4.0 Target discrimination

So far, except for the display, the functions which make the radar work have been introduced. It is time to investigate the physical rules and atmospheric influences that go into producing a usable radar picture for the operator. The most important variable that must be understood is what our radar can see, and what it cannot see, “out there”, as the antenna sweeps around the radar horizon. All seasoned boaters know that it is the obstacle one cannot see which poses the greatest threat to a safe passage.

4.1 Line of sight

Radar is a line-of-sight device, so what can I see? Radar does not “look down” onto the curved surface of the earth, it looks out from the antenna and, like the human eye, it can only see things that are “in its sight”. That also means that radar cannot see anything hidden behind another object. Radar’s ability to see things is fuzzy because it operates at a much longer wavelength than the human eye; therefore, what is in its field-of-view can appear to blur or smear into objects close by. These are the two areas we will investigate next.

4.2 The bends

There is a commonly held illusion that radar can see “everything” out to the limit of its design range and that all will be revealed “map-like” on our display. Wrong! Radar can see a little farther than the human eye, but not much farther. We are all aware of the bending or refraction that occurs when we look at the horizon and beyond. The sun is well below the natural horizon when we watch it rise or set.

4.3 Radar horizon

The amount of bending through the earth’s atmosphere depends upon the wavelength of the waves being discussed. The shorter the wavelength, the less bending occurs. Visible light has a much shorter wavelength than our marine radar and so the amount of refraction is less to the human eye than to radar’s RF energy. In the CPS Advanced Piloting (AP) course it is learned that the distance to the visible horizon can be calculated using the formula:

Distance (visible in NM) = $2.11 \times \sqrt{hm}$ (height-of-eye in metres above the water)

or,

Distance (visible in NM) = $1.17 \times \sqrt{hf}$ (height-of-eye in feet above the water)

The extra bending of the radar waves changes these formulae to:

D (radar in NM) = $2.21 \times \sqrt{hm}$ (antenna height in metres above the water)

or,

D (radar in NM) = $1.22 \times \sqrt{hf}$ (antenna height in feet above the water)

What is obvious from these formulae is that the higher you are above the water the further you can see. Figure 4.1 illustrates that the higher the radar antenna is installed, the better surveillance you will have over the greater area of radar coverage you will achieve.

The Higher The Antenna The Further You Can See.

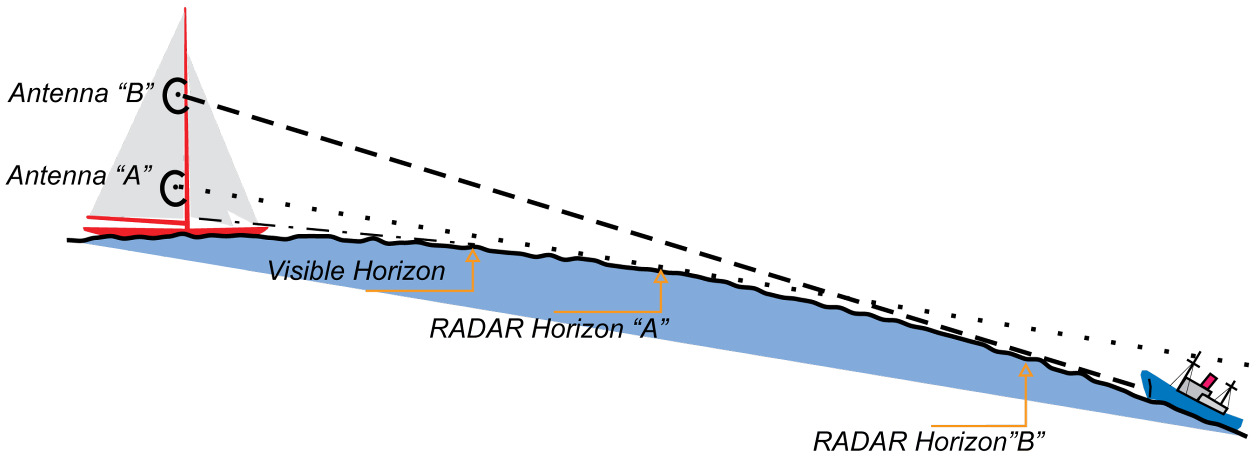


Figure 4.1 Radar horizon

4.4 What can it see?

The following two examples show practical applications of the formulae. One shows metric values the other Imperial values. The height-of-eye and the height-of-antenna used are the same, to give you an idea of the "ideal" distances each can see. The oncoming commercial vessel's height-above-water-level is also given.

