CHAPTER 6.

SURFACE DETECTION.

EARLY HISTORY.

The detection of surface objects was first achieved purely fortuitously whilst using type 79 in the early days of air warning sets, when HMS. SHEFFIELD was surprised to find that a large echo at some 7 miles in the scan was caused, not by an aircraft for which they were searching in vain with binoculars, but by a ship on the same bearing.

The fact that it came about as an aftermath to air warning does not mean that it is any the less important. On the contrary, the technique of surface detection has developed just as powerfully as that of air detection, and has played so incalculable a part in the Battle of the Atlantic that it is difficult to see how Britain could have survived without it.

Even on the important discovery that echoes from surface targets could be obtained, the surface warning aspect of it was not the first application.

The potentialities of this from the Gunnery point of view were appreciated, and a ranging panel was fitted to type 79 to assist the Gunnery department. This led, of course, to the design and construction of RADAR sets purely for Gunnery purposes. They could be, and were, of course, used for surface warning as well, though very restrictedly, since it entailed sweeping with the director which, if continued for long, would wear it out.

The development of surface detection sets on 50 cms. for the Gunnery organisation went ahead exceedingly fast. For pure warning purposes, therefore, the only surface detection facilities available were those obtainable from the WA set in big ships, and WC set in small ships. The type 279 in the VALIANT did actually play a big part in the Battle of Matapan.

But it was the cry for a set which could be fitted in small escort vessels to detect submarines on the surface which gave the great impetus in the production of what is known now as our WS, or 10 cm. equipment. The wolf pack tactics of the U-boat, which attacked on the surface at night at full speed, defeated the protection afforded by the ASDIC, and were, no doubt, designed to this end. The production of a means of detecting this menace on the surface, as a complementary detecting device to the ASDIC, was vital. The type 271 came just in time. Such was its splendid performance that it was at once put into production in a mass-produced and pre-fabricated form.

Our escort vessels in the Battle of the Atlantic were the first to be fitted, quite naturally, since the requirement arose in connection with the tactics involved in breaking the ascendancy of the striking power of the U-boat over the defensive power of the escort.

However, the possibilities of this form of equipment applied to every ship of the Navy, whatever its duty, were obviously enormous, and plans went ahead to fit out every unit in the Fleet with some form of surface warning equipment.

Apart from its tactical possibilities in Fleet actions, and actually fighting the enemy, its applications are manifold in such things as Navigation, Searches and Patrols, Station-keeping, Rendezvous, Shadowing, Torpedo-control, Searchlights, Mine-laying and so on. There is hardly a department in the ship which does not derive a new and potent addition to its efficiency from the WS set.

WS EQUIPMENT.

The family tree of the development of the WS equipment has been dealt with in a previous chapter.

The 271, and later 271Q, was an excellent set, and immediately led to an increased number of sinkings. Since the performance in range approximates to the optical, the height at which it is sited is important. Even in a corvette, in which it is sited as low as it ever would be, ranges on a U-boat were usually obtained at 6,000 or 7,000 yards, and slightly greater on E-boats. On bigger surface targets the range of detection is progressively greater, a bearing accuracy of $\pm 2^{0}$ to 3^{0} was also achieved.

The 273, and later 273Q, was the 271 set developed for larger ships. It is fitted with large parabolic aerial reflectors instead of the cheese aerials, which gave quite a large "splay" in the vertical plane. In this way, a more pencil-shaped beam in all planes is achieved. This type of beam is not suitable for ships who suffer from heavy movement, since it lifts off the surface of the sea. In the 273Q, the aerials are stabilised in the vertical plane to get over this disadvantage. This set, fitted in a big ship, gave reliable detection on a U-boat at eight miles, with a bearing accuracy of $\pm 2^{0}$ to 3^{0}, and is clearly an outstanding piece of equipment.

The 272 equipment, as previously stated, was designed to satisfy the requirements of the intermediate-sized ship which wanted a high aerial site, but would not tolerate the topweight. Its performance depends upon the height of aerial achieved, of course, and its power and accuracies are similar to the 271 set. This is now generally obsolete.

