ROYAL SCHOOL OF ARTILLERY

BASIC SCIENCE & TECHNOLOGY SECTION
GUNNERY STAFF/CAREER COURSES

INTRODUCTION TO RADAR

INTRODUCTION

1. The word **RADAR** is an acronym derived from the expression **RAdio Detection And Ranging**. As the technique was originally conceived, radio waves are utilized to detect the presence of a target and to determine its distance, or range. In its simplest form, a radio transmitter emits electromagnetic radiation and when the radio wave is interrupted by any object such as an aircraft, ship or even a mountain or other land mass, part of the energy is reflected back to a radio receiver located near the transmitter.

2. The reflection is called an **echo**, and the object reflecting it is called a **target**. The presence of an echo indicates that a target has been detected. If the signal is one that was sought, the echo is referred to as a **target signal**, or simply **signal**. If, however, echoes are reflected back from unwanted targets which make it difficult to select the desired target, the unwanted echoes are called **clutter**.

3. The time duration from original transmission of the energy to reception of the echo is a measure of the **range**, or distance of the target. The velocity of electromagnetic waves in free space is approximately 3×10^8 m/s. Therefore, if an object is 150m away, it will take about 0.5 millionths of a second, 0.5μs, for the transmitted energy to reach the target and the same to return. Another way of looking at this is to say that radar range is equivalent to 150m per microsecond of travelling time for the energy.

History

4. Radar has been around now for a long time and in order to give some idea of its development the following list provides a potted history of the main events.

1873 Concept predicted by Maxwell
1888 Hertz confirmed reflection of radio waves
1901 Heaviside performed long range transmission, beyond the line of sight, by reflection from the iono sphere
1924 Appleton used pulsed transmissions to determine the position of the ionosphere
1931 First proposals to use radio reflection for detection of ships and aircraft
1934 Committee for Air Defence of UK initiated military research and gave a crucial 4 year lead over German developments
1937 First detection of ships by aircraft
1938 Thames Estuary Chain Home (CH) radar completed
1939 Britain, Germany, USA - Frantic development
1940 Birmingham Univ - Magnetron Invented (3GHz)
1941 RDF Secret made public
1943 RADAR acronym universally accepted

Functions

5. Radar has been called upon to perform many different functions since its invention. Typical of these are:-

   a. Surveillance
   b. Target Tracking
   c. Guidance
   d. Locating
   e. Height Finding (Altimeter)
   f. Terrain following
   g. Proximity detection

Roles

6. The purist would say that there are only two major roles for a radar, possibly supported by a third, they are Searching, Tracking and Track While Scan (TWS). When searching, a radar is looking for a target, or targets, and once found the target may be tracked. This could be by the same radar switching to that role, or by putting another radar 'on to' the target of interest. In the latter case, the first radar returns to its searching function.

7. The reader should not be misled by the simplicity of these statements. The term 'target' does not simply mean aircraft or mortar round or tangible targets in that sense. A map display shows a host of targets on the ground, each of which is tracked at all times, however, when searching for airborne targets, these may be considered to be clutter. On the other hand, an aircraft radar altimeter relies upon reflection from the ground, which is tracked to display the height above that level.

8. It is possible with many modern radars to perform both functions at the same time and carry out Track While Scan (TWS). This means that plotting of target position must be carried out at regular intervals so that both direction of movement and speed may be deduced, usually by digital computer.

Classes

9. Two main classes of radar are in use, they are referred to as **Continuous Wave (CW)** and **Pulse** radar systems. CW radar is such that the received echoes are processed continuously whilst the transmitter is emitting energy. Thus two separate aerials are required, one for the transmitter and the other for the receiver. It is also necessary to minimise leakage from the transmitter aerial into the receiver aerial, otherwise low power, long range signals are liable to be masked. Pulse radar does not receive during the short transmit period. Therefore, the same aerial can be used for both transmission and reception.

CONTINUOUS WAVE (CW) RADAR

10. It was pointed out above that a continuous transmission results in a continuous echo signal, and that it is impossible to tell which part of the echo is associated with any particular part of the transmission. Consequently for a 'pure' CW radar it is not possible to obtain range. However, by the introduction of some form of modulation, range signature can be obtained. Various mechanisms have been used, one of which will be met later during Doppler Radar systems.

11. With CW radar, it is also difficult to tell whether a received signal is actually an echo from a target or merely leakage from the transmitter, since they both have the same frequency. However, if the target is moving radially with respect to the transmitter, the echo signal will be shifted in frequency. The **Doppler Shift**, fd, or **Doppler Frequency**, is the difference in frequency between the transmitted and received signals. It is then possible to separate the echo from the transmitted signal on the basis of frequency.

12. The amount of frequency shift that occurs for a given target is directly proportional to its speed. Hence, if the difference frequency **fd** can be extracted, it is possible to calculate the radial speed of the target. A radar designed to perform such a role is called a **Doppler Radar**. On the other hand, a radar that uses the Doppler Shift merely to extract the fact that a target is moving is called a **Moving Target Indicator** (**MTI**).

PULSE RADAR

13. CW radar is able to provide velocity information at the expense of accuracy in range. At the same time, lower power transmitters, when compared to pulse radars at a given range, may be used. In order to obtain accurate range signature, common practice is to **pulse modulate** the transmitter. That is, the Radio frequency (RF) energy is emitted in short, high-power pulses. The echoes return in short pulses also, and since during reception the transmitter is off, it is usually possible to associate a given echo with a specific transmitted pulse, and so determine range accurately.

