

After the 10 week specialist RAF training course, he remained a further year as an Instructor. After a brief diversion on aircraft electrics, he was posted to 60 Group, that was responsible for Ground Radar (the new British-American term).

In 1944 he joined a Night-fighter Control Radar unit, to take part in the landings in Normandy. This unit landed on Omaha Beachhead on D-Day, suffering heavy casualties. Radar in the offensive! Returning to the UK, there were urgent tasks to adapt Radar to combat the flying bomb challenge.

In September he was back on the continent with 72 Wing bringing Radar Navigational Aids closer to their targets. After VE Day, he served a Graduate Apprenticeship with the BTH Company, Rugby and Willesden.

Returning to NZ, he spent 20 years with the Railways, on railway and industrial electrification. During this time he was assigned to Post-Graduate training in Public Administration, and later seconded to External Affairs for two years as the Columbo Plan Adviser to the Malaysian Government in Kuala Lumpur.

In 1966 he was appointed to the post of Chief Technical Adviser to the newly formed Standards Association. Work on Building Codes led to research on Technological Law generally, and sponsorship towards a Doctorate in that subject at the University of Auckland.

INTRODUCTION

When I was asked to undertake this Slade Memorial Lecture on radar, my first reaction was to point out the almost impossible task of contracting such a huge subject into the space of one lecture. Then I read through the titles of previous lectures of the series. I concluded that the subject of radar and the vital contribution of electronic expertise to the outcome of World War II, and thus to the very nature of our society today, would be a much needed addition to the series. To make the task practicable, I propose to talk about some basics of “Ground Radar”, and track the beginnings of the radar we know today. The fascinating story of Airborne Radar as it developed from, and in turn fed back to Ground Radar, must be for another occasion.

There were various ideas that preceded radar, but which, for a variety of reasons, lapsed without development. In Germany, basically similar radar developed, but with some vital differences which were to have important consequences. To begin the story in Britain we will introduce Sir Robert Watson Watt. It was he who, like William Webb Ellis, picked up the ball and ran!

First to be described will be the beginnings, the urgent and desperate development of the Radar Chain round the coast of Britain, and its testing in the great attack. It is rare in a radical new development of this magnitude, that the steps are so well recorded. The ensuing test, the “Battle of Britain”, has been rated as one of the most decisive battles in British history, even, some suggest in American history. Radar was a critical factor in the defence. Even as the Chain was being constructed, research and development continued towards shorter wavelengths and the advantages of more directional radiation. So the next section introduces the low-looking radar, and that wonderful asset, the Plan Position Indicator. For the first time practical defence against night attack was possible. Then comes a new function for radar techniques, adapted to provide Radio Navigational Aids. Gee established a lattice of lines which could be portrayed on a map, Gee-H responded to aircraft request, and the more precise Oboe controlled accurate bombing.

Our review of radar would not be complete without mention of New Zealand participation, in local development of equipment, providing equipment and services in the Pacific, and providing trained men for seconding to the RAF, for local defence, and for the Pacific. Then we return to Europe, to look at the major change in the war situation, and when radar changes its role to join the attacking forces. The mobile versions of radar move with the armies, even to land among the first in Normandy. The Nav-Aids also go mobile and continue their services as they move up with the armies. As all this goes on, the battle of measure against counter-measure intensifies to amazing electronic complexity, and there is a brief introduction to this “Radio War”. Finally, some conclusions about the contribution of radar and the electronics industry to Victory in World War II.

Any such account must mention a dominating factor: *Secrecy*. Said to be the best kept secret of the war, this secrecy surrounding radar ruled our lives. Our notebooks in the training schools were “Secret Documents”. One could talk to no one outside about it. One learnt not to ask about matters outside one’s own field. This means that so much of what I have since learnt about radar in general, has had to come from material published after secrecy had been relaxed (see reading list attached). There may well be readers who know a great deal more about a specific matter to which I have given less detail than deserved, but contracting this enormous subject into one short lecture has had its penalties.

The word radar has been used throughout, except where the original code name “RDF” was needed. The term *radio-location* was adopted by Lord Beaverbrook for the general public, when, in June of 1941, the existence of the secret defence was revealed, and he appealed to the Commonwealth for trained men to “man the chain”. The American term RADAR was adopted early in 1944, on the recommendation of Sir Robert Watson Watt, after his return from a UK mission to the United States. It introduced the word *Ranging,* and he was delighted with its additional elegance of being a palindrome.

One further word. As we look back on the part played by radar in guiding death and destruction, we may find it disturbing, particularly as the present world does not seem to have progressed towards eliminating that use. Reality tells us it was a battle against much worse, and that we all owe a great deal to the victory in that battle. I have included the odd light-hearted comment, not to denigrate the sacrifices made, but to recall the spirit of those days, the tremendous morale of great purpose, and the life saving laughter.

BEGINNINGS and the CHAIN is built.

A few years ago my wife and I were exploring the high ground behind the Romney Marsh not far from the grand defensive measure against an earlier invasion threat, the Hythe Military Canal. I was taken to see a huge concrete structure, 25 feet high, and 200 feet long - a gigantic sound mirror, its rigid direction pointing firmly to France. Nothing could illustrate more vividly the hopeless inadequacy of defence measures against air attack as they stood in the mid-thirties. In Germany early in 1933 Hitler was made Chancellor and at the first meeting of the Third Reich was given emergency powers for four years. Churchill described the “darkening scene”, and the fearful fact: Germany under Hitler was Germany rearming. A year later Hitler informed the British Foreign Secretary that the German Air Force, from supposedly nothing, had reached parity with Britain! This startling new situation has been described as having given Hitler the foundation for the successive acts of aggression which were to follow.

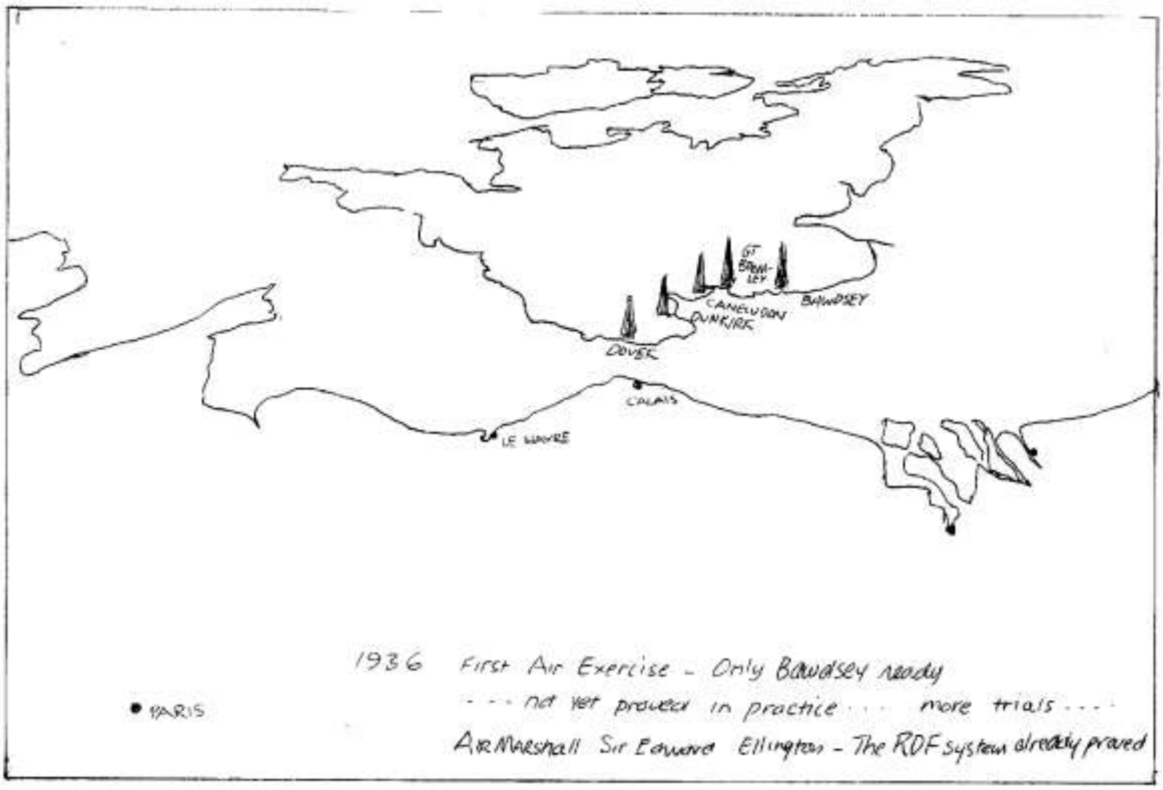
Back in Britain, a scientist in the Research Directorate of the Air Ministry, A.P. Rowe, turned from his pessimism about the acoustic system of aircraft detection, to search records for any possible ideas for better defence. What he found led him to set out in a report the conclusion that unless science could develop some new method of defence, Britain was likely to lose any war that might start in the next ten years. The Director of Scientific Research, H.E. Wimperis, took action by recommending to the Secretary of State for Air that a special group of two or three scientific men be set up to intensify research for defence measures. He pointed at the remarkable recent developments in technology, and said that no avenue, however seemingly fantastic, should be left unexplored. He outlined some thoughts on the radiation of large amounts of energy and what possible effects it could have on aircraft or pilots. The recommendation was accepted and the group was set up as the *Committee for the Scientific Survey of Air Defence*, under the physicist H.T. Tizard.

