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Faculty of Engineering

Department of Electrical and Electronic Engineering

RADAR SYSTEMS

Graduation Project
EE- 400

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ABSTRACT

The objective of studying radar to know its performance and to know its ability of detection targets, and also know the different types of radar (as its classified) and get the knowledge of the construction of the main parts of radar block, especially on the magnetron as oscillator in radar – the main part in radar transmitter which give the antenna high power with high frequency and high stability in the high temperature.

Then we will know the different types of radar display and know the methods of scan radar slides which include the targets map and how there is synchronization between the rotating antenna and scanning beam on screen.

Finally, we will see the final output of radar system which is antenna, and know the different types of radar antenna and the different parameters which determine the radiation patterns and then know types of radar feeders which transfer power to antenna.

This is all our objectives which will take them one by one and its details., so our goal to understand the basic construction of the radar systems , and has the ability to understand its operation of detection the targets and what is the rules or conditions that determined the ability of radar detection.

And at the end of this project we should get the purpose of the radar system and how its work which include also the display systems and antenna systems and its types and the different parameters of it.

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INTRODUCTION

Radar is an electric device that has been widely used, so its waves are very important to deeply study the propagation of radar signals, also a typical block diagram of radar set which is consisted of transmitter, receiver, antenna and indicator.
Conventional radars have been operated at frequencies extending from about 25 to 70000 MC. These are not necessarily the limits since radar can be operated at frequency outside.

Generations of adequate R.F. power is an important part of any radar system. So that the transmitter is selected for any particular application. There are two basic transmitter configurations used in radar. One is the self-exited oscillator exemplified by the magnetron and the other utilizes a low power level by one or more power amplifier tubes.

The types of radar antenna are different from antenna used in communications. Radar antenna must generate beams with shaped directive patterns which can be scanned, since the radar opened at VHF or the UHF bands use array antenna. At the microwave frequencies the parabolic reflector and microwave lenses are used.

The first chapter to know its ability of detection targets, and also know the different types of radar (as its classified) and get the knowledge of the construction of the main parts of radar block, especially on the magnetron as oscillator in radar – the main part in radar transmitter which give the antenna high power with high frequency and high stability in the high temperature, and see also the idea of the high power transmission line to radar antenna which is wave guide.

The second chapter we will know the different types of radar display and know the methods of scan radar slides which include the targets map and how there is synchronization between the rotating antenna and scanning beam on screen and know the early type of scanning slide on radar screen and method of control the display of radar by computer controller.

The third chapter we will see the final output of radar system which is antenna, and know the different types of radar antenna and the different parameters which determine the radiation patterns and then know types of radar feeders which transfer power to antenna and also the technology of radar antenna array and the basic concepts of it.

1.RADAR

1.1 RADAR FUNDAMENTALS:

1.1.1 GENERAL INTRODUCTION:

Radar is an electric device that has been widely used, so its waves are very important to deeply study the propagation of radar signals, also a typical block diagram of radar set which is consisted of transmitter, receiver, antenna and indicator. Conventional radars have been operated at frequencies extending from about 25 to 70000 MC. These are not necessarily the limits since radar can be operated at frequency outside. Generations of adequate R.F. power is an important part of any radar system. So that the transmitter is selected for any particular application. There are two basic transmitter configurations used in radar. One is the self-exited oscillator exemplified by the magnetron and the other utilizes a low power level by one or more power amplifier tubes. The types of radar antenna are different from antenna used in communications. Radar antenna must generate beams with shaped directive patterns which can be scanned, since the radar opened at VHF or the UHF bands use array antenna. At the microwave frequencies the parabolic reflector and microwave lenses are used. The special design which this project contains is a wide-band amplifier or video amplifier, since the RC- coupled voltage and current amplifiers possess flat frequency-response characteristics over range of frequencies. The region of uniform amplification must be wider than possible with simple circuits. Extending the high frequency range of amplifier via adding the compensating elements (inductance or capacitance). Since this amplifier has received considerable attention, different services require different solutions. For example, in TV a uniform application over the range 25 CPS to about 4.5 or 5 MHZ is required, and radar receives uniform responses of 2 to 8 MC.

1.1.2 LEARNING OBJECTIVES :

Learning objectives are stated at the beginning of each chapter. These learning objectives serve as a preview of the information you are expected to learn in the chapter. The comprehensive check questions are based on the objectives. By successfully completing the OCC/ECC, you indicate that you have met the objectives and have learned the information. The learning objectives are listed below .

Define range, bearing, and altitude as they relate to a radar system .Discuss how pulse width, peak power, and beam width affect radar performance .Describe the factors that contribute to or detract from radar accuracy .Using a block diagram, describe the basic function, principles of operation, and interrelationships of the basic units of a radar system .Explain the various ways in which radar systems are classified, including the standard Army/Navy classification system .

Explain the basic operation of cw, pulse, and Doppler radar systems .

1.2 INTRODUCTION TO RADAR FUNDAMENTALS :

The term RADAR is common in today's everyday language. You probably use it yourself when referring to a method of recording the speed of a moving object. The term Radar is an acronym made up of the words radio detection and ranging. The term is used to refer to electronic equipment that detects the presence, direction, height, and distance of objects by using reflected electromagnetic energy. Electromagnetic energy of the frequency used for radar is unaffected by darkness and also penetrates weather to some degree, depending on frequency. It permits radar systems to determine the positions of ships, planes, and land masses that are invisible to the naked eye because of distance, darkness, or weather .

The development of radar into the highly complex systems in use today represents the accumulated developments of many people and nations. The general principles of radar have been known for a long time, but many electronics discoveries were necessary before a useful radar system could be developed. World War II provided a strong incentive to develop practical radar, and early versions were in use soon after the war began. Radar technology has improved in the years since the war. We now have radar systems that are smaller, more efficient, and better than those early versions .

Modern radar systems are used for early detection of surface or air objects and provide extremely accurate information on distance, direction, height, and speed of the objects. Radar is also used to guide missiles to targets and direct the firing of gun systems. Other types of radar provide long-distance surveillance and navigation information .

1.3 BASIC RADAR CONCEPTS :

The electronics principle on which radar operates is very similar to the principle of sound-wave reflection. If you shout in the direction of a sound-reflecting object (like a rocky canyon or cave), you will hear an echo. If you know the speed of sound in air, you can then estimate the distance and general direction of the object. The time required for a return echo can be roughly converted to distance if the speed of sound is known. Radar uses electromagnetic energy pulses in much the same way, as shown in figure 1-1. The radio-frequency (rf) energy is transmitted to and reflects from the reflecting object. A small portion of the energy is reflected and returns to the radar set. This returned energy is called an ECHO, just as it is in sound terminology. Radar sets use the echo to determine the direction and distance of the reflecting object .

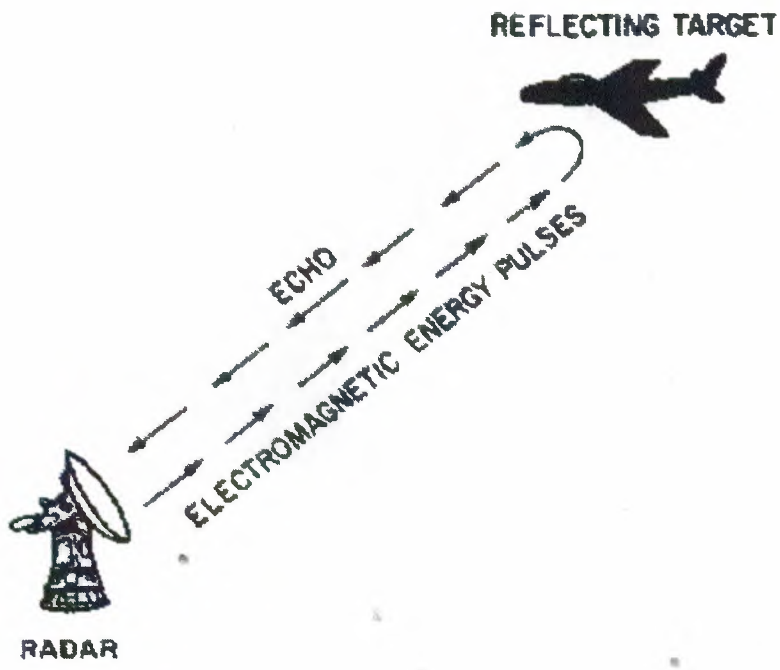


Figure (1.1): Radar echo.

NOTE: The terms TARGET, RETURN, ECHO, CONTACT, OBJECT, and REFLECTING OBJECT are used interchangeably throughout this module to indicate a surface or airborne object that has been detected by a radar system .

Radar systems also have some characteristics in common with telescopes. Both provide only a limited field of view and require reference coordinate systems to define the positions of detected objects. If you describe the location of an object as you see it through a telescope, you will most likely refer to prominent features of the landscape. Radar requires a more precise reference system. Radar surface angular measurements are normally made in a clockwise direction from TRUE NORTH, as shown in figure 1-2, or from the heading line of a ship or aircraft. The surface of the earth is represented by an imaginary flat plane, tangent (or parallel) to the earth's surface at that location. This plane is referred to as the HORIZONTAL PLANE. All angles in the up direction are measured in a second imaginary plane that is perpendicular to the horizontal plane .

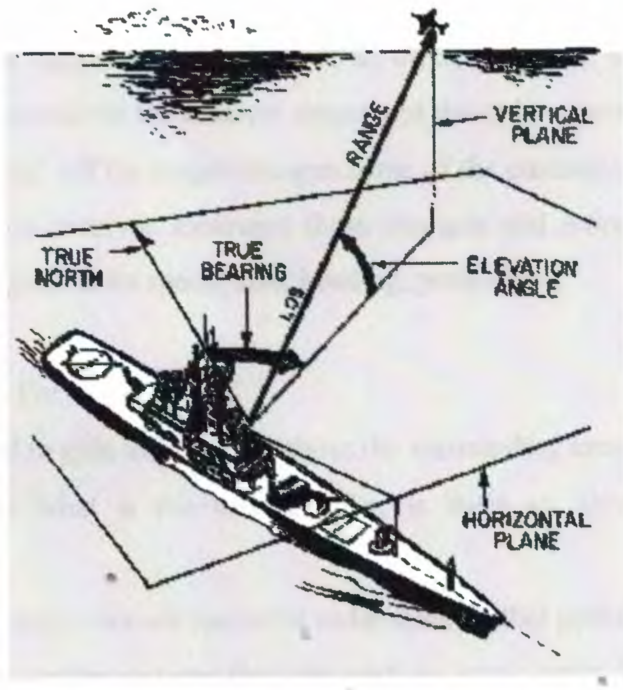


Figure (1.2): Radar reference coordinates.

This second plane is called the VERTICAL PLANE. The radar location is the center of this coordinate system. The line from the radar set directly to the object is referred to as the LINE OF SIGHT (los). The length of this line is called RANGE. The angle between the horizontal plane and the los is the ELEVATION ANGLE. The angle measured clockwise from true north in the horizontal plane is called the TRUE BEARING or

AZIMUTH angle. These three coordinates of range, bearing, and elevation describe the location of an object with respect to the antenna .