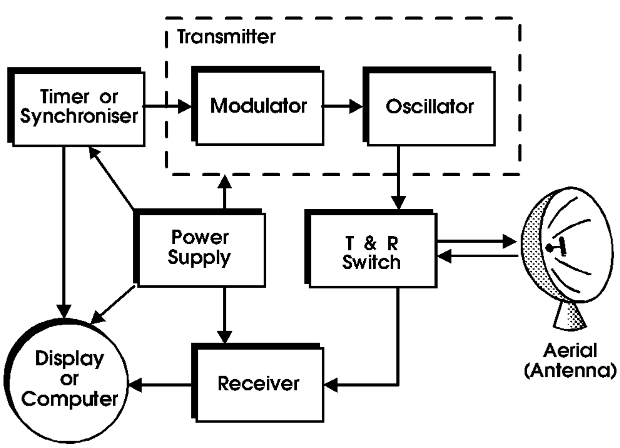


Fig.1. Pulse Modulated Radar

14. Since, in a pulse radar, the transmitter and receiver are not in use simultaneously, one aerial system can be used for both transmission and reception. The aerial is connected to the transmitter during the short transmission pulse and is then switched to the receiver to detect echoes. It is switched back to the transmitter when the next pulse is emitted.

15. A basic system is illustrated at Fig.1. The timer synchronises the transmitter and receiver and furnishes a time base for the display, or computer, as the case may be. Hence, time differences can be measured. The display is usually some form of cathode ray tube, which enables the operator to determine the presence of a reflected signal, also to measure time intervals and, therefore, distances. All AC and DC voltages for the equipment are furnished by the power supply.

16. A radar system (or simply, a radar) has many parts or subsystems. This is analogous to the 'human' system which has, as subsystems, a nervous system, an arterial system, a digestive system, etc. Similarly, the radar system has subsystems such as the receiving system, the timing system and the transmitter system. The word system is frequently omitted in referring to the whole radar or any of its components.

Timer (Synchroniser)

17. The chief function of the timer is to furnish a time signal which synchronises the transmitter with the display or computer. In some radars there is no separate timing circuit, but instead, the transmitter generates its own pulses which synchronise the modulator and the display. However, where it is important to control the emitted **Pulse Width (PW)** or **Pulse Recurrence (Repetition) Frequency (PRF)** accurately, it is preferable to have a separate timing circuit.

18. The timing oscillator may generate a sinewave signal or a string of rectangular or irregular pulses. Its output is then shaped to form the type of impulse which will trigger the transmitter and display. The timing circuit may also furnish marking pulses for the display. These are pips or other markings on the face of a CRT which are accurately spaced in time from inception of the pulse. These markers can then be used to determine the range of a target when the echo appears on the display.

Transmitter

19. The transmitter of a radar may be self-pulsed, in effect functioning as both a transmitter and a timer. This type of transmitter oscillates at both an audio frequency (the PRF) and a radio frequency (usually called the carrier). A small portion of the audio frequency is then tapped off to control the display or computer as the case may be.

20. In most radars, the transmitter receives its timing pulses from a timer circuit. The transmitter is then simply a high-powered RF oscillator modulated by a pulse former which, in effect, turns the transmitter on (during the pulse) and off (during the inter-pulse interval). If the relatively weak signal generated by the timing circuit is insufficient to trigger the modulator, the transmitter will also contain a trigger amplifier, or driver, prior to that stage.

Receiver

21. For most radars the receiver is of the superheterodyne type met during radio. A block diagram is illustrated at Fig.2. The signal from the aerial is fed to one or more RF amplifiers, particularly if an improved signal to noise ratio is required. If not, the RF amplifier may be omitted and the signal fed straight to the frequency changer. A local oscillator (LO), running continuously within the frequency changer, also feeds a signal to beat with the pulsed echoes. The difference frequency is amplified and detected (or demodulated) to produce a video signal which is fed to the display or

computer.

22. The complete radar receiver is not usually in a single box that can be identified separately as a receiver. The RF amplifier is normally placed close to the aerial, whereas the video amplifier is more often inside the display case or computer as required. The other components or circuits are

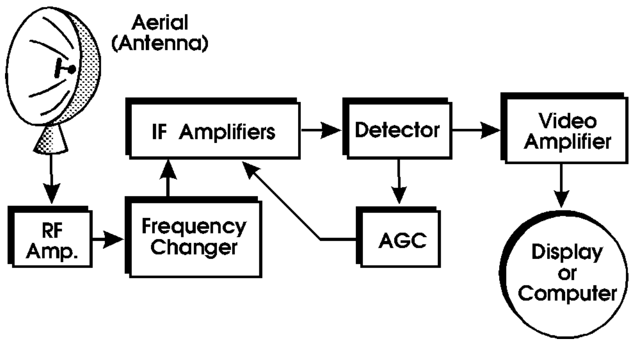


Fig.2. Pulse Radar Receiver

distributed at convenient points in between.

Transmit & Receive (T&R) Switch

23. For a pulse radar, the transmit and receive switching system performs a most important function. Should any of the high power from the transmitter, on its way to the common aerial, pass into the receiver, which is designed to amplify the very small long range echoes, the result could be complete paralysis of the system. It is akin to being deafened by a weapon which is discharged in close proximity to the ear, only many times worse. Thus it is imperative that the transmitter energy is prevented from passing to the receiver.

24. A number of different systems have been designed to carry out this function, all of which behave like a very fast acting switch, reducing leakage to a minimum. It should be noted that received energy must pass through this switch and, hence, it should appear in the receiver block diagram of Fig.2, however, since the energy is merely passing through, the block is omitted from that diagram but any losses associated with it are taken into account at the design stage.

Wavelength (Frequency) Considerations

25. Choice of frequency is determined by the types of RF transmitter oscillators available, power and range considerations, directivity desired, and atmospheric and propagation effects. The higher the frequency the shorter the wavelength. Thus, since an aerial needs to be about 50 wavelengths across for a one degree beamwidth, a given aerial size is effectively larger at a higher frequency because its aperture is more wavelengths long. This makes a more directive beam. On the other hand, higher power transmitters are available at lower frequencies. Again, higher frequencies are attenuated more during propagation, but if the frequency is too low, the aerial size required becomes impractical.