In the meantime, Wimperis put an informal query to a former student and later colleague, R.A.Watson Watt, then heading the Radio Department of the National Physical Laboratory, as to what he thought of this “death ray” business. The brief reply was discouraging about radiation to cause “damage” but did add that a look at “detection” could be a worthwhile. He offered to work out figures and more detail. The “more” came in the now well known Memorandum, setting out as it were the *Charter for Radio Detection and Location of Aircraft*. Much of what was set out was prophetic and accurately forecast the approach, development, and problems. Initially proposed was a “zone of illumination”, with a later move to “searchlight” when higher frequencies could be developed. Advantages of pulse technique were qualified by the need to narrow the pulse from current practice. There was optimism over measuring distance, bearing and elevation. Two alternative approaches were mentioned if later there were unforseen difficulties. Finally the outline of a method for identifying “friends”. The Committee examined the Memorandum at its second meeting on 12 February 1935: the immediate request was for “demonstration”, not of radar, but of the adequacy of the hoped-for reflected wave.

Thus it came about that on 25 February, a small Morris van bearing a hastily contrived receiver and antenna drove into a field near Daventry. The observers were Watson Watt, his assistant Wilkins, and A.P. Rowe. This was to establish whether there was a significant reflection of radiation from an aircraft, using for convenience continuous wave radiation from the BBC Daventry overseas programme with a transmitter power of 10kW and wavelength 50 metres. A receiver had been adapted to neutralise the power of the direct ray. The Heyford bomber flew on the prearranged course up and down 20 miles of the beam. In hushed silence the observers saw substantial deflections on the cathode ray tube. When the plane was eight miles away there was still a significant response on the screen.

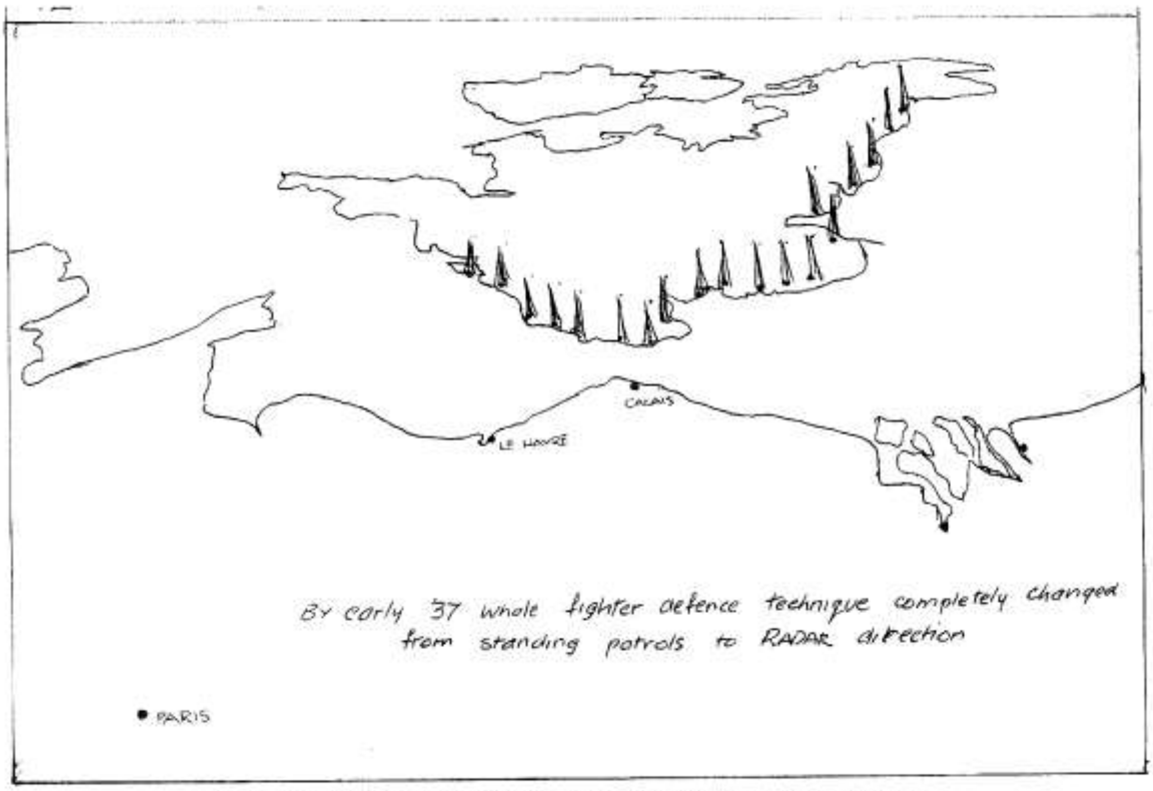
The Tizard Committee, with true British understatement, reported “In the circumstances the result was much beyond expectation”, this the result of an experiment on a subject not even included in the proposal for its formation. But the result was sufficient for an allocation of ten thousand pounds, albeit reluctantly for a “purely defensive” project. Watson Watt and his team then set up their establishment in some ministry buildings near Orfordness and later moved to the legendary Bawdsey Manor. There developments proceeded with astonishing speed. One small illustration of radical approach can be drawn from Watson Watt's account. Silica transmitter valves proposed were rated by the Signals School at 10 kW the pair at 5,000 volts, with the warning “do not exceed”. After step by step raises, a modified bowl and leads, 15,000 volts on the anode produced nearly 200 kW peak power, unheard of at that time.

By December 1935, Treasury approved a five-station Chain, covering the approaches to London. In mid 1936 came the first Air Exercise.



