2.0 Transmitting a radar pulse

Echolocation is a "shout and listen" methodology. Radar works by transmitting a precisely engineered pulse of energy shaped into a narrow beam, from an antenna pointing in a specific direction. When the echo is received from an object we can then "plot" this location accurately in relation to our vessel. We start by looking at the characteristics of the transmitted pulse.

2.1 The "shout"

In Figure 1.3 three of the functions shown generate the pulse of RF energy that is sent to the antenna for radiation into the ether and a fourth one controls the intervals at which these pulses are transmitted.

The power supply of a modern radar is critical to its efficient operation. Its job is to take whatever source of direct current (DC) is available from the ship's electrical supply, remove any of the lumps or bumps in it, regulate varying voltage to the optimum for the radar set, and feed the other functions with this source of stable, conditioned power. This allows the ship's power to be higher or lower than the optimal voltage for the radar. It will result in a greater current draw from a lower voltage supply and a lesser current demand from a higher voltage source.

The steady flow of conditioned power is fed into the pulse forming network function of the radar set. Imagine a hydroelectric dam with a river running into it that has a constant steady flow of water. Located at the dam itself there is a floodgate which can be opened and closed to allow a huge surge of water to escape downstream. The flow of water in from the river will determine how much water and how often a surge may be released. The master timer function controls the opening and closing of the floodgate, allowing a lot of water through occasionally or a lesser amount more often, always equalling the input of new water from the river.

That is how the pulse-forming network operates. With its careful design of electrical capacitors and inductors, the network not only accumulates the steady flow of low voltage power, it is able to release it at a high voltage whenever it is commanded by a trigger pulse from the master timer function. A long time between triggers sends an equally long surge of high voltage current to the transmitter, a shorter spaced trigger pulse reduces the length of the surge, but not its sharp shape or high voltage, usually in the range of 25 kilovolts (thousands of volts - kV).

The surge of high voltage power from the pulse-forming network flows directly to the heart of the transmitter function, the magnetron tube. When the proper high voltage of electricity is applied to a magnetron it produces a steady output of radio frequency energy as long as the high voltage pulse of DC power is applied to it. It is this output of RF energy that forms the radar's shout, which is fed directly to the antenna where it is shaped into the narrowest beam possible. The antenna function is discussed later.

Most of the smaller recreational marine radars transmit a 2 kilowatt (2 kW) pulse, however some are capable of transmitting with 4 kW RF power output. While the focus in this course is with 2 kW of transmitter power, the theory applies equally well to radar sets with 4 kW or more power output.

2.2 Characteristics of a radar pulse

There are a number of trade-offs in trying to reach the maximum effectiveness of a radar pulse. The most obvious is cost versus results. Superior results are accompanied by superior costs. However, when the required transmitter output power has been determined, and the antenna design and size selected, there are still two variables which can be used to optimize the transmitted pulse. They are the length of time the transmitter will transmit, called the pulse width (PW) and the number of times per second this will occur, called the pulse repetition frequency (PRF). The following paragraphs discuss the interrelationships between all of these factors.

2.3 Pulse Width (PW)

The transmitter delivers its power out at one level, 2kW. The length of time the transmitter generates energy can be increased to ensure “illumination” of a target at maximum range, and help to receive a strong enough echo. This time interval is referred to as the pulse width (PW). Conversely, the amount or pulse width of the energy needed for shorter ranges can be decreased by transmitting more frequently, as the range decreases.

In a typical marine radar, you will find three transmitter ranges. One is used for long range surveillance, one for medium ranges and a short range setting for close-in manoeuvring. Note that these are “transmitter” output settings. Most modern displays allow you to select more detailed range display settings within these main transmitter PW groups.

Typical PWs for radar ranges up to 48 NM is 0.7µsec. The medium range setting is usually about 0.25 µsec and the short range PW is near 0.08 µsec long.

2.4 Pulse Recurrence Frequency (PRF)

The second characteristic of the transmitted signal is the number of these pulses that are transmitted in one second. This is referred to as the Pulse Recurrence Frequency (PRF). The greater the distance that you want a radar to see, the longer the time you have to pause between pulses to allow the receiver to “listen”. While this constraint is not a critical factor within the short ranges of a small marine radar, it can influence the differences of available PRFs you might find between smaller range models.

A primary objective in the design of recreational radar is always to obtain the lowest possible power consumption. For any desired transmitter power, the longer the transmitter must transmit, the more DC current has to be supplied to the modulator's pulse forming network. Radar's Pulsed Wave method of operation caters ideally to this need for economy of power consumption. Consider this: for long ranges we need a lot of power, for short ranges we need much less power. We can achieve this by transmitting a long pulse a few times and get a good result over a longer range. Similarly, a shorter pulse transmitted a lot of times will get a better result over shorter ranges.

