CHAPTER 13

RADAR NAVIGATION

PRINCIPLES OF RADAR OPERATION

1300. Introduction

Radar determines distance to an object by measuring the time required for a radio signal to travel from a transmitter to an object and return. Since most radars use directional antennae, they can also determine an object's bearing. However, a radar's bearing measurement will be less accurate than its distance measurement. Understanding this concept is crucial to ensuring the optimal employment of the radar for safe navigation.

1301. Signal Characteristics

In most marine navigation applications, the radar signal is pulse modulated. Signals are generated by a timing circuit so that energy leaves the antenna in very short pulses. When transmitting, the antenna is connected to the transmitter but not the receiver. As soon as the pulse leaves, an electronic switch disconnects the antenna from the transmitter and connects it to the receiver. Another pulse is not transmitted until after the preceding one has had time to travel to the most distant target within range and return. Since the interval between pulses is long compared with the length of a pulse, strong signals can be provided with low average power. The duration or length of a single pulse is called **pulse length**, **pulse duration**, or **pulse width**. This pulse emission sequence repeats a great many times, perhaps 1,000 per second. This rate defines the **pulse repetition rate (PRR)**. The returned pulses are displayed on an indicator screen.

1302. The Display

The most common type of radar display used in the Navy is the **plan position indicator (PPI)**. On a PPI, the sweep starts at the center of the display and moves outward along a radial line rotating in synchronization with the antenna. A detection is indicated by a brightening of the display screen at the bearing and range of the return. Because of a luminescent tube face coating, the glow continues after the trace rotates past the target. Figure 1302 shows this presentation.

On a PPI, a target's actual range is proportional to its echo's distance from the scope's center. A moveable cursor helps to measure ranges and bearings. In the "heading-upward" presentation, which indicates relative bearings, the top of the scope represents the direction of the ship's head. In this unstabilized presentation, the orientation changes as the ship changes heading. In the stabilized "north-upward" presentation, gyro north is always at the top of the scope.

1303. The Radar Beam

The pulses of energy comprising the radar beam would form a single lobe-shaped pattern of radiation if emitted in free space. Figure 1303a. shows this free space radiation pattern, including the undesirable minor lobes or side lobes associated with practical antenna design.

Although the radiated energy is concentrated into a relatively narrow main beam by the antenna, there is no clearly defined envelope of the energy radiated. The energy is concentrated along the axis of the beam. With the rapid decrease in the amount of radiated energy in directions away from this axis, practical power limits may be used to define the dimensions of the radar beam.

A radar beam's horizontal and vertical beam widths are referenced to arbitrarily selected power limits. The most common convention defines beam width as the angular width between half power points. The half power point corresponds to a drop in 3 decibels from the maximum beam strength.

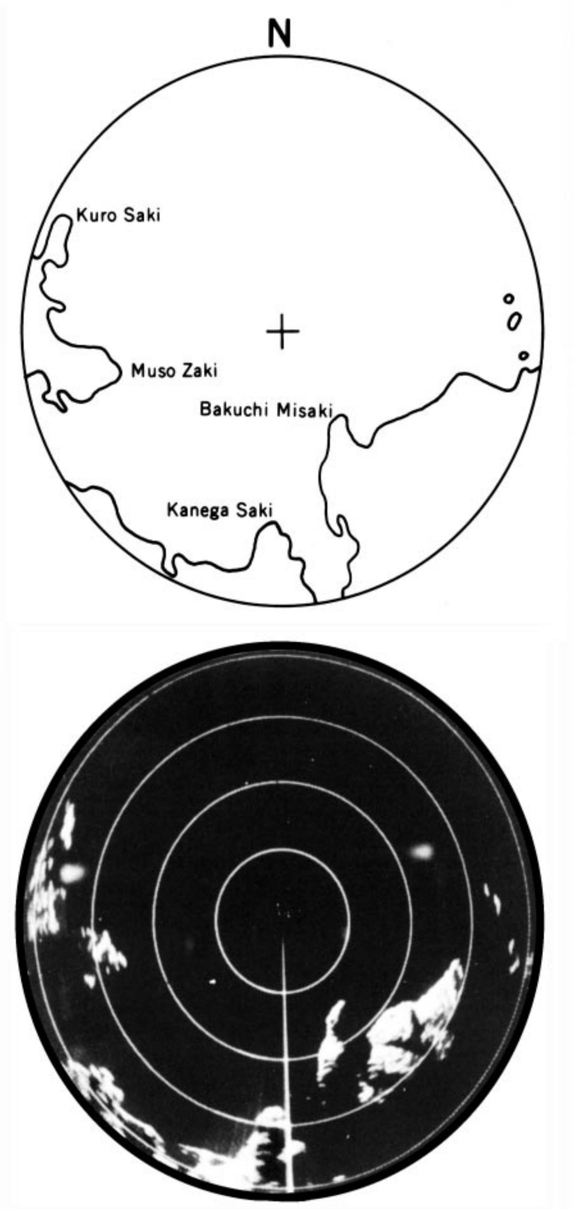
The definition of the decibel shows this halving of power at a decrease in 3 dB from maximum power. A decibel is simply the logarithm of the ratio of a final power level to a reference power level:

$$\text{dB} = 10 \log\left[\frac{P_1}{P_0}\right]$$

where P_1 is the final power level, and P_0 is a reference power level. When calculating the dB drop for a 50% reduction in power level, the equation becomes:

$$\begin{aligned} \text{dB} &= 10 \log(.5) \\ \text{dB} &= -3 \text{ dB} \end{aligned}$$

The radiation diagram shown in Figure 1303b depicts relative values of power in the same plane existing at the same distances from the antenna or the origin of the radar beam. Maximum power is in the direction of the axis of the beam. Power values diminish rapidly in directions away from the axis. The beam width is taken as the angle



HONSHU, NW COAST-APPROACH
TO MAIZURU KO
Radar position: 35°34'.1 N., 135°19'.6 E.
Range ring interval: 1 mile
(Source: Japanese Sailing Directions)

Figure 1302. Plan Position Indicator (PPI) display.

between the half-power points.

The beam width depends upon the frequency or wavelength of the transmitted energy, antenna design, and the dimensions of the antenna.

For a given antenna size (antenna aperture), narrower beam widths result from using shorter wavelengths. For a given wavelength, narrower beam widths result from using larger antennas.