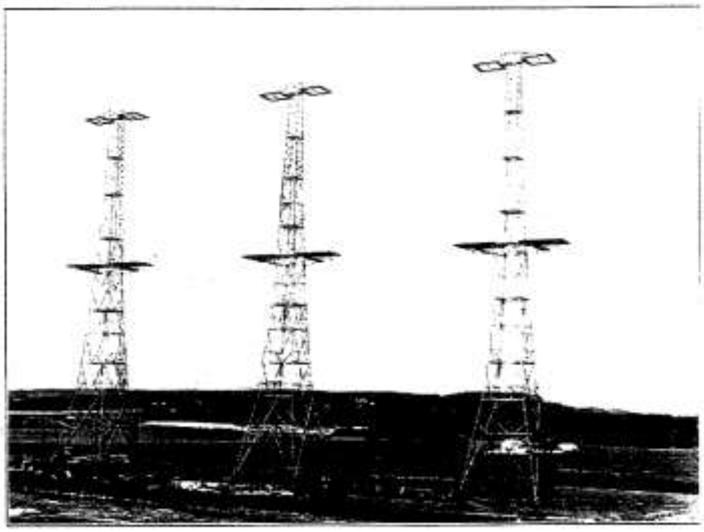
3. Five Station Chain. Approved December 1935.

The five stations were nowhere near completion, the programme was too ambitious, and there had been insufficient time for calibration, but the official verdict was “the RDF system was already proved”. By early 1937 the whole fighter technique of defence had been changed to utilise RDF information from a Chain yet to be constructed. Later that year the Air Exercise of June led to the decision that the scheme for the Main 20-station Chain should be put in hand, with Air Staff wanting them operational by the end of 1939.

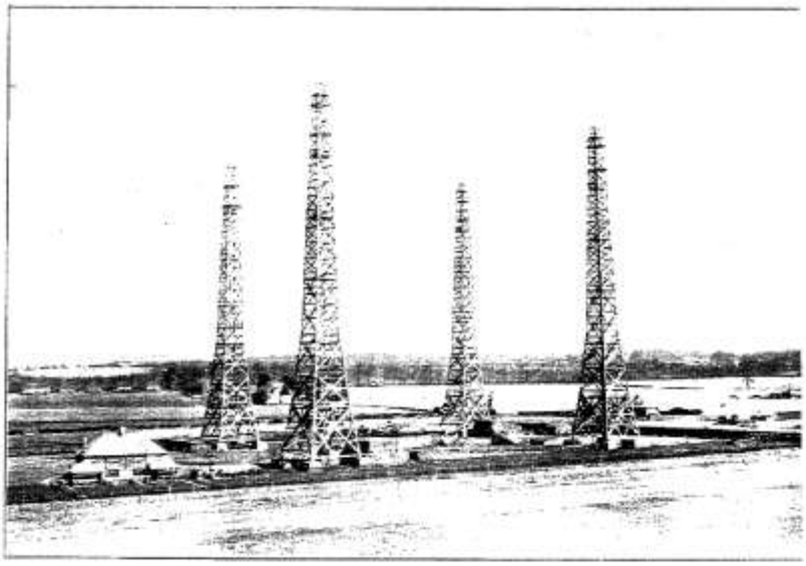


4. Twenty Station Chain (Southampton-Tyne). Approved August 1937.

The task was daunting. Each station would have four 360 ft steel towers to carry the transmitting aerial arrays, four 240 ft wooden towers for the receiving crossed dipoles to give range, direction, and height. The transmitters used demountable, continuously-evacuated valves, delivering over 400kW peak power, with a choice of four frequencies to cope with possible interference. Wavelengths were in the 12 metre range. All main gear was in duplicate. (A magnificent account of life and maintenance on a CH "steam" station by Sandy Voss appears in Radar Stories, pp.154-158 - see refs.)



1. Transmitting towers, East Coast Home Stations



2. Receiver towers CH Stations

In February '38 Austria was occupied. In September, the Munich Crisis brought those first five stations into continuous watch, to be maintained without interruption until victory. The target completion date was moved forward to April '39. More steps were taken on the path to war. Czechoslovakia fell in March, the Italians invaded Albania in April, and the whole Chain went on to continuous watch, to be maintained for the next six years.

Early in '39 the Air Staff decided to share information with Countries of the Commonwealth, and the New Zealand story is outlined below. It was also decided to share information with France. A Grand Plan of three RDF Chains never reached completion, and there were difficulties over agreements for equipment. Perhaps it can be mentioned here, a link in the author's family connections with radar. His elder brother worked for a firm constructing the 240 ft wooden receiver towers. In late '39, he took a team to the south of France to erect towers near Grasse, part of one of those chains. After the fall of France, he just managed to escape with his staff on one of the colliers which evacuated British residents.

The German reaction to such obvious construction work and powerful radiation was always a security concern. In August '39 (just a month before war broke out) they took action to check it over. The Chain plotted a particularly large echo right up the East Coast as far as Scotland. Observers confirmed the source to be a Zeppelin (later identified as LZ130, sister ship to the Graf Zeppelin). There was much speculation as to whether the spy mission had been able to deduce the role of the stations, and whether they would be marked down for early attack. Postwar the details came available. The floodlighting technique adopted for the chain was quite different from most other radar developments. Watson Watt's determined opting for the “third best” (the best will never come, the second best will be too late) had meant the use of readily-available equipment even if so radically adapted. The massive, almost continuous radiation detected by the spy mission, had no relation to their own radar development. German radar had moved directly to those shorter wavelengths and “searchlight” techniques which Watson Watt had firmly relegated till “later”. Just the unexpected power of the transmission from the Chain would have overloaded normal receivers. The pulse recurrence frequency (PRF) of 25 per second, linked to the 50 cycle main power supply, led to the assumption that this was some sort of interference from the grid (the British electricity transmission system). These conclusions were later to influence the decisions on whether to attack radar installations when the Luftwaffe launched the attack on Britain.

The period of inaction that followed declaration of war on September 3, 1939, the “phoney war”, enabled much needed consolidation of the Chain and its operation. Stations were brought up to full power at the rate of about one a week, and operating procedures were practised, through the whole complex system, RDF station, Group, filter room, operations room, fighter station, and the invaluable links with the Royal Observer Corps to plot aircraft inland. The Chain was ready for the great test.

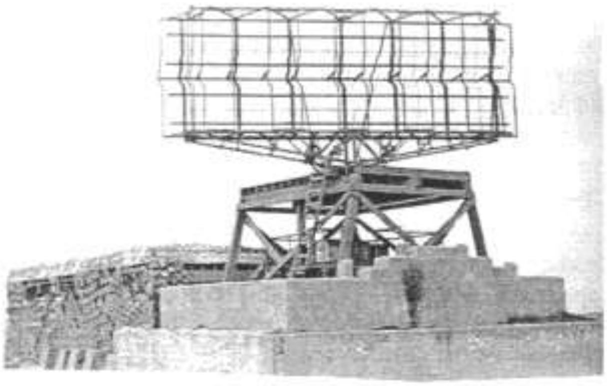
THE CHAIN UNDER TRIAL - THE BATTLE OF BRITAIN

As the final work on the Chain proceeded into 1940, the false quiet was suddenly shattered. In May the German armies attacked though Belgium, and by the end of the month British forces were being evacuated from the sand hills of Dunkirk. In June the French asked for an armistice. By August there were signs of preparation in Channel ports of invasion barges. German intentions were known. An overwhelming air attack would dispose of an inadequate RAF - taking about 4 days! Then a barge-born invasion force would cross the Channel and recalcitrant Britain would join the other European states under Hitler's control. The date for operation “Sea-Lion” was set for September 15, after “Eagle Day”, set for 10 August, had launched the air attack that would achieve air superiority over the Channel.

