

CHAPTER 2

H2S AND ASV

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Introduction

1. H2S is an airborne equipment working on a wavelength of 9·1 cm. It has a double function; to act as a navigational aid and as a blind-bombing device for aircraft of Bomber Command. It was first used operationally in the winter of 1942-1943.

2. During the early test flights with AI Mk.VII it was observed that echoes were returned not only from other aircraft but also from terrestrial objects, and that towns in particular gave quite large responses. This happened despite the fact that the scanning arrangements were not designed for the specific purpose of showing ground returns, and it was apparent that if an equipment were constructed with the primary object of scanning the ground beneath the aircraft, it should prove useful as an aid to bombing. Preliminary experiments carried out on these lines were successful and led finally to the development of the present H2S. The original equipment is now called H2S Mk. I, and although newer marks of H2S are now in service, they differ only in detail; in the elementary account there is no need to differentiate between them.

3. Operational aircraft of Coastal Command also required some form of radar apparatus to detect enemy submarines and surface vessels, and to locate convoys. A type of equipment known as Aircraft to Surface Vessel Equipment, or ASV, had been used for this purpose for some time. It had a wavelength of about 1·5 metres, and the very early apparatus, ASV Mk. I, had already been replaced by a more operationally-efficient version, ASV Mk. II. It was clear, however, that an equipment working on a much shorter wavelength would be more satisfactory, so that when H2S was finally developed for Bomber Command it was also installed in Coastal Command aircraft. The Coastal Command H2S differs slightly from that fitted into bombers, and it is generally called ASV Mk. III. Later Marks are also coming into service.

Information supplied by H2S Mk. II (ASV Mk. III)

4. The later H2S and ASV equipment supplies a map of the ground beneath the aircraft. This map is displayed on the face of a cathode ray tube, and the point on the ground directly beneath the aircraft appears at the centre. Three scales are provided; a small scale map extending to a range of 100 miles, one of intermediate scale extending to 30 miles, and one of large scale, for blind bombing, extending to 10 miles. The map shows coastlines, towns, and surface craft at sea. In H2S equipment, the top of the map always corresponds to true North, and the course of the aircraft is shown by a bright line called a line-of-flight marker, which extends from the centre to the edge of the map. ASV Mk. III differs from H2S Mk. II in only one important detail: the top of the map

corresponds not to true North but to the direction in which the aircraft is heading, so that as the aircraft changes course the whole map rotates.

5. It is possible to measure the accurate bearing and range of a target from the aircraft. The range of distant targets can be found, with sufficient accuracy for navigational purposes, from the small and intermediate scale maps, while the large scale map gives more accurate ranges on the nearer targets, and can be used either for blind bombing or for obtaining the exact ground speed. It is also possible to measure the height of the aircraft above the ground with sufficient accuracy for bombing.

General principles

6. H2S and ASV work on the usual radar principle. A transmitter sends out short pulses of electromagnetic waves of wavelength 9.1 cm. and duration 1 microsecond. The recurrence frequency of these pulses is about 670 per second. Certain objects on the ground scatter the waves falling on them and return echoes to the aircraft. If the surface of the earth were everywhere quite flat, the waves would, of course, be reflected from it as from a mirror, and there would be no energy returned to the aircraft except from the point on the ground directly beneath it. The surface of the sea does indeed approximate to this condition and returns very few echoes. The surface of land, however, is rougher and more broken, and its irregularities give rise to hundreds of small random echoes, which appear for short spaces of time and quickly fade again as the aircraft

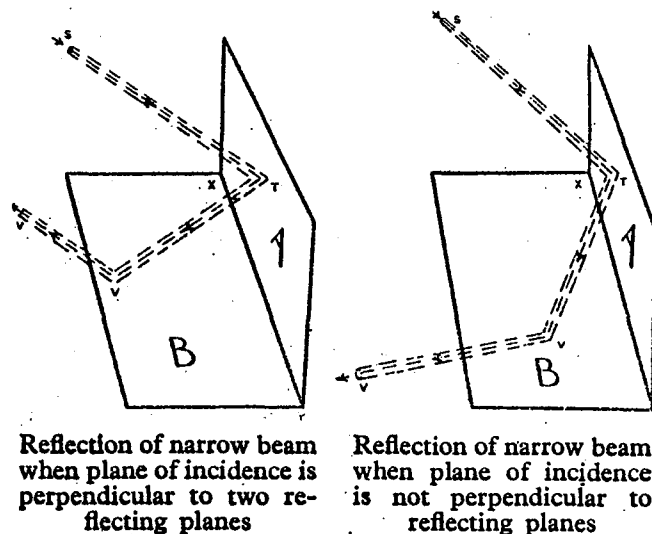


Fig. 1.—H2S beam reflections

changes its position. These echoes give a characteristic shimmering appearance to the map, so that it is possible for the operator to tell at a glance whether he is flying over land or over sea.

7. Certain natural and man-made structures on the earth's surface give a different type of echo from that due to wave irregularities on the ground. This second type of echo is much stronger and more persistent, and is due to scattering from vertical or almost vertical surfaces. It is interesting to note the way in which it usually arises. Fig 1. shows two planes at right angles, the plane A being vertical and the plane B horizontal. Imagine a narrow beam ST of electromagnetic waves from a distant source falling on the plane A at the point T. The waves will be reflected downwards, and will strike the plane B at the point U, where they will be reflected a second time and will travel along the path UV. Now if the direction ST is perpendicular to the line XY where the two planes meet, it is easy to show, by the laws of reflection, that the final path UV after the double reflection is parallel to the original path ST. In other words the beam is returned to the distant source. When the direction of the incident beam is not perpendicular to the line XY, the waves will not be returned along this original path; but will be replaced in the way indicated in fig. 1 (B). Suppose then that the aircraft flies past a large square building, see fig. 2. When it is at the point A the radar pulses

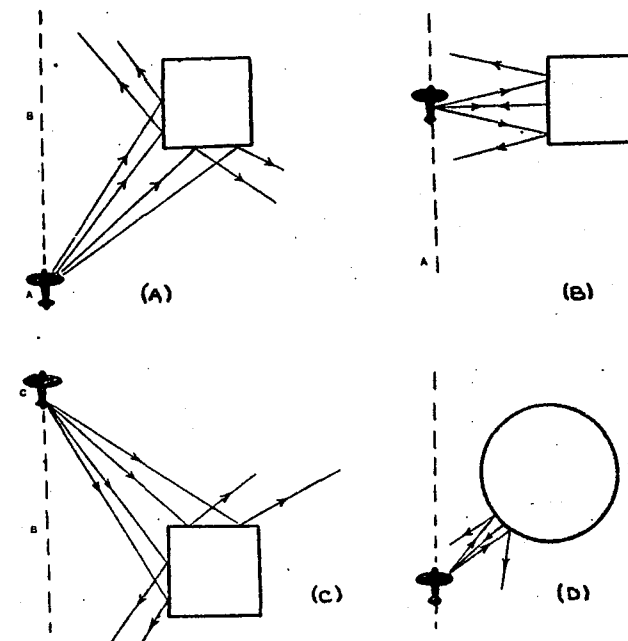


Fig. 2.—Reflection of radar waves from buildings

will be reflected as shown in fig. 2 (A); when the aircraft reaches the point B, opposite to the building, there will be a large return echo, and when the aircraft reaches C the reflected waves will travel away in the direction shown in fig. 2 (C). In other words a large echo will be returned only when the aircraft is exactly opposite to the building. With a circular building, however, see fig. 2 (D), there would always be some energy returned whatever the position of the aircraft relative to the building might be. A town will clearly give a strong response, since it has so many buildings that there will always be some vertical surfaces inclined at the correct angle to return the radiation. If three reflecting surfaces are mutually at right angles in the way indicated in fig. 3, it can be shown that incident radiation reflected from each of the three surfaces in turn always returns along its own path, no matter what its direction of incidence may be. Such a system of surfaces is often called a *corner reflector*, and will always return strong echoes. Buttresses and angles in the walls of buildings will therefore reflect well.

NOTE: Fig. 3 is to be interpreted as a hollow right-angled prism.

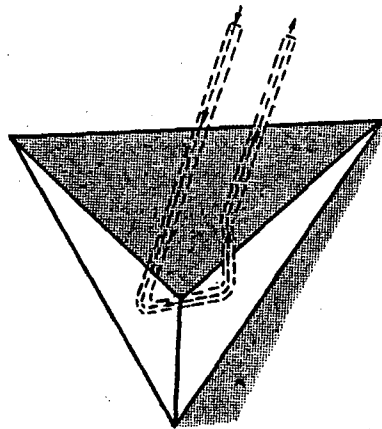


Fig. 3.—Corner reflector

8. It will be seen that echoes are returned principally from objects which have vertical or almost vertical surfaces and sharp edges, and particularly from those which rise sharply from the level surface of the earth. Such objects are buildings, clusters of buildings, cliffs at a coastline, islands, and ships. Hills which rise gradually give no definite response, although high and rocky mountains may be seen.