1.4 A RADAR SYSTEM DESCRIPTION:

1.4.1 Background Information:

What's RADAR stand for again?

- It is Radio detecting and ranging.
- Goal of a radar system is to extract information about an object (the target) which is outside the radar itself.
- Radar systems are very similar to the general communications system.
- The diagram below shows the basic block diagram of a monostatic radar system. Monostatic means that the receiver and transmitter are in the same place.
- A radar system achieves its purpose is by firstly transmitting a signal from its antenna .This signal is in the form of an electromagnetic wave bounces of the target and proceeds to the receiver antenna of the radar system .
- The "bouncing" off the target changes some of the parameters of the transmitted signal and the receiver measures these changes and extracts the information about the target, i.e. its speed, size, heading, position etc.

What is Radar Used For?

- Radar is used to gain information about the surrounding area.
- For example what is the weather like, is there an aircraft, ship, tank etc approaching.
- Like most things there are specialist radar systems that perform difference tasks.
- There are also radar systems that can perform many tasks. These types of radar are called multi-mode radar systems.
- The image above of a nose cone radar is an example of a multi-mode radar system .
- Multi-mode systems using do not perform as well as their single-mode counterparts in any particular task but are used when space is at a premium, like in an aircraft.

- The information gathered by radar systems can be used to control other systems directly, like autopilots, automated weaponry, or can be used to help human supervisors to control aircraft and the like.
- The E-3 AWACS (Airborne Warning And Control System) is an example of an airborne supervisory role of radar.There are many other application of radar system.

1.4.2 The parts of a Radar System

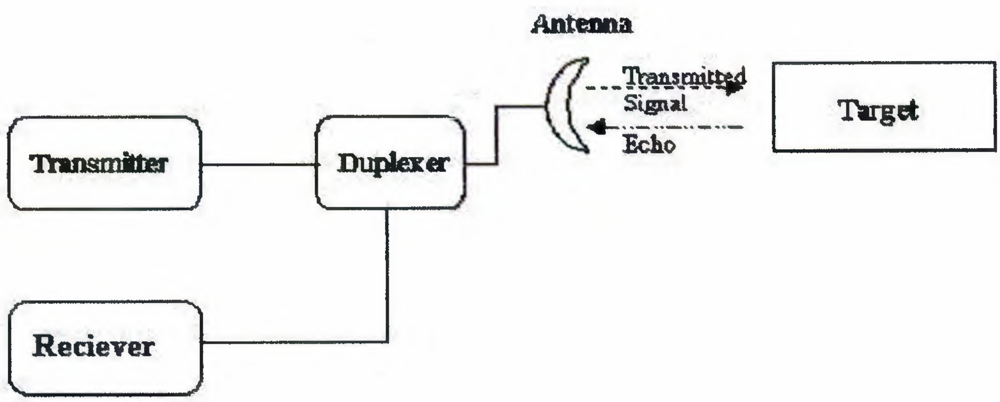


Figure (1.3): radar block

- The transmitter a sends out a signal suitable for passage through the channel.
- The channel a signal transverses the channel twice, once on the way to the target and then on the path back to the antenna.
- The receiver measures the parameters changes caused on the transmitted signal by the target.

What Type of Information Can Be Deduced by Radar System and What type of information can be deduced about a target from its echo?

The most immediate information that can be deduced about a target is the distance to the target. This is a simple time measurement of the time from the transmission of the pulse to the reception of the echo.

The direction to the target can be determined by the angle of the radar antenna's axis.The size of the target is directly proportional to the power of the received echo.

The speed of the target can be determined by the position of the echo's spectrum. The shift from the original transmitted spectrum gives us this information, using the Doppler Effect. More on the Doppler Effect in the Continuous Wave Radar section.

1.4.3 Noise In Radar Systems :

- Like in communication systems, noise plays a big role in radar systems .
- The types of noise are the same as in communication systems except clutter noise which is unique to Radar systems .
- Clutter noise is the sum of all the echoes that return to the receiver from terrain objects like hills, trees etc., objects that are of no interest, in most cases, to the radar system .Clutter noise can to some extent by removed because the object producing the unwanted echo is stationary and this leads to the ability to detect and ignore them.
- The same techniques are used in radar systems to reduce the influence of noise that are communication systems.used in

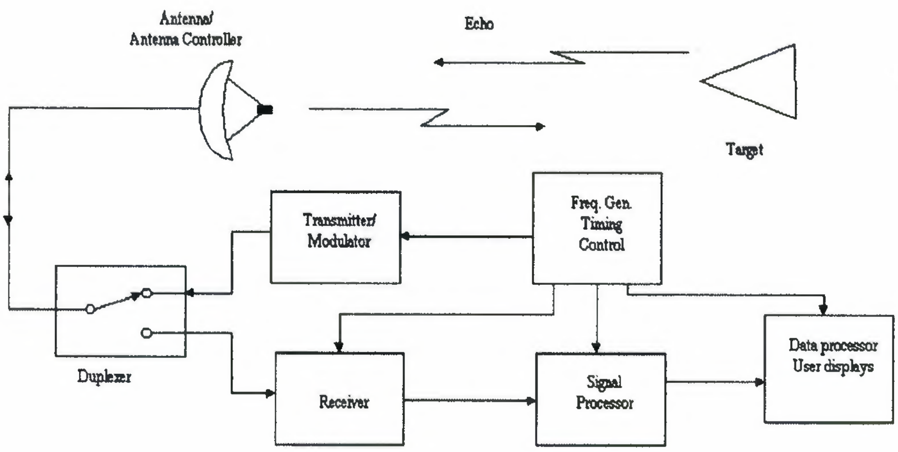
1.4.4 Different Radar System Set-ups:

Most radar systems have the transmitter and receiver in the same location, monostatic radar.There are however systems in use where the receiver and transmitter are in different locations, this is called biostatic, and cases where there are multiple receivers and transmitters, called multistatic.There are cases where the transmitted signal is not of the radio spectrum .For example sonar, which is used for under water detecting. Here the transmitted wave is in the acoustic spectrum. Acoustic systems are also sometimes used for atmospheric sensing.

-Differences and similarities between radar and communication systems:

- The main difference between the communications system and the radar system is that in the radar system the information does not originate at the transmitter. The information originates at the target.
- Radar and communication system have a lot in common.
- Signals that are transmitted by each system are very similar.
- The processing of these signals, especially to reduce noise are also very similar and so not much detail will be given here as it assume the reader has a good understanding of communication systems.

1.5 Components of a Radar System :



figure(1.4). Block diagram of a Monostatic Single Antenna Radar System

- Frequency Generation
- Transmitter
- Modulator
- Duplexer
- Antennas
- Antenna Controller
- Receiver

1.5.1 Frequency Generation, timing and control:

- Generates the frequency and synchronization signals that are required by the system

- It determines when the transmitter fires and how other systems functions relate to the time of transmission
- It controls the system's parameters and passes them to the other modules

1.5.2 Transmitter:

- The transmitter generates the radio signal which is used to illuminate the target

1.5.3 Modulator:

- In pulsed systems, Pulsed Radar (PR), the modulator turns the transmitter on and off .
- In continuous systems, Continuous Wave Radar (CWR), it provides the modulation uses to determine target range.

1.5.4 Duplexer:

- In a monostatic single antenna system the duplexer switches the antenna between the transmitter and the receiver.
- This allows the antenna to be shared between the two functions.
- The switch is usually electronic as the switch has to be made within nanoseconds.

1.5.5 Antenna:

- The antenna concentrates the signal from the transmitter into a narrow beam radiated in the desired direction
- Intercepts the echo from the target in the desired direction.
- Matches the systems impedances to those of the transmission medium.
- Is usually steered so that the antenna can search or track in maying directions .

1.5.6 Antenna Controller:

- Positions the antenna beam to the required azimuth and elevation angles.
- Interacts with the system controller and data processor, reporting the positioning of the beam.
- Antennas can either be mechanically steered or electronically steered as is the case with phased arrays.

1.5.7 Receiver :

- Amplifies the received echo signal to a level sufficient for the signal processor.
- Filters incoming signal removing out-of-band interference. This is called channel selecting filtering.

1.5.8 Signal Processor:

- Processes the target echoes and the interfering signals to increase the target echo signal level and suppress the interference.
- Performs the detection function, i.e. makes the decision of whether a target is present or not.
- Determines target parameters like range and Doppler shift.

1.5.9 Data Processor :

- Stores and processes the location of detected targets.
- In some radar systems the data processor extrapolates the targets' position in a track while scan function.
- In tracking radars the data processor may control the servo for the antenna by processing angular errors into signals that control the antenna's motion.
- In some systems the data may be sent to other locations in a process called netting. Target position is converted into coordinates understandable to all systems in the net. At the receiving end the data processor converts the coordinates back to a format understandable by the local system.

1.5.10 Displays :

The display puts the information extracted from the echo signal by the data processor into a form that is useable by the radar operator and others such as traffic controllers and weapon system operators and supervisors .

1.6 The radar equation for single target :

The energy intercepted by the target will be:

$$\frac{\sigma G P_t}{4\pi r^2} \qquad (1)$$

where

σ is the back scattering cross section of the target.

NOTE: not necessarily equal to the geometrical cross section.

The amount of energy which gets back to the antenna is:

$$\frac{\sigma G P_t}{\left(4\pi r^2\right)^2} \tag{2}$$

The amount of power that is collected by the antenna is:

$$P_r = \frac{A_e \sigma G P_t}{\left(4\pi r^2\right)^2} \tag{3}$$

where : $[P_r]$ = watts

A_e = effective area of the antenna

What are typical values of these quantities?

