An ingenious method has been adopted in the LCT(R)s of enabling them to project their rockets into the required area. The rockets themselves are mounted with a fixed elevation, and therefore employ a fixed range. Thus it is an entirely navigational problem to fire them accurately.

The method adopted is to superimpose over the face of the PPI of the 970 a talc disc, on which is drawn a picture of what the time base will itself paint onto the PPI face on the morning of the attack, from the exact position for firing, having regard to the height of the tide. The LCT(R)s then navigate in such a manner as to make the real coastline painting coincide precisely with the synthetic one at the required moment, which is the moment to fire.

PPI disadvantages: The PPI is not easy for the uninitiated to interpret at the best of times, and when employed for navigational needs the user will require some training. Side echoes and wave clutter both tend to make the picture more difficult to interpret. In addition, the picture of the coastline may look considerably different from the coast itself, due to the fact that the width of the beam smears the fine detail and to the fact that prominent objects tend to mask smaller objects behind and below them. Finally the physical length of the transmitted pulses will also smear finer details in range on the PPI. Hence RADAR transmission on short pulse will at close range give a clearer PPI picture than when long pulse transmission is being employed.

With normal conditions, objects which lie below the visible horizon (viewed from the aerial height above sea level) will not appear on the PPI. The PPI may not give an accurate representation of the charted coastline, particularly at long range, and when the terrain has only a small slope at the coastline and a steep slope further inland.

With practice it should be possible, by studying the chart, to estimate in most cases what objects should appear on the PPI and in what form; also whether the shore line is being truly exhibited. Factors tending towards accurate presentation are:-

a) Large aerial height.
b) Steepness of slope of ground.
c) Shortness of RADAR wavelength
d) Large RADAR power.
e) Short range of objects shown on PPI
f) Narrowness of beam width.
g) Shortness of pulse length.

When in doubt as to whether the actual shore line is being shown, a comparison between the ship's estimated rate of approach, and the apparent rate obtained from the PPI may show that the latter is greater. This would mean that new echoes from points nearer to the shore line are appearing on the PPI as the range decreases, giving the impression of a greater rate of approach. When the apparent rate of approach equals the estimated approach rate, it is probable that the actual shore line is being shown on the PPI. It must still be remembered, however, that if there is a very low beach without much slope it may not show on the PPI at all.

For navigational purposes distinctive features such as islands are very helpful, but it must be remembered that if the ship's position is such that an isolated object such as an island or another ship gives a very large echo, it may well appear on the PPI as three separate objects at the same range, but on different bearings. In extreme cases the three images may coalesce into a single long arc. The true bearing is the bearing of the central object (or centre of the arc), and the effect can be distinguished from three genuine echoes at the same range by reducing the gain of the set, which causes the disappearance of the two outer images before the central image is lost.

The beam width of the RADAR transmission prevents objects being shown to their true size. Echoes will extend for about half the beam width of the transmission on either side of the limiting bearings of the actual object. This must be borne in mind when reading bearings of a tangent of a land echo depicted on the PPI. For example, if half the beam width is four degrees and the bearing of the right edge of an echo on the PPI is 024°, then the true bearing of the actual tangent would be 020°, but this is not necessarily the right hand edge of the land, since there may be low lying land to the right of the land detected by the RADAR.

By the same beam width distortion, the bearing or cut off at the end of a peninsula observed from a position roughly at right angles to its length will not be correct, as the beam will continue to produce a paint on the PPI when its centre line is, in fact, pointing out to sea beyond the peninsula.

The shortcomings of the PPI are perhaps better appreciated if it is kept constantly in mind that the plan presentation is not the product of the eye at, say, two thousand feet - that is purely an illusion. It is the production of the eye, or the beam, sweeping in the horizontal plane, at aerial height above sea level.

The untrained may therefore find it difficult to interpret the PPI, but with practice a reasonably accurate impression of what the coastline is actually like can definitely be gained.

Minelaying.

The use of RADAR, mostly navigationally, has recently been of some importance in minelaying operations. It has been stated by Commodore (M) that the application of RADAR to the navigational and tactical problems involved has enabled a considerable advance to be made in minelaying operations, particularly in low visibility and fog, in which several lays have recently been successfully completed solely by the use of RADAR. Without it they would have been impossible.

Apart from the normal function of RADAR, such as giving warning of approaching surface and air targets, it has particularly important uses for minelayers in obtaining an accurate departure fix for tautwire measurement when shore marks are obscured. In locating the vessel, standing by the mark beacon, on the finding of which the accuracy of the lay very largely depends, and in enabling the squadron screen to maintain accurate station when out of sight of each other, thus increasing the safety of a very dangerous operation.

Bombardment

Another navigational application of RADAR is its use in bombardment. The accuracy of an operation of this sort is almost entirely dependent upon navigational accuracy, and therefore RADAR has helped to find the target more rapidly, which of course leads to a reduction in the time during which a bombardment force needs to be in the area.