As regards the new equipment which is now being sent to sea in quantity: it is designed to give better ranges and better ranging and bearing accuracies, together with a stabilisation of aerials.

The 277 is the most important set, aiming as it does to supersede the 271 and 273. It has greatly increased power, which should give horizon range on any surface object or aircraft at 100 feet or below, a ranging accuracy, using the Sector Selector system, of $\pm$ 50 yards, and a bearing accuracy of $\pm \frac{1}{2}^{0}$. It has a continuously-rotating, variable speed, power-driven aerial, stabilised in elevation and azimuth, feeding in to PPI's and A Display. It has the added facility of being able to stop the aerial rotation on any fixed bearing and elevate it up to 40^{0} for height finding, using an HPI.

For ships which cannot take the weight of a 277 aerial, the 276 has been designed to replace 272. Generally speaking, its technical qualities are identical with the 277, but its aerial system is different. Instead of a paraboloid it has a continuously-rotating cheese to give a greater "splay" in the vertical, since it is stabilised only in azimuth, and therefore lighter. This has the effect of giving better detection against aircraft, and those under 5,000 feet should be detected at 50,000 yards, whilst the same angles and bearing accuracies as with the 277 should be obtained.

The 276 is at present fitted in very many Fleet Destroyers on the trellis mast. It was originally intended to be extempore whilst awaiting the fitting of a 293 designed to replace both 291 and the WS set. Due to the 293 having been adapted to give overall cover between 0^{0} and 70^{0} for target indicating, the ranges for surface detection have proved disappointing. A new 293 aerial, the AQR, has therefore been developed to improve both surface and air performance and this aerial will in due course be fitted in place of all 276 and 293 AUR aerials. The sets thus modified will then be called 293M. The present policy is for Fleet Destroyers to be equipped with both type 293M and also type 291, the latter converted to power rotation to feed PPI displays. Apart from the additional maintenance difficulties, it is really an advantage, since the 291 does give very reasonable surface detection. Should the WS set break down, or be wooded, it will prove an invaluable substitute. This was demonstrated most forcibly in the SCHARNHORST action. The SAVAGE found her WS equipment badly wooded by the bridge structure when chasing the SCHARNHORST, and her 291 gave good detection at 19,000 yards.

Most of the WS sets are also fitted with a ranging panel, upon which accurate range can be obtained for passing through to the Gunnery organisation. This was necessary because certain small ships such as corvettes, have no other Gunnery set for this purpose, and their optical rangefinder is of doubtful value.

Other ships found that their WS sets detected the target quite an appreciable time before their Gunnery sets gave them ranges, and therefore a ranging device with the WS set enabled the armament to tune to the correct range at first detection. The ranging panel L17/18 gave an accuracy of about ± 50 yards.

From the above brief survey of the equipment at the disposal of a ship, its potency to the fighting efficiency both now, and in the future, will be appreciated.

LIMITATIONS OF WS EQUIPMENT.

The inherent inaccuracies of RADAR sets have already been discussed, in WA sets, and they are also similar in a WS set.

Bearing: The weakness in bearing accuracy is less pronounced in the case of a WS set due to the narrowness of the lobe; nor does a slight error in bearing make such an appreciable error in position as it does in the case of a WA set, which works at so much greater ranges. The narrowness of the paint on a WS PPI greatly assists in the reading of more accurate bearings than were previously obtainable on A displays only.

Discrimination: The discrimination of a RADAR set is always a handicap. It should be continually borne in mind that the RADAR set has difficulty in distinguishing on the scan between objects on the same bearing but at slightly different ranges. The set's characteristic in this respect varies with the length of the pulse used. In WS sets using short pulse, a discrimination for range of 100 yards should be obtained, and of approximately 300 yards using the long pulse. This, of course, is considerably better than in WA sets. All WS equipment with the exception of the obsolescent 272 can be operated either on long or short pulse as desired. Long pulse transmission is, however, normal.

Bearing discrimination is the ability to distinguish between targets at the same range but on slightly different bearings. This is dependent on the lobe width of the set, and again is bound to be better in a WS set. The bearing discrimination of a Gunnery set is much improved by beam switching. This will be dealt with in the lecture on Gunnery.