The theoretical differences between maximum visual sighting and maximum radar pickup are then calculated as follows:

Metric

Height-of-eye 5 m – visual horizon = 4.7 NM + 18 m ship's bridge = 9.0 NM (13.7 NM)
Radar antenna 5 m – radar horizon = 4.9 NM + 18 m ship's bridge = 9.4 NM (14.3 NM)
Radar pickup advantage = 0.6 NM

Imperial

Height-of-eye 15 ft – visual horizon = 4.5 NM + 60 ft ship's bridge = 9.1 NM (13.6 NM)
Radar antenna 15 ft – radar horizon = 4.7 NM + 60 ft ship's bridge = 9.5 NM (14.2 NM)
Radar pickup advantage = 0.6 NM

While it is very unlikely (and most inadvisable) that your radar antenna would be at the same height as your normal height-of-eye, these examples do illustrate that radar will give you an early warning of approaching traffic even under ideal conditions of visibility. What is significant about this example is that an antenna mounted only 5 m (16.4 ft) above the water cannot "see" an 18 m (59 ft) high ship's superstructure at the maximum range of 16 NM which is common to most recreational radar, and, that an object on the water's surface will not be seen until it is inside the 5 NM range ring.

Another advantage to mounting the radar antenna as high as is practical is the ability to "see" over the crests of a higher seas, at a time when that might be rather necessary!

4.5 Target discrimination

Target discrimination is the ability of a radar to distinguish and display separate echoes from targets very close together. Two variables affect a radar's effectiveness in target discrimination, range discrimination and azimuth discrimination.

4.5.1 Range discrimination

Range discrimination is dependent upon the "length" of the PW for the range scale being displayed (see Figure 4.2). Consider the long range PW of 0.7 µsec. This time can be directly converted into the distance or length from the leading edge of the radiated pulse to the trailing edge of the same pulse:

PW x speed of light or 0.7 µsec (PW) x 300 m/sec = 210 m [689 ft]

When two targets on the same azimuth are closer together than half of the length of that pulse, the leading edge of the echo returning from the second vessel will reach the first vessel before the trailing edge of the outgoing pulse has passed the first ship (Figure 4.2) below.

