CHAPTER 4 — RADAR NAVIGATION

RADARSCOPE INTERPRETATION

In its position finding or navigational application, radar may serve the navigator as a very valuable tool if its characteristics and limitations are understood. While determining position through observation of the range and bearing of a charted, isolated, and well defined object having good reflecting properties is relatively simple, this task still requires that the navigator have an understanding of the characteristics and limitations of his radar. The more general task of using radar in observing a shoreline where the radar targets are not so obvious or well defined requires considerable expertise which may be gained only through an adequate understanding of the characteristics and limitations of the radar being used.

While the plan position indicator does provide a chartlike presentation when a landmass is being scanned, the image painted by the sweep is not a true representation of the shoreline. The width of the radar beam and the length of the transmitted pulse are factors which act to distort the image painted on the scope. Briefly, the width of the radar beam acts to distort the shoreline features in bearing; the pulse length may act to cause offshore features to appear as part of the landmass.

The major problem is that of determining which features in the vicinity of the shoreline are actually reflecting the echoes painted on the scope. Particularly in cases where a low lying shore is being scanned, there may be considerable uncertainty.

An associated problem is the fact that certain features on the shore will not return echoes, even if they have good reflecting properties, simply because they are blocked from the radar beam by other physical features or obstructions. This factor in turn causes the chartlike image painted on the scope to differ from the chart of the area.

If the navigator is to be able to interpret the chartlike presentation on his radarscope, he must have at least an elementary understanding of the characteristics of radar propagation, the characteristics of his radar set, the reflecting properties of different types of radar targets, and the ability to analyze his chart to make an estimate of just which charted features are most likely to reflect the transmitted pulses or to be blocked from the radar beam. While contour lines on the chart topography aid the navigator materially in the latter task, experience gained during clear weather comparison of the visual cross-bearing plot and the radarscope presentation is invaluable.

LAND TARGETS

On relative and true motion displays, landmasses are readily recognizable because of the generally steady brilliance of the relatively large areas painted on the PPI. Also land should be at positions expected from knowledge of the ship’s navigational position. On relative motion displays, landmasses move in directions and at rates opposite and equal to the actual motion of the observer’s ship. Individual pips do not move relative to one another. On true motion displays, landmasses do not move on the PPI if there is accurate compensation for set and drift. Without such compensation, i.e., when the true motion display is sea-stabilized, only slight movements of landmasses may be detected on the PPI.

While landmasses are readily recognizable, the primary problem is the identification of specific features so that such features can be used for fixing the position of the observer’s ship. 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. The following hints may be used as an aid in identification:

(a) Sandspits 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 when a radar position is being determined relative to shoreline.

(b) Mud flats and marshes normally reflect radar pulses only a little better than a sandspit. 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.

(c) 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.

(d) 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.

(e) 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 pip. Surf breaking on a reef around an atoll produces a ragged, variable line of echoes.

(f) Submerged objects do not produce radar 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.

(g) 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.

Land can be recognized by plotting the contact. Care must be exercised when plotting because, as a ship approaches or goes away from a shore behind which the land rises gradually, a plot of the ranges and bearings to the land may show an “apparent course and speed. This phenomenon is demonstrated in figure 4.1. In view A the ship is 50 miles from the land, but because the radar beam strikes at point 1, well up on the slope, the indicated range is 60 miles. In view B where the ship is 10 miles closer to land, the indicated range is 46 miles because the radar echo is now returned from point 2. In view C where the ship is another 10 miles closer, the radar beam strikes at point 3, even lower on the slope, so that the indicated range is 32 miles. If these ranges are plotted, the land will appear to be moving toward the ship.