$P_t \sim 10^5$ W

$r \sim 100$ km

$G \sim 40$ dB

$A \sim 1\ m^2$

Inserting these numbers into the above equation gives

$$\frac{P_t}{P_r} \approx 10^{19}!!!$$

The gain can be express in terms of the effective area of the antenna and the wavelength of the radar by:

$$G = \frac{4\pi A_e}{\lambda^2} \quad \text{or} \quad A_e = \frac{G\lambda^2}{4\pi} \qquad (4)$$

so substituting (4) into (3) gives:

$$P_r = \frac{\sigma G^2 \lambda^2 P_t}{(4\pi)^3 r^4}$$

This is the radar equation for a point target.

$$P_r = 10\times\log_{10}\left(\frac{P_t\times G_t\times G_r\times\lambda^2\times\sigma}{(4\times\pi)^3\times R_{Tx}^2\times R_{Rx}^2}\right)\ [\mathrm{dBW}]$$

$$= 10\times\log_{10}\left[P_t\times G_t\times G_r\times\left(\frac{\sigma\times c^2}{(4\times\pi)^3\times f^2\times R_{Tx}^2\times R_{Rx}^2}\right)\right]\ [\mathrm{dBW}$$

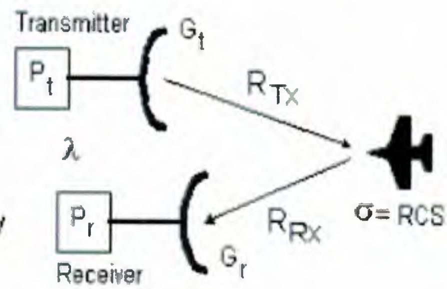
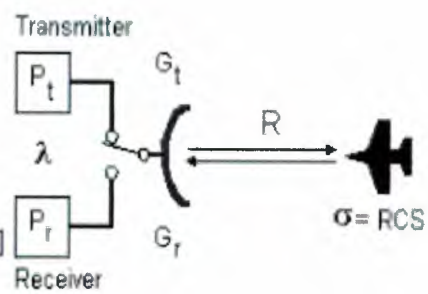


figure (1.5) : Bistatic (Tx and Rx in different locations)

$$P_r = 10\times\log_{10}\left(\frac{P_t\times G_t\times G_r\times\lambda^2\times\sigma}{(4\times\pi)^3\times R^4}\right)\ [\mathrm{dBW}]$$

$$= 10\times\log_{10}\left[P_t\times G_t\times G_r\times\left(\frac{\sigma\times c^2}{(4\times\pi)^3\times f^2\times R^4}\right)\right]\ [\mathrm{dBW}]$$



figure(1.6) : Monostatic (Tx and Rx in same location)

Keep all units consistent. Losses due to atmospheric absorption and antenna polarization are not included.

where: Pr = Received peak power (W)

Pt = Transmitted peak power (W)

Gt = Gain of transmitter antenna (ratio, not dBi)

Gr = Gain of receiver antenna (ratio, not dBi)

l = Transmitted wavelength (m, cm, in, etc.)

s = Radar cross-section of target - RCS (m2, cm2, in2, etc.)

R = Range (m, cm, in, etc.)

RTx = Transmitter range to target (m, cm, in, etc.)

RRx = Receiver range from target (m, cm, in, etc.)

c = speed of light .

1.7 Radar Equation for Distributed Targets :

- Before we derive the radar equation for the distributed targets situation, we need to make some assumptions:
    1. The beam is filled with targets Q: Where/when would this assumption break down?
    2. Multiple scattering is ignored
    3. Total average power is equal to the sum of powers scattered by individual particles.

Recall the radar equation for a single target:

$$\overline{P}_r = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 R^4} \quad (1)$$

- P_r is the average received power
- P_t is the transmitted power
- G is the gain for the radar
- λ is the radar's wavelength
- σ is the targets scattering cross section
- r is the range from the radar to the target

For multiple targets, (1) can be written as:

$$\overline{P}_r = \frac{P_t G^2 \lambda^2}{(4\pi)^3} \sum_i \frac{\sigma_i}{R_i^4} \quad (2)$$

where the sum is over all targets within the pulse volume. If we assume that $h/2 << r_i$,

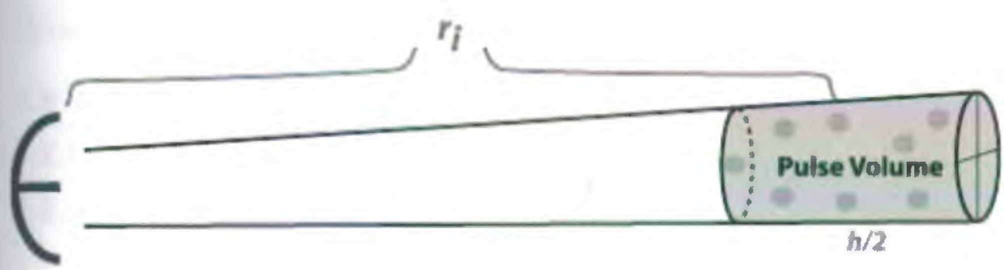


figure (1.7) : reflection from target.

then (2) can be written as:

$$\overline{P}_r = \frac{P_t G^2 \lambda^2}{(4\pi)^3 R_i^4} \sum_i \sigma_i \quad (3)$$

It is advantageous to sum the backscattering cross sections over a unit volume of the total pulse volume.

Hence the sum in (3) can be written as:

$$\sum_i \sigma_i = \left(\sum_i \frac{\sigma_i}{unitvolume} \right) totalvolume \quad (4)$$

where the total volume is the volume of the pulse.

Thus, (4) can be written as:

$$\sum_i \sigma_i = \left(\sum_i \frac{\sigma_i}{unitvolume} \right) \pi \frac{R^2 \theta^2 h}{8} \quad (5)$$

Substituting (5) into (3) gives:

$$\overline{P}_r = \left(\frac{P_t G^2 \lambda^2 \theta^2 h}{512\pi^2 R^2} \right) \sum_i \sigma_i \quad (6)$$

Note that:

P_r is proportional to R^{-2} for distributed targets

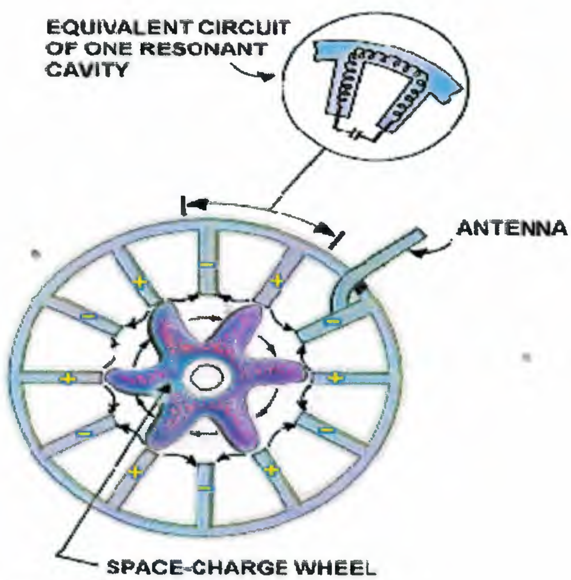
P_r is proportional to R^{-4} for point targets.

1.8 ELECTRONICS RADAR:

1.8.1 MAGNETRON OSCILATOR :

1.8.1.1 INTRODUCTION:

The magnetron is a tube that contains a cathode and symmetrical distribution of anodes in which electrons move under the influence of an internal electric field and an extremely supplied static magnetic field the electron move in complicated crossed paths and under certain conduction powerful oscillation will be sustained.



Figure(1.8) : Electrons form a rotating pattern. (wagner , Gallawa)

Recently the magnetron has been widely developed its development made the various type of microwave radar in which the magnetron is used to supply high power pulses in frequency range of 700 to 24000 MHZ possible.

The magnetron is characterized by its high efficiency of which order 50% to 80% and efficiency are obtained at responsible value of current, voltage and magnetic field in addition to high efficiency.

The physical dimensions of magnetron are of order of the wave length so that even the highest frequency magnetron is not too hard to build from the study of the motion of charged partial under which influence of electric and magnetic field its clear that the electron will move is strongly crossed paths with periods of rotation corresponding to microwave frequencies thus an electron in a uniform magnetic field of 1070 Gausses rotate in a circular path at frequency of 300 MHZ which are the radius of this circuit is given by:

$$R= 3.37 \times (10)^{-6} \sqrt{V}) / B \quad \text{Meter}$$

where :

R= radius of the circular path

V= the electron velocity in equivalent Volt

B= the magnetic flux density in Weber/Mt

By the use of multiseg mental anode oscillation at frequencies higher than that corresponding to the simple rotation can be obtained.

Actually electron motion in magnetic field is of the write nature to produce microwave oscillation.

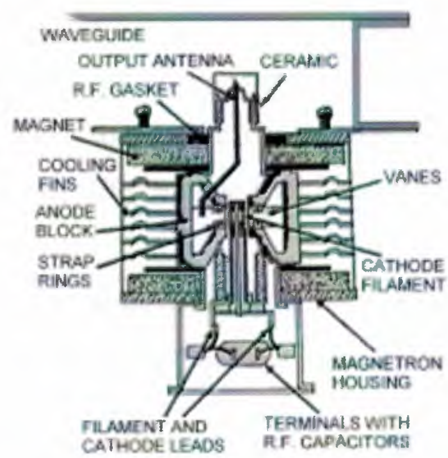


Figure (1.9) Sectional view of a typical magnetron (Courtesy of Michael S. Wagner)

Many kinds of magnetron tubes can be built ranging from a kind of oscillation are also possible. The nature of electron paths is such that a negative resistance can be obtained from only low frequency 700 – 24000 MHZ.

Present interest is concentrated mainly in electronic oscillation of multi segment cavity magnetrons.

1.8.2 EXISTANCE OF SW PATTERNS:

1.8.2.1 Structural form of the Magnetron:

All magnetrons have a cathode in common, anode and an output coupling devices, in addition magnetron may have tuning mechanisms made suppressed and end plates.

Modern multi-cavity magnetron is housed in metal and uses glass only around the high voltage filament leads, and the multi-segmental anode is commonly formed of laminations.

Each of the above structures consist of a number of parallel resonant circuit which forms a series around the inner circumference of the anode, in form of firstly the slots and holes. Where the individual resonant circuit is nearly lamped that there is a capacity across each gap in parallel with the inductance formed by the inner surface of circular holes.

In the other form of anodes the resonant circuit consists of a short section of strip transmission line.

The cathode of multi-cavity magnetron is usually made of appreciable diameter and in tubes for pulsed operation which are directly heated; these make use of oxide emitter. The cathode is usually supported by the filament leads which are brought to the axis of tubes a great precaution are taken to insulate the cathode level for the high voltage which the tube must stand usually. The cathode lead insulator takes up about one third of the volume of the tube.

The output coupling device in a multi-cavity magnetron is usually a loop located at the base of one of the resonant radial anode space and leading out of the tube through a concentric line with a vacuum glass seal.

The multicavity magnetron have iron pole faces built into them with the iron brode close to the cathode and arranged in a way that magnetic field is parallel to the cathode and corrupted created.In some tubes the output coupling is accomplished by means of a tapered T-L feeding from a narrow slot at the base of one of the radial resonant spaces and leading to a waveguide section by a vacuum seal affected by a window at the end of guide section as shown in figure (1.7).

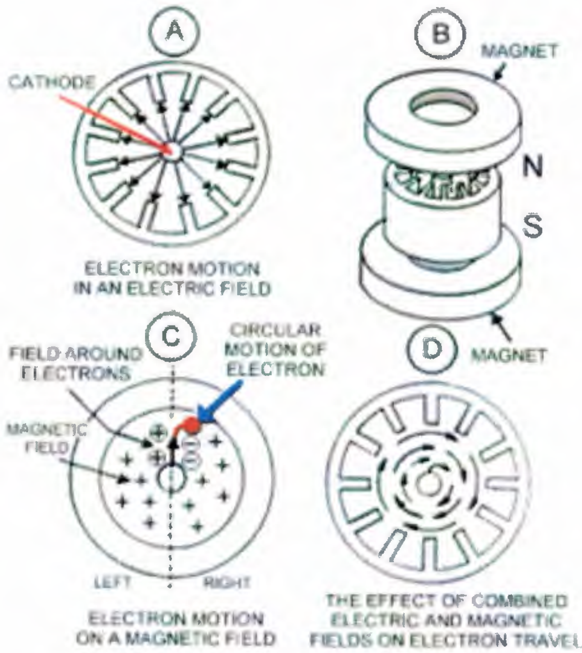


Figure (1.10) Electron motion in a magnetron tube (Courtesy of Michael S. Wagner)

In addition, there are usually stapes inter connected between the anode pole faces in order to separate the natural resonant frequencies of the resonant circuit various tuning devices are also used.