Range discrimination = PW x speed of light / 2

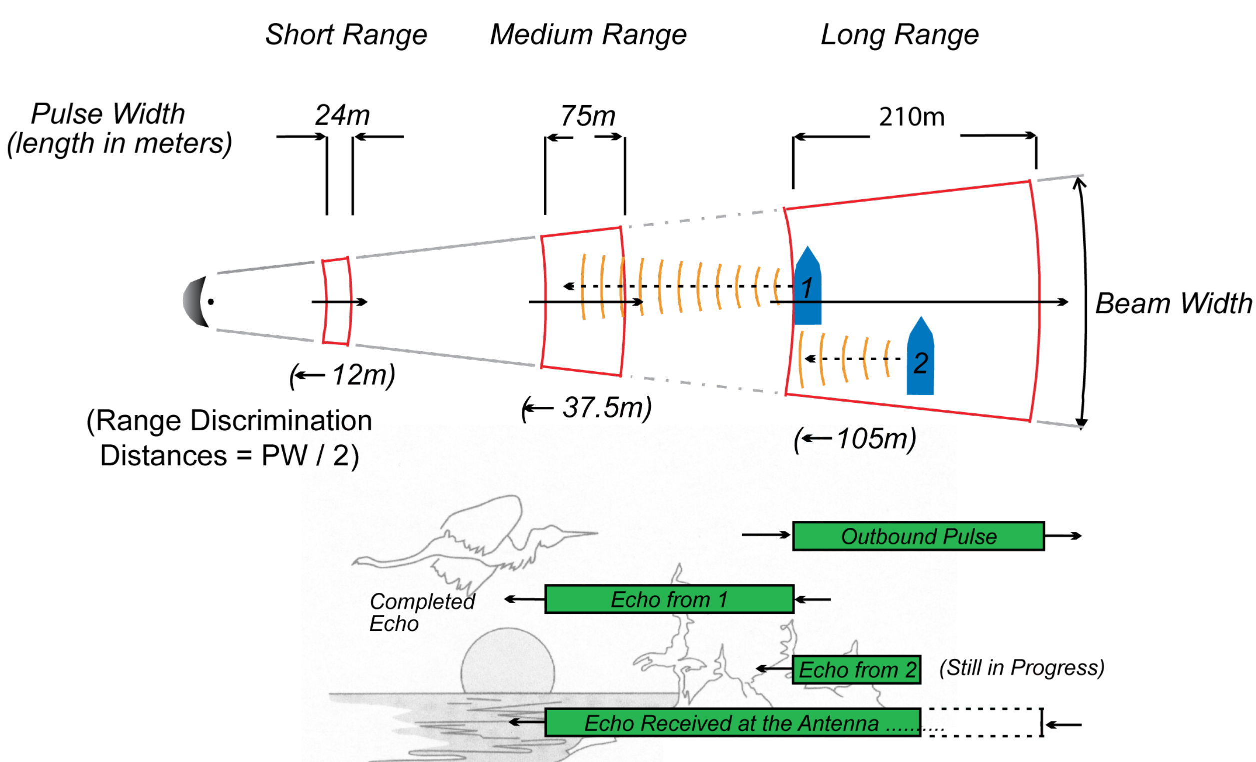


Figure 4.2 PW and range discrimination

This means that the two returns will overlap one another and make it appear as one larger and longer reply, rather than two separate returns. In our long-range example this distance is half of the pulse length, or 105 m (344 ft). However, at medium and shorter ranges the duration of the PW drops, and the range separation needed to paint two distinct targets is reduced to 37.5 m (123 ft) at medium-range settings and 12 m (40 ft) on short-range settings. Where a questionable target is inside the maximum range for a lower PW, switching to the shorter range scale can sometimes show the two separate vessels. Because range discrimination improves with a shorter PW, range discrimination is not often critical. However, a skilled operator will always make allowances for it, until any ambiguity is resolved.

4.5.2 Azimuth discrimination

Azimuth discrimination is the problem of distinguishing between two targets close together in azimuth. The majority of recreational boats equipped with radar use the small 46 cm (18 in) domed antenna. At best, these units can produce a beam-width of 5.2º. Remember, this beam of energy is not sharply defined and, in fact, it rises to a maximum at the antenna's centre azimuth and drops off in a "bell curve" on either side (see Figure 3.6 in Section 3.0). The nominal beam-width is established by measuring the transmitted power as the beam passes over a point. Where the measured power drops to 71% of the maximum, on each side of that maximum, establishes the "width" of the beam. In our reference antenna these points would be from 2.6º before the beam centre, until 2.6º after the beam centre has passed over the measuring point, 5.2º in total. What is the particular significance of this phenomenon?

4.5.2.1 Small single objects

Figure 4.3 illustrates how the passing radar beam might paint a small single point object such as a navigation buoy, blurring its true size.

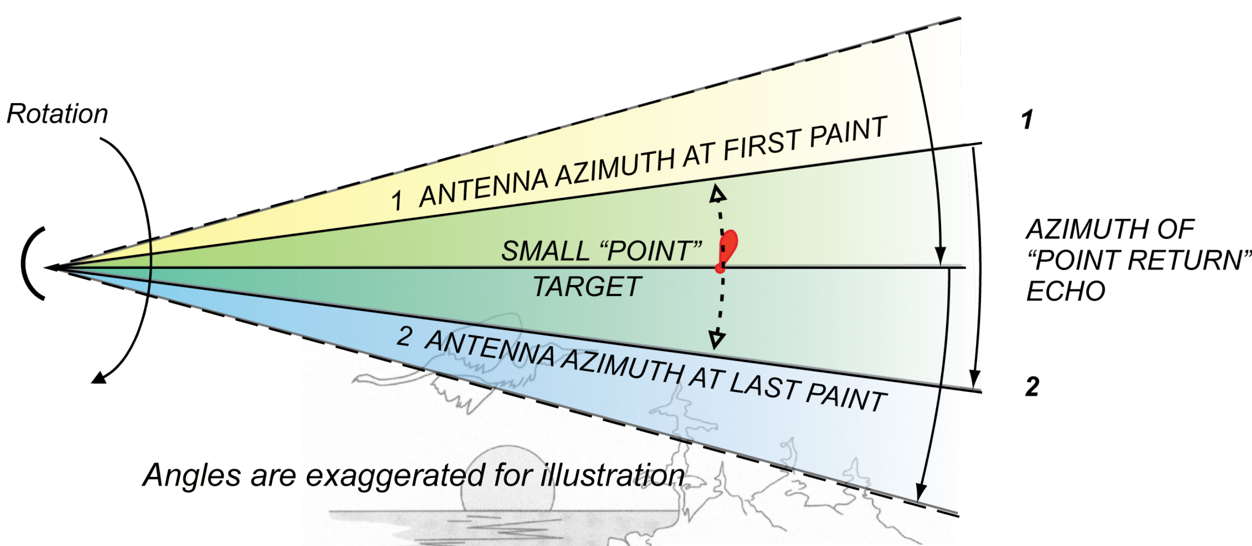


Figure 4.3 Small single point target paint.