In figure 4.1, a smooth, gradual slope is assumed, so that a consistent plot is obtained. In practice, however, the slope of the ground usually is irregular and the plot erratic, making it hard to assign a definite speed to the land contact. The steeper the slope of the land, the less is its apparent speed. Furthermore, because the slope of the land does not always fall off in the direction from which the ship approaches, the apparent course of the contact

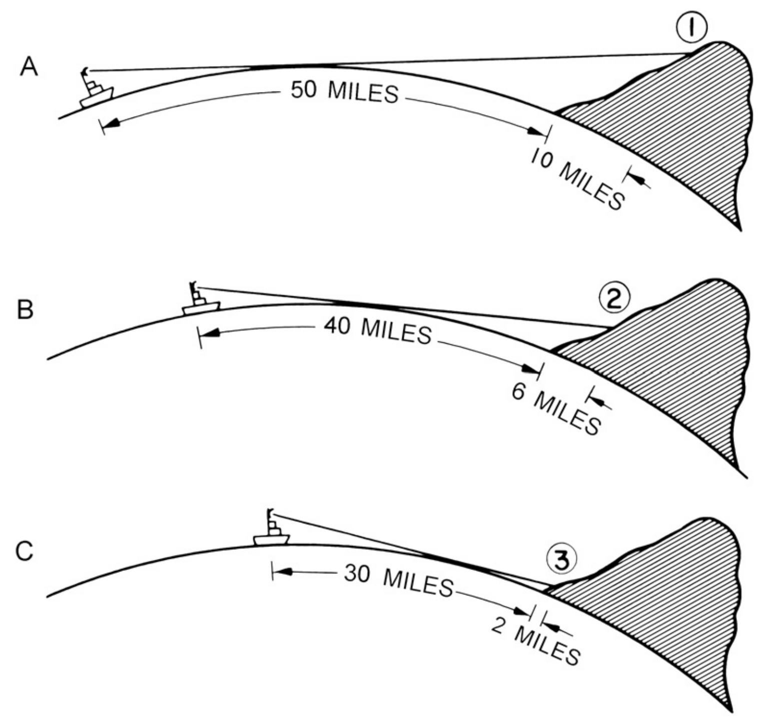

Figure 4.1 - Apparent course and speed of land target.

need not always be the opposite of the course of the ship, as assumed in this simple demonstration.

(h) 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.

(i) 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.

SHIP TARGETS

With the appearance of a small pip on the PPI, its identification as a ship can be aided by a process of elimination. A check of the navigational position can overrule the possibility of land. The size of the pip can be used to overrule the possibility of land or precipitation, both usually having a massive appearance on the PPI. The rate of movement of the pip on the PPI can overrule the possibility of aircraft.

Having eliminated the foregoing possibilities, the appearance of the pip at a medium range as a bright, steady, and clearly defined image on the PPI indicates a high probability that the target is a steel ship.

The pip of a ship target may brighten at times and then slowly decrease in brightness. Normally, the pip of a ship target fades from the PPI only when the range becomes too great.

RADAR SHADOW

While PPI displays are approximately chartlike when landmasses are being scanned by the radar beam, there may be sizable areas missing from the 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 the beam width and pulse length distortion of the PPI display can cause even greater differences.

BEAM WIDTH AND PULSE LENGTH DISTORTION

The pips of ships, rocks, and other targets close to shore may merge with the shoreline image on the PPI. This merging is due to the 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 4.2 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 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.