1.8.2.2 Basic Magnetron Operation :

The theory of magnetron operation is based on the motion of electrons under the combined influence of electric and magnetic fields. For the tube to operate, electrons must flow from the cathode to the anode. There are two fundamental laws that govern their trajectory:

1. The force exerted by an electric field on an electron is proportional to the strength of the field. Electrons tend to move from a point of negative potential toward a positive potential. **Figure 3** shows the uniform electron proceeds to the anode in a curve rather than a direct path.

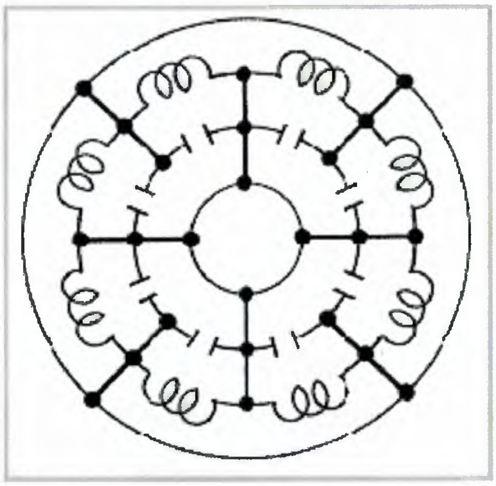
2. The force exerted on an electron in a magnetic field is at right angles to both the field itself, and to the path of the electron. The direction of the force is such that the electron proceeds to the anode in a curve rather than a direct path.

1.8.2.3 Resonant properties of multicavity magnetron:

The resonant system shown before will have a series of natural resonant frequencies are properly determined by an analysis of electro magnetic field of the system. The resonant frequency is that frequency at which the boundary conduction is satisfied.

Upon a knowledge of electro magnetic field. An approximate analysis will be made in term of same equivalent circuit. However it should be remembered that the exact equivalent circuit depends

Let us consider the hole and slot type arrangement, the equivalent circuit of this type shown



Figure(1.11) Equivalent circuit of cavities in parallel because of strapping. (Courtesy of Michael S. Wagner)

C_1---- represents the capacity between the pole faces and the anode.

C_2----represents the capacity between two adjacent pole faces.

L_3----is the inductance of inner surface of circular hole.

This is a poor equivalent circuit because it neglects transmission line effect and the large metal inductance between adjacent spaces.

From this equivalent circuit in figure (3) it is clear that this equivalent to a new pass filter. It will have a pass band in which the attention is zero and the phase shift per section increases uniformly from zero at zero frequency up to –π- Per section at f = fact where (fc is is the cut off frequency). When the total phase shifts along the series of N section is an integer multipli of their standing wave can exist in the circular arrangement. The actual resonant field is formed by the two-waves of equal amplitude traveling in analytically:

$$\beta = (2\pi \times n)/ N$$

Where :

B = phase shift per section

N= mode number

N= number of section or number of gaps

The phase shift function of the circuit can be evaluated by applying Campbell's form, and from this form and the above equivalent we get on the resonant frequency in the form of:

$$(W/wc_1)^2 \quad = \quad 1/C_2 + 1 / 2^*C_1 \, [1\text{-}\cos 2\pi n/N]$$

The resonant frequency response is shown in figure 3.0 from the important observation is that the frequency of the mode is not very different from the next resonant frequency a 15% frequency separation is considered to be good.

The above analysis is not very satisfying for its neglects the mutual inductance between adjacent slots which are expected to be quite high lines of the vector H are parallel to axial of the tube in the slots at the adjacent slots as shown in figure 4. The lines of H divided and return through the adjacent slots according to equivalent

The ratio of the number of lines rotating through adjacent slots to the total number will be nearly equal to unity which that the coefficient of coupling is nearly unity from that mutual inductance can be replaced by the T section. This allows the equivalent circuit we get on the resonant frequency is:

$$W_2 \; = 1/1\text{-}\cos (2\pi n/N).\, 2/ (\acute{\omega}_1)^2 + 1/ (\acute{\omega}_2)^2 \qquad (3)$$

Where:

$\Omega_1 = 1/\surd M_1C_1$,

$\Omega_2 = 1/\surd M_1C_2$

The frequency separation between the mode and its neighbor is very small. Actual magnetron will have characteristics between thus corresponding to the two cases discussed, the behavior is more corresponding to a band pass filter and the low frequency cut off of the filter.

It can be shown that the double ring strapping will increase C and thus lower the resonant frequency of the mode will be the strapping system decrease the inductance L raises the frequency of the combined to increase the frequency and the adjacent resonant frequency.

Multicavity magnetron may be tuned over an appreciable range by changing the slot capacity on the inductance, there are many arrangements making use of both the L-RING and C-RING.

The L-RING Being nearer to the base of the slot will decrease the inductance and the frequency will be increased. While the C-RING being nearer to the interaction gap of the anode slots will increase the capacitance and the frequency will be decreased, where array board rings are ganged so that the L-RING is desired both an L & C rings are ganged so that the L-RING enters as C-RING emerges.

1.8.3 Guided wave radar for level measurement :

In recent times a number of new radar transmitters have been released for level measurement applications. Radar is presented as the "be-all-and-end-all" of level measurement technology the answer to all level measurement applications. But is it true? Boyce Carsella Jr Product Manager of Magnetrol argues the case for guided wave radar.

Upon initial observation radar level transmitters seem perfect. The antenna does not contact the process liquid the high frequency electromagnetic signal travels easily over long ranges and the measurement is unaffected by changes in the process media. So if the price of radar can be reduced to the point where it is competitive with ultrasonic transmitters it should corner the market?

However as more radar transmitters are being installed flaws are coming to light.:

· The output of electromagnetic energy at the antenna of a radar transmitter is typically around 1mW a very weak signal.

· After the energy is launched into free air it begins to weaken very rapidly.

· The signal reaches the level surface where it is reflected back and the reflection off a liquid surface is directly related to the dielectric value of the liquid. Very low dielectrics like hydrocarbon media reflect very little of the signal.

· On the return path to the top of the tank this weakened signal loses more energy until what is received back at the transmitter may be less than 1% of what was initially transmitted.

· Turbulence and some foam types further complicate the matter by scattering the signal off its direct path or absorbing it leaving little or no return signal. This is made worse by spurious signals due to mixers piping and ladders.

Magnetrol's Eclipse transmitter is a two-wire loop-powered 24 DC liquid level device based on the guided wave radar (GWR) principle. Guided wave radar uses a wave guide (probe) to provide the performance of conventional through-air radar but with additional advantages: Though GWR is new to level measurement it was first used in the thirties for underground sensing in communications and geomechanical applications.

GWR combines the principles of time domain reflectometry (TDR) and equivalent time sampling (ETS). Using pulses of electromagnetic energy distance measurements are taken using TDR to measure the transit time of the signal. These signals are captured using ETS in real time (nanoseconds) and they are reconstructed in equivalent time (milliseconds).

A most important benefit of this operating principle is that because the radar signals travel within a waveguide that is physically in contact with the media signal loss is minimised. With GWR the output into the wave guide is extremely small approximately 10 of the output of conventional radar (0.1mW). This can be achieved since the wave guide offers a highly efficient path for the signal to travel down to the surface of the liquid and back. Degradation of the signal is kept to a minimum so extremely low dielectric media (>1.7) can be measured effectively. Variations in media dielectric also have little effect on performance: guided wave radar like conventional through-air radar uses transmit time to measure the media level. The signal reflecting from a surface always has the same transit time regardless of its dielectric value - only the amplitude of the signal changes

Since the signal is contained within the wave guide turbulence and tank obstructions present no problems.

Other parameters which have no effect are varying specific gravity and the presence of vapours and foam. Media build-up and coating have little effect. Coating needs to be considered from the points of view of film and bridging. A film coating is the effect of a viscous or light slurry when the liquid level drops. This type of coating has little effect.

Bridging - when a chunk or slug of media "bridges" the two elements of the probe - can cause significant error however because a level will be detected at that point.

The guided wave radar transmitter is loop powered not line powered so installation costs are reduced considerably. The cost is comparable to standard level measurement technologies. Since the speed of light is constant no level movement is necessary to calibrate the device. In fact field configuration is achieved simply by entering data related to the specific application. Numerous transmitters can be configured on an instrument bench in minutes - all that is needed is a 24V DC supply. The Hart communications protocol assists diagnostics re-calibration and maintenance.

The hardware is much less expensive than conventional radar transmitters. Loop power of course presents technical obstacles to developers: 4mA at 24V DC offers very little in the power budget. The output at the antenna must be significantly reduced by launching less energy and processing is done with less powerful microprocessors and averaging the return signal over a longer time period.

The design of the housing was developed following discussions with end users who expressed a preference for a dual compartment design. It keeps the electronics protected in one compartment by locating the connection terminals in the other compartment. Both compartments are located in the same direction for ease of wiring and calibration. Because they are tilted at an angle of 45° the compartments are easy to access when mounted on the top of a probe.

A quick disconnect high frequency coupling means the housing can be attached to the probe in seconds. The design permits the housing to be rotated 360° to provide optimum wiring and viewing angles.

Two probe options mean that the system is suited to work in a wide range of liquids from light hydrocarbons to water-based slurries at temperatures up to 200°C pressure up to 50bar and lengths from 60 to 610cm. Approvals include CENELEC intrinsically safe FM/CSA intrinsically safe and explosion proof.

2. Types of radar :

Radar systems can be classified by their operational characteristics or by their functions. We will begin by briefly describing the types of radar based on the individual techniques they employ, then we will describe some of the applications of modern radar systems. At the end of this section, we will briefly discuss radar applications by the radio frequency bands used.

2.1 CW RADAR :

The CW radar gun, which operates on the homodyne principle, is a low powered 10mW X-band radar used to acquire target Doppler signatures. With a weight of about 10 kg including its own batteries it is portable and can be set up on a photographic tripod in less than two minutes. This makes it ideal for observing cooperating or non-cooperating battlefield radar targets at ranges of 1 km or less.

The radar has been employed in the collection of radar Doppler signatures from civilian and military targets such as men, wheeled and tracked vehicles and helicopters.