A very interesting report from USS WICHITA on the performance of her RADAR during the bombardment of Kiska, lends support to the useful employment of RADAR for bombardment. She reported that RADAR navigation by the method used proved to be well within the required limits of accuracy. It is believed that the same bombardment run,, or any other bombardment run, could be made in dense fog or at night, safely and effectively, with no means of navigation except RADAR.

She also stated that the assignment of alphabet letter assignations to all prominent land points and possible RADAR navigational targets, was found to be extremely useful, and is strongly recommended for all RADAR navigation. Such accurate designation eliminates the necessity for lengthy and time-consuming discussion between Navigator and RADAR operators as to exactly which target the RADAR is on.

Navigational assistance from shore.

Before leaving the pure navigational aspect of RADAR, it is worth mentioning the value of shore RADAR sets for assisting ships in their coastal navigation.

Any ship navigating close to the British Isles can signal to the local Operational Authority for an estimate of her position when in doubt. If there are a number of vessels in the vicinity it may be necessary for the ship in question to use her IFF to assist the shore stations. There have been occasions when the shore RADAR stations have been able to warn ships that they are standing into danger, without any application from the ships themselves. A typical instance occurred off Duncansby Head when an HM ship was proceeding to Scapa, and appeared not to have made the statutory allowance for tide. As she was heading for the shore, the Naval Operations Room ordered the Duncansby Head lighthouse to be switched on, and disaster was thus averted.

This led to an extension of this practice, and it was found possible to direct ships into anchorages and harbours when they were uncertain of their position, due to fog.

Again a further application developed which enabled HM ships to be directed from shore to suspicious echoes, and amounts to a form of Fighter Direction without the third dimension. This is applicable to both offense and defence. An example of the former is the vectoring of our coastal craft on to enemy convoys on either side of the Channel; and of the latter in assisting a vessel patrolling an area such as the Straits of Gibraltar to intercept suspicious objects attempting a passage.

This system can be extremely useful for the protection of shipping and beaches. Several surface warning sets are landed, together with suitable plotting arrangements and an operations room. To a certain extent they will offset the danger of not having boom defences in newly-captured harbours.

Station-keeping and Rendezvous.

The tendency to employ the RADAR set for station-keeping on all occasions must be resisted. The RADAR set breaks down, or it may perhaps be unpolitic to use it. The Officer of the Watch therefore must be capable of using his normal station-keeping devices, and above all he must train his eye so that he can meet strange situations with confidence. This naturally does not mean that the RADAR set should never be used for station-keeping. It will, on occasion, prove extremely useful, particularly when carrying out difficult and dangerous manoeuvres in low visibility.

Indeed, manoeuvres which hitherto were thought not only to be dangerous, but impossible, are now mere child's play. Instances are too numerous to catalogue. Convoys are being left and joined in thick fog as a matter of routine. The following report of a meeting at Westomp by SC.86 is typical:-

"This was accomplished in a visibility of about 50 yards. Before the days of type 271 it would have been deemed miraculous. As it was, without any difficulty and in perfect safety the group was led in from astern at 12 knots, and dispersed to their places on the screen as HESPERUS continued through the convoy, greeted the Commodore on the loud-hailer in passing, and arrived alongside WALKER's port quarter for the convoy documents on a Coston Line. HESPERUS then went back and collected the two ships from Champly, 15 miles astern. Watson effect was used while steaming through the convoy".

ANTI-SUBMARINE APPLICATIONS.

The three main A/S detecting instruments are H/F D/F, Radar and Asdics. These operate at relatively long, medium and short ranges, but they are complementary, and where all three come into play the target must be passed from one to the other. Thus an A/S escort may move out on the evidence of H/F D/F bearings, gain contact and close by RADAR until the U-boat dives, and carry out the final attack by ASDICS, or alternatively if the U-boat does not dive, but remains surfaced, certain ships can use their RADAR to control "SQUID", or supply accurate ranges to enable fire to be opened with "SHARK".

Special consideration affecting the use of RADAR for A/S warfare: The following are the special considerations which affect the use of RADAR for A/S warfare:-

Range. The U-boat is about the smallest target which RADAR is required to detect operationally. Typical ranges obtainable by sets fitted in A/S vessels are:-

Type	Where fitted and Aerial Height.	Range in yards.	
		Maximum.	Reliable.
277	Frigate (30-40 feet)	12,000	9,000
276	Destroyer (70 feet)	12,000	9,000
293	Destroyer (70 feet)	10,000	7,000
	A/A Sloop (70 feet)	10,000	7,000
271Q	Destroyer, Frigate, Corvette (30-40 feet)	8,000	6,000
272P	Destroyer (70 feet)	6,000	5,000
	Sloop (35 feet)	5,000	4,000
SG	Frigate (75 feet)	9,000	7,000
SL	Frigate (75 feet)	11,000	9,000

The reliable ranges should always be obtained under good conditions; the maximum range of detection, however, may in some cases be greater, as shown above. Under poor conditions, e.g. rough weather, interference from side lobes, etc., the reliable range may be considerably less.