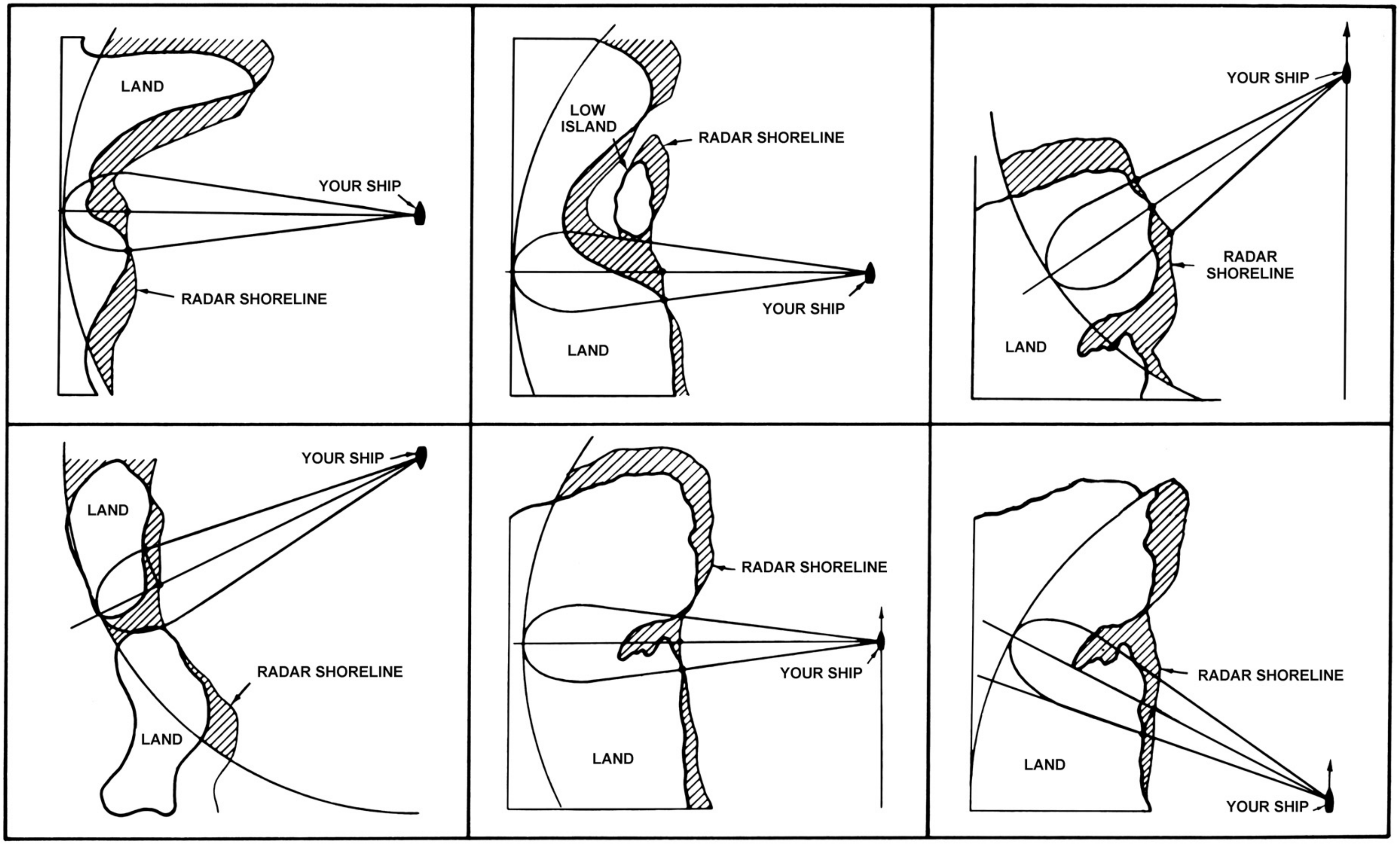

Figure 4.2 - Effects of ship's position, beam width, and pulse length on radar shoreline.

SUMMARY OF DISTORTIONS

Figure 4.3 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:

(a) The low sand beach is not detected by the radar.

(b) 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.

(c) 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.

(d) 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.

(e) Ship No. 1 appears as a small peninsula. Her pip has merged with the land because of the beam width distortion.

(f) 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 FTC could also be used to attempt to separate the ship from land.