9. Although the reflecting properties of two or three planes at right angles plays an important part in producing the large responses from objects on the earth's surface, other factors are also probably present. For instance, in a town there will always be a large number of surfaces such as sloping roofs which are inclined at the correct angle to return

radiation to the aircraft in a single reflection. There will also be many surfaces which will be too rough to reflect the incident waves but will scatter them in all directions, and some energy will be returned to the aircraft no matter what their inclination may be. The resultant echo will therefore be due to these effects added to the corner effect.

MODERN H2S-ASV SYSTEMS

The scanning unit

10. After having considered the way in which echoes are returned from objects on the ground it is necessary to see how the waves are transmitted and received by the aircraft.

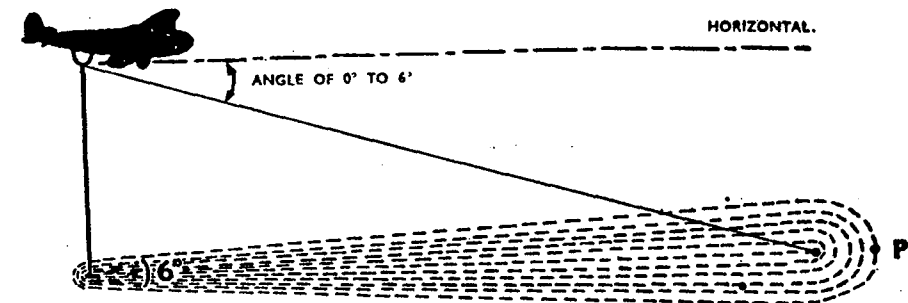


Fig. 4.—Strip of ground illuminated by H2S

11. The equipment uses a common transmitting and receiving aerial system housed in a perspex blister beneath the belly of the aircraft. The older aerial unit consists of a rectangular section of a paraboloidal mirror fed by a half-wave aerial at its focus. The aerial has a reflector and a director to direct the energy into the mirror. This system illuminates a strip of ground in the shape of a sector of a circle about 6 deg. wide extending from the point beneath the aircraft to a great distance as shown in fig. 4. The most remote point of illumination, P, is controlled by means of an adjustable "step" fixed into the top of the mirror, and by varying the position of this step the inclination of the beam can be varied. The usual inclination is about 6 deg. The polar diagram of this system is shown in fig. 5 (A). The newer equipments use a "Cosec θ " aerial system similar to that described in A.P.1093C, Chapter 2, and the mirror is fed by a waveguide. The principal advantage of the newer aerial lies in the improved polar diagram, see fig. 5 (B).

12. Whatever type of mirror system the equipment employs, the whole mirror rotates about a vertical axis at a rate of one revolution per second, so that it scans the ground or sea beneath the aircraft. Since the

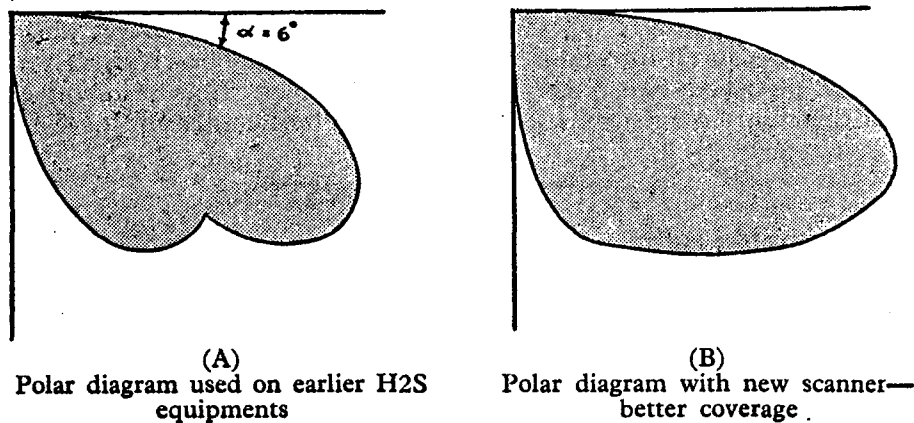


Fig. 5—H2S polar diagrams

illuminated strip of ground is 6 deg. wide, the beam will take $\frac{6}{360}$ seconds or one-sixtieth of a second to sweep over any particular target. The pulse recurrence frequency is 670 per second, so that each echo will be returned $\frac{670}{60}$ times, or about 11 times during each revolution of the scanner.

The cathode ray tube and the production of the map

13. The map is essentially a PPI display on a 6 in. cathode ray tube, and although such a display has already been described it will be helpful to consider this particular display in greater detail.

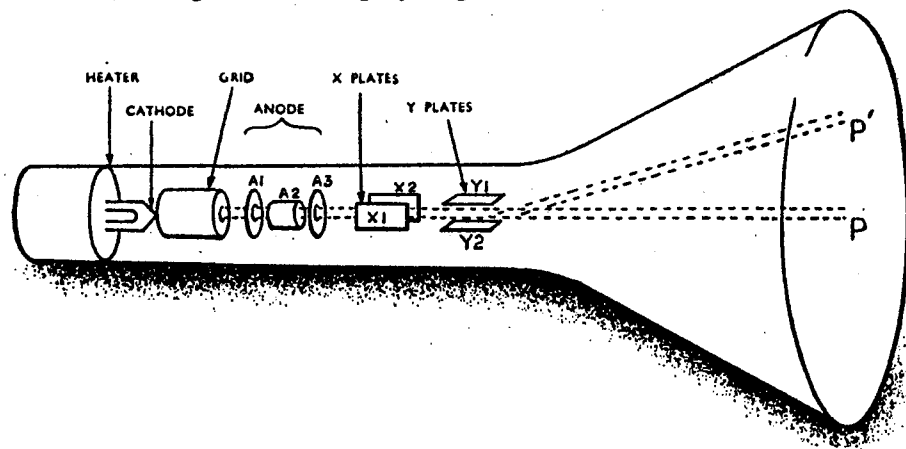


Fig. 6.—Cathode ray tube

14. Fig. 6 shows a typical cathode ray tube. Inside the glass envelope are the heater, the cathode, the grid, the anode, and the deflecting plates. The heater is simply a coil of wire whose function is to raise the temperature of the cathode. When the temperature of any conductor is raised sufficiently it emits large numbers of electrons. These electrons are minute particles much smaller than atoms, and each one carries a relatively high negative electric charge. The anode of the tube consists of three parts, A1, A2 and A3. The parts A1 and A3 are simply discs with small holes in their centres, while A2 is a cylindrical tube. If the three parts of the anode are raised to a much higher potential than the cathode the negative electrons emitted from the cathode are attracted towards the first plate A1, and many of them strike this plate and are absorbed into it. Some pass through the hole at the centre, however, through the tube A2, and through the hole at the centre of A3. They leave A3 with a very high velocity, and travel on to strike the face of the tube at P. The constant stream of electrons striking the tube face at P cause a coating of fluorescent material on the glass in this neighbourhood to glow with a green light. By varying the potential of the cylinder A2 relative to that of the discs A1 and A3 it is possible to focus the electron beam so that the patch of light at P is very small indeed. The grid which is situated between the cathode and the anode is usually maintained at a potential somewhat lower than the potential of the cathode, so that the electrons are discouraged from setting out on the first part of their journey, and it is not until they have left the grid behind that they really gain a high speed. By making the grid slightly too negative it is possible to cut off the electron stream altogether, as slight variation of the grid potential causes a marked change in the number of electrons which finally reach P. Thus, the brightness of the spot of light at P depends on the potential of the grid. The x and y plates are two pairs of parallel plates and are used to deflect the beam. If both x plates and both y plates are at the same potential the spot P will be in the centre of the tube. If, however, the potential of the upper y plate is higher than that of the lower one, the electrons will be attracted to the former and repelled from the latter as they pass, and the spot will move upwards to P'. The distance from P to P' will depend on the difference in potential between the two plates. In the same way a difference in potential between the two x plates will deflect the beam in a horizontal elevation.