Ground wave and sea returns: At very close ranges, during the final stages of the attack, or in the event of a U-boat surfacing inside the screen, difficulties may be caused by the ground wave, and on a rough day by wave clutter. These can be reduced considerably by using short pulse, and reducing the receiver gain or PPI input, and accepting temporary loss of detection of more distant targets. It will be found easier to follow the target among the wave clutter on the PPI than on the A scan. Should the target enter the ground wave, however, it will be necessary to make use of Watson Effect on the "A" scan.

Discrimination: While searching for U-boats, whether on "A" scan or PPI, long pulse length and ample receiver gain or PPI input should be used since these give the maximum detection range. After detection, however, as the attack develops, trouble is frequently experienced from side echoes, blind areas, etc., caused by ships of the convoy, or other hunting vessels. Under these circumstances better discrimination will be obtained by switching to short pulse length and/or turning down the receiver gain or PPI input (type 272P has only one pulse length).

Side Echoes. With powerful modern centimetric sets such as types 271Q, 276, 277 and 293, other ships may give side echoes at ranges which approximate to the first detection range of a U-boat. This, naturally, may well lead to confusion. Therefore when a new echo is detected with these sets at close ranges (i.e. less than 10 - 12 thousand yards) the radar operator should invariably check for side echoes. Checking for side echoes is, of course, greatly simplified when using PPI as opposed to "A" display.

False Echoes: False echoes, whether from rain, birds, waves, etc. most frequently occur at short range, and again may cause confusion. They should soon be apparent for what they are by the intermittent type of echo or by plotting their movements. It will be seen, therefore, that there is a need for starting a RADAR plot at the earliest possible moment after first detection.

Radar Decoys, (Balloons and Spar Buoys): These are used by U-boats to mislead escorts and the maximum ranges of detection of these decoys may compare favourably with the maximum ranges of detection of U-boats. One of the easiest ways of identifying these decoy echoes as such is by plotting. The spar buoy will invariably remain stationary; the balloon will drift down-wind at approximately half or two-thirds wind speed. This again emphasises the need for starting a RADAR plot as soon as possible after first detection.

Schnörkel: In an effort to avoid detection by RADAR, U-boats are making use of this device to enable them to use Diesels for charging batteries and/or proceeding at slow speeds without surfacing. Maximum detection ranges of Schnörkel are small (in the region of 3,000 yards) and unless under very good RADAR conditions may well be detected by eye first. In this connection, to avoid confusion with side echoes, it is advisable where possible for escorts to be stationed more than 3 - 4,000 yards apart. The detection of Schnörkel will call for great alertness on the part of the RADAR operators. It should be remembered that this device invariably has a search receiver which, although not at present capable of detecting 10 centimetre transmissions, is able to pick up transmissions from type 242 or 291. In view of the large number of small echoes obtained at 3000 - 4000 yards, each "possible" Schnörkel echo should be confirmed by ASDICS, using hand transmissions if outside 2,500 yards, and closing if necessary.

The identification of U-boat echoes: Owing to comparatively short range of detection of U-boats there is very little time in which to establish the identity of a new echo which is not showing IFF. Apart from the possibilities of decoys, false echoes, etc., the points to be considered are:-

(a) Whether U-boats are known to be operating in the area.
(b) Evidence from H/F D/F or ASDICS
(c) Sighting by aircraft etc.

If U-boats are known to be about, an unidentified echo first detected at the appropriate range must always be assumed to be a U-boat until proved to the contrary.

The requirement for rapid echo identification and the particular difficulties of achieving this in Anti-Submarine warfare emphasises the need to keep the RADAR operators fully informed of the position of ships in company (and any changes), so that they may more easily spot a new echo. They should also be givendetails such as the present course and speed, and any other information including future movements likely to be of assistance to them. A mooring board or similar plotting device on which to note the ranges and bearings of other ships in company, convoy, etc., should be provided in the RADAR Office, so that they can have an up-to-date picture of the situation at all times.

Stationing and conduct of Anti-Submarine Escorts: The capabilities of the RADAR equipment fitted will be a major feature in determining the stationing of escorts or the type of anti-submarine screen to be adopted. This applies particularly at night or in low visibility. Other considerations such as Asdic frequencies, fitting of H/F D/F, number of escorts, etc., must also be taken into consideration. From a purely RADAR aspect, it is possible to extend the distance between escorts to twice the reliable detection range of a U-boat, taking into account prevailing weather conditions. The limitations of the equipment fitted in certain ships must, however, be remembered, e.g. certain destroyers have their WS equipment blanked on a forward bearing by the bridge superstructure and funnel, etc., while in other ships there is a blind arc aft. Type 271Q, 272P are not convenient sets to operate over an astern sector because of the position of the aerial stops.

<u>Action on obtaining suspected U-boat echo</u>: The action taken by an escort on obtaining a U-boat echo will naturally be governed mainly by the situation in which the ship finds herself. One of the main considerations however is the need for starting a RADAR plot as soon as possible after initial detection.