Presentation of target: The detection results obtained on a surface target are obtained from the hull and superstructure, and in much lesser degree from the masts and the rigging, so that the greatest ranges of detection are obtained from a ship beam on. Better reflection is obtained on metal objects than any others, and therefore these will give the greatest detection ranges.

Wave Clutter: As has previously been stated, the height of aerial site plays a large part in the detection ranges obtained. At Gibraltar there is a Naval 10 cm. set which gives a detection range of some 120 miles. It is as well to remember, though, that a greatly increased detection range of this sort often calls for sacrifices in other directions - and in this case the efficiency of nearby detection is seriously impaired by what is known as "wave clutter". This is a phenomenon attributable to echoes from the sea close to, which obscure the first part of the scan, and thus make it almost impossible to pick out big echoes, much less the small ones. Therefore the operational requirements will normally determine the siting of the set, not only from the point of view of arcs of sweep, but also in "height of eye". It is usually easier to follow ship echoes through the wave clutter on a PPI than it is on an "A" display. Wave clutter can usually be reduced by judicious employment of gain or input controls and suppression units where fitted.

Watson effect: The minimum range of detection of a set is very often as important as the maximum, and this is particularly applicable to WS equipment when dealing with the E-boat or U-boat, and also in navigation, where navigational marks such as buoys need to be detected at short range.

As has been explained, the initial part of the beam suffers interference from the ground-wave leak, which in WS sets may extend to two thousand yards, as against four or five miles in the WA set. Even this can be very serious when closing an E-boat or running down a U-boat.

It has been found that, if the echo is strong enough, and the gain control is turned up to maximum, the echo appears in the ground wave as a bright spot hanging on a pendulum, and can be followed, fairly accurate ranges being obtained from observation of the scale marking immediately below the pendulum spot. Best bearing is obtained by noting that bearing of the aerials which causes the pendulum spot most closely to approach the time base. This is known as Watson effect, and is a valuable operational consideration.

Fig. 1

Side Echoes: The back echo usually associated with rod reflectors is not found with a WS set due to the efficiency of the parabolic reflector, made possible by the short wavelength; but an evil does occur in this type of set, in the form of side echoes. This has in the past been caused by physical obstructions in the way of the beam, and has therefore varied in strength as the beam was trained. This has led to the creation of a 271 lantern with no "struts". In later sets, the 277, 276, 293 etc. no lantern is supplied at all, the cheese rotates in the open. Unfortunately, the greatly increased power in the modern 10 cm. sets is now causing side lobes in some strength, and is one of the greatest shortcomings of this type of equipment. A further primary difficulty lies in the construction of a perfect parabolic reflector which will in fact concentrate the radar pulses into a narrow directional beam of energy. A standard has now been reached which nearly approaches this result, but there are still imperfections , and in plan view the transmitted energy can roughly be shown thus:-

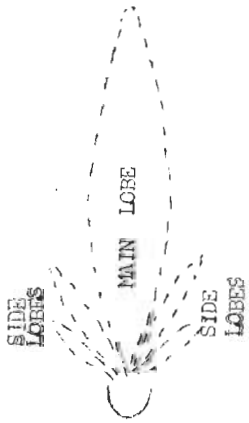

Fig. 2

It creates difficulties for the operator in that he obtains from the nearer objects three echoes, all on different bearings, as the beam sweeps past. A trained operator can usually, with a certain amount of difficulty, pick out which is the real echo and which are side lobe echoes. It is easier to recognise on the PPI., though it tends to obscure the PPI picture with a great many unwanted "paints" and adds to the confusion.

Sweeping: The limitations imposed by the necessity for sweeping are sometimes not realised. It is clearly necessary to sweep slower with narrow beam sets than with wider beam sets when searching under normal conditions, and this leads to the likelihood of picking up a new echo at somewhat less than the maximum range, which is more pronounced in WS sets - though this is, to some extent, counter-balanced by the fact that surface targets do not approach at such a high speed as air targets. When using a PPI, however, the aerials are rotated considerably faster in the case of WS sets, so the consideration of speed of target's approach can really be neglected. It does generally occur, however, that a distant object will produce an echo on an A display earlier than it would on a PPI. Thus if an operator suspects that he has a new echo on the outer range limits of his PPI, his best method of confirming it is to slow down his rate of sweep, or to carry out a hand-controlled investigation of the suspect sector. This slowing down of aerial rotation will make it more likely that the paint will show itself clearly on the PPI. This procedure is recommended only for occasions when commencement of plot at maximum ranges is essential. In general a continuous all round sweep should be carried out if aerials are power rotated, the aerial rotation speed being slower for long range search than for close range tracking.