4.5.2.2 Large single vessels

Consider a much larger target. You will remember that the size and material of a target's construction has a significant effect upon when, and how strong, a radar return it can generate. Under most conditions a large metal target is able to start reflecting solid echoes well before the leading edge of the "official" antenna beam has reached it (see Figure 3.6), and will continue after it has passed, making it paint over more than the nominal 5.2° beam-width (Figure 4.4). Whereas, a very small fibreglass hull target might not return any usable paint until the maximum power is reached at the very centre of the beam illuminating it, such was shown in Figure 4.3. This effect is the main cause of the significant differences in radar pickup range between objects in view.

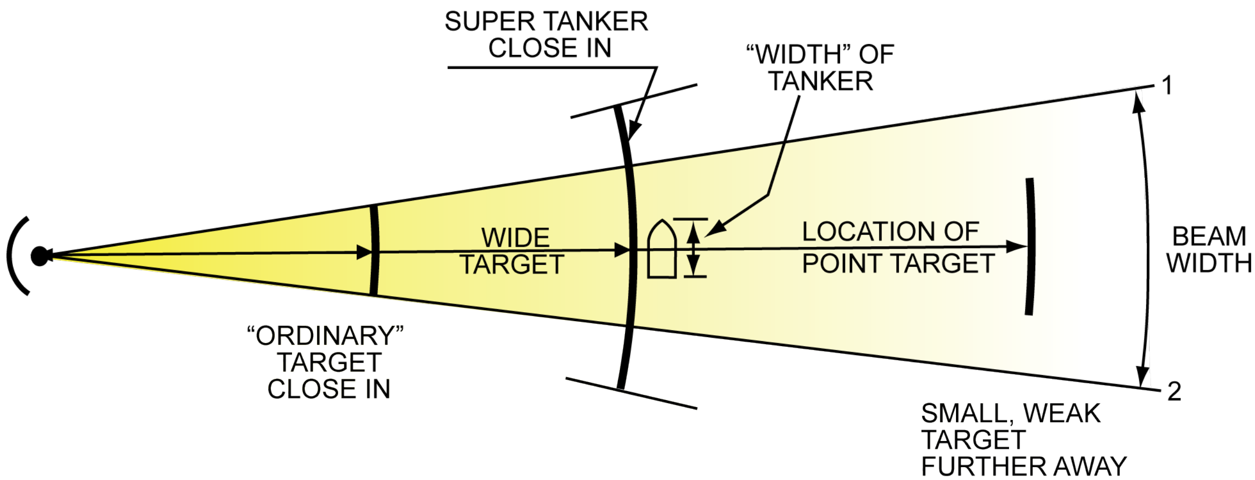


Figure 4.4 Large single target paint.

4.5.2.3 Overlapping targets

The third effect of azimuth discrimination is this. If two vessels of equal "strength" are at the same range and are less than the beam-width of the antenna apart, the beam will start illuminating the second target before it has finished passing over the first one. The result will be an elongated return from the "double target" as shown in Figure 4.5 below.

This anomaly cannot be resolved using range (PW) changes. Resolution relies upon the observation skills of the operator. Radar receivers have a control called Gain, which is described in more detail in Section 6.0. It is similar to the volume control on a radio or stereo. Note that a careful temporary reduction in receiver Gain will reduce the overall strength of a return leaving only the strongest middle portion to be displayed. This can, and often does, show two weak target paints at close azimuths and similar ranges.