With radar waves being propagated in the vicinity of the surface of the sea, the main lobe of the radar beam is composed of a number of separate lobes, as opposed to the single lobe-shaped pattern of radiation as emitted in free space. This phenomenon is the result of interference between radar waves directly transmitted, and those waves which are reflected from the surface of the sea. Radar waves strike the surface of the sea, and the indirect waves reflect off the surface of the sea. See Figure 1303c. These reflected waves either constructively or destructively interfere with the direct waves depending upon the waves' phase relationship.

1304. Diffraction And Attenuation

Diffraction is the bending of a wave as it passes an obstruction. Because of diffraction there is some illumination of the region behind an obstruction or target by the radar beam. Diffraction effects are greater at the lower frequencies. Thus, the radar beam of a lower frequency radar tends to illuminate more of the shadow region behind an obstruction than the beam of a radar of higher frequency or shorter wavelength.

Attenuation is the scattering and absorption of the energy in the radar beam as it passes through the atmosphere. It causes a decrease in echo strength. Attenuation is greater at the higher frequencies or shorter wavelengths.

While reflected echoes are much weaker than the transmitted pulses, the characteristics of their return to the source are similar to the characteristics of propagation. The strengths of these echoes are dependent upon the amount of transmitted energy striking the targets and the size and reflecting properties of the targets.

1305. Refraction

If the radar waves traveled in straight lines, the distance to the radar horizon would be dependent only on the power output of the transmitter and the height of the antenna. In other words, the distance to the radar horizon would be the same as that of the geometrical horizon for the antenna height. However, atmospheric density gradients bend radar rays as they travel to and from a target. This bending is called **refraction**.

The following formula, where h is the height of the antenna in feet, gives the distance to the radar horizon in nautical miles:

$$d = 1.22\sqrt{h}\ .$$

The distance to the radar horizon does not limit the distance from which echoes may be received from targets. As-

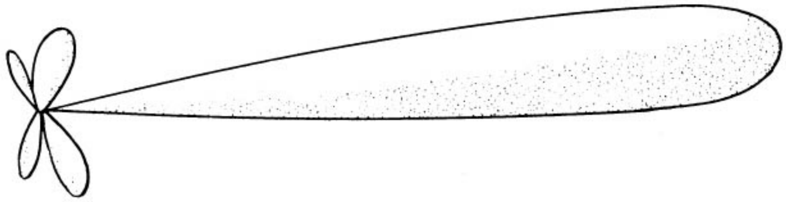


Figure1303a. Freespace radiation pattern.

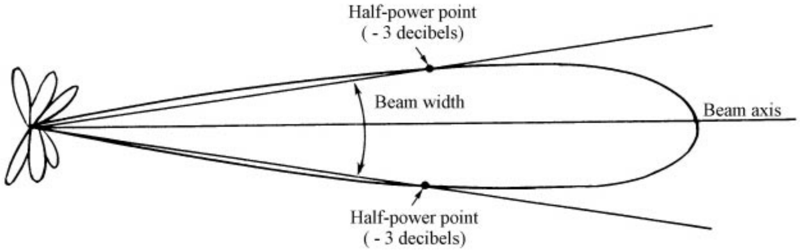


Figure1303b. Radiation diagram.

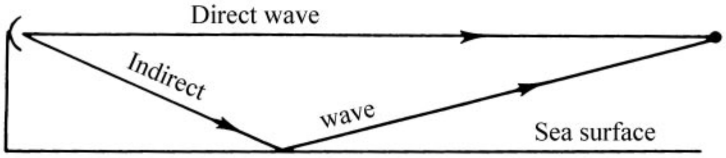


Figure1303c. Direct and indirect waves.

suming that adequate power is transmitted, echoes may be received from targets beyond the radar horizon if their reflecting surfaces extend above it. Note that the distance to the radar horizon is the distance at which the radar rays pass tangent to the surface of the earth.

1306. Factors Affecting Radar Interpretation

Radar's value as a navigational aid depends on the navigator's understanding its characteristics and limitations. Whether measuring the range to a single reflective object or trying to discern a shoreline lost amid severe clutter, knowledge of the characteristics of the individual radar used are crucial. Some of the factors to be considered in interpretation are discussed below:

- **Resolution in Range.** In part A of Figure 1306a, a transmitted pulse has arrived at the second of two targets of insufficient size or density to absorb or reflect all of the energy of the pulse. While the pulse has traveled from the first to the second target, the echo from the first has traveled an equal distance in the opposite direction. At B, the transmitted pulse has continued on beyond the second target, and the two echoes are returning toward the transmitter. The distance between leading edges of the two echoes is twice the distance between targets. The correct distance will be shown on the scope, which is calibrated to show half the distance traveled out and back. At C the targets are closer together and the pulse length has been increased. The two echoes merge, and on the scope they will appear as a single, large target. At D the pulse length has been decreased, and the two echoes appear separated. The ability of a radar to separate targets close together on the same bearing is called **resolution in range**. It is related primarily to pulse length. The minimum distance between targets that can be distinguished as separate is half the pulse length. This (half the pulse length) is the apparent depth or thickness of a target presenting a flat perpendicular surface to the radar beam. Thus, several ships close together may appear as an island. Echoes from a number of small boats, piles, breakers, or even large ships close to the shore may blend with echoes from the shore, resulting in an incorrect indication of the position and shape of the shoreline.

- **Resolution in Bearing**. Echoes from two or more targets close together at the same range may merge to form a single, wider echo. The ability to separate targets is called **resolution in bearing**. Bearing resolution is a function of two variables: beam width and range between targets. A narrower beam and a shorter distance between objects both increase bearing resolution.

- **Height of Antenna and Target**. If the radar horizon is between the transmitting vessel and the target, the lower part of the target will not be visible. A large vessel may appear as a small craft, or a shoreline may appear at some distance inland.

- **Reflecting Quality and Aspect of Target**. Echoes from several targets of the same size may be quite different in appearance. A metal surface reflects radio waves more strongly than a wooden surface. A surface perpendicular to the beam returns a stronger echo than a non perpendicular one. For this reason, a gently sloping beach may not be visible. A vessel encountered broadside returns a stronger echo than one heading directly toward or away.

- **Frequency**. As frequency increases, reflections occur from smaller targets.