26. Radars have been operated successfully from 100MHz to frequencies of millions of MHz. However, most radars still operate in the frequency range 1,000MHz to 20,000MHz (20GHz). During the second World War, radar frequencies were given letter designations which have stuck, particularly for radar engineers. Hence, the frequencies near 10,000MHz(10GHz) are called X-band, those near 3,000MHz(3GHz) are S-band, and those near 1,000MHz(1GHz) are called L-band. The exact frequency limits of the bands were not well-delineated. Thus, 2,000MHz(2GHz) is sometimes S and sometimes L. Another less frequently used designation is C-band for frequencies around 5,000MHz(5GHz). Added to all this is the NATO series of designations, which bear no relation to those original bands, but are now used for military radar specifications, and form the subject of a separate handout.

Display

27. The display device in a radar system is usually a cathode ray oscilloscope and is generally referred to as a **scope**. There are many different types of presentation. The simplest is called an A-scope and is illustrated at Fig.3. The horizontal sweep is calibrated in time or range from left to

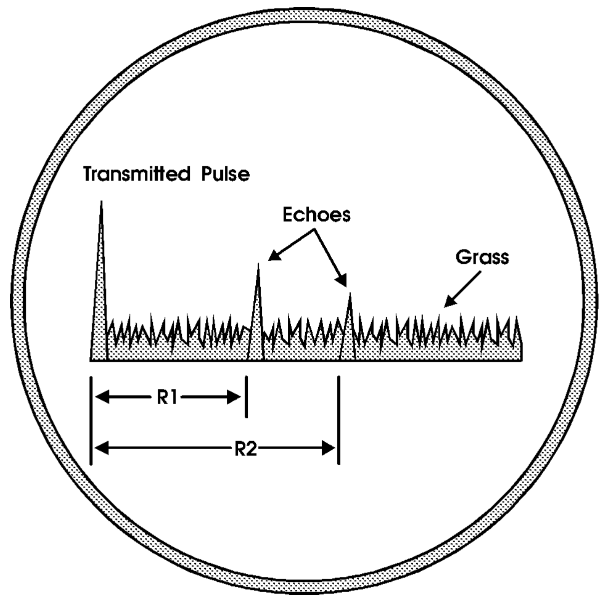


Fig.3. A-scope Presentation

right, and any vertical displacement is simply the amplitude of the signal.

28. The sweep begins with an indication of the transmitter pulse caused by some of the transmitted signal leaking into the receiver. Any echoes then appear as pips, horizontally displaced. In most display systems of this type the rate at which the timebase is refreshed, which is equal to the PRF, is high enough to ensure that little or no 'flicker' is present and, hence, the picture appears to be continuous. The range of a target can be determined directly from the calibration of the horizontal sweep. In Fig.3, two echoes are shown, one at range R1 and a weaker one at a range R2. It should be noted that the horizontal sweep is not a sharp line, it is a constantly shifting pattern of short vertical excursions. This is caused by the noise in the receiver and is called **grass**. It will be discussed in more detail later in the course.

29. The highly directive aerial used with most radars illuminates the target and receives an echo, only when pointing in the right direction. Thus, when a target appears on the A-scope, the operator knows that it is in the same direction as the aerial is pointing. It is also possible to plot range against azimuth on the face of the scope. This is called a B-scope presentation. Another type, called C-scope presentation, plots elevation vertically and azimuth horizontally. B-scopes and C-scopes are used infrequently and in specialist

applications such as mortar locating and aircraft ground controlled approach radars.

30. The **Plan Position Indicator**, or **PPI** presentation, shown at Fig.4, plots a map of the area being scanned. The position of the aerial is represented by a dot at the centre of the scope. A target's range is indicated by its distance from the centre, which is scaled in time depending upon the maximum range in use. The target echo (T in the figure) appears only when the aerial is pointing at the target, and the bearing angle is indicated by its angular distance from the vertical.

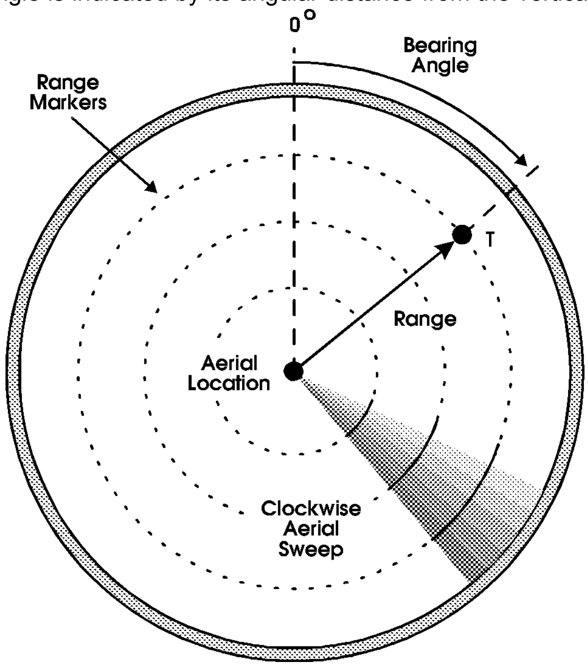


Fig.4. Plan Position Indicator (PPI) Presentation

This type of display is used in many different radars of the surveillance type.

TYPES OF RADAR

31. Two types of radar are defined, called **Primary** and **Secondary** respectively. A primary radar emits energy which travels out and is reflected back to the receiver. The echoes are then processed and displayed in the form required. No other system is necessary to support this radar, which operates independently. Secondary radar, on the other hand, requires a co-operative target. The target must receive and process an interrogating signal, then reply in the form required by the other radar. If a reply is not forthcoming, it may mean that the target is hostile and further action must be taken, as is the case with **Identification Friend or Foe (IFF)**. It is also possible that navigational data, such as the range and bearing of an aircraft, or other surface vehicle, from some given ground beacon, is being sought, and alternative secondary radars may be used to acquire that information. Typical of such devices are **Tactical Airborne Control And Navigation (TACAN)** and **Distance Measuring Equipment (DME)** systems.

32. IFF and other secondary radars always involve coding and decoding of signals, rather than the mere echo returns processed by primary radar. This means that all possible friendly 'targets', whether surface shipping, land based vehicles or aircraft, must carry an appropriate transponder in order to be identified.