The contacting ship will normally close the suspicious echo at maximum speed until within ASDIC range (having due regard to Gnat precautions). When within ASDIC range if the U-boat has dived speed should be reduced and an ASDIC sweep commenced either side of the last known RADAR bearing. If the U-boat does not dive, however, action using the SQUID or SHARK will normally result. In either case, accurate ranges and bearings from the RADAR will be required.

<u>Other Escorts:</u> Until the echo is identified as that of a U-boat, other escorts are unlikely to take action other than moving across to cover the gap caused by the contacting ship moving out to investigate. Once the identity of an echo has been established as being a U-boat, the resulting action will conform to "Group" or other local orders.

<u>Detection of a U-boat by aircraft:</u> In this case, provided the aircraft can reach the position of the U-boat while it is still surfaced or within 15 seconds of diving, the aircraft will normally carry out an attack. In any case, if surface ships are in the vicinity the aircraft will endeavour to home or direct them to the scene of the action.

The main method of achieving this, is for the ships to home on to the aircraft's IFF. The aircraft should be showing IFF Code 4 (see C.B.04092, Selection 13, paragraph 2(b)).

<u>Types of Sweep:</u> In order to get sufficiently accurate ranges and bearings for plotting purposes it will usually be necessary to "hold" a U-boat contact, thus sacrificing all-round warning. This will be especially applicable if it is required to use RADAR information for the control of "SQUID" or "SHARK". At the same time, however, provision should be made for another ship to continue the all-round sweep or for own ship to carry out an occasional all-round sweep for the purposes of:

(a) Detecting any other U-boat which may be in the vicinity.

(b) Confirming the position of other ships relative to own ship, and convoy, etc.

Due regard should be given to the fact that U-boats are fitted with Search Receiver capable of detecting our RADAR transmissions, and therefore in order not to give away the fact that he has been detected, it may be necessary to continue the sweep while closing the contact.

Except when necessary to hold a specific target, an all-round sweep is recommended. Sector sweeping however, may be used under special circumstances. With new sets (276, 277, 293, SG, etc.) continuous all-round sweeping is the normal procedure, using the best rate of sweep for surface detection, i.e. 4 r.p.m. for 277, 7½ r.p.m. for types 276 and 293. Sector sweep should only be employed when it is desired to obtain the maximum range of detection over a small arc, i.e. if the U-boat's approximate bearing is already known. Even under these circumstances, however, an occasional all-round sweep should be ordered, for reasons given above.

The decision whether to order an all-round or sector sweep should be based on the following considerations:-

(a) If there is a chance of a U-boat surfacing inside the screen, an all-round sweep should be ordered.

(b) If the number of escorts is inadequate to form a complete RADAR screen, an all-round sweep should be carried out.

(c) If sufficient escorts are available to form a complete RADAR screen, and the chances of the U-boat surfacing inside the screen are remote, the use of a sector sweep should slightly increase the initial range of detection.

(d) When by virtue of proceeding at high speed there is no necessity for sweeping over an arc astern naturally a sector sweep on the ahead bearings should be used.

In all cases, where sector sweeping is employed, the method should be the same as for ASDICS, i.e. from aft to forward, using a bow overlap of 20° except when the arc of sweep extends to less than 40° on the bow, when it is permissible to sweep from forward to aft.

With hand-trained sets (271Q, 272P, etc.) the rate of sweep should normally be 180° a minute in calm weather under good conditions, and approximately 90° a minute in adverse conditions or rough weather, and when investigating an arc. With these sets, if fitted with PPI, the rotation speed should normally be about 360° a minute, in this case sweep being continuous from aft through ahead to aft again, alternately clockwise and anti-clockwise.

Range Scale to use: The 15,000 yard scale should normally be used with all types of WS equipment for anti-submarine work. This gives the best discrimination and accuracy, and a U-boat is unlikely to be detected outside this range even under conditions of anomalous propagation. It is necessary, however, for an occasional sweep on the 75,000 yards scale to be carried out in order to detect any larger targets which may be in the vicinity.

Co-operation with Asdics: As, in anti-submarine warfare we are dealing with targets which may submerge or surface at will, it is necessary for the closest co-operation to exist between the ASDIC and RADAR offices. This should be achieved either by direct voice-pipe or via the operations room or bridge.

Radar Control of A/S Weapons.

Control of "Squid": In order to allow the "Squid" to be fired at a surfaced U-boat on which the ASDIC may not be able to gain contact, developments have been going forward which now enable RADAR to supply the necessary information to the special ASDIC instruments, namely the Range and Bearing Recorders.

To achieve success with the SQUID it is necessary to have accurate ranges and bearings, plus accurate rate of change of bearing. If RADAR can be made to supply accurate ranges and bearings of a U-boat at short ranges to the ASDIC instruments, they will automatically convert these into course to steer and deflection, and fire the mounting at the correct range. In order to achieve this, a new Radar Range Transmission Unit has been brought into being. It is the Outfit RTC, and is really a modified version of Outfit RTA.