Atmospheric noise, sea return, and precipitation complicate radar interpretation by producing **clutter**. Clutter is usually strongest near the vessel. Strong echoes can sometimes be detected by reducing receiver gain to eliminate weaker signals. By watching the repeater during several rotations of the antenna, the operator can discriminate between clutter and a target even when the signal strengths from clutter and the target are equal. At each rotation, the

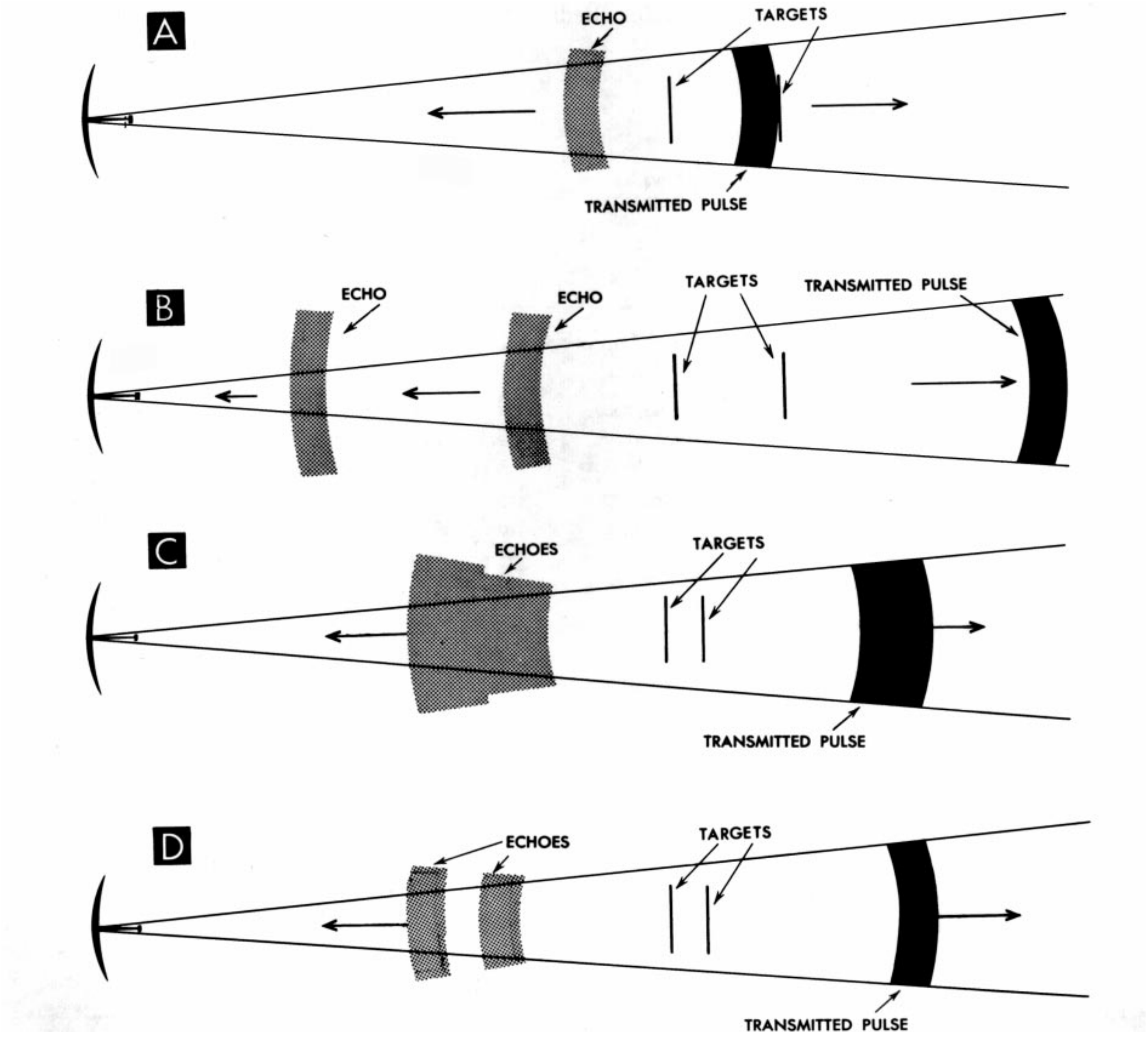


Figure 1306a. Resolution in range.

signals from targets will remain relatively stationary on the display while those caused by clutter will appear at different locations.

Another major problem lies in determining which features in the vicinity of the shoreline are actually represented by echoes shown on the repeater. Particularly in cases where a low lying shore is being scanned, there may be considerable uncertainty.

A related problem is that certain features on the shore will not return echoes because they are blocked from the radar beam by other physical features or obstructions. This factor in turn causes the chart like image painted on the scope to differ from the chart of the area.

If the navigator is to be able to interpret the presentation on his radarscope, he must understand the characteristics of radar propagation, the capabilities of his radar set, the reflecting properties of different types of radar targets, and the ability to analyze his chart to determine which charted features are most likely to reflect the transmitted pulses or to be blocked. Experience gained during clear weather comparison between radar and visual images is invaluable.

Land masses are generally recognizable because of the steady brilliance of the relatively large areas painted on the PPI. Also, land should be at positions expected from the ship's navigational position. Although land masses are readily recognizable, the primary problem is the identification of specific land features. Identification of specific features can be quite difficult because of various factors, including distortion resulting from beam width and pulse length, and uncertainty as to just which charted features are reflecting the echoes.

Sand spits and smooth, clear beaches normally do not appear on the PPI at ranges beyond 1 or 2 miles because these targets have almost no area that can reflect energy back to the radar. Ranges determined from these targets are not reliable. If waves are breaking over a sandbar, echoes may be returned from the surf. Waves may, however, break well out from the actual shoreline, so that ranging on the surf may be misleading.

Mud flats and marshes normally reflect radar pulses only a little better than a sand spit. The weak echoes received at low tide disappear at high tide. Mangroves and other thick growth may produce a strong echo. Areas that are indicated as swamps on a chart, therefore, may return either strong or weak echoes, depending on the density and size of the vegetation growing in the area.

When sand dunes are covered with vegetation and are well back from a low, smooth beach, the apparent shoreline determined by radar appears as the line of the dunes rather than the true shoreline. Under some conditions, sand dunes may return strong echo signals because the combination of the vertical surface of the vegetation and the horizontal beach may form a sort of corner reflector.

Lagoons and inland lakes usually appear as blank areas on a PPI because the smooth water surface returns no energy to the radar antenna. In some instances, the sandbar or reef surrounding the lagoon may not appear on the PPI because it lies too low in the water.