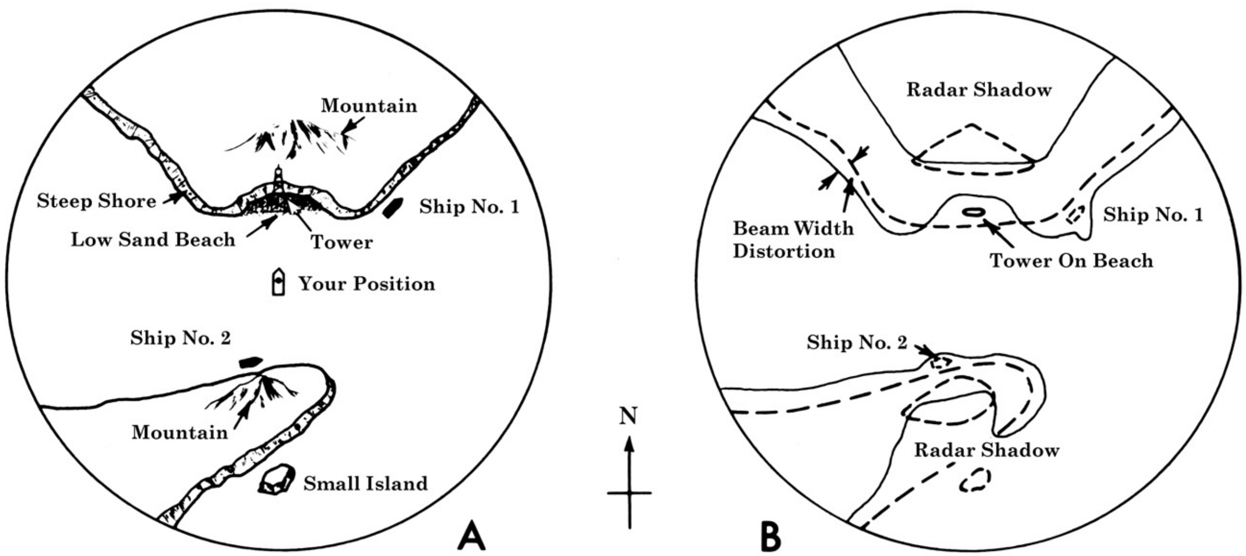

Figure 4.3 - Distortion effects of radar shadow, beam width, and pulse length.

RECOGNITION OF UNWANTED ECHOES AND EFFECTS

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 (False) Echoes

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. This 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 (see figure 4.4).

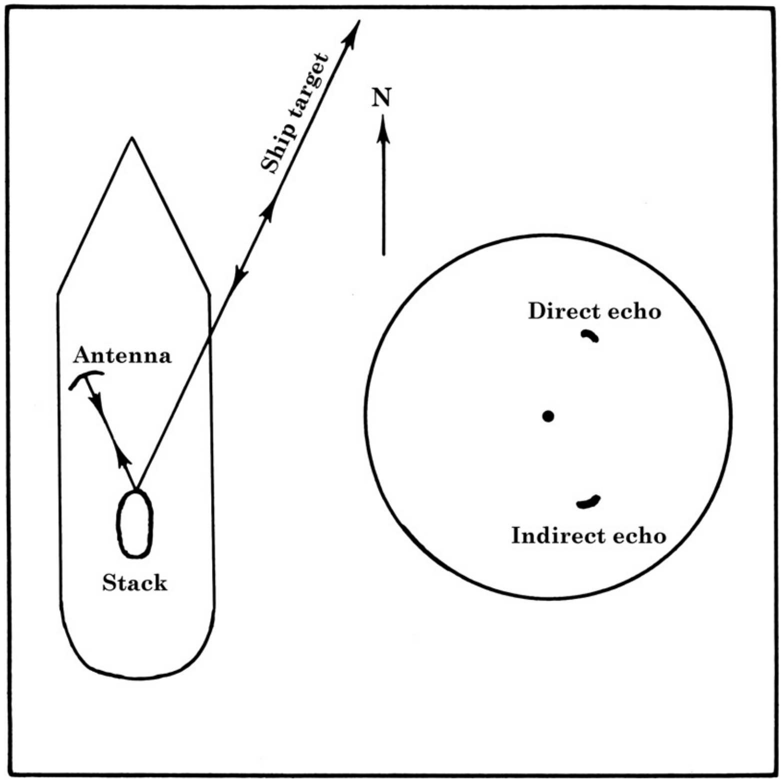

Figure 4.4 - Indirect echo.