New radar has recently been constructed for JEM studies. This is shown below. The microwave head transmits about 35 mW of power at X-band which is focused by a 45 in parabolic dish. The operator views the target visually using a gun-sight (there is a small hole in the dish) and simultaneously listens to the signature of the aircraft through headphones. The radar is mounted on a post on which there are roller and journal bearings for azimuth and elevation. The operator steers the antenna assembly manually. The whole system is attached to the bed of a small truck.

The signatures are recorded with a bandwidth of about 20 kHz using a commercial audio recorder. Metal tapes are employed with Dolby noise reduction. The signatures are digitized later using a SoundBlaster board.

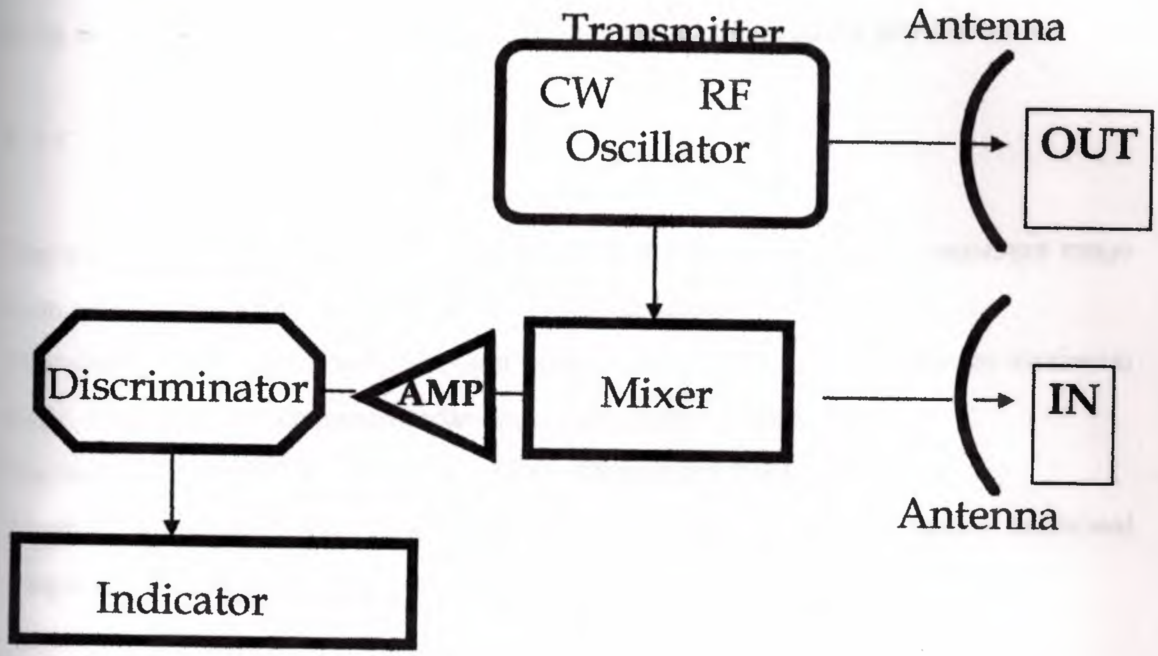


figure (1.12): continous wave radar components.

The following applet allows you to calculate the signal to noise ratio of a received radar signal according to the radar equation . A CW radar transmits and receives simultaneously, so it uses the Doppler frequency shift produced by a moving target to separate the weak echo from the strong transmitted signal. A simple CW radar can detect targets, measure their radial velocity (from the Doppler frequency shift), and determine azimuth angle from the direction of arrival of the received signal. To determine range, however, a more complicated waveform must be used.

. 2.2 Pulsed Radar System:

2.2.1 Operation of a Pulsed Radar System:

The frequency generation and timing system, discussed in Parts of a Radar System, periodically cause the transmitter to generate a pulse or burst of illumination electromagnetic energy.

The power levels of this burst vary depending on the environment and the required performance of the system.

The width of the pulse can vary between nanoseconds and milliseconds. The transmitted pulse is not a true "pulse", i.e. it is not one single peak of electromagnetic energy. A carrier waveform is in fact transmitted for the pulse duration.

The transmitter unit, which transmitted the RF pulse, then waits for the echo.
If the echo is received D t seconds later then the range can be easily worked out as:

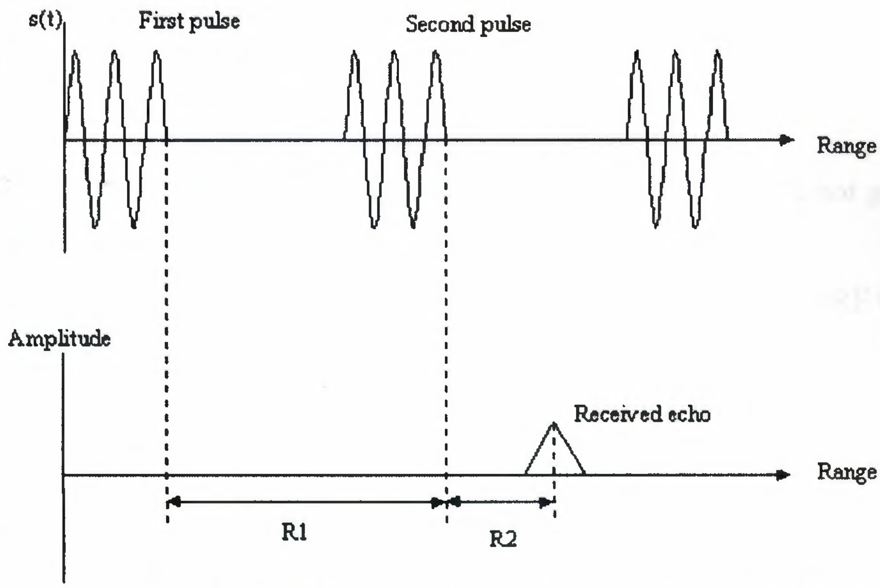
$$R = C \cdot Dt / 2$$

The transmitter does not wait indefinitely for the echo as there is a maximum range from which a targets echo is so weak it can not be detected.
Therefore the transmitter waits for inter pulse period (IPP) which dictates the maximum range, Rmax, which the pulsed radar system can detect a target.
The inverse of the IPP is the pulse repetition frequency (PRF).
Another factor, apart from Rmax, that influences the PRF is the antenna rotational frequency. The antenna rotates so as to try to detect targets all around it.

To measure the time delay it takes for the echo to reach the receiver we need a reference point in the transmitted signal. The echo that will be picked up by the receiver from the target will be an attenuated version of the transmitted signal and so its shape will be very similar to that of the transmitted pulse.

The pulse shape to be transmitted therefore needs to have, one and only one, sharp reference point.

2.2.2 Range Ambiguity:
Range ambiguity results from the fact that we only wait a limited period of time for an echo from a target before the next pulse is transmitted.
Range ambiguity occurs when if for some reason we get an echo from a distance greater then Rmax, i.e. after a second pulse has been transmitted.The receiver then can not tell from what range the echo came from.



Example of range ambiguity. The range to the target could be R2 or R1+ R2.

Figure(1.13) : rang ambiguity.

If for instance the target echo was detected 0.000005 seconds after a pulse, and the IPP is 0.0006. Rmax for this system is therefore 90km. The echo could therefore have come from a range of 750m or 90.75km.

It is therefore the IPP or the PRF that determines the amount of range ambiguity.

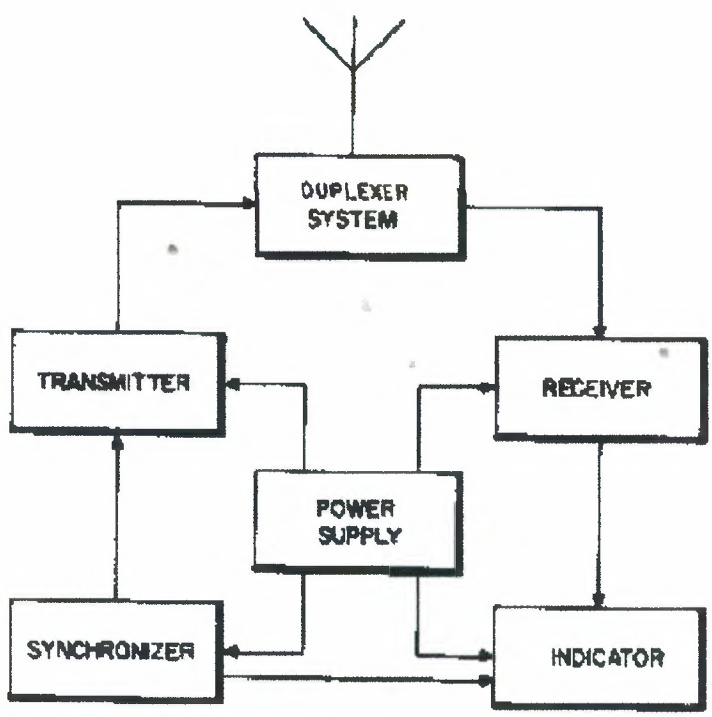


figure (1.14) : pulse radar

- What can be done about range ambiguity?

If we set the PRF to a large enough value we can be certain we will not get any echoes from greater then Rmax.

But there are other factors like antenna rotational speed that limit the PRF value.

Therefore we can not remove the problem entirely.

2.2.3 Range Resolution :

Range resolution is the ability of the system to distinguish between two targets that are closely positioned.

The echoes of the two targets must therefore not overlap to such an extent that they ca not be still recognized as two separated echoes. Therefore the shorter the pulse duration period the higher the range resolution.

2.3 Over The Horizon Radar :

The main problem of modern radar is involved in increasing the operating range. This is usually limited by line of sight, i.e. the horizon, in conventional radar systems.

To over come the line of sight problem there is great interest in using high frequency radars (3-30 MHz), where the radar signal is reflected by the ionosphere. This technique can be used to detect targets that are completely obscured by the horizon. The other is to use ground wave radar. We will look here at high frequency OTH radar as it is the most common.

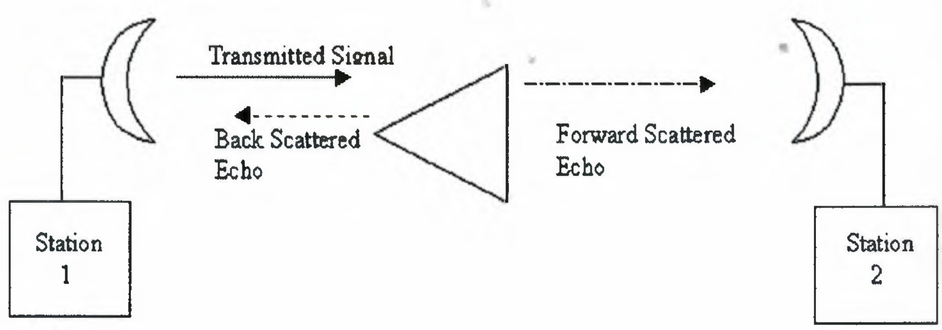


figure (1.15) : OTH RADAR

OTH radar may either work using back scattering, like most conventional radar systems, or using forward scattering.