15. Fig. 7 (A) shows a view of the face of the tube with the x and y plates seen end-on. The two pairs of plates are mutually perpendicular. Suppose that the potentials of the x plates vary in the way shown in figs. 8 (A) and 8 (B). The plate x1 is first made positive in potential while x2 is made negative, so that the electron beam is deflected. Since the electrons will be attracted to x1 and repelled from x2 the spot of light

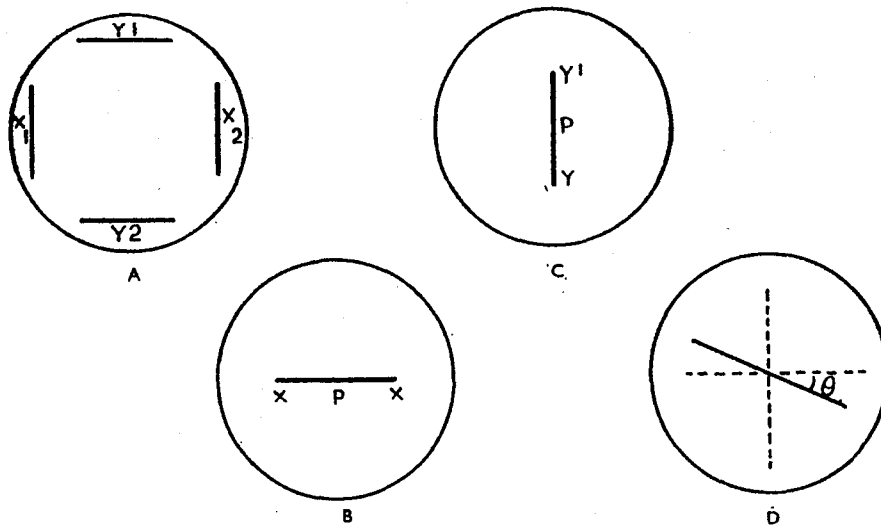


Fig. 7.—Development of PPI display

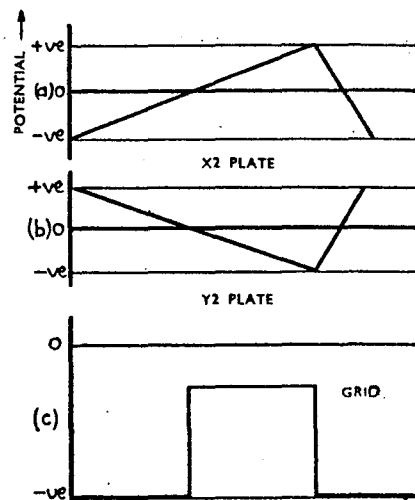


Fig. 8.—Potentials on a PPI tube

will move across the tube face to the point X. As time goes on the potential of x_1 falls uniformly while that of x_2 rises uniformly, so that the spot moves through P to X1. The potentials then reverse again so that the spot will fly back. If the potentials continue to vary in the sawtooth manner shown in fig. 8, this process will repeat itself again and again, and if it repeats itself sufficiently rapidly the movement of the

spot will be no longer visible, but a continuous line or trace XPX1 will appear on the tube face. If the potential variation shown in fig. 8 had been applied to the y plates instead of the x plates, the trace would have been vertical.

16. Suppose that saw-toothed voltage waves are applied to both the x and y plates simultaneously. If these two waves have the same amplitude, the trace will be inclined at an angle of 45 deg. If, however, the amplitude on the y plates is greater than that on the x plates, the y deflection will be greater than the x deflection so that the timebase will be inclined at a different angle, θ in fig. 7 (D). Moreover, by varying the relative amplitudes of the waves applied to the two it will be possible to incline the trace at any desired angle.

17. In the H2S equipment two pairs of saw-tooth waves of frequency 670 cycles per second are applied, one to each pair of plates. These waves are supplied by an apparatus known as a *magslip*, described in para. 20, and their amplitudes are varied in such a way that at each successive journey the angle of inclination of the trace is slightly greater than it was during the previous journey, so that the trace appears to rotate. The *magslip* is geared to the scanner in such a way that each rotation of the scanner corresponds to one complete rotation of the trace. The potential of the grid of the tube is not uniform but is varied in the way indicated in fig. 8 (C). When the spot commences its journey from the left-hand side of the tube, its potential is so strongly negative that no electrons reach the tube face. It is only when the spot reaches the centre point P that the grid potential is raised sufficiently to allow the electron to pass, and immediately the spot reaches its farthest limit, X, the potential falls again and is kept strongly negative until the spot once more reaches P on its next journey. The result is that the first half of the trace and the flyback are blacked out, and all that appears on the tube is a radial line PQ (fig. 9). This radial line rotates in synchronism with the aerials.

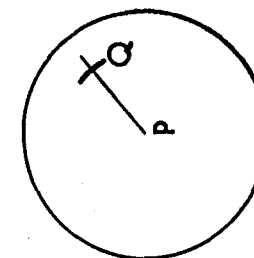


Fig. 9.—Appearance of echo on tube

18. The transmitter is so timed that a pulse of waves is sent out at the exact instant that the spot reaches P. The return signal is received some time later, and is applied to the grid of the tube so as to brighten up the trace. While the 6 deg. beam from the scanner sweeps past a target, it causes about 11 successive responses. Thus the return signal will brighten about 11 successive traces each time the aerials revolve. The appearance of the echo will therefore be a rather long, bright smear, similar to that shown at Q in fig. 9. The distance PQ is proportional to the time taken for the pulse to complete its double journey, or to the range of the target, while the direction PQ corresponds to the direction of the target for the aircraft. In this way the map appears on the face of the tube. The inner surface of the face of the tube is coated with a material which continues to glow for a short space of time after the trace has passed, so that the echo persists during the intervals between the successive sweeps of the trace. It is usual to adjust the potential of the grid so that the trace is not quite bright enough to be seen, and only becomes visible when the grid is made more positive by the signal. In this way only the echoes can be seen, and the trace itself is made quite invisible.

19. When a target is very distant its echo is usually considerably thinner than the echo from a nearer target. Thus on running up to a large town the appearance on the tube will be similar to that shown in fig. 10, and will vary as indicated by the echoes a, b and c. This is because the incident waves fall on the distant town from a direction almost parallel to the ground, and consequently only the front row of buildings returns echoes, while the buildings behind are shielded. As the aircraft approaches more closely, and its angle of elevation increases, the "thickness" of the town begins to show, and when the aircraft is almost overhead the town appears in its own shape.

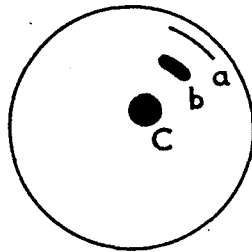


Fig. 10.—Appearance of town at different ranges

The magslip and line-of-flight marker

20. The magslip consists essentially of three coils arranged in the way shown in fig. 11. Two of these coils, the stator coils, are stationary

and have their axes at right angles. The third, the rotor, has its axis in the same plane as the axes of the stators, but can rotate about an axle perpendicular to this plane. A saw-toothed voltage wave is applied to the terminals of the rotor coil, and an electromotive force is induced

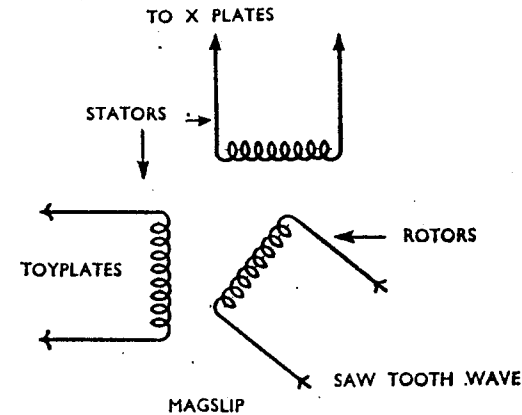


Fig. 11.—Magslip theory

in each of the stators, so that similar saw-toothed voltage waves appear between their terminals. The relative amplitudes of these stator voltage waves depends, however, on the position of the rotor. The voltage waves from one stator are amplified and applied to the x plates of the PPI tube, while the waves from the other are amplified and applied to the y plates. Thus the direction of the trace on the tube, which depends on the relative amplitudes of the saw-toothed waves applied to the x and y plates, is controlled by the position of the rotor. As the rotor rotates with uniform velocity, the trace on the tube will also rotate with the same uniform velocity. The rotor is geared to the scanner, and establishes the necessary relationship between the direction of the trace and the direction in which the scanner is looking.

21. In ASV Mk. III equipment the stator coils are fixed relative to the framework of the aircraft, and are so positioned that whenever the scanner looks along the direction in which the aircraft is heading—that is along the aircraft in the direction of a line drawn from tail to nose—the trace is directed from the centre to the top of the tube. Thus the top of the map always corresponds to the direction of flight in the way described previously.