33. Within the transponder, an interrogating signal is received and decoded, leading to the necessary return signal being produced. Interrogation is based upon the delivery of a pulse pair, separated in time by a period dependent upon the 'mode' of operation. Early systems used three possible codes based upon a train of pulse pairs separated by 3µs, 5µs or 8µs. The transponder uses a delay mechanism, and

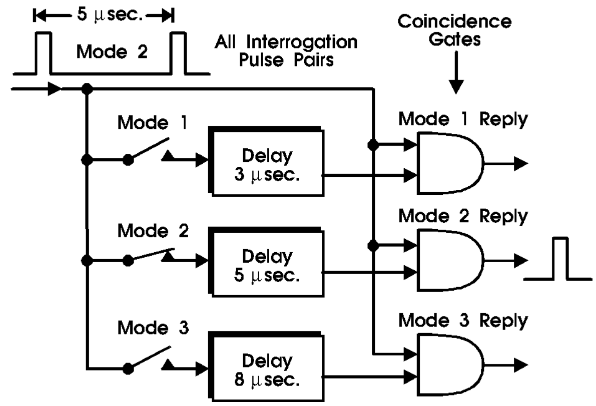


Fig.5. IFF Coincidence Gating

coincidence gating, to decode and reply as illustrated at Fig.5.

34. Every line in the coincidence system receives all the interrogating signals, whichever mode is used. It is only that AND gate which is preceded by the correct delay, switched on, that will be able to reply. The first pulse of a pair arrives and is delivered to both AND gate and delay mechanism. Since the first pulse cannot reach the second input to the AND gate until it has passed through the delay. The gate cannot open, as shown by the timing sequence of Fig.6.

35. When the second pulse of the pair arrives it is delivered to both the AND gate and the delay mechanism. It arrives at the gate just as the first pulse reaches the end of the delay line. Hence, both appear together at the coincidence gate, in this case that for mode 2, which opens for a single pulse period to initiate the reply. Of course, the second pulse eventually passes through the delay and reaches the AND gate,

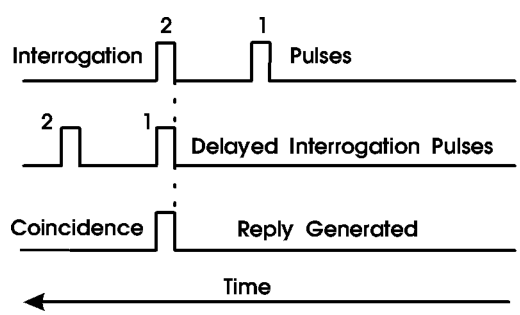


Fig.6. Coincident Gate Timing

however, there is no other pulse to coincide and open the gate.

36. In Fig.5, mode 2 is the only one selected for reply, so the system would not reply to mode 1 or mode 3 interrogations because they are switched out. Should they both be switched on, to enable reply, they will only produce a response to their own particular interrogations, because the other pulse pairs do not cause coincidence to occur. In practice, mode 2 is selected permanently and a coded reply is given in that mode, which corresponds to the specific carrying vehicle. In this way particular friendly targets can be identified.

Arrangements also exist for an emergency alarm to be raised by similar coded replies from the IFF system.

Beam Formation

37. It is not possible for a radar to form an instantaneous 'picture' of three dimensional space because this would mean transmitting a massive amount of energy in all directions at the same time, and then waiting for replies, also from all directions. Thus, a radar must use some method of scanning to fill the volume of interest. Various techniques exist for doing so, most of which are based upon

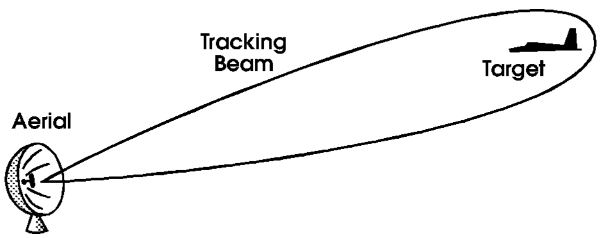


Fig.7. Cigar Shaped Tracking Beam

a parabolic reflector, similar to that used within an electric torch or flashlight.

38. Radar beams can be formed, which are either narrow in one dimension and wide in the other, or are cigar shaped, in a similar manner to the illumination from a torch. Fig.7, illustrates a cigar shaped beam that is normally used for tracking, and any radar employing an aerial that produces this pattern is usually 'put on' by another radar. On the other hand, it is possible to fill a volume of airspace by scanning horizontally and vertically. Thus targets can be illuminated in three-dimensional space if necessary. However, scan-

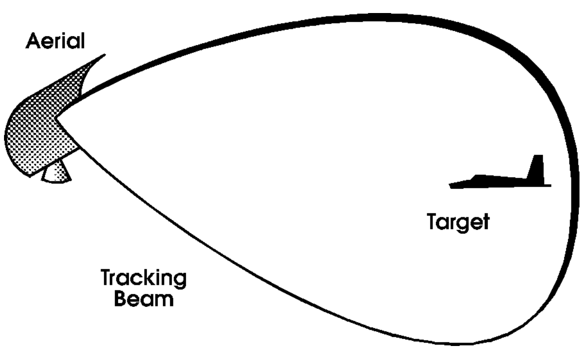


Fig.8. Fan Shaped Surveillance Beam

ning rates may be very high, leading to inertia and volume of coverage problems for the radar designer.

39. For surveillance systems, the type of beam illustrated at Fig.8, is more likely to be used. These fan shaped beams provide coverage, perhaps from ground level to high altitude, that enables the scanning system to rotate continuously, filling the volume of airspace around the radar location. Clearly, this type of radar would normally employ a PPI type of display, which provides a two-dimensional picture of the area scanned. It would be necessary to 'put on' a tracking radar, or employ TWS for target engagement.