RTC can only be fitted in ships which have RADAR types 271Q, 276, 277 or 293. A spot strobe is used in RTA for all range scales, but in the RTC the long range scale is converted into a 3,500 yard scale, and has a step strobe. The medium and short range scales remain the same. On the 3,500 yards scale the ground wave extends for approximately 200 yards, perhaps slightly less. To obtain best range discrimination short pulse length should be used, and with this an accuracy of ± 5 yards range and ± 1° bearing should be achieved at 400 yards.

As RADAR range is to be superimposed on the ASDIC Recorder it is necessary to have the RADAR and ASDIC ranges calibrated together. Further, in this calibration an allowance must be made for distance, RADAR aerials to mounting or gun, and in order to avoid changing the setting up of the ASDIC Recorder the allowance normally made on RTC should be equivalent to distance, ASDIC Oscillator to RADAR aerials. One method of calibrating the RADAR to ASDIC is to employ an O.A.S. target, or a submarine, towing buffs fitted with RADAR Reflector.

Ranges and bearings are transmitted from the RADAR office to the ASDIC office by "M" type transmission, and automatically mark the Range and Bearing Recorders. When in RADAR control, the RADAR aerials control the training of the ASDIC Oscillator and this in turn, naturally, controls the stylus on the Bearing Recorder, which under these conditions have a continuous potential on them. As far as range is concerned, this passed through a range attachment known as "Transmitter, Range, RADAR/ASDIC". This instrument causes the Range Recorder to be marked at the correct range, through the medium of the stylus. Thus, with an operator sweeping across the target the Bearing Recorder will mark with a continuous weaving line. The Bearing Recorder Operator should adjust his lines of light to the mean of this trace. The Range Recorder will continue to be marked in a similar manner to when ASDICS are supplying the range, and the drill for the Range Recorder Operator will remain the same. A changeover switch is situated in the ASDIC Office to control whether ASDIC or RADAR information shall be used on the Bearing and Range Recorders.

The fact that the RADAR aerials control the movements of the ASDIC Oscillator ensures that should the submarine dive, and the target be lost to RADAR, the ASDIC Oscillator will be on the correct bearing and contact should be gained by ASDICS almost immediately, thus not upsetting the attack. The changeover switch also sets the automatic fuzing of the SQUID to shallow, thus SQUID projectiles should explode in very close proximity to the U-boat.

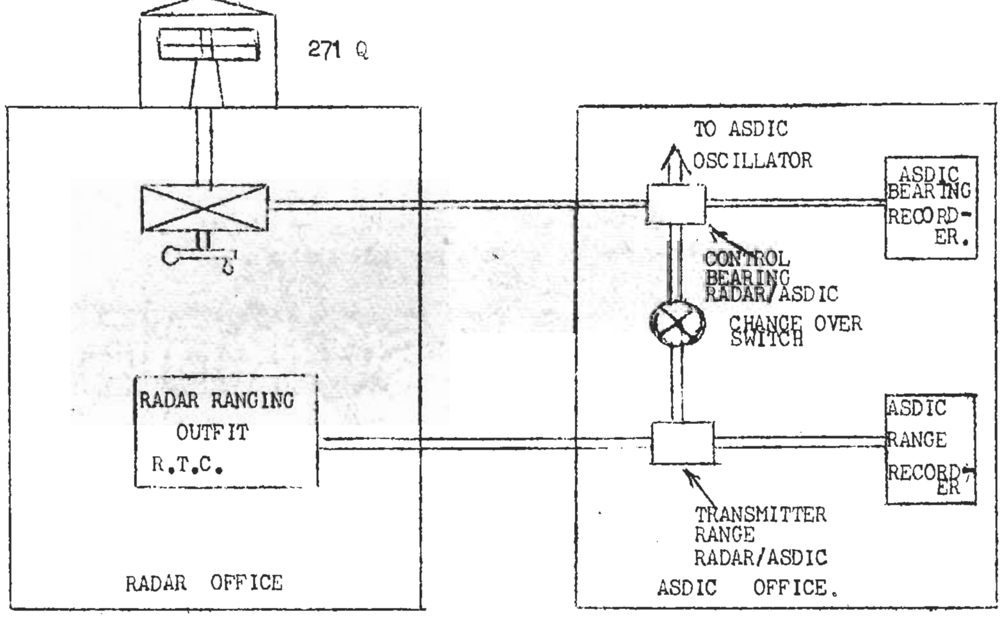
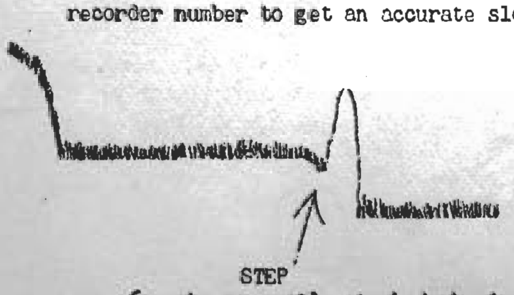
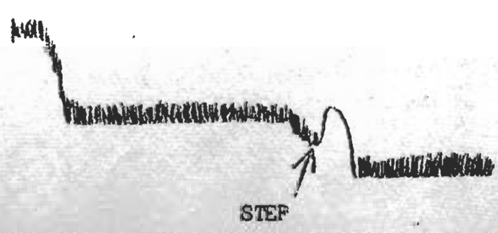


Fig. 4 Schematic Layout.