22. In H2S equipments the stator coils are themselves mounted on a rotatable framework, and the position of this framework is controlled by the gyro-compass so that the coils retain this position relative to the

true North direction and not relative to the structure of the aircraft. The result is that directions on the map correspond to true geographical directions and do not depend in any way on the course on which the aircraft is flying. It is usual to arrange the orientation of the stator-coils in such a way that the top of the map on the tube always corresponds to true North.

23. In H2S apparatus it is necessary to show the line-of-flight of the aircraft on the map. This is accomplished by the line-of-flight marker, or *course marker*, which is operated from the scanner. Whenever the scanner is looking along the aircraft in the direction of flight it automatically closes a contact. This applies a high potential to the grid of the PPI tube so that the trace is brightened along its whole length from the centre to the edge of the tube. Each time the scanner sweeps round, one timebase is brightened in this way, so that the operator sees a bright radial line on the map and the direction of this line is his line-of-flight.

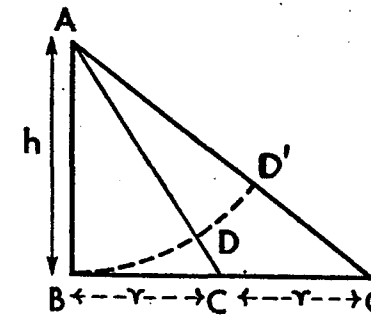
The distortion of the map

24. On the face of the PPI tube it is possible to show any one of the following four maps:—

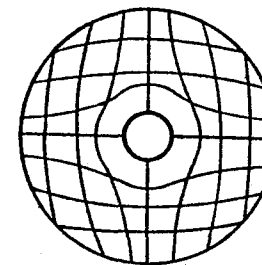
- (1) The 10-mile scale where the radius of the PPI represents 10 miles.
- (2) The 30-mile scale where the radius of the PPI represents 30 miles.
- (3) The 50-mile scale where the radius of the PPI represents 50 miles.
- (4) The 50-100 miles scale which is used entirely for locating beacons, and on which the time-base starts at a range of 50 miles and extends to 100 miles, so that points in the centre are at a range of 50 miles while points round the edge are at 100 miles range. This is really an extension of the 0-50 mile map.

25. The first three are the maps most often used, and they are subject to a peculiar kind of distortion. This distortion arises because the apparatus measures not the ground range but the slant range of a target, and its nature will be apparent from fig. 12(A). An aircraft is shown situated at the point A whose height above the ground is h ; the point on the ground nearest to the aircraft is the point B directly below. No echo, except the echo of an airborne object, can appear on the display tube at a smaller range than this. Further, the point B will always give an echo no matter in what direction the aerials are pointing, because

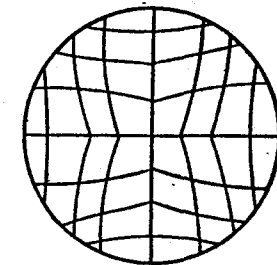
some radiation always travels vertically downwards. The result is that the point B appears as a ring of radius h at the centre of the map, and that no echoes can be seen inside this ring.



(A) How distortion arises



Outward distortion of map showing hole at centre
(B)



Inward distortion of map when hole is closed
(C)

Fig. 12.—H2S distortion

26. Consider the point C at a distance r from B. Its apparent range on the map will be the slant range AC. A second point C^1 , whose ground range from B is just $2r$ will appear on the map at a range C^1 . Now, although BC^1 is twice BC , it is easy to show that AC^1 is less than twice AC . In other words, if the map had no distortion the point C^1 would be twice as far from the centre as the point C, whereas in fact C^1 is less than this distance from the centre. It is hence possible to show that the distortion of the map is of a kind indicated in fig. 12(B). If the surface of the earth were covered with perfect squares, their appearance on the map would be similar to that shown in the sketch. This form of distortion is known as *outward distortion*. It becomes less marked at longer ranges, since as the range increases the slant distance, AC , and the distance measured along the ground, BC , become more nearly equal.

27. The distortion, particularly on the 10-mile map, has one good effect. Suppose that a bomber is directly over a town. All the echoes lie in a compact mass at the centre of the tube, and if there were no hole at the centre it would be difficult to distinguish one from another or to find the bearing of any particular one accurately. The effect of the distortion, however, is to scatter the echoes so that they appear farthest apart and the angular discrimination is greatly increased. This is useful in blind bombing.

28. For purposes other than bombing the hole at the centre of the map is a disadvantage, and in order to reduce the distortion and close the ring there is a control known as the 10-MILE ZERO KNOB. By turning this knob it is possible to change the time at which the trace commences its journey relative to the time of the transmitter pulse. By adjusting this control suitably the hole can be completely closed. The map will still be distorted; however, since the range of any point C, fig. 12(A) now appears to be the slant range AC minus the height AB, or the length DC, and this length is not proportional to the ground range BC. The second point C₁ at twice the range of C has an apparent range DC₁, and C₁D₁ is more than twice DC. The distortion in this case is an inward distortion, so that squares drawn on the ground have the appearance indicated in fig. 12(C). By suitably adjusting the zero control, the two distortions can almost be made to neutralise, and there is some position at which the radius of the hole is less than h, where the map is almost, though not quite, distortionless.

29. On the 30-mile scale the hole is approximately one-third of its size on the 10-mile scale, and the distortion is not serious. The diameter can be varied by a screwdriver control, but no knob is provided and the operator is generally expected to work with the control fixed. On the 50-mile scale the hole is very small and its radius cannot be varied.

Measurement of range

30. For ordinary navigational purposes the equipment need only supply approximate ranges on towns and coastlines. For blind bombing, however, it is necessary to measure range accurately.

31. The fact that the equipment measures slant range is unimportant for navigational purposes, since the error involved will be relatively small, and on the 0-30, 0-50, and 50-100 miles maps no correction need be applied. On the 0-10 miles scale, however, it is necessary to allow for the height of the aircraft, and a correction must be applied to convert

the slant range into ground range. It is clear from fig. 12(A) that the ground range of the point C is

$$r = BC = \sqrt{AC^2 - h^2}$$

where AC is the slant range, so that it is a simple matter to find the value of r if both the slant range and the height are known. There is one difficulty, however. If r is not large in comparison with h, in other words if the aircraft is almost over the target, the ground range r will be changing rapidly as the aircraft flies up, but the slant range AC will be changing relatively slowly. This means that a small error in the measurement of AC will mean a large error in the measurement of r. It is therefore better to measure not the slant range AC but the difference DC between the slant range and the height, since a small percentage error in measuring this quantity will not cause such a large error in r. We then have

$$\begin{aligned} r^2 &= (h + DC)^2 - h^2 \\ &= 2h \times DC + DC^2 \end{aligned}$$

and if h is known, r can be found by measuring DC. The calculation is not made every time a range is taken, but is performed by graphical methods which will be described later. In measuring the ground speed it is necessary to take two ranges on a target with a fixed interval of time between the two, using a stop watch.

32. For purposes of range measurement the map is supplied with a range marker. This marker is produced by brightening each trace for a very short period of time, and appears as a bright ring, whose centre is the centre of the PPI tube. The time at which the brightening occurs relative to the transmitter pulse is controlled by a range knob, and by rotating this knob the radius of the bright circle can be varied. When the circle touches any required echo on the tube the range can be read off from a calibrated scale, more details of which appear in para. 39.