PULSE INTERVAL

40. The electromagnetic signal transmitted from a pulse radar is emitted in the form of short bursts of energy called pulses. The **Pulse Repetition Frequency (PRF)** is the number of pulses emitted per second. In typical radars the aerial moves constantly in search of echoes. As the RF beam passes a target, echoes will reflect from it for only as long as pulses hit that target. Since a certain minimum number of echoes is necessary to produce an indication at the receiver, the number of pulses hitting the target during each pass of the aerial must exceed this minimum. The minimum PRF, then, is fixed by the aerial speed and by the receiver and display requirements.

41. It is desirable to have an echo of a pulse return to the radar before the next pulse is emitted, in order to avoid ambiguities. For example, Fig.9 shows how the display is triggered by each transmitter pulse. After the very first pulse is transmitted, an echo returns before the second one goes out and appears at the correct range on the timebase. However, another echo returns from the first transmitter pulse just after the second has been transmitted. This long range echo is displayed at a false short range on the timebase. It has happened because the range scan restarts as the

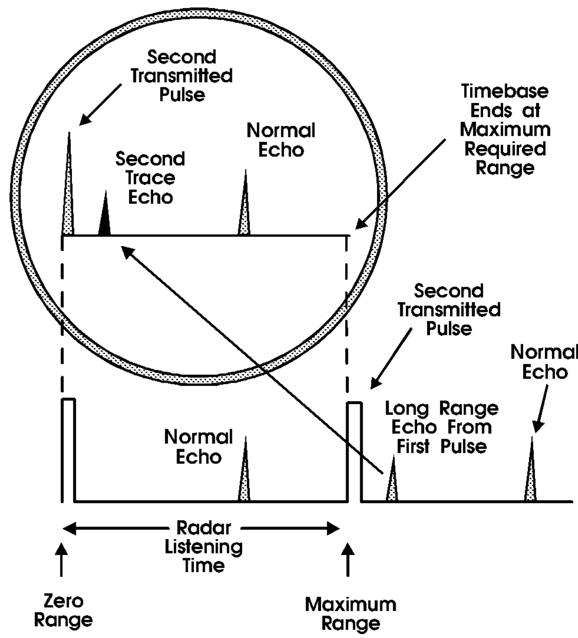


Fig.9. Maximum Range and Second Trace Echoes

transmitter fires the second time. Because of this, the long range signal is called a **Second Trace Echo**.

42. The reason for second trace echoes being processed is that the transmitter has been triggered at too high a PRF. The time period between pulses is called the **Pulse Interval** which is the reciprocal of the PRF. That is,

$$\text{Pulse Interval} = \frac{1}{\text{PRF}}.$$

The problem of second trace echoes may be solved by reducing the PRF and, hence, increasing the pulse interval. This will allow more time for long range echoes to occur after the timebase has finished but before the next transmitter pulse, therefore, they will not be displayed. If necessary, the receiver can be cut-off during the period after the end of a trace and before the next one starts in order to prevent long range echoes even being processed. When this is done, the extra time is called **Dead Time**. Fig.10, shows the effect when an appropriate amount of dead time is introduced into a radar pulse envelope. The second trace ambiguity has then been removed.

43. If it is known that no target exists beyond say 75km, then, since radar range is equivalent to 150m/μs, a pulse interval of at least (75km/150)=500μs is permissible. If, on the other hand, the radar is looking for targets as far as 90km away,

then the pulse interval must be equal to or greater than (90km/150)=600µs. Both of these figures make no allowance for dead time and would be the maximum permissible PRF for the radar. It should be noted that since the pulse interval is the reciprocal of the PRF. That is,

$$\text{Pulse Interval} = \frac{1}{PRF}.$$

A pulse interval of 500µs corresponds to a PRF of 2,000

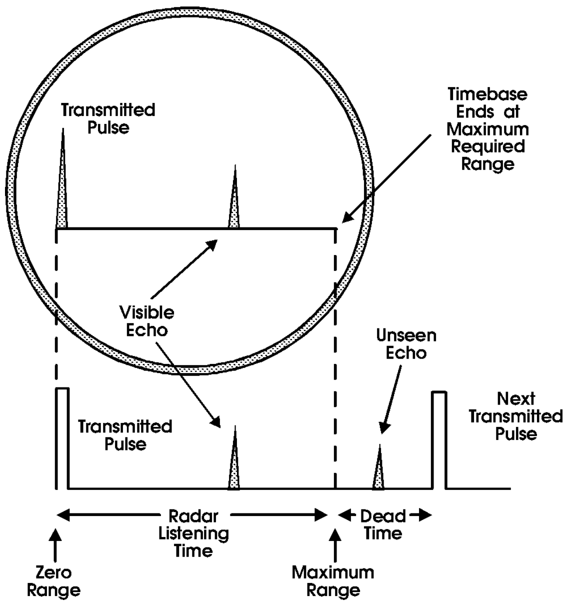


Fig.10. Elimination of Second Trace Echoes

pulses per second (pps). The interval necessary to avoid ambiguities fixes the maximum repetition frequency.

44. In general, the time, To, required between pulses, for a radar operating at maximum unambiguous range, Rmax, must be such that the transmitted signal is able to reach that maximum range and return, before the next pulse is transmitted. Thus,

$$\text{Pulse Interval} = \frac{2\times Rmax}{c} = To$$

Where c = velocity of EM waves.

45. **Example**. A radar operating at a maximum unambiguous range of 15km would require a minimum pulse interval of:-

$$To = \frac{2\times15\times10^{3}}{3\times10^{8}}$$

Therefore To = 100µs

Thus the maximum pulse repetition frequency must be

$$PRF = \frac{1}{100\times10^{-6}}.$$

Therefore PRF = 10,000pps

46. **Example**. A radar operating with PRF equal to 5,000pps, would have a maximum range of:-

$$To = \frac{1}{PRF}.$$

$$= 200\mu s$$

Therefore

$$Rmax = \frac{c\times To}{2}.$$

$$= \frac{3\times10^{8}\times200\times10^{-6}}{2}$$

Rmax = 30km

PULSE WIDTH

47. The width of the transmitter pulse, **PW =** τ, is determined by the **minimum range** and **range discrimination** required. In the interests of minimum range, the transmitter must be turned off and the aerial switched to the receiver by the time the echo from the nearest target of interest comes back. Thus, if the pulse width is 1µs, anything closer than 150m will not be seen. On the other hand, the pulses cannot be too short, or the amount of energy being reflected will be insufficient to be detected by the receiver. Clearly, a balance must be struck between minimum range, and the receiver signal energy requirements.