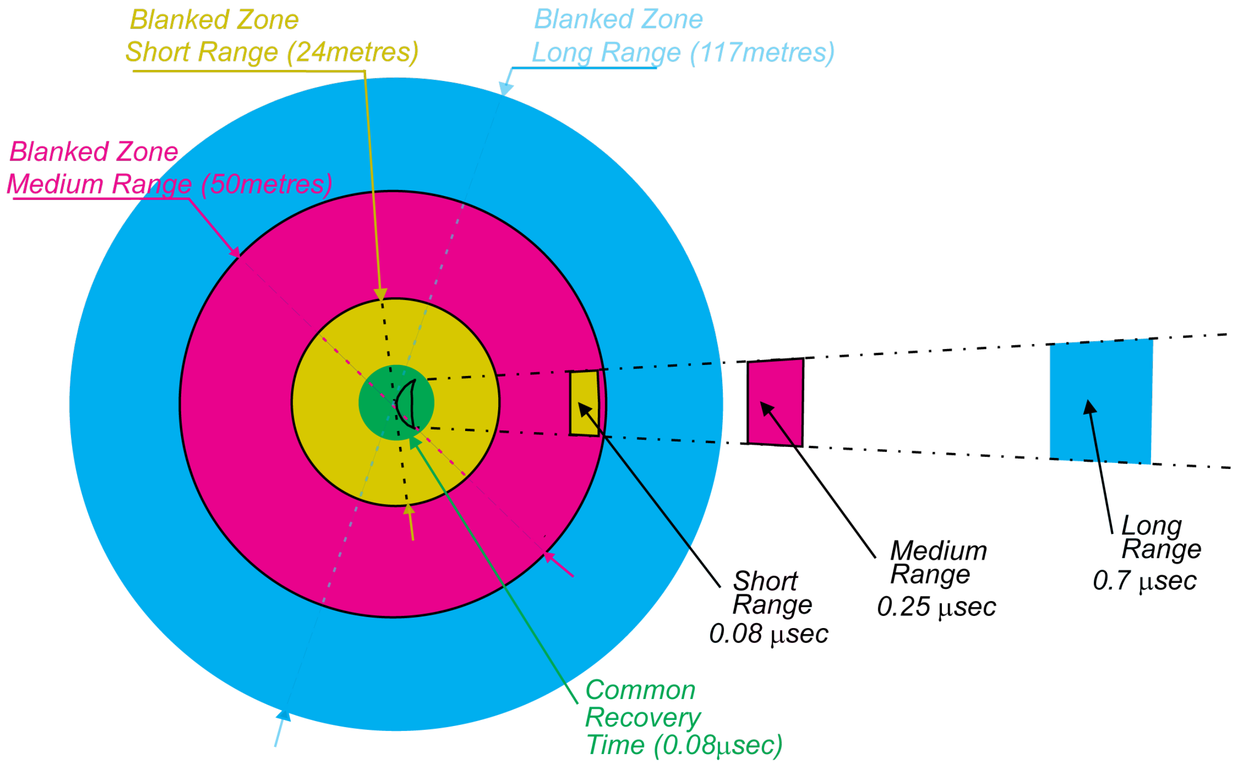
Both the fewer long pulses and the many short pulses can be obtained from a modest, steady flow of DC current between the power supply and the modulator! This is how a 2 kW radar only consumes about 35 watts to 40 watts of 12v DC power.

From the specifications of our theoretical example of a typical radar we find:

a) long range - PW is 0.7 µsec, and PRF is 750 Hz (pulses per sec);
b) medium range - PW is 0.25 µsec, and PRF is 1500 Hz; and,
c) short range - PW is 0.08 µsec, and PRF is 2250 Hz.

2.5 Blanked zones

Why? Well, not only is this good for reducing power consumption, control over the length of the transmit time and how often we transmit the pulses has a significant effect upon what we can see and what is hidden from us. As the transmitter transmits, the receiver is electronically "blanked" by the Antenna Switching System. There is also a small additional amount of time after the transmitter pulse has passed by before the receiver sensitivity is fully restored, about 0.08 µsec, although new technology is reducing this time somewhat. This means that the radar is "blind" during the combination of PW and the 0.08 µsec recovery time (see *Figure 2.1*). If we convert this time into distance we discover that there is a "doughnut like ring" around our radar in which it is impossible to "see" any radar returns.



Not to scale, some dimensions are exaggerated for clarity.

Figure 2.1 - Radar blanking zones.

This "blanked zone" can be calculated:

[(PW + recovery time) x speed of light] /2
Note: the /2 allows for the returning echo

long range - [(0.7 + 0.08) x 300 m per sec] /2 = 117 m
medium range - [(0.25 + 0.08) x 300 m] /2 = 49.5 m
short range - [(0.08 + 0.08) x 300 m] /2 = 24 m

This gives us potential blanking radii around the antenna of approximately:

a) on long range –115 m (380 ft);
b) on medium range – 50 m (162 ft); and,
c) on short range – 24 m (72 ft).

While this blind area is not likely to be a potential navigation hazard on short range, a lot could be happening inside the 115 m on the long range display scale. Prudent operators will always remain aware of this "hole" in the middle of their radar display.

2.6 Summary

- A radar transmitter is able to form a precisely tailored pulse of energy as long it is fed clean steady power.

- The radar pulse can be generated as longer or shorter bursts of RF energy to provide the optimum display of long, medium or short range information as the operator requires.

- All radars have a blind spot around the antenna that varies in range with the transmitted pulse width and any system recovery time.

- Because of the pulse width, there is an area of blanked space around the antenna in which no radar returns can be seen, the shorter the PW, the smaller the blanked zone.

Next - The radar antenna

We will look at the radar antenna and see how it forms the transmitted energy into a usable radar beam.