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.

Figure 4.5 illustrates a massive indirect echo such as may be reflected by a landmass.

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Figure 4.5 - Indirect echo reflected by a landmass.

Side-lobe Effects

Side-lobe effects are readily recognized in that they produce a series of echoes on each side of the main lobe echo at the same range as the latter. Semi-circles or even complete circles may be produced. Because of the low energy of the side-lobes, these effects will normally occur only at the shorter ranges. The effects may be minimized or eliminated through use of the gain and anticlutter controls. Slotted wave guide antennas have largely eliminated the side-lobe problem (see figure 4.6).

Multiple Echoes

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 (see figure 4.7).

Second-Trace (Multiple-Trace) Echoes

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 on changing the pulse repetition rate (PRR); their hazy, streaky, or distorted shape; and their erratic movements on plotting.

As illustrated in figure 4.8, a target pip is detected on a true bearing of 090˚ at a distance of 7.5 miles. On changing the PRR from 2000 to 1800 pulses per second, the same target is detected on a bearing of 090˚ at a distance of 3 miles (see figure 4.9). The change in the position of the pip indicates that the pip 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.

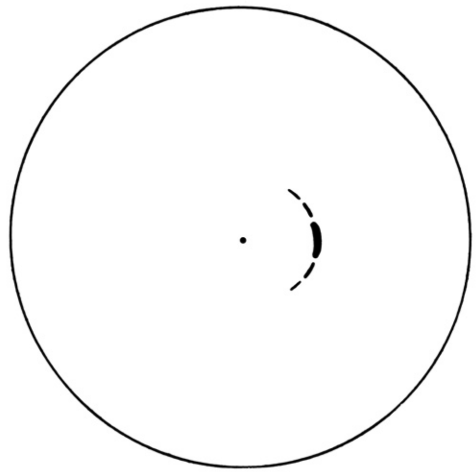

Figure 4.6 - Side-lobe effects.

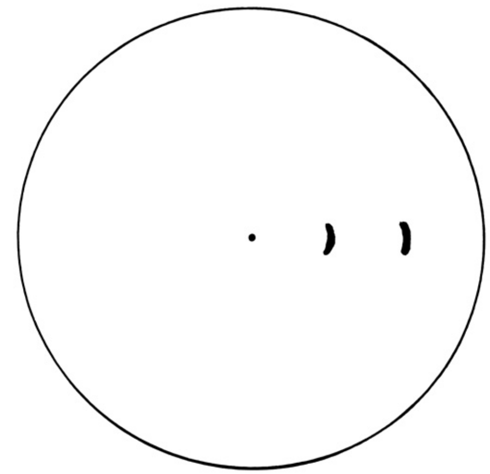

Figure 4.7 - Multiple echoes.

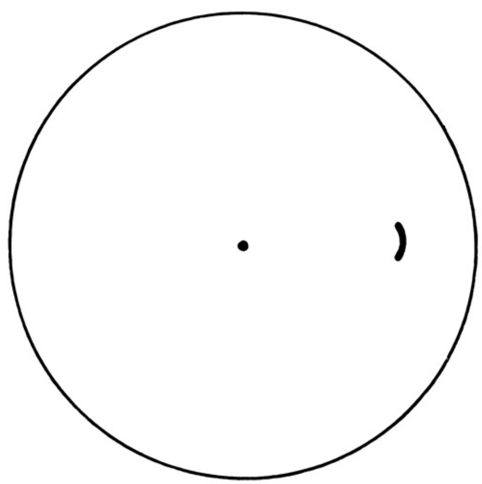

Figure 4.8 - Second-trace echo on 12-mile range scale.