48. Pulse width, PW, also determines the minimum separation of multiple targets that can be distinguished by the radar, called range discrimination. As the two targets move closer together, there comes a point at which their reflected signals merge into one large signal. A point illustrated by Fig.11. It then becomes very difficult, even impossible, to separate the two echoes. The minimum separation that can be detected by the radar will be a time interval that allows the pulse to strike the second target, and then just join the back of the first echo as it leaves the first target to return to the radar. This is equal to one half of the pulse

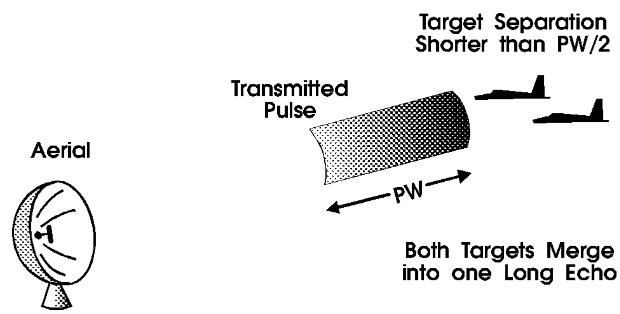


Fig.11. Range Discrimination

width. Hence, the range discrimination is identical to the minimum range and is specified as Rmin=PW(µs)×150m.

49. It can be concluded from the last few paragraphs, that a highly accurate short range tracking radar will have a high PRF and narrow pulse width. This will allow a short maximum range with frequent update of data, and at the same time, provide a short minimum range and range discrimination, in order to track grouped targets separately. On the other hand, a long range search radar will have a low PRF and wider pulse width. This will allow a long maximum range with more energy per pulse, however, range discrimination will be poor, but at long range that may not be too severe a problem.

DUTY CYCLE

50. A typical pulse envelope is shown at Fig.12. The pulse repetition frequency is designated PRF, and 1/PRF is the pulse interval (PI). The pulse width is τ. The power emitted during the pulse is called the **Peak Power**, and it is designated P_{PK}. If the transmitter were running continuously, giving out the same total amount of energy, it would emit a much lower power level, indicated by P_{AV} in the figure. This is called the **Average Power**.

51. The peak power, P_{PK}, is maintained for a period τ, and, since energy = power × time, this is equivalent (in total energy) to

a continuous average power, P_{AV}, maintained for a duration equal to the pulse period, or 1/PRF. Thus,

$$P_{PK} \times \tau = P_{AV} \times \frac{1}{PRF}.$$

or $$P_{AV} = P_{PK} \times \tau \times PRF$$

The product of pulse width times repetition frequency, $\tau \times PRF$, is called the **Duty Cycle**. If a little though is given to this product, it can be seen that it is the ratio of the time the transmitter is firing to the total period between pulses. In other words, if the transmitter is operating continuously, the duty cycle is 100%. This, of course, is rarely the case and pulse radars operate at a duty cycle that does not overdrive the transmitter oscillator and damage it. Thus, a manufacturer specifies both peak power, P_{PK}, and average power,

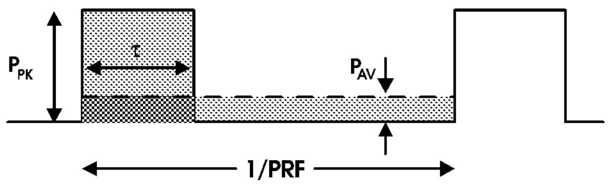


Fig.12. Pulse Envelope Average Power

P_{AV}, for his transmitter oscillators and the designer must avoid exceeding both.

52. **Example.** If a 1MW radar pulse lasts 1µs and is repeated 800 times per second, then

Duty Cycle $= \tau \times PRF$ $(=\tau/\text{Pulse Interval})$
$= 1 \times 10^{-6} \times 800$
$= 0.0008$
$= 0.08\%$

The average power is equal to the product of the peak power and the duty cycle. In this case it is

P_{AV} = Duty cycle $\times P_{PK}$
$= 0.0008 \times 1 \times 10^{6}$
$= 0.8$kW.

Which is 0.08% of the peak power.

SELF TEST QUESTIONS

Read each question carefully and then select the single answer that you consider to be fully correct.

1. Radar energy is sent between a transmitter and receiver located 1500m apart. The time it will take the energy to cover that distance is approximately:-

   a. 0.1sec
   b. 5µsec
   c. 1.5µsec
   d. 5msec

2. The two main roles that a radar may be considered to perform are:-

   a. surveillance and guidance
   b. tracking and locating
   c. guidance and locating
   d. surveillance and tracking

3. Many radars are impaired by the presence of ground returns, often referred to as clutter. Ground returns are important signals to an:-

   a. aircraft radar altimeter
   b. anti-aircraft surface to air missile radar
   c. artillery mortar locating radar
   d. airline cloud collision warning radar

4. A radar is considered to be CW if it:

   a. transmits pulses continuously
   b. uses a single antenna dish
   c. never interrupts its transmissions
   d. uses none of the techniques above

5. The two main classes of radar are:-

   a. Doppler and CW
   b. CW and Pulse
   c. Doppler and Pulse
   d. CW and secondary