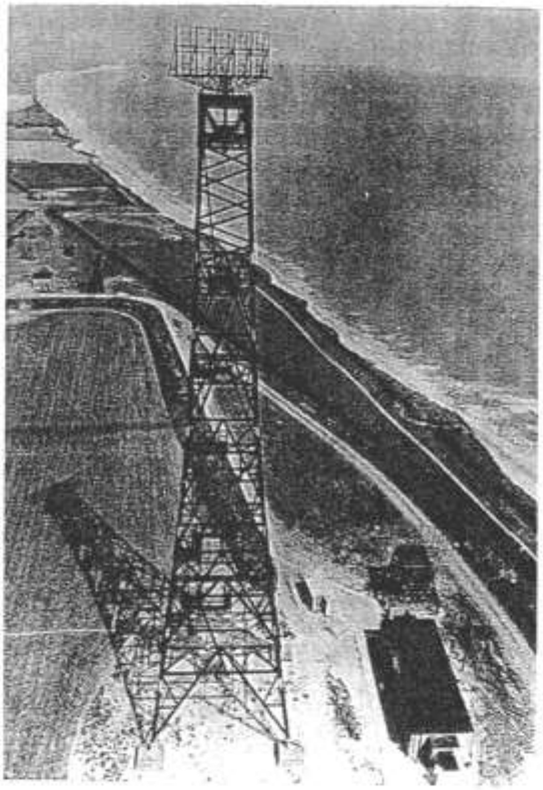
Only the briefest outline of events can be given here to describe radar participation. The opening assault, August 12, on fighter stations, included five attacks on southern radar stations. Four of these were back on the air again within 6 hours, 3 hours, and less than one hour interruptions. Ventnor on the Isle of Wight took over a week to resume watch, in order to dispose of delayed action bombs. Only one further major attack on a radar station occurred. Apparently Goering had his own views confirmed by the zeppelin spy mission, that whatever the stations might be, they posed no threat. After the bombing he ordered no further effort to be "wasted", because the stations were back in action so quickly. The attacks on airfields continued through August into September, every day except when bad weather provided brief respite. The pattern remained the same, raids detected early by radar, fighters directed to meet them often over the coast. A figure often quoted is that one fighter under radar direction is worth three without. Another view, from a senior German signals officer, concerned the loss of morale in the attackers, when almost invariably they were met by a force of a strength and in a position, that was competent to do battle with them. This was from an RAF they had been led to believe was negligible. In the record of losses, even when more accurate figures toned down the claims, the attacking forces invariably lost more planes than the defenders. Pilots too had more chance of being available again if they bailed out over home territory.

As the results came through, and as the resistance continued in spite of Hitler's assessment of "the hopeless military position" of England, operation Sea-Lion was progressively postponed. On the afternoon of 7 September, radar spotted incoming raids which were presumed to be against fighter airfields. Instead successive waves bombed the Arsenal, oil tanks and the docks: London was under attack. As night fell, the flames provided a beacon on which later waves directed more bombs. In day action the Luftwaffe lost 38 to the RAF's 28. At night, there was a clear indication towards the next radar defence needs, there was only one plane shot down. On Sunday, 15 September, a series of massive raids used five fighters for each bomber - 679 fighters to 139 bombers. 56 Luftwaffe planes were shot down, out of which 34 were bombers. Churchill has described the fateful moment when, in the 11 Group Operations Room, where the radar plots were guiding the decisions on the disposal of fighter forces, he asked Sir Keith Park "What other reserves have we?" The reply came "There are none". Most of the squadrons had descended to refuel. If further raids caught refuelling planes on the ground the result could be disaster. Then the plots showed continued eastward movement of Luftwaffe planes - they were turning back!

That night the RAF attacked in strength ports from Boulogne to Antwerp. On September 17 the Fuehrer decided to postpone Sea-Lion indefinitely. He had given up that curious hope that "Britain might yet be seized by mass hysteria"!



5. Standard Chain Home Low (CHL) installation, Beachy Head



6. CHL on 185 ft tower and 20 ft gantry at Hopton

THE LOW LOOK: CD, CHL, GCI

While the urgent effort went to the "third best", the practical Chain, about 12m wavelengths, part of the Bawdsey group looked at higher frequencies for airborne equipment, AI for Air Interception, and ASV for Air to Surface Vessel. Successful development at 1.5m was then extended back to Ground Radar, to provide GL (Gun Laying) and CD/CHL capable of detecting low-flying aircraft and surface vessels (CD for Coast Defence, and CHL for Chain Home Low). At this frequency, practical aerial arrays could be devised of a size which could be turned to direct a beam at the target. The first sets had primitive turning by crank handle, bicycle chains and weary airmen. Rotating a beam now provided the opportunity to bring in the PPI (Plan Position Indicator) so familiar these days as to need no description. The idea had been mooted in the early discussions, but put to one side (WW's "ice box") until the move to higher frequencies.

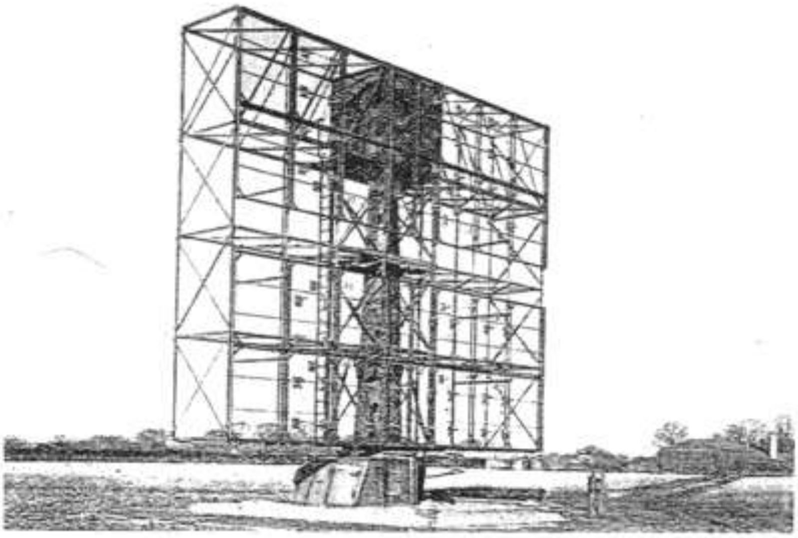
Towards the end of 1940, the common Transmit/Receive aerial switching and the rotating transmission line coupler enabled a single aerial to be used, and electric-drive steady-rotation to permit continuous display on the map-like PPI.

The standard mounting for a CHL aerial was on a wooden gantry, and the site chosen to achieve the maximum height above the reflecting ground or sea surface and thus ensure the lowest cover. In some low lying areas, such as the

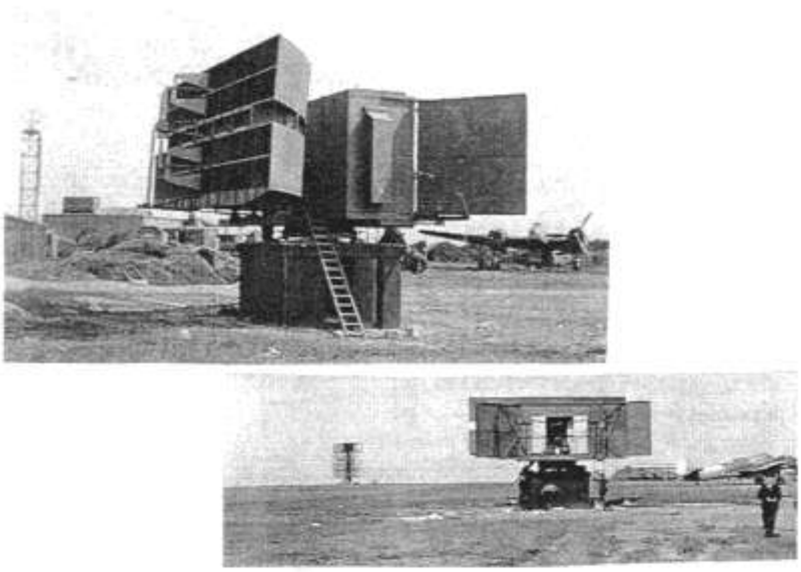
Norfolk coast, aerials were mounted on towers. An unusual location at Bawdsey was on one of the cantilevered platforms on a CH tower. The CHL was not normally equipped to establish heights, but that could be estimated by experienced operators. CHL stations usually passed their plots to the filter room through the local CH, which often acted as parent station. Other CHL's were independent units, sending plots direct to filter rooms.