Measurement of height

33. The equipment measures the height of an aircraft by noting the range of the first ground return. It would be possible to do this by measuring the radius of the hole in the centre of the map, but it would not be easy to obtain very accurate results in this way, and in practice it is usual to measure height by means of a special *height tube* carried for the purpose. The height tube is a cathode ray tube whose time base is applied to the y plates only so that the trace is always vertical, and the signal is applied not to the grid as it was in the PPI tube, but

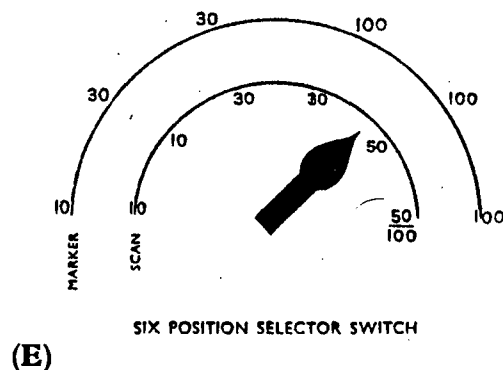
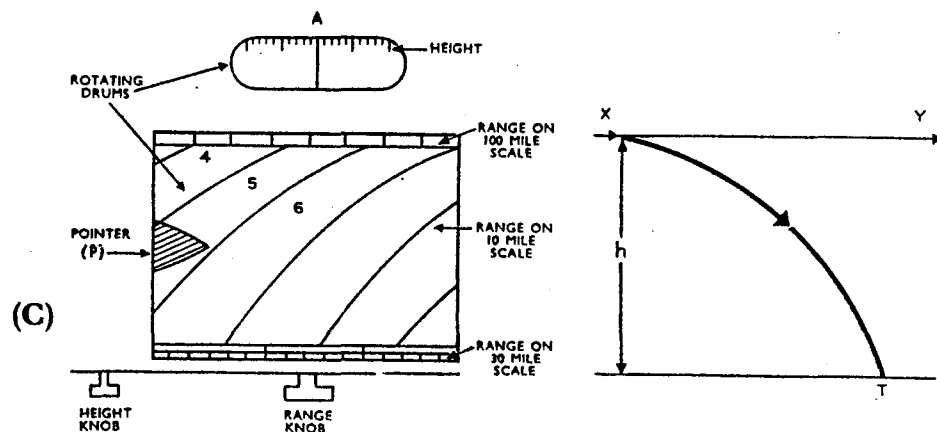
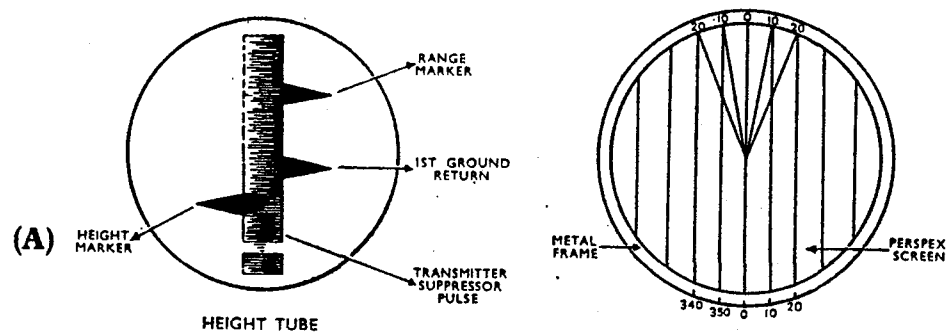


Fig. 13.—H2S display and controls

to the x plates, so that it appears as a horizontal deflection of the trace. Fig. 13(A) shows the appearance of the display. The blank space near to the bottom of the tube is caused by the transmitter suppressor pulse which cuts out the receiver to prevent damage while the transmitter is sending out its burst of waves. The deflection at the left-hand side of the trace is the height marker. The ground return appears as a persistent echo on the right-hand side of the trace. The range marker also appears on this tube as well as on the PPI tube.

34. The first ground return is the only important echo in the height tube, since all other echoes flash through so quickly as the scanner rotates that they can hardly be seen.

35. To find the height of the aircraft it is only necessary to turn a control knob until the height marker is opposite to the echo, and the height can be read off from a calibrated scan which is described in para. 39.

36. The range marker on this tube is simply a duplicate of the marker in the PPI tube. It is used here to check the height and range calibrations, and if the range and height markers are put opposite to one another the height and range should clearly have the same value, and the aircraft height is obtained.

(D) Measurement of bearings

37. Accurate bearings are required on both Bomber Command and Coastal Command equipments. Bearings are measured in both cases by means of a perspex disc which is mounted in a circular metal frame in front of the tube. The frame and disc, which are shown in fig. 13(B), can be rotated about their centre point. The use of the device is self-explanatory; and it will measure bearings accurately to within ± 3 deg.

Use of the height and range controls

38. The unit containing the height and range indicators has a display similar to that shown in fig. 13(C). The displays themselves are marked on two drums, A and B, which rotate about vertical arcs. When the height control knob is turned it does three things:—

- (1) It moves the height marker *on the height tube only*;
- (2) It moves the point P up or down the left hand side of the drum B, and
- (3) It rotates the drum A.

When the range control knob is rotated, it does two things:—

- (1) It moves the range marker on *both the height tube and the range tube*, and
- (2) It rotates the drum B.

39. On the 30- and 100-mile scales, where the slant range only is taken, the ranges are read off from fixed pointers at the centre of the display. The range on the 100-mile scale is marked along the top of the drum, and the range on the 30-mile scale is marked along the bottom. On the 10-mile scale, where it is necessary to allow for the height of the aircraft, the range is read from the tip of the pointer P. On the centre of the drum between the 100-mile and the 30-mile scales are drawn a number of lines of constant range, each line being marked with a number indicating the range in miles to which it corresponds. In reading the range of an echo on the 15-mile scale it is first necessary to find the height by moving the height marker to a position opposite to the first ground return on the height tube. The pointer P will move with the height marker, and its final position will be determined by the height of the aircraft. The next operation is to adjust the range marker on the PPI tube until it touches the inside edge of the echo. The drum B will now be in a position corresponding to the range reading, and the lines of constant range on the drum are so arranged that the particular curve which corresponds to the range of the target just touches the tip of the pointer P. Thus to find the ground range on the 15-mile scale it is necessary :—

- (1) To move the height marker to the correct position on the height tube ;
- (2) To move the range marker to the correct position on the range tube ; and, finally,
- (3) To read off the range from the drum by noting the range curve which touches the tip of the pointer P.

Blind bombing procedure

40. To direct a bomb on to a target it is necessary to know the height and the ground speed of the aircraft and the range of the target. For high-altitude bombing it is also necessary to take into account the wind speed and the ballistic properties of the bomb, since different types of bomb have different wind resistances and fall with somewhat different trajectories. In the first instance, one can neglect the effect of wind resistance, however, and suppose that the bomb falls with uniform acceleration, so that its trajectory will be similar to that shown in fig. 13(D). The aircraft is at a height h above the ground and it releases a bomb at the point X. The bomb will continue to travel forward with the speed of the aircraft during its time of fall, and when it reaches the ground the aircraft will be at a point Y vertically above the target. The

distance XY is determined by the speed of the aircraft and the time of bomb fall. Knowing these two quantities it is possible to calculate the point at which to release the bomb, and this calculation is performed automatically by the equipment. The equipment will determine :—

- (1) The height of the aircraft, and hence the time of bomb fall ;
- (2) The range of the target at any instant ; and
- (3) The ground speed of the aircraft.

41. A number of red lines (not shown in the sketch) are drawn on the part of the range drum concerned with the 10-mile scale. These lines are marked 100, 150, 200, 250 and 300. The figures stand for the ground speeds of the aircraft. Having picked out the target and found the ground speeds accurately, the height pointer P is set correctly and the drum is turned until the red curve corresponding to the ground speed of the aircraft touches the pointer P. This puts the height marker on the PPI tube at the correct bombing range. As the aircraft approaches the target the echo will draw nearer to the preset range marker, and when it reaches the marker the operator knows that he is at the point X (fig. 13(D)), and that it is time to release his bombs.

42. Very often, the target is so close beneath the aircraft at the point of bomb release that it may be barely visible among the large amount of clutter from the direct ground return. To overcome this difficulty there is a second set of red curves on the range drum. These curves are shown as dotted lines to differentiate them from the previous red curves which are drawn as full lines, and they are marked with the same numbers but are labelled "30 seconds." To use these curves, the navigator sets up his height marker correctly as before and turns the drum B until the dotted curve corresponding to his ground speed touches the pointer P. This time, however, he has to wait for exactly 30 seconds after the target has touched the range marker before he releases the bombs. These 30-second curves are probably more useful than those previously described. In practice it is necessary to allow for wind resistance in calculating the point of bomb release, and for this purpose tables are provided. These tables tell the bomb aimer what length of time must be subtracted from the 30 seconds for an aircraft flying at any given height and speed in order to allow for the windage on any particular type of bomb.

The 6-position selector switch

43. One difficulty in switching from one scanning range to another is that of identification. Suppose that the observer is looking at a target

on the 50-mile scale map, and that he brings the range marker up to it and follows it. As he approaches the target he will wish to switch to the 30-mile scale, and when he does this the whole appearance of the map will change. Moreover, on the 30-mile scale the setting of the range marker is different from its setting on the 50-mile scale, and if he switches both scale and range marker over at the same time, the marker will move away from the echo, so that the identification of the target will be very difficult. In order to make the identification easier the scale and the range marker are switched by the selector switch shown in fig. 13 (E). There are six positions of this selector switch. In the extreme left-hand position, marked 10, 10, both the map and the range marker use the 10-mile scale switching so the next position changes range scale to 30 miles, but leaves the scale of the map as it was. The third position gives the 30-mile scale for both map and marker. The remaining 3 positions give similar combinations. When the operator wishes to switch from the 50-mile to the 30-mile map, therefore, he first moves the selector switch from position 5 to position 4. This changes the scale of the map but leaves the range scale unchanged so that the range marker still touches the target on the new map. It is then an easy matter to recognise the target, and the switch can be turned to position 3. The range marker will then move off the target, but this does not now matter since the echo has already been identified and the marker can easily be brought back by turning the range knob.