Coral atolls and long chains of islands may produce long lines of echoes when the radar beam is directed perpendicular to the line of the islands. This indication is especially true when the islands are closely spaced. The reason is that the spreading resulting from the width of the radar beam causes the echoes to blend into continuous lines. When the chain of islands is viewed lengthwise, or obliquely, however, each island may produce a separate return. Surf breaking on a reef around an atoll produces a ragged, variable line of echoes.

One or two rocks projecting above the surface of the water, or waves breaking over a reef, may appear on the PPI. When an object is submerged entirely and the sea is smooth over it, no indication is seen on the PPI.

If the land rises in a gradual, regular manner from the shoreline, no part of the terrain produces an echo that is stronger than the echo from any other part. As a result, a general haze of echoes appears on the PPI, and it is difficult to ascertain the range to any particular part of the land.

Blotchy signals are returned from hilly ground, because the crest of each hill returns a good echo although the valley beyond is in a shadow. If high receiver gain is used, the pattern may become solid except for the very deep shadows.

Low islands ordinarily produce small echoes. When thick palm trees or other foliage grow on the island, strong echoes often are produced because the horizontal surface of the water around the island forms a sort of corner reflector with the vertical surfaces of the trees. As a result, wooded islands give good echoes and can be detected at a much greater range than barren islands.

Sizable land masses may be missing from the radar display because of certain features being blocked from the radar beam by other features. A shoreline which is continuous on the PPI display when the ship is at one position, may not be continuous when the ship is at another position and scanning the same shoreline. The radar beam may be blocked from a segment of this shoreline by an obstruction such as a promontory. An indentation in the shoreline, such as a cove or bay, appearing on the PPI when the ship is at one position, may not appear when the ship is at another position nearby. Thus, radar shadow alone can cause considerable differences between the PPI display and the chart presentation. This effect in conjunction with beam width and pulse length distortion of the PPI display can cause even greater differences.

The returns of objects close to shore may merge with the shoreline image on the PPI, because of distortion effects of horizontal beam width and pulse length. Target images on the PPI always are distorted angularly by an amount equal to the effective horizontal beam width. Also, the target images always are distorted radially by an amount at least equal to one-half the pulse length (164 yards per microsecond of pulse length).

Figure 1306b illustrates the effects of ship's position, beam width, and pulse length on the radar shoreline. Because of beam width distortion, a straight, or nearly

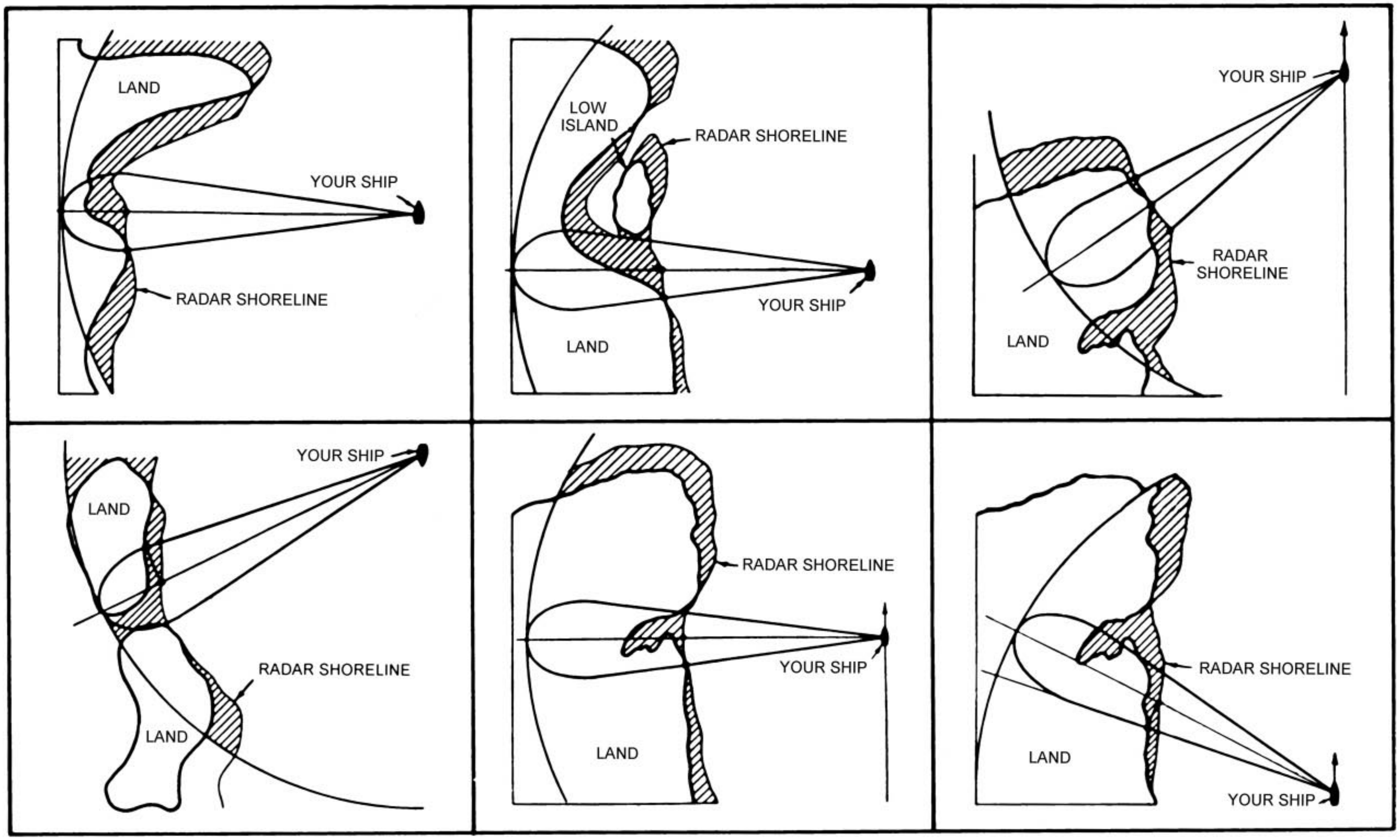


Figure 1306b. Effects of ship’s position, beam width, and pulse length on radar shoreline.