The second line of low-looking stations was virtually complete by September '41. In some areas stations were originally set up as CD stations, but their aircraft detection was so effective that they were absorbed into the CHL group and were operated by 60 Group. Wrens were retained at these stations to ensure that ships were plotted by the right people! (WRNS, Womens Royal Naval Service, in case the name is a puzzle).

In the latter stages of the Battle of Britain, when there was a switch to night bombing, there was a devastating realisation of the near impossibility of night interception, even if AI, airborne Aircraft Interception radar, could be brought to adequate function and availability. Some means of control was urgently needed. Then with the CHL, the plan position indicator was possible. A CD/CHL station, equipped with a PPI experimented with interception of some night flying mine-laying aircraft by directing fighters to within AI range. The trial was successful and the technique was rapidly developed. Very soon plans were in hand for a pattern of mobile GCI stations covering inland areas. Their success led to perhaps the first programme of industry-designed complete stations, with a massive steel framed aerial system, underground Tx, Rx and turning gear and distant permanent building for operations. Being in Britain, it had to have an affectionate name, it became the “Happidrome”. Of the mobile equivalent, more to be said later, when we discuss radar on the offensive.



7. Fixed Ground Control Interception station (Type 7).
The "Happidrome"



8. Type 14 (10 cm) GCI at Hope Cove. A fixed GCI in the distance.

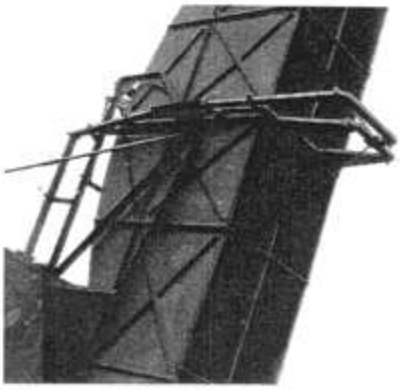
THE EXTRA-LOW LOOK: Centimetric Radar

While great effort was being devoted to the establishment of the immediate defensive CHAIN, other projects were set up to continue the search for possible improvements, with the ideal always in mind of those higher frequencies. At the University of Birmingham, a team was looking into better means of generating higher frequencies with the higher power outputs needed. The role of cavities in this strange high frequency world, where transmission could be by pipe, led to the trials of the cavity magnetron, with results that startled even the researchers - such as the sudden melting of an output probe. Power outputs moved up to significant kilowatts at a wave length of 10 cm. The first production models, urgently needed, were produced by resources allied to the researchers, such as university labs.

A far seeing decision was taken to share this vital discovery with the

Americans: a mission visited the United States and offered this as a gesture of the remarkable cooperation that prevailed. (A GCI unit was also sent to reveal this vital development to our not-yet-official allies). Developments in the production of microwave radar were to follow, but back in Britain radar on these high frequencies was rapidly brought into service on the experimental pragmatic style that marked so much this story. In airborne equipment, new AI and ASV sets, Aircraft to Surface Vessel, were produced, exploiting the ability to use smaller paraboloids in place of the "Christmas tree" aerial arrays so offending to aerodynamics. A radical new concept was developed by a groundward looking radar displaying on a Plan Position Indicator the prominent features of the ground below. It was given the code name of H2S, was a powerful aid to navigation, and became an effective weapon in the war against U-boats.

In defensive ground radar, the Luftwaffe had learnt of the low-level gap in radar coverage. What could be termed "nuisance raiders" would approach the coast flying low, rapidly climb through CHL levels, and only then appear in the Chain illumination. They would then dive to their target, often a coastal town, release their bomb-load, and run for home at low level. Militarily insignificant, it was politically critical as affecting civilian morale: the extra low-look was needed urgently. The basic new type unit was the Type 14, with a horizontal "cheese" aerial, sweeping a vertical fan of radiation continuously rotated. Its partner, Type 13, gave much improved height-finding by moving a horizontal fan up and down over the appropriate angles. Seacoast "bandits" were successfully intercepted. For low-lying Coastal Defence (CD) stations, special installations were devised, with paraboloids mounted on towers, to give the best range at sea-level.




9. Type 13 (vertical cheese) 10 cm heightfinder


10. Extra low coverage for low-flying sites. Parabolic aerials with the EHH frame. (Creswell, and North Foreland).

RADAR NAVIGATIONAL AIDS: GEE, GEE-H, and OBOE

Late in 1940 doubts were raised about the accuracy of RAF bombing, and “the Prof” (Professor Lindeman, Churchill's personal scientific adviser) was commissioned to investigate. The results were disturbing. Although Bomber Command believed targets had been found, analysis showed that two thirds of the crews actually failed to strike within five miles of it. Churchill pushed for action. As in so many cases in this story of radio development, ideas or principles were known but had been put on one side until more critically important defence measures had been attended to. The group of RNA (Radio Navigational Aids) developed were not strictly radar in that this has come to mean the detection of reflected waves, but they are included here because they used pulse technique, were developed by the same people, and used the speed of radio waves to determine distance. They were operated by radar personnel, under the wing of 60 Group. The author's association with them came with their move to the Continent, as the mobile ground stations followed up the battle lines, and is described later.

Gee (Type 7000)

The first system to go into action became the most widely used of the war. Service trials began in '41, and general operation in '42. Its particular advantages were that the signal only had to be received, not reflected (therefore its effective range was greater, up to about 350 miles) no transmission was required by the user (enabling radio silence); and was independent of the number of observers (could not be saturated by demand). An excellent short presentation of the systems and their working appears in Latham and Stobbs (see references). Here only the briefest summary can be given. In a pair of radio stations Station A transmits a pulse. Station B receives this pulse, and retransmits it after an exact time interval. The listener can read the time interval between his reception of the two pulses. From a chart of points of the same time interval, superimposed on a map, he may read a line of positions. From a second slave station C, a second set of lines provides a second line of positions. Where the two lines cross marks the position on the map. Sometimes a third slave station could be added.

The system depended on accurate determination of time intervals, and Latham notes the delight of the radio enthusiast admiring the elegance of the circuit techniques devised. As the timing depended on the leading edge of the pulse, the output of the standard radar transmitter had to be “smartened up” for Gee. As the transmission had to be continuously available for users, stand-by precautions had to be greater. Mention is made of five transmitters being provided for a Gee station to reinforce reliability.

Oboe (Type 9000)

Again, principles had been discussed, but development had to await resources and facilities. Radar could be very accurate on range, but less so in direction. As in Gee-H, accurate placing can come from two well-separated stations. In Oboe, the plane flies along on one arc of constant range from the “cat”, directed by dots and dashes into a channel of about 35 yards width. As it progresses along this arc, the second station, the “mouse”, signals range markers until it reaches the calculated point for the bomb release signal. This has been continuously calculated by the computer (aptly named Micestro). To achieve necessary ranges of up to 300 miles, the echo from the aircraft had to be amplified by a transponder on board. This meant the loss of radio silence, a loss considered worth while for gain in accuracy. It was used by the Pathfinder force in the main bombing campaign against Germany, and in many special raids needing particular accuracy, such as against flying-bomb sites, and even mercy missions dropping food to starving Dutch.

Gee-H

As in Oboe, Gee-H measures a bombing target by ranges from two ground stations, but by the aircraft interrogating those stations. Gee indicators, slightly modified, were used, with some extra equipment. In Oboe, the calculations and the bomb release decision is done on the ground: in Gee-H the navigator on the plane must align the pulses, in a rather more stressful situation. The system was used widely by both the RAF and the US Air Forces.