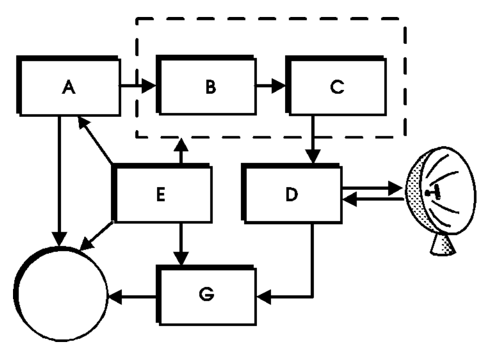
6. The target information that can be acquired from a 'pure' CW radar includes:-

   a. velocity, bearing and elevation
   b. elevation, bearing and range
   c. range, bearing and velocity
   d. range, bearing, elevation and velocity

7. A 'pure' CW radar is to be modified so that it can provide target range information. This could be achieved by:-

   a. using one antenna for transmission and another for reception
   b. extracting the doppler shift and calculating velocity
   c. converting it to a moving target indicator (MTI)
   d. modulating the transmitter

8. The basic block diagram of a pulse radar is illustrated below. The block marked with an 'A' is the:-



   a. display
   b. magnetron
   c. T & R switch
   d. master timer

9. In a pulse radar:-

   a. the power required to get an echo from a given range is less than that required in a CW radar
   b. separate transmitter and receiver aerials are required
   c. energy is emitted in short high power bursts
   d. transmission and reception are carried out simultaneously

10. In a pulse radar, the main function of the master timer is to:-

   a. furnish a time signal which synchronises the transmitter with the display or computer
   b. direct energy from the transmitter to the receiver
   c. generate a constant radio frequency output
   d. modulate the transmitter

11. The modulator of a pulse radar:-

   a. is used to direct energy between antenna and receiver
   b. sets the timing for the whole system
   c. is employed because the relatively weak timing signal is not powerful enough to modulate the transmitter
   d. is used to direct energy between transmitter and antenna

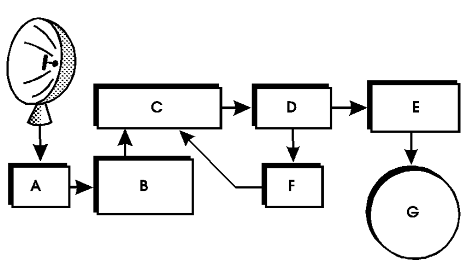
12. The basic block diagram of a pulse radar is illustrated at question 8. The block marked with an 'D' is the:-

   a. display
   b. magnetron
   c. T & R switch
   d. master timer

13. A standard radar receiver:-

   a. is of the superheterodyne type
   b. employs a frequency changer
   c. uses AGC
   d. incorporates all three techniques at a, b and c above

14. The basic block diagram of a pulse radar receiver is illustrated below. The block marked with a 'B' is the:-



   a. frequency changer
   b. RF Amplifier
   c. video amplifier
   d. IF amplifiers

15. In a pulse radar system, the T&R switch:-

   a. is employed to prevent damage to the transmitter during reception
   b. adjusts the gain of the receiver to keep the signal level approximately the same all the time
   c. directs energy from transmitter to antenna, and antenna to receiver as required
   d. does all three of a, b and c, above

16. The basic block diagram of a pulse radar receiver is illustrated at question 14. The block marked with an 'E' is the:-

   a. frequency changer
   b. RF Amplifier
   c. video amplifier
   d. IF amplifiers

17. Wavelength of transmission is a factor incorporated in radar design. One important consideration is that:-

   a. higher power transmitters are available at the longer wavelengths
   b. a given aerial size produces a less directive beam at shorter wavelengths
   c. longer wavelengths are attenuated more during propagation
   d. shorter transmitter wavelengths means larger aerials for a given beamwidth

18. In radar design, frequencies around:-

   a. 10,000MHz are considered to be 'X' band
   b. 5,000MHz are considered to be 'S' band
   c. 3,000MHz are considered to be 'L' band
   d. 1,000MHz are considered to be 'C' band

19. In considering radar displays:-

   a. a PPI shows elevation and azimuth
   b. the 'A' scope shows range and bearing
   c. the 'C' scope shows elevation and azimuth
   d. all three of a, b and c, above, are true

20. One of the features of a primary radar is that:-

   a. it is completely self-contained
   b. the target receives, rather than merely reflecting an echo
   c. where IFF is involved a coded reply is processed
   d. the target must have a transponder in order to reply

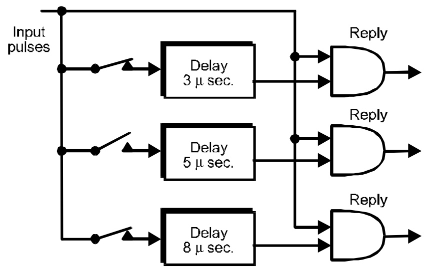
21. The beam of energy produced by a radar can take a number of forms. The beam most suited to tracking would be:-

   a. a vertical fan
   b. cigar shaped
   c. a horizontal fan
   d. a shape unlike those described at a, b and c, above

22. A pulse radar is designed to operate at a maximum range of 45 km. The time interval required for energy to reach maximum range and return to the receiver is:-

   a. 150 μsec
   b. 300 μsec
   c. 150 msec
   d. 300 msec

23. A pair of pulses each 1μsec wide is delivered to the IFF coincidence gate illustrated below. In this case, a reply would be initiated, if the time from the start of the first pulse to the start of the second pulse is:-



a. 3μsec only
b. 5μsec or 8μsec
c. 3μsec or 8μsec
d. 8μsec only

24. A pulse radar requires 750 μsec for its energy to travel to maximum range and return to the receiver. The maximum range of this radar is approximately:-

a. 112 m
b. 60 km
c. 60 m
d. 112 km

25. A pulse radar requires 750 μsec for its energy to travel to maximum range and return to the receiver. The PRF of this radar is:-

a. 133 pps
b. 1,333 pps
c. 667 pps
d. 6,667 pps

26. A pulse radar operates at a PRF of 4,000 pps. The likely maximum range for this radar is approximately:-

a. 7,500 km
b. 3,750 km
c. 75 km
d. 37.5 km

27. A pulse radar is designed to operate at a maximum range of 250 km. The PRF of this radar is approximately:-

a. 600 pps
b. 300 pps
c. 60 pps
d. 30 pps

28. A pulse radar is designed to operate at a maximum range of 750 km. The time interval required for energy to reach maximum range and return to the receiver is:-