Identification of target: Though identification has, up to date, proved an extremely weak link in the function of the air and surface plots, a great deal can be done by the operator if he is experienced, to distinguish between the variations in echo which are obtained from land, aircraft and ships, and unwanted phenomena such as meteorological conditions. This is discussed in a later chapter.

Super Refraction and Sub Refraction: The ranging capability of a WS set, though not its accuracy, will be affected by certain meteorological conditions. Conditions in which it is likely that unusually long ranges will be obtained are:-

1. Prevailing calm or light winds.
2. Clear or only partly-clouded skies.
3. High or fairly high relative humidity.
4. Atmospheric conditions conducive to very good visibility coupled with high sea surface temperature.

Reduced ranges may occasionally be encountered in maritime waters under such conditions as low lying fogs. For instance, the majority of reports of sub refraction emenate from ships operating in the area N.E. of Canada's maritime provinces and off Newfoundland.

TACTICAL APPLICATIONS GENERALLY.

Though the surface warning set does not give the same warning range as an air warning set, it is none the less valuable. The greater warning range is naturally required with the aircraft, since it travels more than ten times the speed of surface craft. It is fortunate, in fact, that it is this way round.

Low visibility: It is during the night and low visibility that the WS set comes into play. The uncertainty of fighting in these conditions is liable, under previous circumstances, to make the result more dependent upon luck than skill, and for a period it was the policy of the British Fleet to avoid action in such conditions. The escape of the German Fleet after Jutland is a typical example of how night may benefit the weak. It is interesting to speculate how Jutland would have ended had our Fleet been fitted with RADAR in those days. Compare the escape of the German Fleet on this occasion with the recent destruction of the SCHARNHORST, and something of the advance which has taken place and the reason why the British Fleet now has nothing to fear from night action, and actually seeks it, may be understood more readily.

THE SCHARNHORST: This important action demonstrated to the full how the surface warning set in the DUKE OF YORK enabled that ship not only to place herself in the most favourable position for engaging the enemy, but also to enable the whole Gunnery Control system to function smoothly - every man on his toes in readiness for the moment. In the words of the Official Report of this action "the order to open fire was awaited with some confidence", and indeed with some justification, since the illumination of the SCHARNHORST revealed her guns fore and aft. It would be difficult to overestimate the value of this classic example of complete surprise achieved by RADAR.

The Tactical Plot: Unlike the Fighter Direction Plot, the Tactical Plot is not new. It has been developed considerably since the last war, when it was realised that the British Fleet was fighting at a disadvantage at night through a lack of it. The need for an up-to-date picture to show the Captain, based on all information available, was felt then with a force equal to the overpowering need felt now for the Action Information Centre, following on the vast increase in volume and accuracy of intelligence deduced from RADAR.

The Tactical Plot previously has been supplied almost entirely by enemy reports from aircraft and surface craft by day, and surface craft by night; as a result, the picture has been difficult to interpret, due to errors in navigation on the part of various units reporting. The use of the reference position was designed to get over this. Furthermore, a great deal of enemy reports have in the past been based purely on eye estimations. RADAR, of course, has altered all this and generally tightened up the accuracy of the picture. In fact, the WS RADAR set produced a sudden and altogether astounding increase in the volume and accuracy of the intelligence supplied to the Tactical Plot. It has extended the eyes of the Fleet in such a manner that night is being turned into day; and what RADAR lacks in identification obtained from the human eye is more than counterbalanced by the great accuracy of the plot produced. Small wonder, then, that a greatly expanded plotting organisation is now being developed - with the advantage of a skiatron display coupled to an A.R.L. Automatic Plot. The Action Information Organisation and the Auto-RADAR Plot are dealt with in some detail in an earlier chapter.