RADAR operators should be instructed to work on the short pulse length and as the echo grows, to reduce the gain in order if possible to maintain an echo amplitude of about 6x. The echo should be kept strobed as shown in the diagrams below. It will be noted that the smaller the echo, the greater the "nick" between the strobe and the echo should be. In the case of bearing, operators should be instructed to sweep steadily across the target, taking care not to wander too far off on either side, otherwise an irregular trace on the Bearing Recorder will result, and it will be difficult for the recorder number to get an accurate slope.



6x echo correctly strobed showing just a "nick" of step strobe before echo.



Small echo correctly strobed showing slightly greater "nick" between step strobe and echo.

Control of SHARK: The "SHARK" projectile has been designed specifically for use against surfaced U-boats, instead of the ordinary type of shell. It is specially designed so that at short ranges and low trajectory it will not ricochet but continue its trajectory straight into the water. Thus if this missile can be made to land just short of a surfaced submarine it should strike the pressure hull, causing lethal damage. To achieve this naturally calls for accurate ranges. Outfit RTC can also be used to supply these, and in this case a five yard step drum range receiver is fitted at the gun; thus accurate ranges should always be readily available to the Officer of the Quarters. If a ship is fitted with "SHARK" and "SQUID", the one RTC will cater for both weapons.

TORPEDO APPLICATIONS.

The Torpedo Control Problem.

The RADAR requirements for Torpedo Control differ in several respects from those for Gunnery and are chiefly influenced by the comparatively low speed of the torpedo, which is of the same order as that of its target.

Except at very short ranges, the torpedo must be fired from a position from which the rate of approach of torpedo and target is high and the track of the torpedo crosses that of the target at a broad angle. These requirements can only be met by firing from a position on the bow of the enemy.

Thus, successful torpedo fire depends, firstly on the achievement of a suitable firing position. Secondly it requires a correct estimation of the probable movements of the enemy during the run of the torpedoes in order that the salvo or zone of torpedoes may be directed to cover the enemy's probable action to as wide a degree as possible.

The Local Operations Plot: The problem is thus largely one of tactical appreciation and the primary requirement is for a picture of the tactical situation in the form of a plot. This is most effectively provided by the Local Operational Plot, derived mainly from RADAR sources.

During the approach, the information required from the plot may be summarised as follows :-

(a) A general tactical picture to assist in the selection of the torpedo target and of the most suitable firing position.
(b) The course or courses to steer to achieve this position.
(c) An early indication of the probable line of fire to ensure the safety of friendly forces.
(d) A picture from which to forecast the enemy's most probable future movements.
(e) An accurate estimate of the enemy's present course and more particularly his speed.

The line of sight: The only remaining requirement is a fairly accurate bearing of the enemy at the moment of firing. This is obtained by the Torpedo Sight or Binocular if the enemy is visible. For blind fire, a RADAR line of sight is required and is obtained from the PPI presentation of the Warning Surface RADAR.

The degree of bearing accuracy from this source is sufficient for all practical purposes, and, since the more accurate Gunnery RADARS may, and most probably will, be directed at other targets, the WS set has been selected to provide the line of sight.

Controlled fire at night: Before the introduction of RADAR, night torpedo fire from destroyers in company was a matter for individual estimation in each ship. The sudden appearance of the enemy at close range allowed no time for a considered plan and as a result, torpedoes were fired haphazard, no attempt to co-ordinate the fire from individual ships being possible.

RADAR has provided the means of estimating the enemy's movement before sighting and improvements in R/T communication, the means of directing the fire from a formation of destroyers or cruisers for a preconceived plan.

Blind fire: In certain circumstances, blind fire at long range may offer better chances of success, particularly against an unsuspecting enemy, than close attack within visual range.

The decision to adopt this policy must be dictated by the tactical situation, always bearing in mind that the shorter the range, the shorter is the time available to the enemy to take evasive action.

Torpedo Control Installations: The development of RADAR has resulted in the following changes to existing Torpedo Control Installations.

(a) The removal of the calculating portion of the Torpedo Control Equipment to the Operations Room, to facilitate the calculation of settings at night, leaving the actual sight in the external control position.

(b) The installation of direct communication between the Torpedo Sight, the Calculating Position and the Local Operational Plot provided for tactical appreciation

(c) The provision of a Torpedo Bearing Transmitter at the WS PPI in the Operations Room to enable the RADAR bearing of the torpedo target to be passed to the sight and the Calculating Unit.

(d) The provision of a simple Distant Ship Restriction Indicator for use with the PPI to determine the safety of friendly units not visible to the eye.