NEW ZEALAND AND WAR-TIME RADAR

The first New Zealand link to the development of radar that was taking place in Britain came early in 1939. The march towards war had become inevitable, and the place that radar defence would take in the conflict had become clear. There was concern in the Air Ministry as to what role the sister nations of the Commonwealth could take in sharing this powerful defence technique as they in turn faced threatening aggression. Because all effort in Britain was being directed to the urgent needs of their defence, it could be desirable for Commonwealth countries to develop their own equipment, and at the same time build up staff trained in the new techniques.

On 24 February 1939, the Secretary of State met the Commonwealth High Commissioners in London and told them of the new developments. It was agreed that the respective governments be asked to send a physicist to study this new defence technique so that each country could then take action to meet their own special needs, in terms of what assistance could be made available from Britain.

New Zealand chose to send Dr Earnest Marsden (later to be Sir Earnest), then Secretary of the Department of Scientific and Industrial Research. In earlier days he had been in the Rutherford Laboratory on work that led to the discovery of the atomic nucleus. From there he was appointed as Professor of Physics at Victoria University College while still only 25. In World War I he saw service with NZ Divisional Signals in France. He returned to the Chair after the war, and later became head of DSIR. After his discussions and introduction to radar developments, Dr Marsden returned to NZ bringing with him, in addition to highly secret technical information, a partially completed 1.5m ASV radar and a number of critical components. He had arranged for a flow of further technical information, and for supply of materials as they could be spared.

The remarkable developments that followed have been meticulously described by R.S. Unwin (see references). Here can be included only a brief summary. Two laboratory groups were set up, one in the Radio Section, NZPO, and the other at Canterbury University College. A special one year University course in radio physics was established at Auckland and at Christchurch. Our isolation in the midst of vast oceans, with long coastlines, meant that the chief danger would be from enemy surface raiders. The need was for Coast Defence (CD), radar assistance for the guns defending main ports and for Coast Watching (CW), simple sets to maintain watch from various points on the coast, usually remote and with difficult access.

By mid-1940, the first CW set was operating for the Navy at Auckland, an airborne ASV was under trial, and an experimental air and surface warning set was operating on the cruiser HMS Achilles. By the end of the year, CD sets were operating for the Army at Auckland and at Wellington, and three CW sets for the Navy. By 1944 the CW sets, after giving great service, had been replaced by microwave sets. CD sets were improved with higher power transmitter tubes and sophisticated antennas: a total of 12 sets were supplied to the Army.

In 1941, the entry of Japan into the war changed the emphasis. Air warning sets based on the CW design were made for the Far Eastern Fleet based at Singapore, and some were used by the NZ Navy. The fate of the others is obscure, one is thought to have fallen into Japanese hands. The experimental ASV was overtaken when British ASV MkII came available from July 1941. The widespread use of this set called for the provision of

ASV beacons. These were designed in Christchurch and tropicalised for Pacific duty. The changed situation now called for radar defence against air attack but by this time British equipment was available and overseas versions of CH, CHL, and GCI were involved.

Late in 1941, NZ appointed a Scientific Liaison Officer to Washington to ensure full information on microwave techniques. Supplies of components were obtained under lend-lease and design and construction began on mobile units suitable for use anywhere in the Pacific. There is no doubt, Unwin reports, that the mobile microwave [units] produced in NZ were well ahead of contemporary efforts by USA and Australia in the South Pacific. About the same time, a mobile Long Range Air Warning unit was designed and built, with the help of industry, University and PWD (Public Works Department), specifically to be able to be landed from the sea, and brought into operation using a Yagi antenna (on 100 MHz), within half an hour. The American SCR270 took up to 3 days, too slow to support sea-borne landings.

19

11a. Mobile radar convoy. 15000 Group.
Type 11, (50 cm) | Type 13, (10 cm heightfinder) | Type 14, (10 cm) | Operations | Type 15 (1.5 m)

11b. Type 11 (50 cm)

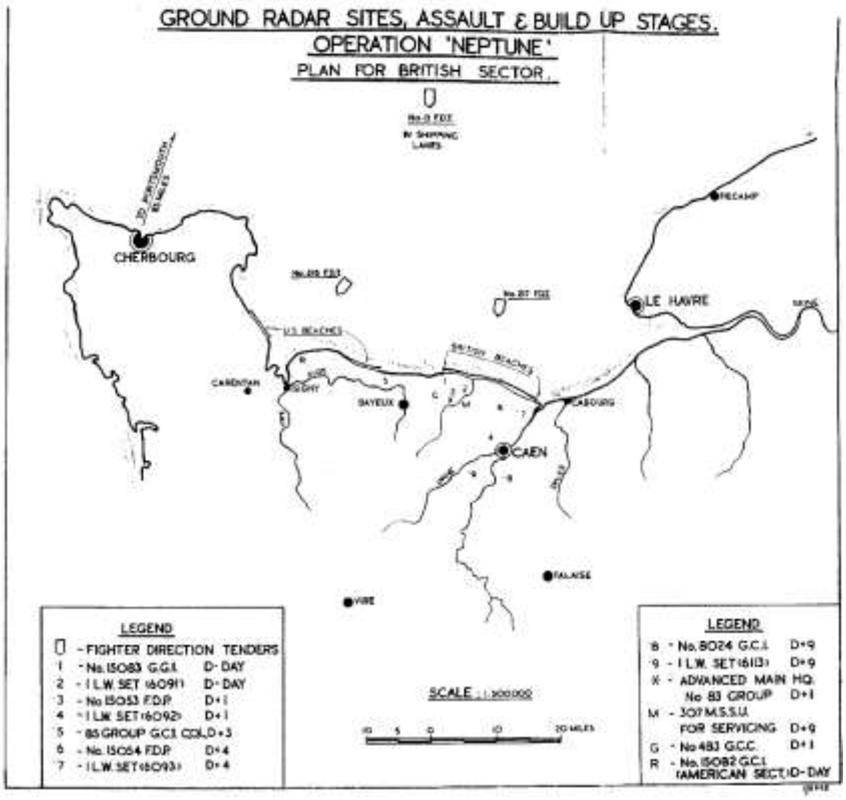
11c. Type 15 and operations caravans

Unwin covers specifically radar development. An equally important contribution from New Zealand was providing trained men. Even before the British call in June 1941 to the Commonwealth for trained men “to man the Chain”, NZ had been sending men recruited into the RNZAF for service attached to the RAF for radar duties. Two groups, each of about 20, were despatched without further training, as they were drawn from electronics industry, radio amateurs, or University. At RNZAF Wigram, the E&W School ran successive courses giving basic instruction to later recruits. Until December 1941, the groups were sent to England for service with the RAF. After that date they were somewhat arbitrarily divided between England and home or Pacific service. I have been unable to locate specific figures, but figures of well over 1000 seem probable. Accounts of their experiences have been collected and published in two volumes of “Radar Stories” (see references).

RADAR ON THE OFFENSIVE - Landing in Normandy

In and among the fields and hedge-rows of England, as the war moved from defence to offence, the mobile radar convoys waited and trained for action to come. Commando training included wet landings. Mobility would enable rapid follow-up as new territory is captured. Simple early-warning sets, and later the mobile CHL (overseas version) sets had given army support in the Middle East. As they waited for the Second Front, some of the mobiles were advanced to greater sophistication. A full GCI function to control night-fighters, had been added, complete with a caravan housing an operations room, and with the complex communications necessary. Two more wavelengths had been added. Type 11 sets operated on 50 cm, the same as the principal German radar, a precautionary measure against enemy jamming. The newest centimetric radar, Type 14, appeared in mobile form, truck mounted. The horizontal “cheese” aerial could be stowed for transport. Its partner, Type 13, could lower its vertical “cheese” aerial and stow it for transport, giving the convoy that improved height-finding. The whole convoy needed about 25 vehicles.