In the not too distant future, fighting will be carried out at the maximum range of the weapon, whatever the visibility. Such is the advance in fighting technique which is being made.

The Plot Officer in the Bridge Plotting Room has a duty very similar to the Air Plot Officer in the Air Direction Room, inasmuch as he has to keep displayed an up-to-date filtered picture of what is happening for the Command, and if possible, forecast situations which may develop. Co-operation between Bridge and Plot is, of course, vital, and should need no emphasis.

It is the duty of the Action Information Organisation to feed all departments of the ship with information they require, whether it is Navigation, Torpedo-Control, Gunnery Control or ASDIC. Each one has its own special call on RADAR warning of the surface target, and arrangements are being made not only to give that warning in each case, but also the subsequent tactical assistance, in the form of continuous range and bearing which might be required to effect accurate blind fire with torpedoes or guns - or the ramming of a U-boat on the surface.

Action on obtaining an echo: On a new echo being obtained which cannot immediately be identified, it will probably call from the Captain or Officer of the Watch a decision as to whether immediate counter-attacking action should be taken or a policy of holding off until the position clarifies itself. In the first instance, it is necessary to avoid running down the target before either its movements can be ascertained for certain, or own ship has been brought to the necessary degree of readiness; and in the second case, it will be necessary to avoid losing touch and do everything possible to assist the RADAR operator to obtain good RADAR results. The initial action will usually, therefore, be to put the echo on a relative bearing which will cut down the closing rate and give time for the development of an accurate plot. Only in this way will it be possible for further action, whether it be investigation shadowing, avoiding or attacking, to be decided on and to be implemented.

It may often occur that the only action to take is to run towards, or perhaps away, immediately, and not adopt the "softly catch monkey" tactics as outlined above; as for instance, when a U-boat or E-boat appears very close and constitutes an immediate and dangerous threat to the convoy or force being protected. Usually the action taken here is more calculated to be instantaneously obstructive than setting in motion the apparatus for the calculated destruction of the enemy.

It now remains to take the numerous applications of surface detection and examine them in more detail.

Summary: To sum up: though this equipment has provided a most vital asset to our Fleet and plays an invaluable part in giving rest to Commanding Officers and crews - it must also be remembered that the Fleet does continually get scares and disturbances which come to nothing, and must be counted on the debit side; furthermore, let us not forget that RADAR often breaks down or becomes inoperative for one reason or another. No relaxation on the part of lookouts and their training can be tolerated for a second.

Finally, RADAR has caused us to examine old problems afresh and under a new light, and these will be discussed later in the lecture; but it is true to say that, amazing though the advance has been due to RADAR, it has not in fact as yet altered the Basic Tactical Doctrines to which officers have been brought up.

SHADOWING.

The general requirements of a "shadower" are to keep the enemy under accurate and continuous observation without coming within effective gunfire. Until the arrival of RADAR, this was a tiresome and very often painful duty to undertake. The difficulty was to appreciate as early as possible any alterations in course and speed of the enemy from a range which was outside gun range. It usually resulted in the shadower varying rapidly between being too far away or too close, due to the slowness with which the human eye appreciates changes in range.

RADAR'S assistance: The RADAR set, of course, gives just what is required - a rapid indication of any change of range, though rather slower in change of bearing. A continuous study of the RADAR display therefore, is the complete answer to shadowing. Shadowing history was, in fact, made when SUFFOLK shadowed the BISMARCK. Here was an instance when the Captain spent a very large percentage of his time in the RADAR office - which is a good pointer at the sign of the times when speculating as to the position of the Captain in a ship fitted with an up-to-date Action Information Organisation.

The trouble which bothered the SUFFOLK, of course, was that the only set at her disposal for shadowing, at that time, was the 284, which, due to its limited range, placed the SUFFOLK within gun range. The new WS equipment gets over this trouble, at any rate for a cruiser shadowing the enemy's heaviest ship. This, again, was clearly borne out in the recent SCHARNHORST action.