a. 5 μsec
b. 5 msec
c. 50 msec
d. 500 μsec

29. A pulse radar requires 1550 μsec for its energy to travel to maximum range and return to the receiver. The maximum range of this radar is approximately:-

a. 4,640 km
b. 464 km
c. 2,320 km
d. 232 km

30. A pulse radar requires 125 μsec for its energy to travel to maximum range and return to the receiver. The PRF of this radar is:-

a. 8,000 pps
b. 800 pps
c. 1,600 pps
d. 16,000 pps

31. A pulse radar operates at a PRF of 12,000 pps. The likely maximum range for this radar is approximately:-

a. 125 km
b. 25 km
c. 1250 m
d. 12.5 km

32. A certain radar operates with a transmited pulse width of 3.5μsec. The range discrimination of this radar is:-

a. 5,250 m
b. 52.5 m
c. 525 m
d. 52.5 km

33. Two fighters ground attack are approaching a vital point in line astern with a distance of 125 m between them. In order that they be separately detected head on by a radar, the pulse interval of that radar must not:-

a. exceed 83.39 nsec
b. exceed 0.834 μsec
c. be less than 83.39 msec
d. be less than 0.834 μsec

34. When second trace echos appear on the display of a pulse radar, it means that the:-

a. PRF is too high
b. pulse length is too short
c. PRF is too low
d. pulse length is too long

35. The maximum range of a certain radar is to be 50 km. The PRF at which it would normally be expected to operate is approximately:-

a. 1500 pps
b. 3000 pps
c. 750 pps
d. 4500 pps

36. A radar is designed to operate against very small targets at ranges up 120km. However, when operating at the appropriate PRF, signals above the minimum detectable level can be received from some unwanted targets at greater distances. It is decide to build in 40% dead time. In this case the PRF would be changed to:-

a. 892 pps
b. 1,249 pps
c. 3,123 pps
d. 820 pps

37. A certain radar has a PRF of 2,000 pps. It is decided that the range of the radar is to be increased by 45 km. In this case the PRF must be:-

 a. increased by 750 pps
 b. reduced to 125 pps
 c. remain unaltered
 d. reduced by 750 pps

38. A certain radar operates with a pulse interval of 100 µsec and a pulse width of 1 µsec. The duty cycle for this transmitter is:-

 a. 0.01
 b. 0.1
 c. 0.001
 d. 0.0001

39. An air defence radar operates at a PRF of 10,000 pps with a pulse width of 5µsec. The duty cycle for its transmitter is:-

 a. 0.05%
 b. 0.05%
 c. 5%
 d. 50%

40. A 25 kW radar operates at a PRF of 2500 pps with pulse width at 3µsec. The average transmitter power is:-

 a. 5.333 MW
 b. 187.5 W
 c. 18.75 kW
 d. 18.75 W

41. A certain 40 kW radar is required to operate at a PRF of 12,000 pps. The average power rating of the transmitter oscillator is 2 kW. The maximum pulse width that could be used should not:-

 a. be less than 4.17 µsec
 b. exceed 2.085 µsec
 c. be less than 8.34 µsec
 d. exceed 4.17 µsec

42. A radar that has switchable ranges of 20km and 70km is to be used with a transmitter which has an average power rating of 1500W together with a peak output power of 30 kW. The pulse widths that can be employed on the 20km and 70km ranges respectively should be:-

 a. no greater than 6.67µsec and no greater than 23.35µsec
 b. no less than 6.67µsec and no greater than 23.35µsec
 c. no greater than 6.67µsec and no less than 23.35µsec
 d. no less than 6.67µsec and no less than 23.35µsec

43. An air defence search radar with a beamwidth of 1° scans through one full rotation every second. The PRF of the radar is 1800pps. The number of times it hits the target during each scan is:-

 a. 20
 b. 15
 c. 10
 d. 5

44. A search radar system with a beamwidth of 4° operates at a PRF of 6000pps. The receiver processing circuits require at least 50 target hits for an alarm to be initiated. The rate at which the beam is scanned should be no higher than:-

 a. 40 RPM
 b. 60 RPM
 c. 80 RPM
 d. 100 RPM

45. The transmitter duty cycle of a radar could be described as the:-

 a. ratio of average power to peak power
 b. number of times per second the transmitter is fired
 c. ratio of transmitter on time to pulse interval
 d. ratio of transmitter on time to transmitter off time

46. A certain radar operates at a PRF 15,000 pps and pulse width of 5 µsec. The maximum range and range discrimination respectively for this radar are approximately:-

 a. 15 km and 750 m
 b. 10 km and 750 m
 c. 18 km and 1500m
 d. 12 km and 1500m

47. A certain radar has a duty cycle of 0.01%, a pulse interval of 200 µsec and a mean power of 1.5 kW. The peak power of the radar would be:-

 a. 1.5 MW
 b. 15 MW
 c. 15 kW
 d. 1.5 kW

48. The maximum range and range discrimination of a certain radar are 12 km and 1500m respectively. The duty cycle for this radar would be:-

 a. 0.125
 b. 125%
 c. 1.25%
 d. 124.9

49. A certain radar operates with a pulse interval of 100 µsec and a pulse width of 100 ns. The PRF and range discrimination for this radar is approximately:-

 a. 1,000 pps and 15 km
 b. 1,000 pps and 15m
 c. 10,000 pps and 15 km
 d. 10,000 pps and 15 m

50. A mortar locating radar is being designed that should have a maximum range of 25 km. When using the maximum PRF for this range, some possible targets are liable to produce second trace echos at 5 km. One answer to this design problem is to:-

 a. increase the PRF slightly
 b. do nothing and don't worry about it
 c. terminate each timebase 167 µsecafter the transmitter has fired then wait a further 33 µsec before firing again
 d. terminate each timebase 150 µsecafter the transmitter has fired then wait a further 30 µsec before firing again