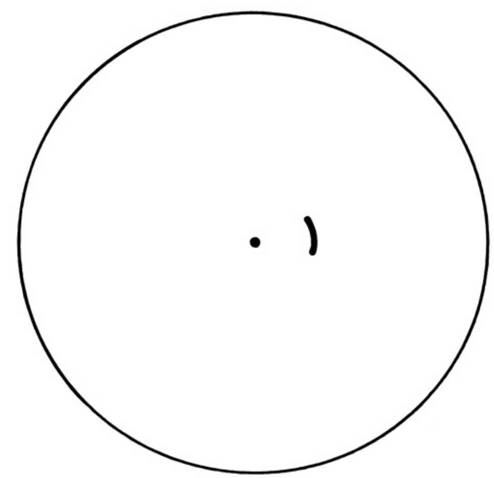

Figure 4.9 - Position of second-trace echo on 12-mile range scale after changing PRR.

Figure 4.10 - Normal, indirect, multiple, and side echoes.

Figure 4.10 illustrates normal, indirect, multiple, and side echoes on a PPI with an accompanying annotated sketch.

Electronic Interference Effects

Electronic interference effects, such as may occur when in the vicinity of 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.

Blind and Shadow Sectors

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 be such that a blind sector is produced. With lesser reduction in the intensity of the beam beyond the obstructions, shadow sectors, as illustrated in figure 4.11, can be produced. Within these shadow sectors, small targets at close range may not be detected while larger targets at much greater ranges may be detected.

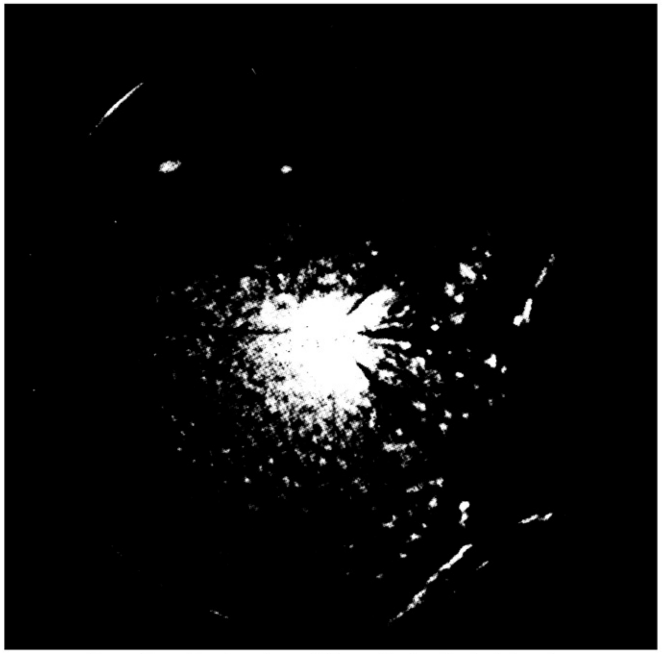

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Figure 4.11 - Shadow sectors.

Spoking

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. Should the spoking be confined to a narrow sector, the effect can be distinguished from a ramark signal of similar appearance through observation of the steady relative bearing of the spoke in a situation where the bearing of the ramark signal should change. The appearance of spoking is indicative of need for equipment maintenance.

Sectoring

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

Serrated Range Rings

The appearance of serrated range rings is indicative of need for equipment maintenance.

PPI Display Distortion

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, this static electricity effect, which produces a distorted PPI display, lasts no longer than a few minutes.

Hour-Glass Effect

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.

Overhead Cable Effect

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. See figure 4.12 for display of overhead cable effect.