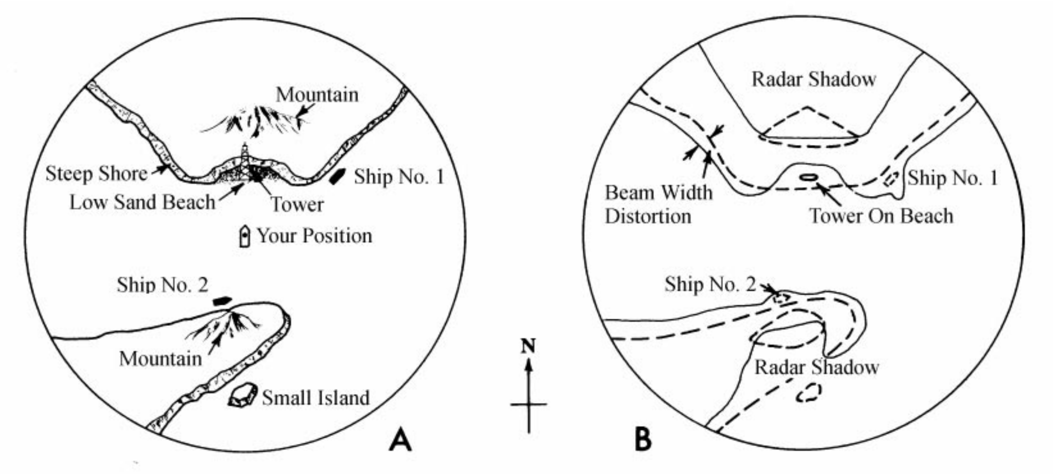


Figure 1306c. Distortion effects of radar shadow, beam width, and pulse length.

straight, shoreline often appears crescent-shaped on the PPI. This effect is greater with the wider beam widths. Note that this distortion increases as the angle between the beam axis and the shoreline decreases.

Figure 1306c illustrates the distortion effects of radar shadow, beam width, and pulse length. View A shows the actual shape of the shoreline and the land behind it. Note the steel tower on the low sand beach and the two ships at anchor close to shore. The heavy line in view B represents the shoreline on the PPI. The dotted lines represent the actual position and shape of all targets. Note in particular:

1. The low sand beach is not detected by the radar.
2. The tower on the low beach is detected, but it looks like a ship in a cove. At closer range the land would be detected and the cove-shaped area would begin to fill in; then the tower could not be seen without reducing the receiver gain.
3. The radar shadow behind both mountains. Distortion owing to radar shadows is responsible for more confusion than any other cause. The small island does not appear because it is in the radar shadow.
4. The spreading of the land in bearing caused by beam width distortion. Look at the upper shore of the peninsula. The shoreline distortion is greater to the west because the angle between the radar beam and the shore is smaller as the beam seeks out the more westerly shore.
5. Ship No. 1 appears as a small peninsula. Her return has merged with the land because of the beam width distortion.
6. Ship No. 2 also merges with the shoreline and forms a bump. This bump is caused by pulse length and beam width distortion. Reducing receiver gain might cause the ship to separate from land, provided the ship is not too close to the shore. The Fast Time Constant (FTC) control could also be used to attempt to separate the ship from land.

1307. Recognition Of Unwanted Echoes

The navigator must be able to recognize various abnormal echoes and effects on the radarscope so as not to be confused by their presence.

Indirect or false echoes are caused by reflection of the main lobe of the radar beam off ship’s structures such as stacks and kingposts. When such reflection does occur, the echo will return from a legitimate radar contact to the antenna by the same indirect path. Consequently, the echo will appear on the PPI at the bearing of the reflecting surface. As shown in Figure 1307a, the indirect echo will appear on the PPI at the same range as the direct echo received, assuming that the additional distance by the indirect path is negligible.

Characteristics by which indirect echoes may be recognized are summarized as follows:

1. The indirect echoes will usually occur in shadow sectors.
2. They are received on substantially constant bearings, although the true bearing of the radar contact may change appreciably.
3. They appear at the same ranges as the corresponding direct echoes.
4. When plotted, their movements are usually abnormal.
5. Their shapes may indicate that they are not direct echoes.

Side-lobe effects are readily recognized in that they produce a series of echoes (Figure 1307b) on each side of the main lobe echo at the same range as the latter. Semicircles, or even complete circles, may be produced. Because of the low energy of the side-lobes, these effects will normally

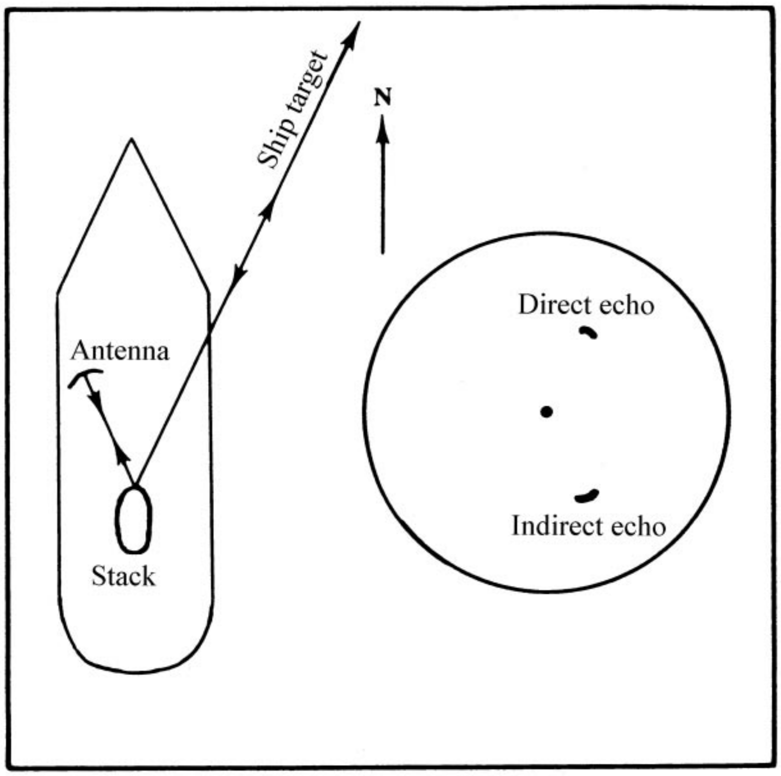


Figure 1307a. Indirect echo.

occur only at the shorter ranges. The effects may be minimized or eliminated, through use of the gain and anti-clutter controls. Slotted wave guide antennas have largely eliminated the side-lobe problem.