Plans for Operation Neptune (the initial landings in Normandy) aimed at extending radar cover at the earliest possible moment. Two GCI mobiles were to be landed on the invasion beaches on D-day, controlling night-fighters to protect the beach-head that night, the classic time for defenders to launch the all-out counter-attack. Moored in mid-Channel would be three ship-mounted radars (FDTs, Fighter Director Tenders). These would take over fighters from their home airfields, and pass them over to the newly landed shore based sets. All were geared towards the interception of enemy raiders, with the two-fold responsibility for defensive and offensive action. Of the two mobiles, one was allocated to the British Sector, and one to the American. Each convoy was embarked on five LCTs (Landing craft, tanks), a measure of the value placed on radar service.



12. "Operation Neptune" map showing FDTs and Units 15082 and 83.

In the event, unit G15083 landed successfully and the Type 11 unit was operating behind the British beach-head on the night of June 6 1944. Our Unit G15082 was allocated to the American beach we later came to know in its code name of Omaha, scheduled to land at H+5 (at full tide, through obstacle-cleared lanes, to directions by the beach master). We shared in the disaster that overwhelmed the initial landings, and fortunately did not know that General Bradley was considering abandoning the assault because of the unexpected opposition of a division of German infantry actually engaged in anti-landing exercises. After an attempt to land at 0930, fortunately aborted, we were eventually landed about 1630 near low tide. This was below the massive landing obstacles, enemy fire had prevented their clearance. Vehicles were trapped in soft sand and rising water, and many of those that made it ashore were being picked off by accurate shell fire, until a way through barriers had been cleared. Casualties were heavy, nearly half of our team of 120. The battered remnants were reinforced by replacements landed later, but could not move to the planned site because it was still in enemy hands. By the evening of D+4 No 15082 was on the air and that night the fighters controlled scored one enemy aircraft destroyed and another damaged. Another GCI unit intended to cover enemy attempts to evacuate Cherbourg took up its site very close to one of the major German fortresses, assumed to have been well subdued. After it had apparently driven off attack from the Navy (shells passing low over our heads) attention was turned to us. We were able to withdraw under fire without casualty.

13. Omaha Beach, morning of D+1. Anti-landing obstacles and some burnt-out vehicles of Radar Convoy 15082.

From the beach-heads mobile radar support of the advancing armies followed right through to victory. A location map for 27 August (D+77) shows over 40 units. A later map from the 20 September, showed nearly 60 units, from Ostend down behind the front to Nancy in the south. The development of airfreighted or air-transportable equipment came in time for two Light Warning sets to take part in the Arnhem operation. Casualties were so severe that the radar equipment was never erected, and survivors fought as ground troops. The nearest mobile (now called FDP - Forward Director Post) was moved up to Eindhoven, and some idea of its success may be gained from pilots flying under its control claiming, over three days (25-27 September) 76 enemy aircraft destroyed, and 54 damaged.

Nav-Aids in the Liberation of North-West Europe

Because of the immense importance of the Gee system to the projected landings in Europe and the following campaign, planning began early. The Southern Chain was strengthened and extra frequencies arranged to counter expected jamming. Sites were selected on the Continent for future stations.

Mobile units had been developed, both light, for rapid follow up of military advance, and heavy, for more secure sites. In the landings, Gee was used by both the British and Americans for airborne operations, for seaborne landings, for mine sweeping and later navigation in cleared channels. It played a critical part in Operation "Taxable", where aircraft dropping "window", and Naval units simulated the advance of a massive invasion fleet towards the Pas de Calais

A new section of 60 Group was formed to take charge of RNA stations. This, No.72 Wing, had special problems, as while its units were under the administrative control of the Second Tactical Air Force (2/TAF), they would be situated mostly in the American areas. The results varied from frustrating difficulty to extraordinary co-operation. Occasionally support had to be called for from higher authority, particularly when, behind a front line advance, there was vigorous battle between a whole host of radio services competing for one hilltop.

No.72 Wing HQ landed on Sword Beach early in September, with a very civilised landing from an LST. A bulldozer heaped sand at the ramp for easy exit! With quarters at Chateau Mathieu (near Monty's HQ) we received the mobile convoys from the beaches, and from there the mobile siting parties went forward to reconnoitre the positions selected. With the break-through from St Lo, and the rapid advance, all but one of the five chains originally planned became redundant. The first continental chain, the radically revised Rheims Chain, was operational by early October. The next chain had to be changed, after all the maps had been produced, because the site chosen for the B slave was still in enemy hands. As the situation stabilised, heavy 7000 units moved to free the light 100 stations for advance or standby duty. Then, in December '44 the sudden counter attack through the Ardennes endangered the C slave site at La Roche. Both the light and heavy unit were withdrawn successfully, in spite of frost, snow, mud, and very heavy military traffic. So proceeded these astonishingly complex operations, selecting sites, preparing maps, changing to meet military situations, and maintaining continuous transmission once in action. In the battle for access, a notable occasion was when the Supreme Commander ruled that 72 Wing units were to be given priority over all military Signals units.

OBOE on the Continent

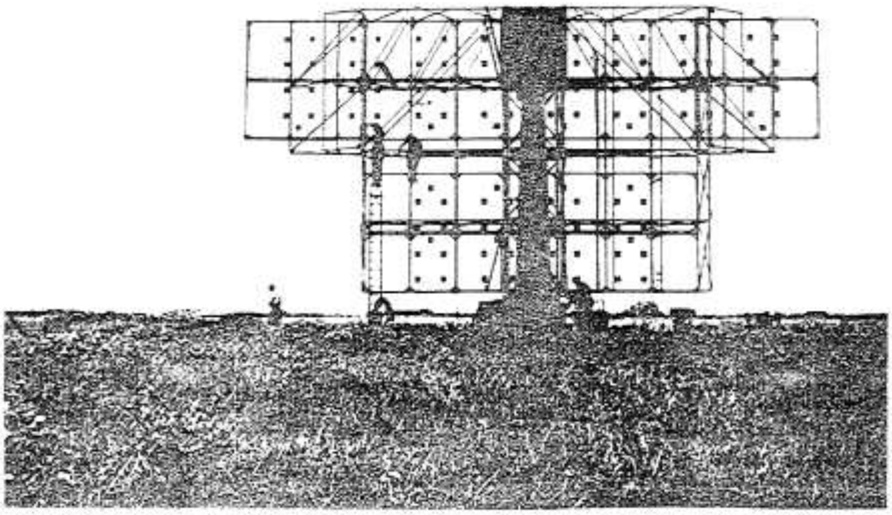
Mobile Oboe units (Type 9000) had been developed to enable cover to move up with the advancing armies. Each convoy included two Oboe trailers, each weighing some 10 tons, and towed by Matador tractors, and 16 other vehicles. The first landed in August '44, but because of the rapid advance of the allied armies, had to be diverted to Paris, and then into Belgium, and the second of the pair a month later. The first operation was not a success, with a breakdown in W/T, snipers in the woods between Cat and Mouse, mines and an explosion causing damage. After some settling down, and concern over accuracy, Oboe was used till the cessation of hostilities by aircraft of No 8 Group, and in the pathfinder squadron of the Ninth Air Force. Three Oboe units were threatened in the Ardenne offensive, but were also successfully withdrawn. Quite an achievement in the light of our later knowledge that Field Marshall Von Runstedt had detailed an armoured column to capture the 72 Wing units at La Roche.