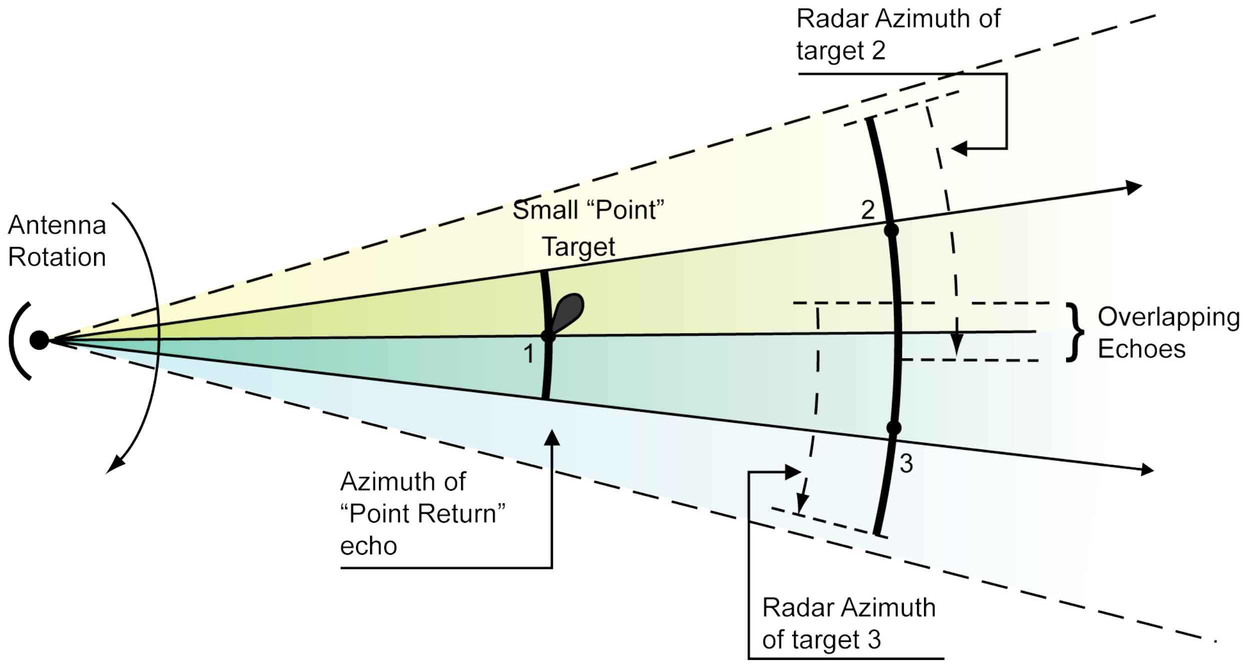
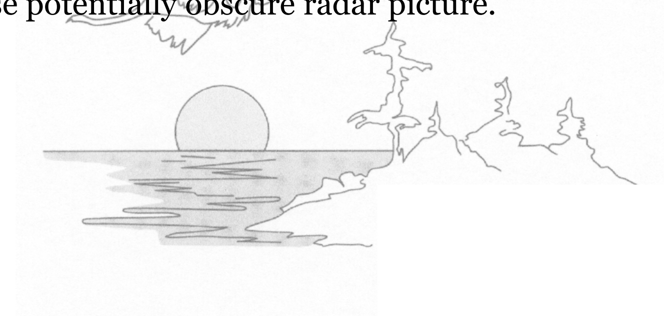


Figure 4.5 Overlapping target returns.

4.5.3 Display interpretation

Where one target is significantly larger than the other, assuming that the middle of a merged double return is “halfway” between two vessels can lead to an erroneous judgement. While a gain reduction may merely “extinguish” the weaker target from the display, often the actual position of the larger target can be established. The position of the weaker target can then be estimated when the gain is returned to its usual setting.

Beam-width also smears the features on your display. Small pinpoint targets, such as a navigation aid, may themselves be very small in azimuth width, but they may still cover an arc 5.20 wide. A head of land or narrow harbour entrance can be difficult to distinguish when the blurring caused by the wide beam passes over it; this effect is examined in more detail in Section 9.0. That having been said, experience quickly enables average operators to use their observation and correlation abilities to make sense of an otherwise potentially obscure radar picture.



4.6 Summary

- Due to the earth's curvature, large and small objects at medium to longer ranges may be below the radar horizon and not detectable. The higher the antenna, the farther the radar can see.

- The radar horizon for an antenna mounted 5 m (or 15 ft) above the water is only 4.7 NM (or 4.9 NM) away. All objects beyond those distances are below the antenna's horizon, less than one third of the specified maximum range of the average small marine radar installation.

- Radar does not provide coverage like a map. Only objects that are clearly in the sight of the radar antenna can be painted and therefore expected to produce a usable echo.

- Pulse Width can cause two objects in close range proximity to appear to merge so that they may not be visible as distinct paints, the shorter the PW the better the discrimination.

- A properly calibrated radar is extremely accurate in range, but it can be ambiguous in azimuth.

- Two objects in close azimuth proximity may not be visible as distinct paints. The narrower the beam-width the better the discrimination.

Next - Operating the radar

It is time to apply what has been learned about the functions and physics of radar operation to the last, and most obvious, function of the radar, the display console. In the next section we will investigate its various controls and dials and how they affect the radar and the quality of the display.