Defensive Counter Measures: Tactical counter measures against the torpedo fire of the enemy require, above all, a clear picture of the situation in order that evasive manoeuvres may be correctly timed to reduce to a minimum the chances of running into a zone of enemy torpedoes.

Future Developments.

Sufficient experience of the new equipment and the facilities available from the Action Information Organisation has not yet been gained to indicate whether they are adequate for the needs of Torpedo Control. The need for a separate Torpedo Plot is a possible requirement, but existing Warning Surface RADARS appear capable of providing all necessary RADAR information to a sufficient degree of accuracy. Torpedo fire is still a gamble and the gambler who best appreciates the chances is the ultimate winner.

RADAR IN AIRCRAFT.

Aircraft are all fitted with RADAR of one type or another, depending on the duties for which they are designed.

The aircraft which are required to work with the Fleet and over the sea are naturally fitted with a form of RADAR which will assist them to detect surface craft.

This type of equipment has important uses in the destruction of U-boats, the detection and shadowing of enemy surface craft, the finding of an enemy force which is to be attacked by a striking force, and also finding a friendly force which is to be covered.

Aircraft which are employed on night-fighting are provided with equipment purely for air to air work for the interception of enemy bombers in low visibility, after the ground control stations have placed them within a reasonable distance of the approaching formation.

Heavy bombers, on the other hand, are more concerned with equipment which facilitates blind bombing.

Air RADAR equipment: The H2S equipment used by the heavy bombers had already been mentioned, and is of no great interest to the student of RADAR applied to the Navy.

The AI set used by the night fighters is now a 10 cm. equipment, and works well. There is a new AI equipment using the X band coming out shortly which is suffering at present from bad maintenance troubles. A certain amount of research in night fighting by Naval fighters is being carried out based on the experiences of the American Fleet in the Pacific. It has not reached an advanced stage, however. AI equipment will be found in Naval fighters.

ASV: The equipment known as ASV (Air, Surface Vessel) fitted to all aircraft which work with the Navy in their everyday task of exerting sea power in all its forms, whether Fleet Air Arm, R.A.F., or Coastal Command, is of the most interest to the Executive Officer.

Indeed, it must now be plain to all that the aircraft makes an indispensable contribution to Naval activities, not only in combatting the U-boat but in all its other tasks. That being the case, it is essential that Naval Officers should appreciate to the full the air point of view, and the RADAR possibilities of the ASV set is no exception to this if co-operation is to be complete.

The ASV equipment is common to both R.A.F. and F.A.A. aircraft, and has proved particularly successful in the latter.

The original ASV sets were on 214 mc/s, and were actually the same sets which were taken over as WC sets in the Navy and called 286. The next ASV set, the Mark II, and Mark IIN, were designed on 176 mc/s, and the latter is still in general use.

The modern ASV set has two main functioning principles. It can be designed either to throw out a beam ahead (Fig.6) or on the beam (Fig.7).

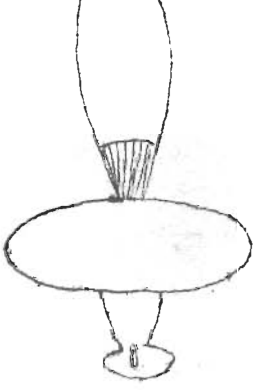


Fig. 6

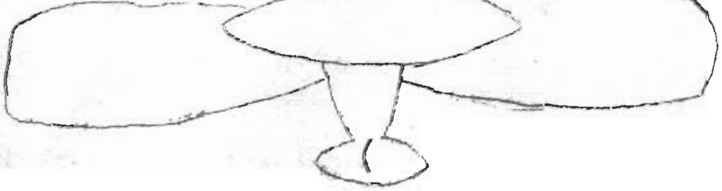


Fig. 7

In big aircraft, facilities for both are provided so that it can be switched from one to the other, whereas in smaller aircraft the ahead beam only is arranged. Fleet Air Arm aircraft fall into the latter category.

The aerials are arranged so that the transmitting aerial faces forward, and throws out a broad beam. Two sets of receiving aerials are used, one facing each bow. This gives the best compromise between early detection of objects ahead of the aircraft, and maximum breadth of sweep when on search, and has proved satisfactory. Each aerial is connected to the receiver alternately and the type of presentation is vertical, as in Fig. 8 .

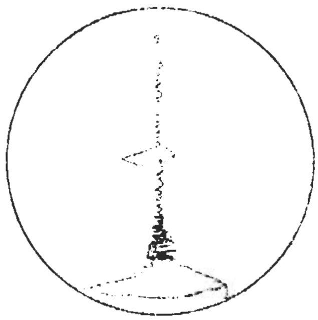


Fig. 8

Echoes from the port bow receiving aerial are fed into the left side of the display and from the starboard bow into the right side. If the object detected is right ahead, equal-sized echoes will appear in each side, and thus by swinging the aircraft a bearing can be obtained. By matching the two echoes the aircraft can be kept flying straight towards the target.

The observer normally watches the cathode ray tube, though an additional and remote tube is fitted in the air gunner's position to give relief to the observer.