Multiple echoes may occur when a strong echo is received from another ship at close range. A second or third or more echoes may be observed on the radarscope at double, triple, or other multiples of the actual range of the radar contact (Figure 1307c).

Second-trace echoes (multiple-trace echoes) are echoes received from a contact at an actual range greater than the radar range setting. If an echo from a distant target is received after the following pulse has been transmitted, the echo will appear on the radarscope at the correct bearing but not at the true range. Second-trace echoes are unusual, except under abnormal atmospheric conditions, or conditions under which super-refraction is present. Second-trace echoes may be recognized through changes in their positions on the radarscope in changing the pulse repetition rate (PRR); their hazy, streaky, or distorted shape; and the erratic movements on plotting.

As illustrated in Figure 1307d, a target return is detected on a true bearing of 090° at a distance of 7.5 miles. On changing the PRR from 2,000 to 1,800 pulses per second, the same target is detected on a bearing of 090° at a distance of 3 miles (Figure 1307e). The change in the position of the return indicates that the return is a second-trace echo. The actual distance of the target is the distance as indicated on the PPI plus half the distance the radar wave travels between pulses.

Electronic interference effects, such as may occur when near another radar operating in the same frequency band as that of the observer's ship, is usually seen on the PPI as a large number of bright dots either scattered at random or in the form of dotted lines extending from the center to the edge of the PPI.

Interference effects are greater at the longer radar range scale settings. The interference effects can be distinguished easily from normal echoes because they do not appear in the same places on successive rotations of the antenna.

Stacks, masts, samson posts, and other structures, may cause a reduction in the intensity of the radar beam beyond these obstructions, especially if they are close to the radar antenna. If the angle at the antenna subtended by the obstruction is more than a few degrees, the reduction of the intensity of the radar beam beyond the obstruction may produce a blind sector. Less reduction in the intensity of the beam beyond the obstructions may produce shadow sectors. Within a shadow sector, small targets at close range may not be detected, while larger targets at much greater ranges will appear.

Spoking appears on the PPI as a number of spokes or radial lines. Spoking is easily distinguished from interference effects because the lines are straight on all range-scale settings, and are lines rather than a series of dots.

The spokes may appear all around the PPI, or they may be confined to a sector. If spoking is confined to a narrow sector, the effect can be distinguished from a Ramark signal of similar appearance through observation of the steady relative bearing

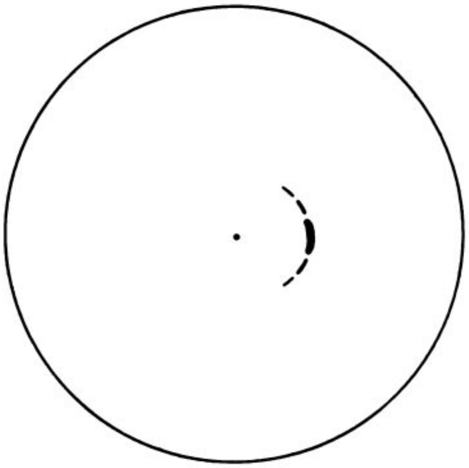


Figure 1307b. Side-lobe effects.

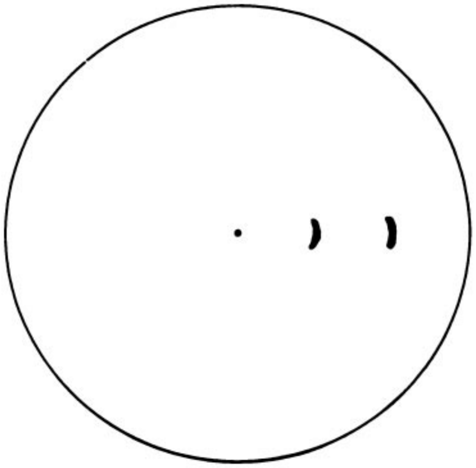


Figure 1307c. Multiple echoes.

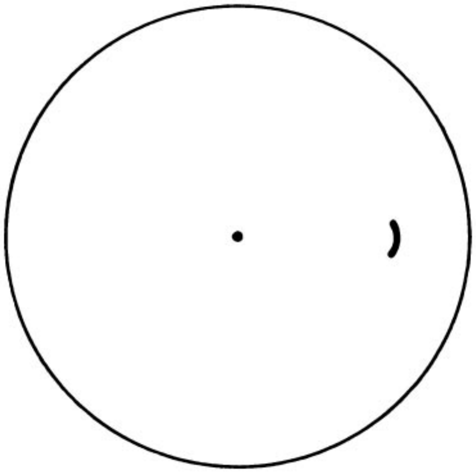


Figure 1307d. Second-trace echo on 12-mile range scale.

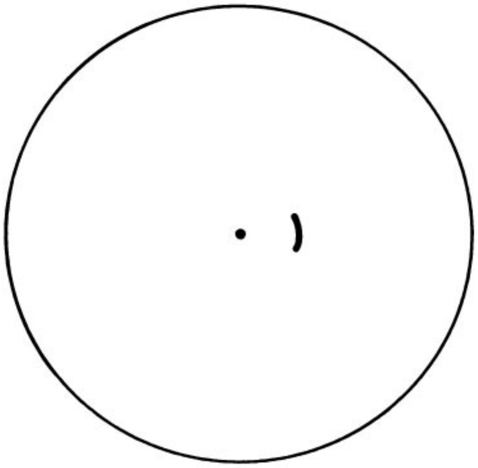


Figure 1307e. Position of second-trace echo on 12-mile range scale after changing PRR.

Figure 1307f

of the spoke in a situation where the bearing of the Ramark signal should change. Spoking indicates a need for maintenance or adjustment.

The PPI display may appear as normal sectors alternating with dark sectors. This is usually due to the automatic frequency control being out of adjustment.

The appearance of serrated range rings indicates a need for maintenance.

After the radar set has been turned on, the display may not spread immediately to the whole of the PPI because of static electricity inside the CRT. Usually, the static electricity effect, which produces a distorted PPI display, lasts no longer than a few minutes.

Hour-glass effect appears as either a constriction or expansion of the display near the center of the PPI. The expansion effect is similar in appearance to the expanded center display. This effect, which can be caused by a nonlinear time base or the sweep not starting on the indicator at the same instant as the transmission of the pulse, is most apparent when in narrow rivers or close to shore.