Back scattering has already been discussed. Froward scattering is when the receiver and transmitter are separated and are in a straight line with the target in the middle.

Most OTH radar systems use a single hop technique as illustrated below. This technique gives a range of about 3000Kms.

To transmit signals over such a long range and still be able to detect the back scattered echo means that very high powered transmitters are required. If the receiver and the transmitter are close together then a large amount of noise can be induced into the receiver by the transmitter. For the above reason some OTH systems separate the receiver and the transmitter and are therefore biostatic systems.

An example of a separation of receiver and transmitter is found in a US OTH radar installation in Maine where the receiver and transmitter are separated by 162km. This radar has a minimum range of 800km and a maximum range of 3000km. the range resolution of such a system is about 2km and velocity resolution of about 27km/h.

Australia has an OTH radar system set-up near Alice Springs which monitors northern Australia.

2.3.1 Case Study - WARF OTH RADAR :

WARF stands for Wide Aperture Research Facility.

Uses of the WARF facility include :

- The continued study of OTH radar systems
- Detection of ships and aircraft.
- Observations of the state of the ocean.
- Study of the ionosphere.
- Features of the WARF facility include :

A giant receiving array which is 2.5km long. It is formed by two rows of 256 asymmetric vertical monopoles, each about 5.5m long. The antenna array may be electronically steered +/- 32 degrees in both the east and west directions. The gain of the receiving antenna is about 30dB.The system has a fine azimuth resolution of 0.5 degrees. The range resolution is about 1.5km.

Target signals are extracted from interference and clutter using correlation and filter processing techniques, along with Doppler processing

2.4 Simple Pulse Radar :

Pulse radar is by far the most widely used technique and represents what might be called "conventional" radar. Even in more complex radar systems, a pulse-modulated waveform is generally used. These more advanced radars are distinguished from simple pulse radar by the fact that they have additional features that provide enhanced performance.

The figure above is a simplified representation of a pulse that might be generated by the transmitter of a medium-range radar used for aircraft detection. The waveform in the figure is a visual representation of the changes in output voltage of the transmitter over time. The numbers in the figure are hypothetical, but they are similar to what might be expected for a ground-based radar with a range of 50 to 60 nautical miles (or 90 to 110 kilometers) such as those used for air traffic control at airports.

The pulse width in this example is given as one millionth of a second (1 microsecond), and the time between pulses is given as one thousandth of a second (1 millisecond), which corresponds to a pulse repetition frequency of 1,000 hertz (Hz) or cycles per second. Note that the figure shows only a few cycles of the waveform during the pulse; in reality, a system like this could have 1,000 cycles of the wave within each pulse. The pulse power, called the peak power, is shown here as 1,000,000 watts (1 megawatt). Since this system does not radiate continually, however, the average power, which is used to measure the capability of a radar system, is much lower than the peak power. In this example, for instance, the average power would be 1,000 watts (1 kilowatt).

An echo signal from a target might be as weak as one trillionth of a watt. What this means is that the power levels in a radar system may be very large on the transmitter side and very small on the receiver side. Another example of extremes encountered in radar systems is timing. An air surveillance radar might have a pulse duration of one microsecond, while other types of radar can have equivalent pulse widths a thousand times smaller, in the nanosecond range.

2.5 Moving Target Indication (MTI) Radar :

MTI is a form of pulse radar that measures the Doppler frequency shift of the reflected signal to detect moving targets, such as aircraft and tanks, and to distinguish them from stationary objects that do not have a frequency shift. Almost all ground-based aircraft surveillance radar systems use some type of MTI.

2.6 Pulse Doppler Radar (With High Pulse Repetition Frequency):

Pulse Doppler radar is another form of pulse radar that uses the Doppler frequency shift of the reflected signal to eliminate "clutter" and detect moving objects. The difference between pulse Doppler radar and MTI lies in their respective pulse repetition frequencies (prf). For example, a high-prf pulse Doppler system might have a prf of 100 kilohertz (kHz), while a typical MTI system has a prf of about 300 Hz. The MTI uses a lower PRF so as to obtain an unambiguous measurement of range. The tradeoff is that such a system yields highly ambiguous readings of radial velocity and can even miss some detections. Conversely, pulse Doppler, with its high PRF, yields unambiguous radial velocity measurements but highly ambiguous range readings. Range in pulse Doppler is sometimes resolved by the transmission of multiple waveforms with different prfs.

2.7 Pulse Doppler Radar (With Medium Pulse Repetition Frequency) :

This type of pulse Doppler radar operates at a lower PRF (10 kHz, for example) than the high-prf systems, and it yields ambiguities in both range and Doppler shift measurements. It is, however, better for detecting aircraft with low closing speeds than is high-prf pulse Doppler. An aircraft-mounted medium-prf pulse Doppler radar might have to use as many as seven or eight different prfs to obtain accurate target information.

2.8 High-Range-Resolution Radar :

This is a type of radar that uses a very short pulse width to provide extremely accurate range measurements. Such radars provide range resolution from several meters to a fraction of a meter, and they can profile a target and measure its length in the range dimension.

2.9 Pulse-Compression Radar :

For accurate range measurements at long distances it would be desirable to transmit very short pulses with high peak power and high-energy waves. Unfortunately, this ability is limited in practice by voltage breakdown, or arcing in the transmitter or antenna. Thus, high-range-resolution radars with short pulses are limited in peak power and, therefore, also in operating range. Pulse compression solves this problem by transmitting a long, high-energy pulse that is modulated in either frequency or phase. The modulation allows the pulse to be compressed in the receiver, thus achieving the range resolution of short-pulse transmission with longer pulses.

2.10 Synthetic Aperture Radar (SAR) :

With conventional pulse radars, the resolution in range is much better than what can be achieved in angle. Recall that angle (also called cross-range) accuracy is greatest with narrow beam-width transmission. Unfortunately, this is hard to achieve except with the very largest antennas. There is, however, a way to obtain good cross-range accuracy by resolving the angle in terms of Doppler frequency shift. Remember that when an object is moving toward the radar it compresses the reflected energy, thus raising the frequency, and that when the object is moving away it does just the reverse, lowering the frequency. Not surprisingly, this effect also happens when the radar is moving and the target is stationary. This can be accomplished by mounting a radar on an aircraft or spacecraft and viewing the ground.

Imagine a wide-beam radar with good range resolution mounted on an airplane. As the airplane flies past a target on the ground, the radar emits multiple pulses that are partially reflected by the target back to the antenna. As the airplane approaches the target, the Doppler effect causes the echo frequency to rise. But at a certain point (when the plane passes closest to the target) the echo frequency begins to fall again. The point of peak frequency rise represents the cross-range position of the target. Another way to describe this process is to say that all of the observations made during a certain travel distance of the airplane (and radar) are recorded or stored in computer memory and processed together later. The effect is that of having a very large antenna, the diameter of which is the distance traveled by the airplane. This distance is called a synthetic aperture, and the process is called synthetic aperture radar, or SAR. With SAR, cross-range measurements comparable to the best range measurements can be achieved. SAR processing has been used extensively on aircraft and spacecraft to observe the Earth and on deep-space probes to study the planets in our solar system. See previous comments on SAR.

2.11 Inverse Synthetic Aperture Radar (ISAR):

ISAR systems employ the same principle as SAR, except that in this case the radar is stationary (i.e., ground-based). ISAR depends on the target's movement to provide the Doppler frequency shift between various parts of the target and the radar unit in order to obtain high-resolution cross-range measurements. If ISAR is used for cross-range determination in conjunction with either a short-pulse or pulse-compression radar for ranging, a two-dimensional, high-resolution image of the target can be obtained.

2.12 Side-Looking Airborne Radar (SLAR):

This is the same as Synthetic Aperture Radar (SAR).

2.13 Bistatic Radar :

A bistatic radar is one that uses separate antennas for transmission and reception as opposed to monostatic radar where a single antenna is used for transmitting and receiving. In bistatic radar the transmitter and receiver are at different locations. Bistatic radars depend upon forward scattering of the signal from transmitter to receiver. Bistatic scattering characteristics of dense, strongly scattering media are important in many practical applications, including millimeter-wave scattering from snow, ice, and trees.

2.14 Tracking Radar :

This type of radar employs a large "dish"-type antenna that emits a narrow, symmetrical "pencil" beam. The purpose of tracking radars is to track a single target in both range and angle to determine its path, or trajectory, and to predict its future position. Single-target tracking radar provides target location almost continuously, with a typical tracking radar measuring target location at a rate of ten times per second.

2.15 Scatterometer Radar :

This type of radar measures backscatter accurately to obtain information such as wind speed over oceans. Radar images are composed of many dots, or picture elements. Each pixel (picture element) in the radar image represents the radar backscatter for that area on the ground: darker areas in the image represent low backscatter, brighter areas represent high backscatter. A useful rule-of-thumb in analyzing radar images is that the higher or brighter the backscatter on the image, the rougher the surface being imaged.

2.16 Track-While-Scan Radar :

Also known as automatic detection and tracking, or ADT, this is a type of surveillance radar that provides tracking of all targets within its field of coverage by measuring their locations on each rotation of the antenna. Rather than showing individual detections (blips) on the screen, an ADT radar usually displays tracks or vectors of the targets that reveal both their direction and speed.

2.17 3-D Radar :

Conventional air-surveillance radars measure target location in terms of range and azimuth angle, but elevation angle, from which target height can be calculated, can also be determined. In fact, tracking radars measure elevation angle, as well as range and azimuth. So-called 3-D air surveillance radar measures range in the conventional manner but uses an antenna that is rotated about a vertical axis to determine azimuth angle and has either fixed multiple beams in elevation or a pencil beam that is scanned up and down to measure the elevation angle.

2.18 Electronically Scanned Phased-Array Radar :

This is really just a special antenna and not a radar, as such. One of the problems in radar tracking is the necessity to move large antenna structures mechanically in order to point them at targets. Electronically scanned phased-array antennas can rapidly reposition their beams, giving them the capability to track many targets simultaneously without the necessity of antenna movement. The type of radar used with such an antenna can be most of the above.

2.19 Frequency-Modulated Continuous-Wave (FM-CW) Radar :

In this type of CW radar, the frequency of the transmitted signal is continually changed, generally in a linear manner, so that there is an up-and-down alternation in frequency. This means that the frequency of the returning echo signal will differ from the signal then being transmitted. The difference between the two frequencies is proportional to the range of the target, so the measurement of the frequency difference allows range to be determined. Phase modulation of CW signals has also been used to obtain range measurements. The most common form of FM-CW radar is the radar altimeter used in aircraft to determine height above the ground.

2.20 Weather radar :

2.20.1 introduction:

Weather radar's inauguration held on 20th of September in 2000.The radar is 515 m above sea level and it is 24 m high. Compared to other weather radars in Finland Luosto radar has a digital receiver and larger antenna giving better resolution of observations, which is especially important in the winter conditions of Lapland. The radar is also used in development of radar technology and signal processing algorithms. Doppler-radar covers almost the whole Lappland without the most northest part .