ASV(X): The ASV(X) equipment which is being produced operates somewhat differently. Due to the short wavelength a parabolic reflector is employed, and the whole is mounted underneath the aircraft in a nacelle facing forward. The nacelle has somewhat the appearance of a car headlamp and inside it the reflector is power rotated in a plane close to the horizontal. Arrangements are made for the aerial to sweep in succession slightly above, exactly in, and slightly below the true horizontal. This ensures that changes in altitude of the aircraft will not lead to areas of sea being left unswept by the RADAR beam. The results of this sweep in two dimensions will be thrown on a PPI.

Performance of ASV: The actual performance of the ASV sets depends on the inclination of the ship detected, the detection bearing from the aircraft, the state of the sea, the skill of the operator, and of course, the efficiency of the set itself.

Generally speaking an aircraft throws out a beam ahead, as in Fig. 9 .

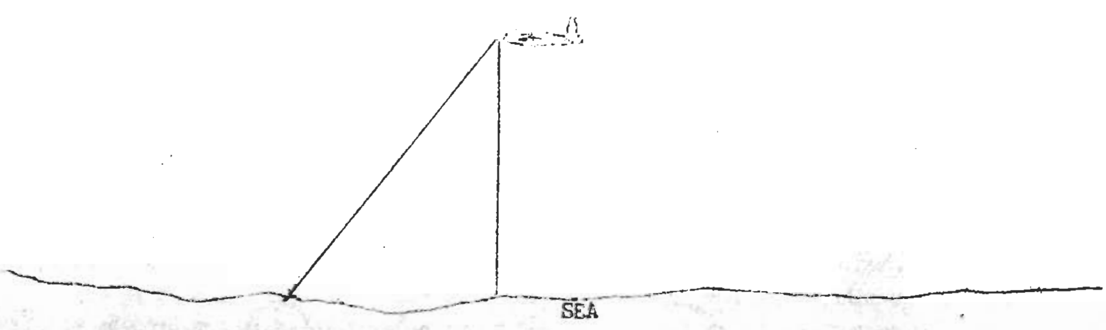


Fig. 9

The distance ahead of the aircraft at which detection is achieved is dependent on the height of the aircraft. The higher the aircraft the greater the range. However, another limitation on the ASV set is increased by an increase in height known as Sea Returns. These are reflections obtained off the surface of the sea which appear on the first part of the display and obliterate any small echoes. These become more and more pronounced as the height increases and usually extend to a distance on the display of approximately six times the height. It also tends to be worse in rough seas.

As has been stated, the performance of the ASV set is also affected by the bearing on which the detection is made, due to the arrangement of the aerials with the ahead beam. The best bearing of maximum sensitivity is clearly at 45^0 on either bow.

In general, an aircraft at 10,000 feet can detect a battleship at 40 to 50 miles, a destroyer at nearly 30, and a submarine at about 5.

Tactical employment: The actual height at which the aircraft would patrol on any particular mission is dependent therefore upon the type of target which is the primary objective, the duty which is assigned (i.e. either attack or shadowing), the state of the sea and the state of the clouds.

In practice, for aircraft on reconnaissance, probably a height of 5,000 or 6,000 feet is the best, though in low visibility, when searching for U-boats, about 800 feet will be the best.

In aircraft which have the beam and ahead aerials, the latter is normally used in low visibility since it sweeps out the biggest area; whereas the former is used in good visibility in order to obtain a detection before the aircraft is sighted by the U-boat. This would not occur in good visibility using the beam aerials. Both, of course, have an unswept area down the centre, due to sea returns. A popular form of sweep is to use the beam aerials, switching to ahead for ½ mile every 8 minutes. This helps to combine the advantages of both.

The ASV RADAR has increased the value of the aircraft's co-operation with the Navy tremendously, it has given great accuracy to its enemy reports and the employment of the RADAR link, instead of the V/S link, is a good example of this. It has enabled the aircraft not only to find the enemy more easily, but also to shadow him from far greater ranges, and continue both night and day. The tactics of the striking aircraft have been greatly altered since it is now possible to approach the enemy blind and remain hidden in clouds until the very last minute possible. The ASV has its applications also to the spotting aircraft.

The value of the RADAR set to the aircraft for navigation is as important as any application. Navigational fixes from prominent landmarks and beacons, the facility of homing, and location of not only the parent ship but also other aircraft in touch with the enemy, and the assistance in positioning illuminants such as flares and flame floats, are a few examples.

METEOROLOGICAL.

One final application which might be mentioned in closing is the use of the RADAR set for measuring the height of meteorological balloons, upon the accurate estimation of which depends much valuable information concerning the winds in the upper air for the use of aircraft. If these balloons are fitted with trailing dipoles, the CA RADAR set will give the required information very accurately.

From this limited survey of RADAR applied to the detection of surface craft and objects and other miscellaneous applications, officers will perhaps be able to appreciate in no small measure some of the wonderful possibilities it has brought to Naval warfare - things indeed, which would not have been credited even five years ago.