The echo from an overhead power cable appears on the PPI as a single echo always at right angles to the line of the cable. If this phenomenon is not recognized, the echo can be wrongly identified as the echo from a ship on a steady bearing. Avoiding action results in the echo remaining on a constant bearing and moving to the same side of the channel as the ship altering course. This phenomenon is particularly apparent for the power cable spanning the Straits of Messina.

1308. Aids To Radar Navigation

Radar navigation aids help identify radar targets and increase echo signal strength from otherwise poor radar targets.

Buoys are particularly poor radar targets. Weak, fluctuating echoes received from these targets are easily lost in the sea clutter. To aid in the detection of these targets, **radar**

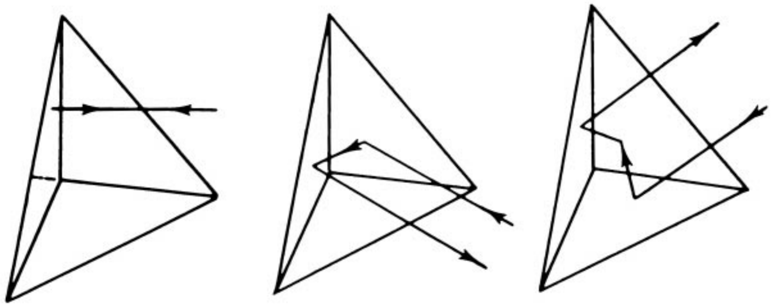


Figure 1308a. Corner reflectors.

reflectors, designated corner reflectors, may be used. These reflectors may be mounted on the tops of buoys. Additionally, the body of the buoy may be shaped as a reflector.

Each corner reflector, shown in Figure 1308a, consists of three mutually perpendicular flat metal surfaces. A radar wave striking any of the metal surfaces or plates will be reflected back in the direction of its source. Maximum energy will be reflected back to the antenna if the axis of the radar beam makes equal angles with all the metal surfaces. Frequently, corner reflectors are assembled in clusters to maximize the reflected signal.

Although radar reflectors are used to obtain stronger echoes from radar targets, other means are required for more positive identification of radar targets. **Radar beacons** are transmitters operating in the marine radar frequency band, which produce distinctive indications on the radarscopes of ships within range of these beacons. There are two general classes of these beacons: **racons**, which provide both bearing and range information to the target, and **ramarks** which provide bearing information only. However, if the ramark installation is detected as an echo on the radarscope, the range will be available also.

A racon is a radar transponder which emits a characteristic signal when triggered by a ship's radar. The signal may be emitted on the same frequency as that of the triggering radar, in which case it is superimposed on the ship's radar display automatically. The signal may be emitted on a separate frequency, in which case to receive the signal the ship's radar receiver must be tuned to the beacon frequency, or a special receiver must be used. In either case, the PPI will be blank except for the beacon signal. However, the only racons in service are "in band" beacons which transmit in one of the marine radar bands, usually only the 3-centimeter band.

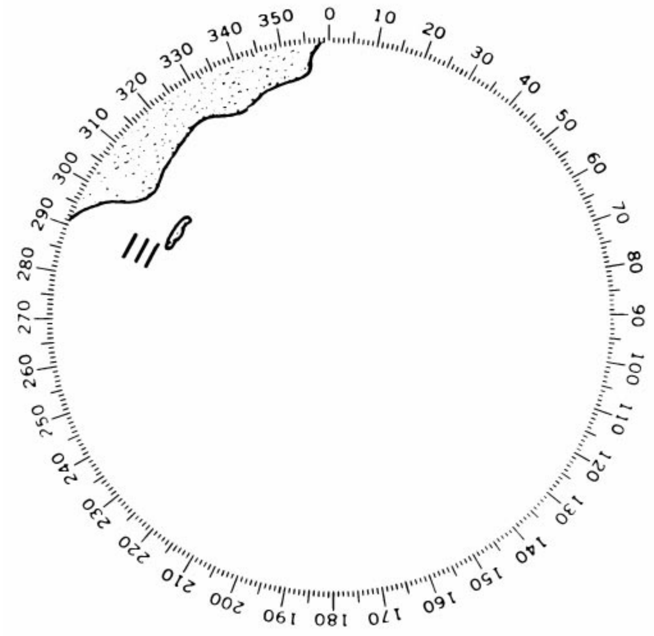


Figure 1308b. Coded racon signal.

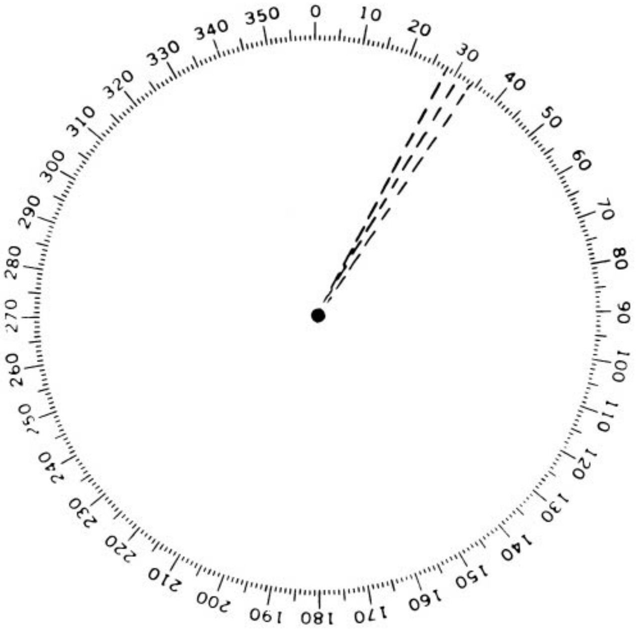


Figure 1308c. Ramark signal appearing as a broken radial line.

The racon signal appears on the PPI as a radial line originating at a point just beyond the position of the radar beacon, or as a Morse code signal (Figure 1308b) displayed radially from just beyond the beacon.

A ramark is a radar beacon which transmits either continuously or at intervals. The latter method of transmission is used so that the PPI can be inspected without any clutter introduced by the ramark signal on the scope. The ramark signal as it appears on the PPI is a radial line from the center. The radial line may be a continuous narrow line, a broken line (Figure 1308c), a series of dots, or a series of dots and dashes.