The fishpond unit

44. Bomber Command aircraft often carry an additional unit known as the *Fishpond unit*. This unit has a separate display tube which shows the H2S map on a much larger scale, so that the radius of the tube represents only 5 miles, and the hole in the centre of the map occupies a considerable area of the tube. Any other aircraft flying below the bomber will return an echo, and if its range is less than the height of the bomber, the operator will see its echo somewhere in the hole. The wireless operator usually uses the fishpond unit and watches the map so that he can give warning of the approach of enemy aircraft.

Lucero

45. Lucero is an apparatus used in conjunction with H2S and ASV Mk. III. Its function is to interrogate ground beacons and IFF equipment carried by other aircraft. It has a separate transmitter, receiver, and common aerial unit of its own, but its echoes are displayed on the H2S tube. A fuller description appears in chapter 6 which deals specifically with radar beacons.

Summary of data

46. H2S

Range on land :	40-50 miles.
Accuracy :	± 2 per cent. on 100-mile and 30-mile scales. ± 100 yards on 10-mile scale.
Accuracy of bearing :	About ± 3 deg., though no great accuracy required.

H2S Mk. II with Lucero

Range on responder beacons :	About 90 miles at 4,000 ft. under favourable conditions. The extra 50-100 mile range scale is included for use with beacons.
Range on IFF sets :	60-80 miles.
Range on BABS :	Up to 14 miles at 1,000 ft. (<i>See beacons in Chap. 6</i>).
Accuracy of range on BABS :	± 200 yards at 6 miles.
Sector discrimination on BABS :	± 1 deg.

Transmitter

Peak pulse power :	About 50 kW.
Pulse length :	1 microsecond.
Pulse recurrence frequency :	6 per second.
Wavelength :	9.1 cms.

Aerial system

Scanner rotating at rate of 1 revolution per second. Details described in text above.

RECENT DEVELOPMENTS IN H2S DESIGN AND LATER MARKS OF ASV

47. The preceding description refers to H2S Mks. II, IIA and IIB, as installed in aircraft of the main bombing force. On reference to the summary of H2S equipments given in A.P.1093C, Chapter 4, it will be seen that other Marks of H2S were under development. Mks. IV, VI and VII are not dealt with here. Mk. V is an American equipment (AN/APS.15) which has been used for ASV, refer to ASV Mk. X—in

para. 69. In connection with recent improvements in design since the introduction of H2S Mk. II, the chief points of interest are as follows :—

- (1) Scan distortion correction.
- (2) Display of a track marker.
- (3) Roll-stabilisation of the scanner.
- (4) Increased discrimination by reducing the operational wavelength.

Scan distortion correction

48. The distortion of the map mentioned in para. 24 has been greatly reduced by a change in design of the indicating unit. The scan-corrected display is known as indicating unit type 184, and is fitted in H2S Mks. II C and III.

49. It was stated that by adjusting the *10-mile zero knob* the hole in the map can be completely closed up, thus reducing the distortion to some extent but not completely eliminating it. When this is done, the distance of a target echo from the centre of the cathode ray tube is a reading of the slant range minus height of the target. But if the aircraft changes height, it is necessary to reset the 10-mile zero control whose function is to control the start of the trace relative to the time of triggering of the transmitter. It is possible, however, to arrange that the setting of the *height marker control* determines the start of the trace so that the hole in the centre of the map is completely closed provided the correct height is set in. This arrangement has been made in indicator unit, type 184. The operator does not need to re-set the 10-mile zero. Provided he sets in the correct height no hole will appear in the map, and an object on the ground beneath the aircraft always appears in the centre of the cathode ray tube.

50. In the earlier indicating units some distortion of the map occurs when the hole is completely closed, as shown in fig. 12(C). This takes place because the cathode ray tube is provided with a linear timebase, i.e. the electron beam moves outwards from the centre of the tube with uniform speed. In order that there should be no distortion at all the beam should be made to move rapidly away from the centre of the tube, and then move slowly as it approaches the circumference, thus expanding the central area of the map so that distances on it are exactly proportional to ground ranges. The manner in which the electron beam should move to produce a distortionless picture varies with the height of the aircraft, but this difficulty is overcome in indicator unit, type 184 by providing an additional control known as the *distortion corrector*. When this knob is set by the operator to the aircraft height the timebase is speeded up

by the correct amount in the central part of the tube, and the map is expanded in that region so that the inward distortion is almost eliminated. Distances between any two points in the tube face are then very nearly proportional to ground range. Even when these special precautions have been taken the map scale is not quite perfect in the centre, because it is difficult to design electrical circuits which will make the electron beam move fast enough at the beginning of the timebase.

Display of track marker

51. In H2S Mk. II equipment the aircraft heading or course is indicated by a bright radial line which appears when the *LINE-OF-FLIGHT* switch is depressed. This line is designated the *course marker* in more recent equipments. If there is no wind, and if the pilot sets his course so that a target point is on the course marker, the aircraft eventually passes directly over the target, and the echo is seen to remain on the marker line as the range diminishes, until the crossing point is reached. If, however, a cross wind is blowing, the aircraft drifts and the echo is seen to drift off the course marker. In this case the course marker does not indicate the future track of the aircraft, i.e. the path on the map over which it will fly. On the other hand, if the aircraft course and airspeed are known, as well as the wind speed and direction, the track can easily be plotted; for, provided these quantities remain constant, the track is a straight line displaced from the course marker line by the angle of drift. In H2S Mks. II C and III equipments, which use indicating unit, type 184, the calculation is done automatically, and the track is displayed as a bright radial line on the cathode ray tube. The data mentioned above are fed into the Mk. XIV bombsight, which calculates the drift angle, and the information is fed out electrically and displayed on the H2S tube. Two marker lines are therefore available according to the position of a two way switch on the indicating unit which is marked *COURSE* and *TRACK*.

Roll-stabilisation of the scanner

52. When an aircraft is flying straight and level, the axis of rotation of the scanner is perpendicular to the earth's surface, and the centre point on the H2S map corresponds to a point vertically below the aircraft. If the aircraft banks, the axis of rotation of the scanner is tilted with respect to the earth's surface and a displacement of the H2S map results. This sliding of the display during evasive action on a bombing run makes accurate bombing difficult. To overcome this difficulty new scanners have been developed which are gyro-stabilised against roll. As soon as the scanner platform is displaced by about one deg. from the horizontal, a gyro comes into action to develop a restoring force. This

stabilisation remains effective for displacements up to 30 deg. to either side. The platform is not stabilised against pitch, or displacement of the scanner's axis as the aircraft climbs or dives, as this can usually be avoided during bombing operations. Stabilised scanner platforms are installed in H2S Mks. II C and III A, and also in other Marks.

Increased discrimination

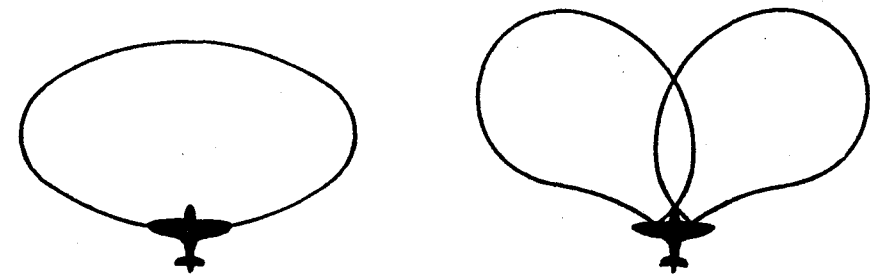
53. As shown in fig. 4 the strip of ground illuminated by the H2S, Mk. II scanner is roughly a sector of angle 6 deg. Suppose that the beam is sweeping over an isolated object such as a chimney. A 6-deg. arc is then seen on the H2S tube. If the beam width is reduced, a correspondingly smaller arc appears on the tube, until when an extremely narrow beam is used the echo of the chimney appears as a point of light on the tube. Hence in order to discriminate between objects on the ground that are fairly close together it is necessary to use as narrow a beam as possible.