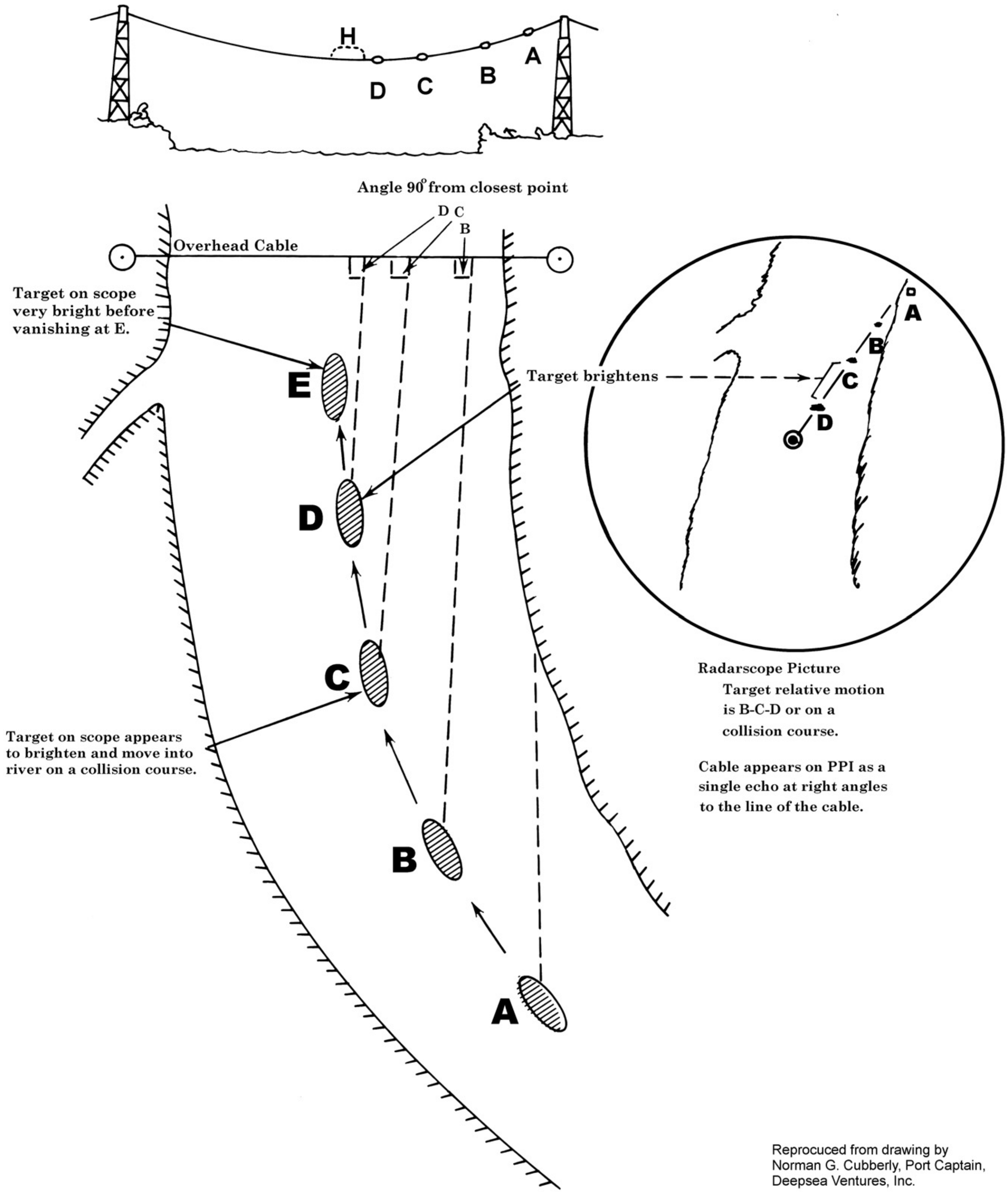

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Figure 4.12 - Overhead cable effect.