MEASURES AND COUNTERMEASURES

No account of World War II Radar could be complete without a mention of the Radio War, the War within a War. Every new technique by one side called for countermeasures by the other, both needing intense analysis of possible effects. Space permits only the briefest mention. (Detailed accounts will be found in Price and Pritchard, see reading list)

Jamming: Precautions against jamming had been built into early British radar (such as AJJU - anti-jamming jitter unit) but in the first years of the war there was curiously little. Perhaps it was about attitudes, in Britain there was confidence that their secret radar, developed from nothing, was far ahead of anything the enemy could have. In fact, there had been a patent taken out in Germany in 1904 for a shipborne warning system, with some advanced techniques but commercially unsuccessful. As Germany rearmed, their radar development went direct to higher frequencies, the *Freya* (on 2.5m) and later the *Wurzburg* (on 50 cm) so the mighty towers of the Chain must have looked most unlike what they knew as radar. Further, the German military experience in continental operations had developed the swift strike by very mobile land forces, supported by their own air power. Radar had not a significant role. (The navy had begun its use, however, with a *Freya* visible on the sunken *Graf Spee*). So the need for serious jamming had not appeared.

Two events changed matters, first, in February '42, the escape up-channel of the two German Battleships that had been bottled up in Brest, after skilful German jamming had been increased very slowly to baffle the watchers successfully. Then, about a fortnight later, came the Bruneval raid. On both sides there was a realisation that a “high frequency war” had begun, and that each could expect aggression of all forms against radar. This was to continue for the rest of the war.



14. Countermeasures Type 7 Aerial with extended "wings" to pick up Flying Bomb sites on the continent

Security Dilemma: As each new technique was developed, there was concern that its use in action may mean handing it to the enemy. In August '41, a German pathfinder aircraft shot down was complete with a captured *Gee* set, being used for navigation by the enemy. Various devices, such as coding and frequency changes, had to be applied to discourage this compliment.

H2S, the airborne device that gave a radar picture of the surface below, promised great advantages in bombing accuracy, and submarine detection. The indestructible nature of the *Magnetron* within meant that use over enemy territory would mean certain discovery. The decision was taken, a set captured, and the German team examining was said to have made a working copy in 10 weeks. With the secret revealed, both U-boats and aircraft learned to detect radiation from H2S, and thus radio-locate the attacking bomber.

Window was the code name given to *metallic strips* dropped to produce false echoes. The threat of its use had been a concern from first beginnings. It appears that again that both sides held back from its use, each fearing that the advantage gained by the first user would be less than that gained by the enemy in prompt retaliation. The British device, strips of metallised paper, would give immediate advantage to Bomber Command, but Fighter Command objected. After the fierce argument, Churchill himself ruled “open the window", in June 43. In the first raid to follow (on the port of Hamburg) RAF losses were cut from the expected five percent to about a half per cent. Surprisingly, it was nearly six months before the Germans used their version. The usual ingenuities followed, more refined use of *Window,* and more refined radar. However German counter-measures were hampered by bomb damage to factories affecting production, and it seems that technically they were mostly a step behind.

Intelligence was a vital factor in the Radio War, about which a key figure, *R.V. Jones*, has written. The powers of deduction used by his team to identify the workings of German radar were amazing, and tribute must be paid to the many in Resistance movements who gathered information at risk of their own lives. In February '42, classic Intelligence deductions located a new type of German radar, near Bruneval, on the French coast. Combined Operations were enlisted to mount what is thought to be the most successful cutting-out raid of the war. Paratroops supported an RAF radar mechanic, who was able to prise out vital portions of the German set, and the team was then picked up from the beach. (Jones, in his report, referred to this as the second raid on this track. The first, he explained, was in AD1346, the route of Edward III to Crecy!)

Deception: Winston Churchill, in 1943, had said: "In wartime, truth is so precious that she should always be attended by a bodyguard of lies". So, in the critical latter years of war on the offensive, and for the critical landings in Europe, every resource was necessary to ensure success against desperate resistance. And here *Deception* on a large scale was called upon, much of it dependant on radar, to reinforce the German High Command belief that the

Allied main offensive would be across the Straits of Dover. A phantom army, complete with appropriate radio traffic, was set up in South East England. From there, two spoof invasion fleets set off on the night of June5, 1944. Aircraft making a series of elliptical orbits, and dropping *Window*, simulated two great convoys of ships advancing at 7 knots, with an accuracy made possible by flying along the grid lines of *GEE*. Navy craft in the convoy provided jamming, just enough to confuse the picture but still permit the false echoes to be seen. The operations were astonishingly successful, the actual landings coming on the enemy as a surprise both in time and space.

V-Weapons: V1 and V2: Radar took a vigorous part in countermeasures against both *Flying Bombs* and the *V2 Rocket* principally in locating and bombing launching sites. At some CHL stations extra range to locate V1 sites was sought by winding up voltage on the transmitter, and by extending aerial arrays. But for V2, to detect a rocket in its momentary appearance en route to the stratosphere, before its supersonic return to earth, could be asking the impossible. The flood-lit curtain, however, could snatch an echo. At the selected CH stations, a camera, and observers on 15 minute shifts, monitored the radar trace continuously, and the information from a number of stations would then be analysed to identify a launching site. (The camera was code named *Oswald* and occasionally a signal would come into Group, reporting *Oswald sick.*) Sadly, there could be no question of giving warning to the quite random point of arrival.

SOME CONCLUSIONS

The Radar Approach: Watson Watt affirmed the "Third Best" theory to direct the urgently needed defensive Chain to practicable development - in time! The plotting was more approximate in height and direction, but excellent in range. German development, to meet different needs, moved direct to higher frequencies. The Wurzburg became the "bowl fire" of photo reconnaissance. Two were needed to control interception, one to follow the bomber and the other the fighter. The display was by an elaborate mechanism that threw spots of light on glass, the Seeburg Table, with great accuracy but less flexibility. I believe the "curtain of illumination" of the Chain, was the ideal for its task of dealing with the massive air attacks launched by the Luftwaffe in its early role of clearing the air for military invasion. When shorter wavelengths were developed, the British went direct to continuously rotating beams painting the map-like picture on the PPI already described (which was never used significantly by the Germans during the war). The move to centimetre wavelengths then continued those techniques with vastly improved quality and have formed the basis of commercial radar and air traffic control today.

There have been some reports that pilots were not happy with losing their "freedom of the skies", and that some followed their own tactics, choosing for instance, a higher altitude than that given by ground controllers for meeting an attack. But as the war progressed, there was growing recognition of the "Boffins" in operational success, and reduction of casualties. Even before the end of 1940, the pattern of development of radar was spreading acceptance of "science" into every operational aspect of the war, and had an influence far beyond the immediate and critical functioning of radio detection.

In his "Three Steps to Victory", Watson Watt has set out some of the comments from reports of the time. "Stuffy" Dowding, Head of Fighter Command**,** reported that RDF "constituted a vital factor in the Air Defence of Great Britain". His successor, Lord Douglas, said that we would not have won the Battle of Britain "if it had not been for the radar chain". Air Vice-Marshall Hart, later Chief Signals Officer at Supreme HQ for General Eisenhower, reported on his interrogation of his opposite number in the German forces. "It was in fact the ability of the RAF to meet the enemy with a force of a size that enabled them to offer combat wherever the enemy came in and irrespective of how many simultaneous and diverse attacks he might make, that made the enemy lose confidence in his own intelligence system and eventually made him lose the Battle(s) of Britain". Sir Arthur Tedder, in more poetic terms, suggested that a monument under Dover skies to the saviours of Britain should have three figures, one representing the young RAF pilots, the second of Lady Houston (for her part in giving us the fighter planes), and the third of Watson Watt.

To link ourselves, and the United States to these assessments, I can do no better than to quote the "father of radar" Watson Watt himself, when he suggested that the Battle of Britain was the most decisive battle - in American history! Now for the final emphasis on the nature of the dark ages that might have descended on us should the Hitler regime have taken over Britain and possibly much of the world, I would like to return to the Brunevald raid of 1942. The German radar operator was captured and brought back to England. While co-operative, he had only limited technical knowledge. The Head of German radar explained in post war discussion that he had only low priority for staff, and not the reserve of skilled people because *Hitler had early banned all amateur radio.* From what indeed did that Victory in the Air save us!

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