54. There are two possible ways of increasing H2S discrimination by reducing the beam width. The first method is to increase the aperture of the aerial system by designing a larger scanning mirror. This means that a much larger perspex blister must be fitted to the aircraft. The second method is to increase the frequency of the transmitter, i.e. to make use of a shorter wavelength. In recent Marks of H2S, both methods are used. Mks. III and IV are X-band equipments radiating on a wavelength of 3 cm. By using an X-band transmitter, and an aerial system of about the same size as in earlier designs, the beam width can be reduced to about 3 degrees. H2S Mk. III C employs a 3 cm. transmitter with a 6-ft. aerial array, so that still better definition is obtained. Future equipments are designed with higher-powered transmitters to ensure adequate range, and with as narrow a beam width as possible to obtain high discrimination. A list of H2S equipments is given in A.P.1093C, Chapter 4.

ASV Mk. II

General principles

55. The older ASV equipment, ASV Mk. II, is obsolescent and has been replaced by the later marks. It works on the radar principle, having a transmitter which radiates pulses of RF waves of frequency 176 Mc/s and a receiver which detects and displays the return signals. Echoes are received from ships, submarines and coastlines.



A—P.D. of forward-looking transmitter A.S.V. Mk. II

B—P.D. of forward-looking receiver A.S.V. Mk. II

Fig. 14—ASV Mk. II polar-diagrams, forward-looking

56. The smaller types of Coastal Command aircraft, such as Beauforts and Hudsons, carry a transmitting aerial situated beneath the nose of the plane so that the polar diagram is similar to that shown in fig. 14(A). There are two receiving aeriels, one beneath each wing, and echoes are received on each of these alternately. The polar diagram of the receiving aeriels is shown in fig. 14(B) whence it is clear that one aerial looks rather to the starboard side and the other to the port side of the aircraft. The echoes are displayed on a cathode ray tube whose trace is vertical (fig. 15), and it is arranged that echoes from the starboard-looking aerial deflect the trace to the right while echoes from the port aerial deflect it to the left. Thus the echo of a target at a point T (fig. 14(B)), which is in front and to the starboard side of the aircraft, will appear on the tube as a double deflection of the trace, the right-hand deflection being greater than the left-hand one. From the appearance of the display the operator knows that to home on the target he must turn to the starboard until the two halves of the echo are equal in length, and that he will then be heading directly towards the target.

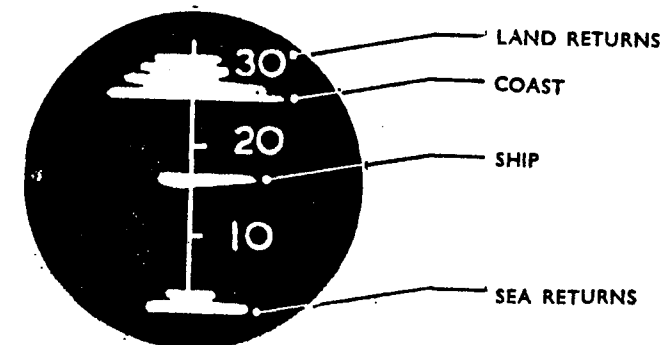


Fig. 15.—ASV Mk. II display tube, forward-looking

57. Larger aircraft, such as Whitleys, Wellingtons, Liberators, Sunderlands and Catalinas, have, in addition to the aerials already described, sideways-looking arrays. The sideways-looking transmitting array is a broadside array containing four stacks each of two aerials mounted above the body of the aircraft, and its polar diagram is shown

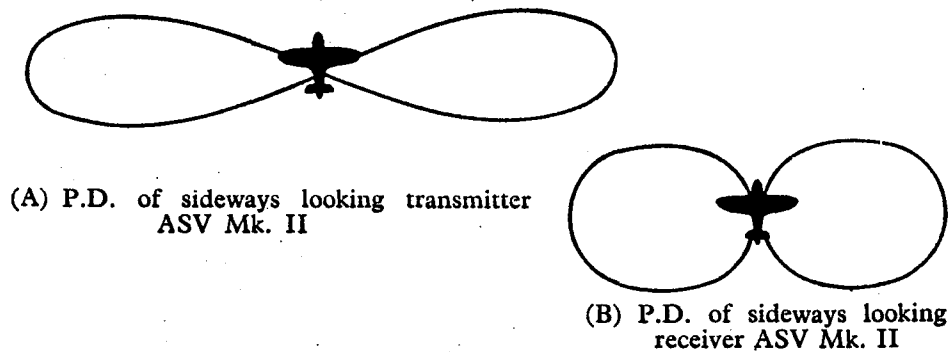


Fig. 16—ASV Mk. II, polar diagrams, sideways-looking

in fig. 16(A). There are two receiving aerials, one mounted at either side of the body of the aircraft, so that they have polar diagrams similar to those shown in fig. 16(B). Again, the echoes are received by each aerial in turn, and an echo from the starboard receiving aerial deflects the trace to the right, while that from the port aerial deflects it to the left. The operator can use either these or the forward-looking aerial systems at will. The sideways-looking system is usually employed for searching, and the forward-looking system is for homing on to the target.

58. By means of a range switch the velocity of the scan can be varied, and the time base on the tube can represent either 9, 36 or 90 nautical miles range. The range can be read directly from a scale marked in nautical miles.

59. The equipment will itself, with its own radar pulses, interrogate beacons, and beacon responses can be seen on the display tube.

60. Performance

Range on surface craft	up to 12 miles
Range on coastlines	50-70 miles
Range on responder beacons	80-90 miles
Range on BABS beacons	20 miles at 1,000 ft.

LATER MARKS OF ASV.

61. As explained in para. 1, when H2S Mk. II was finally developed for Bomber Command it was also installed in Coastal Command aircraft.

Slight modifications were required, and the equipment was called ASV Mk. III. The chief modification effected was the fitting of a different reflector to the aerial system so that a beam more suitable for searching from low altitudes was produced. Many of the equipments were installed in Wellington aircraft for attacking surfaced submarines. For night attack the usual method is to home on the target using the radar equipment until the range is one mile, and then obtain a "visual" by switching on the Leigh light. The H2S drum for computing ground range, and the height marker, are no longer required. The bombing scales are therefore replaced by range scales reading nautical miles. The height marker is preset at one mile, and is made to appear on the PPI tube, thus providing a fixed one-mile marker ring which indicates when the Leigh light should be switched on.

62. Several new equipments are in operation, and more are under development. A full list is given in A.P.1093C, Chapter 4.

General trend of ASV design

Transmitter frequency

63. Beamwidth and discriminating power already discussed in connection with H2S are also of importance in ASV equipments, particularly when the reflecting object is small as in the case of a surfaced submarine in the end-on aspect. The echo cannot be picked out on the cathode ray tube unless discrimination is good so that it can be distinguished among the general clutter of sea returns. The use of the *Schnorkel* by enemy submarines has recently led to an increased demand for better discrimination. X-band as well as S-band transmitters are now being used for ASV. On X-band a narrow beam can be more readily obtained without unduly increasing the size of the aerial system. ASV Mks. VIII A (AN/APS.3) and X (AN/APS.15) are American X-band equipments which are in use. ASV Mk. XI (ASVX) is a British X-band equipment which was designed for the Naval Air Arm, while Mks. XIII and XIV are improved versions of ASVX.

Transmitter power

64. It is most important that ASV radar apparatus should have as good a maximum range as possible in order to increase the probability of locating enemy vessels when using a given number of patrolling aircraft. A powerful transmitter is essential for obtaining long range echoes, and for this reason every opportunity is taken to increase the power and efficiency of the magnetron transmitting valves used in recent

designs. The ASV Mk. III S-band transmitter has a power of roughly 50 kW, and in favourable circumstances surfaced submarines can be detected at a maximum range of 15 miles. A more recent S-band high-powered transmitter used in Mk. VI is rated at 200 kW., and maximum range is 25 to 30 miles.

65. The X-band magnetrons which are used at present are not capable of producing quite as much power as the new S-band types, but, as the X-band beams are usually narrower, the available energy is more concentrated. The X-band ranges are therefore comparable with those obtained by using more powerful S-band transmitting valves. Very good ranges have been obtained on ASV Mk. X (AN/APS.15) which employs an X-band magnetron developing about 40 kW. In favourable circumstances submarines have been detected at 35 miles with this apparatus and schnorkels have been seen at 12 miles. It must be appreciated that range figures vary a great deal with the conditions of the sea, and also according to the aspect of the vessel; for example, if a vessel is approached end-on the maximum range of detection will be reduced to about two-thirds of the value for the broadside aspect. The figures quoted for ranges above are for broadside aspects.