Shadowing positions: After a preliminary identification, RADAR therefore enables the shadower to carry out her mission probably outside enemy gun range and frequently outside visibility distance. The job is made easier if other friendly vessels keep either well inside, or well outside the RADAR range of the ship making the first contact.

The best shadowing position to take up is dictated by a number of considerations. It can equally well be carried out from any position from which the RADAR set will bear; but as the RADAR set is more accurate for range than for bearing, an alteration of course will be appreciated sooner when shadowing from the beam, and an alteration in speed when shadowing from astern - but this factor is insufficiently marked to over-ride other considerations.

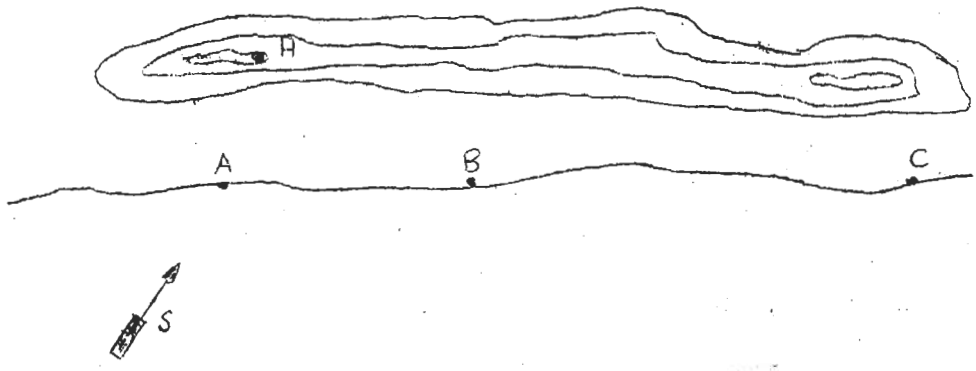

Fig. 3

many days at sea without sights. The RADAR operator reports to his navigator a strong land echo on the port bow, at some 20 miles distant. The tendency is for the Navigator to show signs of relief that he is approximately where he estimated he was, and assume that the echo obtained was from a position "A". In actual fact, of course, there is no reason why it should be position "A" at all - the echo might have been obtained from "B" or "C". Unless the echo is obtained from a prominent and therefore easily recognisable landmark, such as the Wolf Rock or Eddystone Lighthouse, it is impossible to say exactly whence it originates. It is a great temptation to assume it comes from the place from which it is hoped to come. This difficulty is being alleviated to some extent by the institution of shore beacons at suitable places in the world where landfalls are likely to be made. This enables the Navigator to enjoy the advantages of identification, since each beacon has its own characteristic response, and its exact navigational position can be found in the appropriate publications.

RADAR Beacons are dealt with in detail in another chapter. Even though the shore RADAR Beacon helps considerably, the Navigator may continue to be in difficulties in areas where no beacons are sited - and of course, when using RADAR to assist him in reconnoitring enemy coasts.

The next snag that arises is due to the inherent tendency for a RADAR set to reject the lowland and pick up the high land more readily. In WA and WC sets this is very pronounced but even in WS equipment there is a likelihood of such occurrence at extreme ranges. That being the case, it is quite possible that in the example chosen, the echo which "S" obtained was actually from the hill "H", and that the ship in actual fact therefore, was considerably closer to the shore than she imagined.

PPI Advantages: The advent of the PPI has, of course, added a fillip to the use of RADAR for navigation. The effect of the RADAR beam sweeping through a piece of coastline is to cause a portion of the PPI to be "lit up" and in this way the revolving time base of the PPI paints onto the fluorescent face of the PPI a picture of the coastline, adjacent islands, shipping, and other RADAR reflecting objects.

The surface warning sets set up ashore for working across the Channel along the South and South-east Coast, pain a clear picture of both sides of the Channel, and all land which is within range of the set.

This valuable asset is used in the RAF for blind bombing. A set called H2S is employed, and a modified version called 970 has been adapted for use by Landing Craft in the Navy. The success of an amphibious operation depends largely on accurate timing by, and positioning of, the landing craft. Usually an enemy coast is not abounding in prominent navigational marks visible at night, and furthermore, the landing craft themselves have no great facilities for accurate navigation, and the 970 is proving an invaluable substitute.