RADAR PILOTING

1309. Introduction

When navigating in restricted waters, a mariner most often relies on visual piloting to provide the accuracy required to ensure ship safety. Visual piloting, however, requires clear weather; often, mariners must navigate through fog. When conditions render visual piloting impossible and a vessel is not equipped with DGPS, radar navigation provides a method of fixing a vessel's position with sufficient accuracy to allow safe passage. See Chapter 8 for a detailed discussion of integrating radar into a piloting procedure.

1310. Fixing Position By Two Or More Simultaneous Ranges

The most accurate radar fixes result from measuring and plotting ranges to two or more objects. Measure objects directly ahead or astern first; measure objects closest to the beam last. This procedure is the opposite to that recommended for taking visual bearings, where objects closest to the beam are measured first; however, both recommendations rest on the same principle. When measuring objects to determine a line of position, measure first those which have the greatest rate of change in the quantity being measured; measure last those which have the least rate of change in that quantity. This minimizes measurement time delay errors. Since the range of those objects directly ahead or astern of the ship changes more rapidly than those objects located abeam, measure objects ahead or astern first.

Record the ranges to the navigation aids used and lay the resulting range arcs down on the chart. Theoretically, these lines of position should intersect at a point coincident with the ship's position at the time of the fix. However, the inherent inaccuracy of the radar coupled with the relatively large scale of most piloting charts usually precludes such a point fix. In this case, the navigator must carefully interpret the resulting fix. Check the echo sounder with the charted depth where the fix lies. If both soundings consistently correlate, that is an indication that the fixes are accurate. If there is disparity in the sounding data, then that is an indication that either the radar ranges were inaccurate or that the piloting party has misplotted them.

This practice of checking sounding data with each fix cannot be overemphasized. Though verifying soundings is always a good practice in all navigation scenarios, its importance increases tremendously when piloting using only radar. Assuming proper operation of the fathometer, soundings give the navigator invaluable information on the reliability of his fixes. When a disparity exists between the charted depth at the fix and the recorded sounding, the navigator should assume that the disparity has been caused by fix inaccuracy. This is especially true if the fathometer shows the ship heading into water shallower than that anticipated. When there is a consistent disparity between charted and fathometer sounding data, the navigator should assume that he does not know the ship's position with sufficient accuracy to proceed safely. The ship should be slowed or stopped until the navigator is confident that he can continue his passage safely.

1311. Fixing Position By A Range And Bearing To One Object

Visual piloting requires bearings from at least two objects; radar, with its ability to determine both bearing and range from one object, allows the navigator to obtain a fix where only a single navigation aid is available. An example of using radar in this fashion occurs in approaching a harbor whose entrance is marked with a single, prominent light such as Chesapeake Light at the entrance of the Chesapeake Bay. Well beyond the range of any land-based visual navigation aid, and beyond the visual range of the light itself, a shipboard radar can detect the light and provide bearings and ranges for the ship's piloting party.

This methodology is limited by the inherent inaccuracy associated with radar bearings; typically, a radar bearing is accurate to within 5° of the true bearing. Therefore, the navigator must carefully evaluate the resulting position, checking it particularly with the sounding obtained from the bottom sounder. If a visual bearing is available from the object, use that bearing instead of the radar bearing when laying down the fix. This illustrates the basic concept discussed above: radar ranges are inherently more accurate than radar bearings.

Prior to using this single object method, the navigator must ensure that he has correctly identified the object from which the bearing and range are to be taken. Using only one navigation aid for both lines of position can lead to disaster if the navigation aid is not properly identified.

1312. Fixing Position With Tangent Bearings And A Range

This method combines bearings tangent to an object with a range measurement from some point on that object. The object must be large enough to provide sufficient bearing spread between the tangent bearings; often an island is used. Identify some prominent feature of the object that is displayed on both the chart and the radar display. Take a range measurement from that feature and plot it on the chart. Then determine the tangent bearings to the island and plot them on the chart.

1313. Fixing Position By Bearings To Two Or More Objects

The inherent inaccuracy of radar bearings discussed above makes this method less accurate than fixing position by radar range. Use this method to plot a position quickly on the chart when approaching restricted waters to obtain an approximate ship's position for evaluating radar targets to use for range measurements. Speed is the advantage of this method, as the plotter can lay bearings down more quickly than ranges on the chart. Unless no more accurate method is available, do not use this method while piloting in restricted waters.

1314. Fischer Plotting

In Fischer plotting, the navigator adjusts the scale of the radar to match the scale of the chart in use. He then overlays the PPI screen with a clear surface such as Plexiglas and traces the shape of land and location of navigation aids from the radar scope onto the Plexiglas. He then transfers the surface from the radar scope to the chart. He matches the chart's features with the features on the radar by adjusting the tracings on the Plexiglas to match the charts features. Once obtaining the best fit, he marks the ship's position as the center of the Plexiglas cover.

RASTER RADARS

1315. Basic Description

Conventional PPI-display radars use a **Cathode Ray Tube (CRT)** to direct an electron beam at a screen coated with phosphorus. The phosphorus glows when illuminated by an electron beam. Internal circuitry forms the beam such that a "sweep" is indicated on the face of the PPI. This sweep is timed to coincide with the sweep of the radar's antenna. A return echo is added to the sweep signal so that the screen is more brightly illuminated at a point corresponding to the bearing and range of the target that returned the echo.

The raster radar also employs a cathode ray tube; however, the end of the tube upon which the picture is formed is rectangular, not circular as in the PPI display. The raster radar does not produce its picture from a circular sweep; it utilizes a liner scan in which the picture is "drawn," line by line, horizontally across the screen. As the sweep moves across the screen, the electron beam from the CRT illuminates the **pixels** on the screen. A pixel is the smallest area of phosphorus that can be excited to form a picture element.

In order to produce a sufficiently high resolution, some raster radars require over 1 million pixels per screen combined with an update rate of 60 scans per second. Completing the processing for such a large number of pixel elements requires sophisticated, expensive circuitry. One way to lower cost is to slow down the required processing speed. This speed can be lowered to approximately 30 frames per second before the picture develops a noticeable flicker.

Further cost reduction can be gained by using an **interlaced display**. An interlaced display does not draw the entire picture in one pass. On the first pass, it draws every other line; it draws the remaining lines on the second pass. This type of display reduces the number of screens that have to be drawn per unit time by a factor of two; however, if the two pictures are misaligned, the picture will appear to jitter.

Raster radars represent the future of radar technology, and they will be utilized in the integrated bridge systems discussed in Chapter 14.