The Meteorological Institute provides weather radar pictures for both internal and external use. Radar and satellite pictures are an essential tool for the meteorologist on duty and are of use in research also. For the public these radar pictures have become familiar from for example the weather forecasts presented in the evening news .

2.20.2 How does a weather radar work:

As it turns, the radar antenna sends out short high-powered bursts of microwave energy in different directions. When such a pulse meets an obstacle, e.g. raindrops, the energy is scattered; a very small part of this arrives back at the antenna. The radar measures the strenght of the received signal and its delay time, which is proportional to the range of the obstacle. Thus the intensity of the rain, as well as its position and height, can be determined. With a Doppler radar the speed of the raindrops can also be measured. Although the transmitted pulse is very powerful, the signal received at the antenna from the scattering raindrops is extremely weak. This places great demands on the stability and sensitivity of the radar receiver. The received signal is composed of the combined effects of the scattering from a great number of raindrops; the radar can measure conditions within a rainshaft, and can also penetrate to measure other rain areas beyond .

2.20.3 Technical aspects:

The main units in a weather radar are the antenna with its pedestal, the transmitter, the receiver and the associated computer systems. The main computer controls all aspects of the radar's operations and passes on the measurement results to the FMI main office in Helsinki .

Technical data :

Antenna diameter: Luosto 6.1 m, other radars 4.2 m ,

Radome diameter: Luosto 9.1 m, other radars 6.2 m ,

Beamwidth: Luosto 0.7 degrees, other radars 1 degree ,

Transmitter: radial magnetron ,

Frequency: 5600-5650 MHz

Wavelength: approx. 5.3 cm ,

Transmitted pulse power: 250 kW

Average transmitter power: 300 W

3. Electronic Warfare And Radar Systems:

There are two basic forms of electronic warfare:

- Electronic Countermeasures (ECM).
- Electronic Counter Countermeasures (ECC).

Both of these approach have become highly developed since World War II.

ECM methods can be broken up into two broad categories:

- Noise Jamming. This attempts to mask an enemy's radar echo in heavy noise and degrade the radar's performance .
- Deception jamming. This attempts to lead an enemy's radar into making erroneous measurement of parameters.

Again these categories can be broken down further into active and passive systems:

- Active systems emit energy to accomplish their goals.

- Passive systems emit nothing but instead reflect the enemy's radar to accomplish their goals.

3.1 Noise Jamming:

1. Active Noise Jamming.
2. Passive Noise Jamming.

Noise degrades the performance of radar systems just as it does with communications systems.It reduces the maximum range for detection, range and velocity calculation. Noise jamming is a relative cheap and effective way of implemented ECM.

1-Active Noise Jamming:

- This is the emission of some type of noise toward an enemy's radar.
- Not always white noise is used.
- The noise can be barrage, spot, sweeping or occasional.
- The overall effect is to reduce the signal to noise ration of the enemy's radar system.

2- Passive Noise Jamming:

Where as active noise jamming emitted noise to reduce the SNR there are other ways of ever increasing N or decreasing S.

Some typical methods used in passive noise jamming are:

- Chaff - thousands of dipole reflectors, pieces of aluminium, that are ejected from aircraft and ships. The reflectors are scattered by the wind and form clouds that reflect a sizeable amount of a radar's signal.
- Shape of the target - Good design practices can dramatically reduce the target cross-sectional area which is directly proportional to the amount of the radar's signal that the target reflects .
- Absorbing covering - Special paints and coatings are used to absorb any radiation from a radar and so reduce the amount that is reflected.
- Interference Coatings - Coatings that are produced so that the reflections for the coating and the reflections for the metal of the target neutralise each other .
- Scattering Coverings - Scatters the incident wave in many direction so as to direct a minimum amount of the transmitted energy back to the radar antenna .

3.2 Deception Jamming :

Methods involving the distorting of the enemy's radar signals to mislead the enemy. More sophisticated method then noise jamming.

-Passive Deception Jamming :

An example of passive deception jamming is :The use of decoys - small drone aircraft, which can be made to appear larger than they are by use of corner reflectors.

-Active Deception Jamming :

Here the limits are endless in the permutations of countermeasures and counter countermeasures.An example of active deception is:

False Targets - False targets are created by a jammer by transmitting a signal similar to the one transmitted by the enemy radar. The enemy radar mistakes this jamming signal for an echo for a signal it has transmitted. This method can be effectively used to disguise the number and the location of aircraft, ships etc.

3.3 ECCM :

The best way to reduce the effect of ECM on a radar system is to design:

- receivers with high SNR.
- good dynamic range - can vary operating frequency to get away from jamming.
- good shielding of components.
- antennas should have low sidelobes
- good system to detect and ignore slow moving targets like chaff.

There are always ways of jamming a particular radar system if there is unlimited amount of money available .

3.SUMMARY:

The following paragraphs summarize the important points of this chapter .

RADAR is an electronic system that uses reflected electromagnetic energy to detect the presence and position of objects invisible to the eye .

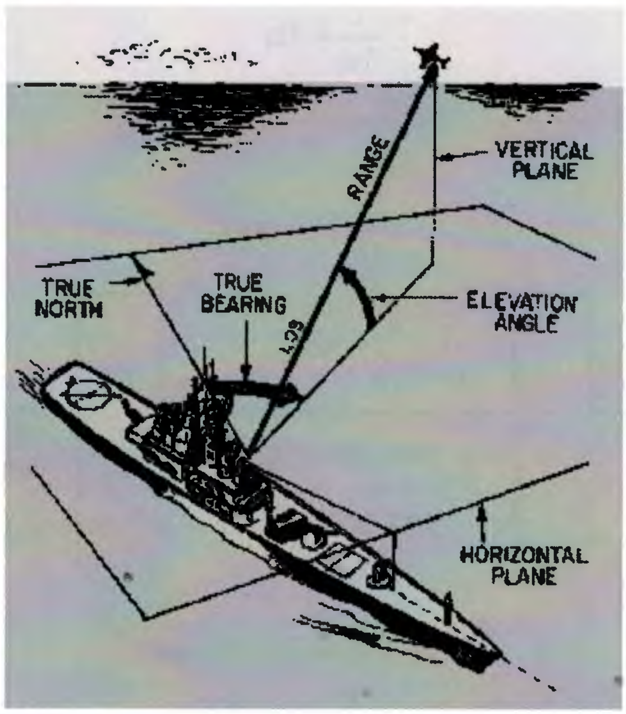
TARGET POSITION is defined in reference to true north, the horizontal plane, and the vertical plane .

TRUE BEARING is the angle between true north and the line of sight to the target, measured in a clockwise direction in the horizontal plane .

ELEVATION ANGLE is the angle between the horizontal plane and the line of sight, measured in the vertical plane .

RANGE is the distance from the radar site to the target measured along the line of sight. The concepts are illustrated in the figure .

RANGE to any target can be calculated by measuring the time required for a pulse to travel to a target and return to the radar receiver and by dividing the elapsed time by 12.36 microseconds .



Figure(1.16): range

RANGE to any target can be calculated by measuring the time required for a pulse to travel to a target and return to the radar receiver and by dividing the elapsed time by 12.36 microseconds

$$\text{target range} = \frac{\text{elapsed time}}{\text{12. 36 microseconds per nautical mile}}$$

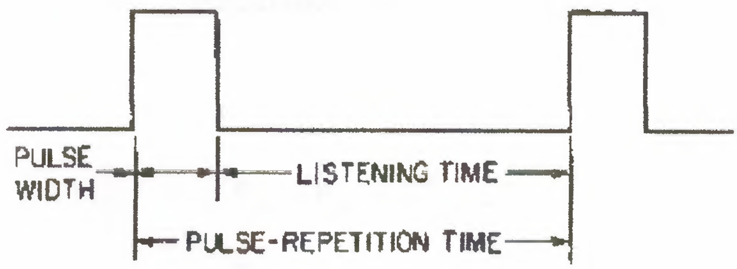
The MINIMUM RANGE of a radar system can be calculated from the formula:

$$\text{minimum range} = (\text{pulse width} + \text{recovery time}) \times 164 \text{ yards/microsecond}$$

The MAXIMUM RANGE of a pulse radar system depends on the CARRIER FREQUENCY, PEAK POWER, PULSE-REPETITION FREQUENCY, and RECEIVER SENSITIVITY .

PULSE-REPETITION TIME is the time between the beginning of one pulse and the beginning of the next pulse and is the reciprocal of prf .

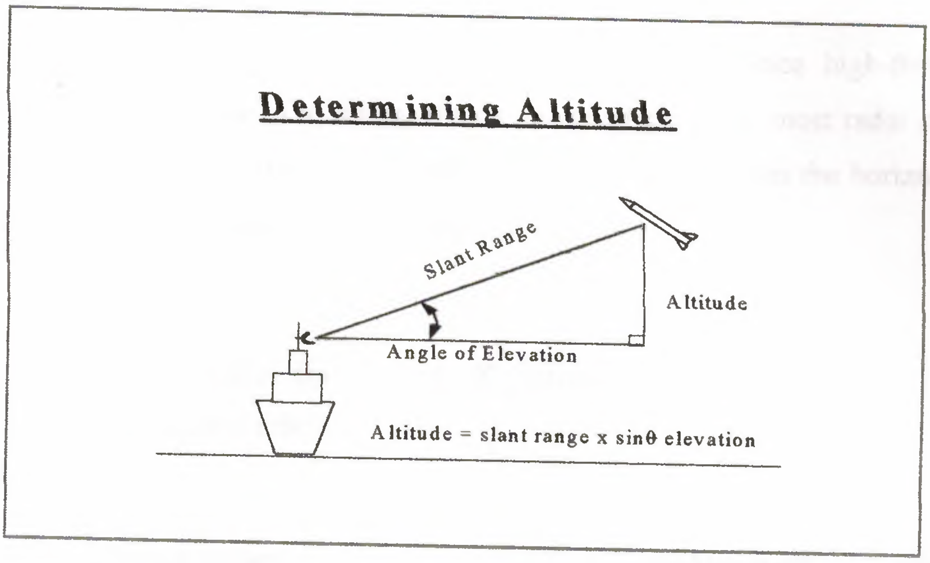
$$prt = \frac{1}{prf}$$



figure(1.17) pulse time digram

AMBIGUOUS RETURNS are echoes from targets that exceed the prt of the radar system and result in false range readings. The maximum (unambiguous) range for a radar system can be determined by the formula

$$R_{max} = \frac{162,000 \text{ mile/second}}{2} \times prt$$



Figure(1.18) : detriming altitude.

The PEAK POWER of a radar system is the total energy contained in a pulse. Peak power is obtained by multiplying the maximum power level of a pulse by the pulse width .

Since most instruments are designed to measure AVERAGE POWER over a period of time, prt must be included in transmitter power measurements. The formula for average power is :

$$P_{avg} = P_{pk} \times \frac{pw}{prt}$$

or

$$P_{avg} = P_{pk} \times pw \times prf$$

The product of pw and PRF is called the DUTY CYCLE of a radar system and is the ratio of transmitter time on to time off .