Beam shape

66. It was stated that ranges can be increased by concentrating the available energy from the transmitter into a narrow beam. The S-band designs of ASV, (Mks. III and VI), use scanning mirrors somewhat similar in design to the H2S reflector, which produces a beam narrow in azimuth but wide in elevation.

67. The beam does not resemble that of a searchlight, but is wedge shaped. The object of this design is the production of an illuminated strip on the ground or sea, so that all points within range of the transmitter will be illuminated once for each turn of the scanner, and a complete map obtained on the cathode ray tube. For ASV working it is not quite so important that complete coverage should be obtained for one individual turn of the scanner, and in some equipments the beam is produced by a parabolic reflector so that it is narrow in elevation as well as in azimuth. The energy is then more concentrated and maximum ranges are improved; and, as the aircraft usually fly low when searching, a fairly good coverage is still obtained with this type of beam. If the beam is narrow in elevation, it is usually necessary to provide some means of altering the tilt of the mirror in elevation so that the sea below the aircraft, and also out towards the horizon, can be satisfactorily covered. In other words, if the beam is concentrated in this way some kind of scanning action is desirable. This may be either manual or automatic. In some equipments for example, ASV Mk. V (American ASG1) and ASV Mk. V A (American AN/APS.2,

a parabolic beam reflector is fitted, and by operating a tilt switch the beam may be set at any desired elevation. The best possible maximum range is therefore obtained, but the searching process is rendered a little more complex because the operator must adjust the scanner tilt control during search. ASV Mk. XI (ASVX designed for the Naval Air Arm) has a beam 5 deg. in horizontal cross-section and 8 deg. in the vertical plane, and the tilting of the scanner is automatic. When searching the scanner revolves once at +1.4 deg., followed by a revolution at -2.8 deg. and one at -7 deg., thus securing a coverage from one quarter of a mile out to fifty miles range and preserving the advantages of the concentrated beam.

Sector scan

68. Many ASV equipments use an all-round-looking scanner for search purposes, but sometimes facilities are provided for restricting the searching movement. The mirror may be made to swing to-and-fro in azimuth over any desired sector—an arrangement called *sector scanning*. If a weak echo is observed the beam can be oriented approximately in the direction of the target, and made to oscillate in azimuth so that only a small sector of the tube is in use. The beam then passes over the target vessel more frequently, and the echo may be improved. Sector scanning is useful when the operator is interested in searching in a specified direction.

69. ASV Mk. X (AN/APS.15) has a double sector-scan switch. The first selector switch determines the width of the sector swept out by the scanner in steps of 30 deg., and the second selector determines the azimuth of the central line of the sector relative to the aircraft heading. Sector scan facilities are provided on some of the more recent ASVX equipments. The sector width may be varied from 5 to 60 deg., provided that the extreme limits of the swing do not exceed 75 deg. port or starboard from the line-of-flight.

Attenuation of transmitted signal

70. For the detection of aircraft carrying ASV radar, enemy vessels have been equipped with a listening device consisting of an ultra-short-wave receiver for detecting the radar pulses. The strength of the received pulses increases as the aircraft approaches the vessel, and it is therefore possible to estimate the rate of approach. As a counter measure an attenuator can be fitted to the ASV equipment between the transmitter and the aerial system, as in ASV Mks. VI and VI A. As the aircraft approaches the target vessel the attenuator is adjusted so that the intensity of the radar beam is gradually reduced. This can be done without diminishing the echo too much because very much less transmitter power

is required at short ranges. The presence of the aircraft can still be detected by the listening device when the attenuator is used, but it is no longer possible to tell whether it is approaching or not. ASV Mk. VIA has an automatic attenuator requiring no adjustment by the operator.

Spiral scan for ASV

71. AI Mk. VIII (*see* Chapter 1), which employs a spiral scan with a cone of search of semi-angle 45 degrees, has been modified for use as ASV. The beamwidth is about 12 deg. both in azimuth and elevation and fairly good ranges are obtained. The ninety-mile and eight-mile range-deflection timebases are used instead of the AI radial timebase, and when the aircraft has been headed towards the target vessel the scanner is switched over to a conical scan of semi-angle 3 deg. An automatic device is fitted which gives audible or visual warning at a predetermined range. The modified AI equipment is known as ASV Mk. XII.

Stabilised scanners

72. Gyro-stabilised scanners, already mentioned in connection with H2S are fitted in some of the later marks of ASV. They are designed for use with X-band narrow beam transmitters because high discrimination cannot be obtained unless the scanner is stable. ASV Mk. XIII is an improved version of Mk. XI (Naval Air Arm ASVX) with a more powerful X-band transmitter and a roll-stabilised scanner; Mk. XIV is similar but has a scanner stabilised for both pitch and roll.

Lock follow with automatic bomb release

73. ASV Mk. VIA designed for Coastal Command has some new features. The transmitter is a high-powered (200 kW) S-band magnetron fitted with an automatic attenuator. When the operator has "locked" the scanner on to a target vessel, range and azimuth information are transmitted automatically and continuously to an indicating meter in the pilot's cockpit. A computer is installed and it is possible for the bomb-load to be released without using a Leigh light, provided that the attacking aircraft flies at constant speed and height.

74. The scanner produces a wedge-shaped beam rotating through 360 deg. for searching, but once an echo has been observed the scanner driving-motor is switched off when the scanner is pointing approximately at the target. The mirror is energised by two waveguides displaced slightly in azimuth from its focal point. The energy is fed from the transmitter through each waveguide in turn, the switch-over taking place many times per second. The beam therefore alternates rapidly between

two positions 5 deg. apart in azimuth. This arrangement is called an *azimuth split beam*. If the target is slightly displaced from the main axis of the mirror, the signals vary in amplitude according to the position of the beam; but, when the mirror is pointing directly at the target, steady signals are received all the time because the signal amplitudes are equal for both beam positions. Electrical circuits are arranged to lock the mirror on to the target vessel, and to keep the mirror pointing straight at the target. This is known as a *lock-follow* or *auto-follow* system.

75. A pilot's indicator is provided with two pointers, one to show target range from 0 to 12 nautical miles, and the other to indicate azimuth from 30 deg. port to 30 deg. starboard. Radar bearings and ranges are continuously and automatically transmitted to the pilot's meter, once the mirror has locked on to the target.

76. The Leigh light indicator has two pointers on it. The first of these indicates the bearing of the Leigh light, and the second indicates the bearing of the target obtained from the radar apparatus. The light can be kept in the correct direction ready for use by keeping the needles aligned.

- (1) *Search*. During the searching process the mirror is spinning in the usual manner and the operator watches the tube for targets. If a target is located the aircraft is directed towards it.
- (2) *Leigh light attack*. When the range is less than 10 miles the scanner is stopped with the mirror pointing approximately in the direction of the target. An "inching switch" is provided so that the mirror can be rotated by a small amount in either direction, until the echo comes up as a bright spot on the PPI tube and as a deflection signal on the height tube. A small bright spot called a strobe (*see* Chapter 1, AI Mk. V) is visible on the height tube trace, and the operator rotates the manual strobe control until the bright spot moves along the trace and comes directly on to the echo. This is known as *setting the strobe*. The auto-follow switch is then depressed and the scanner aligns on the target, and should remain aligned thereafter. When the auto-follow mechanism is switched on, the pilot's indicator is illuminated. As the range diminishes the strobe on the height tube trace remains coincident with the target echo, and range and azimuth are continuously displayed on the pilot's meter. The pilot flies so that the azimuth needle is kept central on the scale. Azimuth is also shown on the Leigh light meter so that the light can be aligned ready

to switch on. This is usually done at one-mile range. On the indicating unit there is a "velocity meter" which shows the rate at which the range is diminishing, i.e., the rate at which the echo and strobe are moving down the height tube trace. If, because of excessive sea returns or for any other reason, the strobe slips off the echo and remains stationary on the trace the auto-follow system will fail to operate. The velocity meter then reads zero. The operator should therefore watch the velocity meter during the run in, and if it slips back to zero he must reset the strobe and proceed as before.

- (3) *Blind bombing.* Provided that the problem of identification can be overcome, blind bombing runs may be carried out with

ASV Mk. VIA. The searching process and transmission to automatic follow are carried out as above. The attacking aircraft must fly at constant height and speed, and the pilot must avoid "weaving" when approaching the target vessel. The height is set on the computer by the operator at the beginning of the run. Three coloured lamps—green, amber, and red—flash on at intervals as the range diminishes so that the operator can tell that the computer is working. The red lamp lights up at about 4,000 ft. range and the bombs are released when it goes out. The release point depends on the ground speed and height. If the pilot decides at the last moment, not to attack, an over-riding switch in the cockpit can be placed in the "safe" position.

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