The formula for the peak power (using average power) of a radar system is :

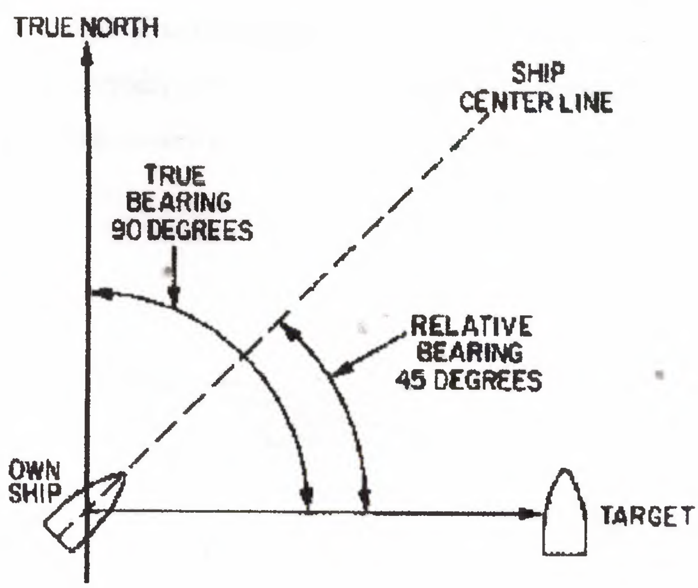
$$P_{pk} = \frac{P_{avg}}{\text{duty cycle}}$$

Antenna height and ROTATION SPEED affect radar range. Since high-frequency energy does not normally bend to follow the curvature of the earth, most radar systems cannot detect targets below the RADAR HORIZON. The distance to the horizon for a radar system can be determined by the formula :

$$\text{radar horizon distance} = 1.25\sqrt{\text{antenna height in feet}}$$
(in nautical miles)

The slower an antenna rotates, the larger the HITS PER SCAN value. The likelihood that a target will produce a usable echo is also increased .

The bearing to a target may be referenced to true north or to your own ship. Bearing referenced to true north is TRUE BEARING and bearing referenced to your ship is RELATIVE BEARING, as shown in the illustration. The bearing angle is obtained by moving the antenna to the point of maximum signal return .



Figure(1.19) bearing

Radar systems that detect only range and bearing are called TWO-DIMENSIONAL (2D) radars. Radars that detect height as well as range and bearing are called THREE-DIMENSIONAL (3D) RADARS .

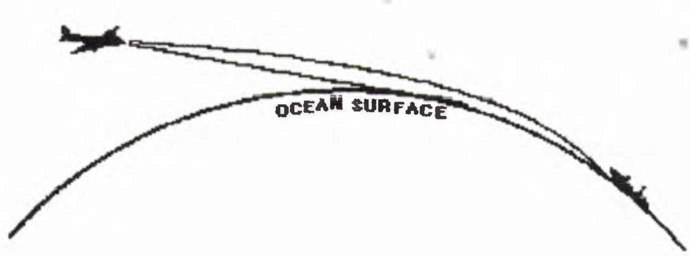
The target RESOLUTION of a radar system is its ability to distinguish between targets that are very close together .

RANGE RESOLUTION is the ability to distinguish between two or more targets on the same bearing and is primarily dependent on the pulse width of the radar system. The formula for range resolution is:

resolution = pw X 164 yards per microsecond

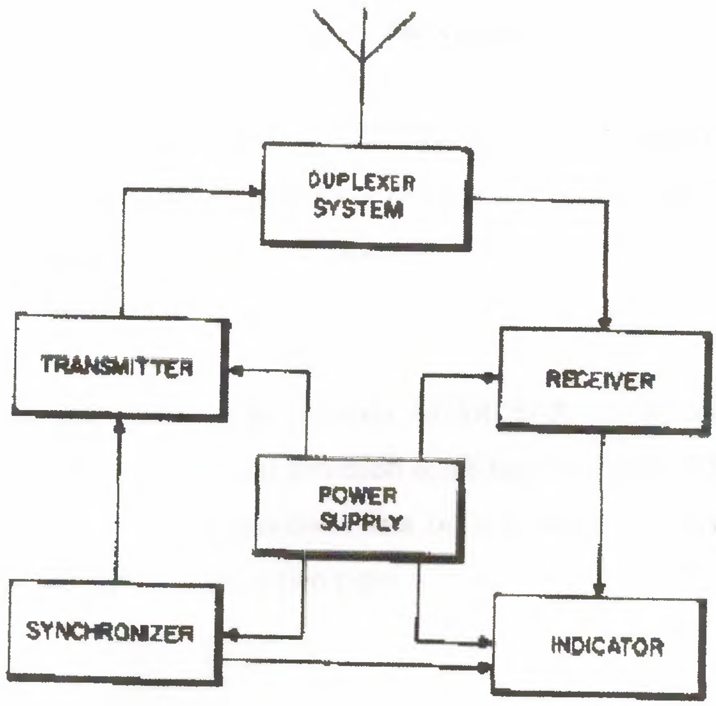
BEARING RESOLUTION is the ability of a radar to separate targets at the same range but different bearings. The degree of bearing resolution is dependent on beam width and range. The accuracy of radar is largely dependent on resolution .

ATMOSPHERIC CONDITIONS affect the speed and direction of travel of electromagnetic wavefronts traveling through the air. Under normal conditions, the wavefronts increase uniformly in speed as altitude increases which causes the travel path to curve downward. The downward curve extends the radar horizon as shown in the illustration. The density of the atmosphere, the presence of water vapor, and temperature changes also directly affect the travel of electromagnetic wavefronts



Figure(1.20) travel of waves

The major components in a typical PULSE RADAR SYSTEM are shown in the illustration. The SYNCHRONIZER supplies the timing signals to coordinate the operation of the entire system. The TRANSMITTER generates electromagnetic energy in short, powerful pulses. The DUPLEXER allows the same antenna to be used to both transmit and receive. The RECEIVER detects and amplifies the return signals. The INDICATOR produces a visual indication of the range and bearing of the echo .



Figure(1.21) pulse radar system

SCANNING is the systematic movement of a radar beam while searching for or tracking a target .

STATIONARY-LOBE SCANNING is the simplest type of scanning and is usually used in 2D search radar. Monopulse scanning, used in fire-control radars, employs four signal quantities to accurately track moving targets. The two basic methods of scanning are MECHANICAL and ELECTRONIC .

Radar systems are often divided into operational categories based on energy transmission methods--continuous wave (cw), frequency modulation (fm), and pulse modulation (pm)

The CONTINUOUS WAVE (cw) method transmits a constant frequency and detects moving targets by detecting the change in frequency caused by electromagnetic energy reflecting from a moving target. This change in frequency is called the DOPPLER SHIFT or DOPPLER EFFECT .

In the FREQUENCY MODULATION (fm) method, a signal that constantly changes in frequency around a fixed reference is used to detect stationary objects .

The PULSE-MODULATION (pm) METHOD uses short pulses of energy and relatively long listening times to accurately determine target range. Since this method does not depend on signal frequency or target motion, it has an advantage over cw and fm methods. It is the most common type of radar .

Radar systems are also classified by function. SEARCH RADAR continuously scans a volume of space and provides initial detection of all targets. TRACK RADAR provides continuous range, bearing, and elevation data on one or more specific targets. Most radar systems are variations of these two types .

2.DISPLAYS AND DISPLAYS SYSTEM

2.1 introduction:

All types of displays use a cathode Ray Tube (CRT) as the device that actually displays the data, a Radar Plan Position Indicator (P.P.I) or Television Display

The basic CRT consists of a heater and cathode assembly that generates a cloud of electrons, focusing system that attracts the cathode electron beam and

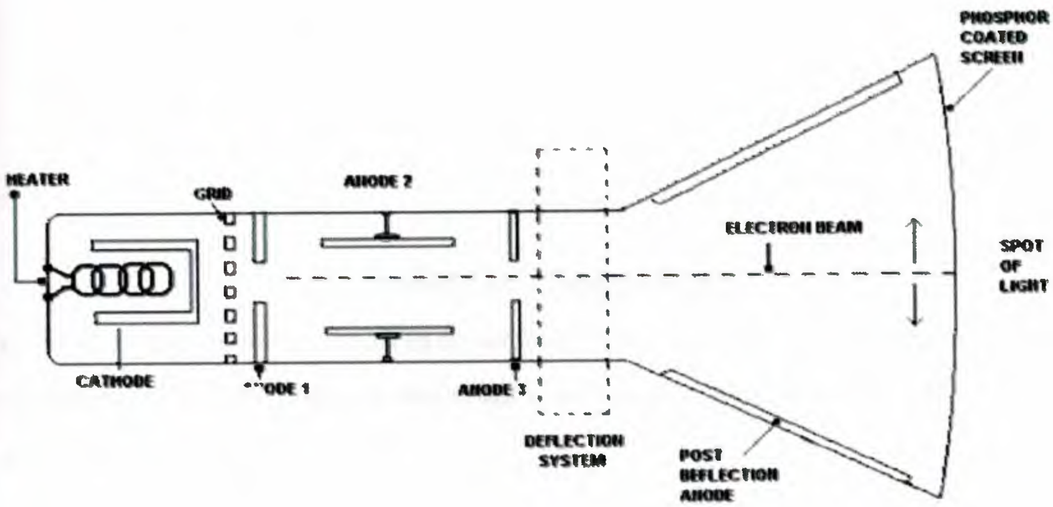


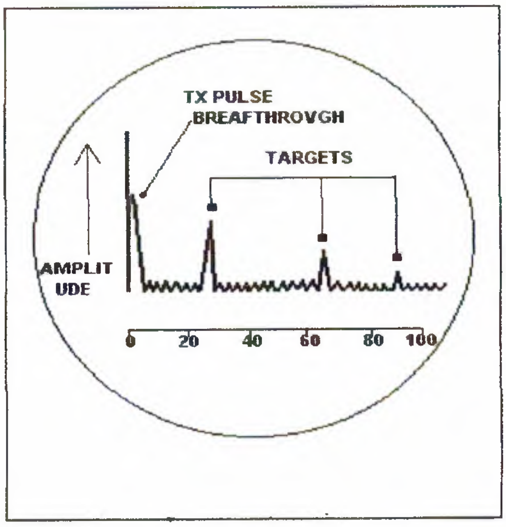
Figure (2.1): display

focuses it into abeam of electrons. This beam is then deflected by either an electromagnetic electrostatic deflection system and hits a phosphor coated screen. The speed that the electron bea hits the screen causes the phosphors to glow leaving a `trail` where the electron Spot has been (long persistence). A grid electrode between the cathode and first anode is used to modulate the intensity of the electron beam, which in turn will vary the intensity of the spot of light on the screen.

The simplest radar display is where a ramp waveform is applied to the X detected video fed to the Y deflection system.This results in the A scan display.

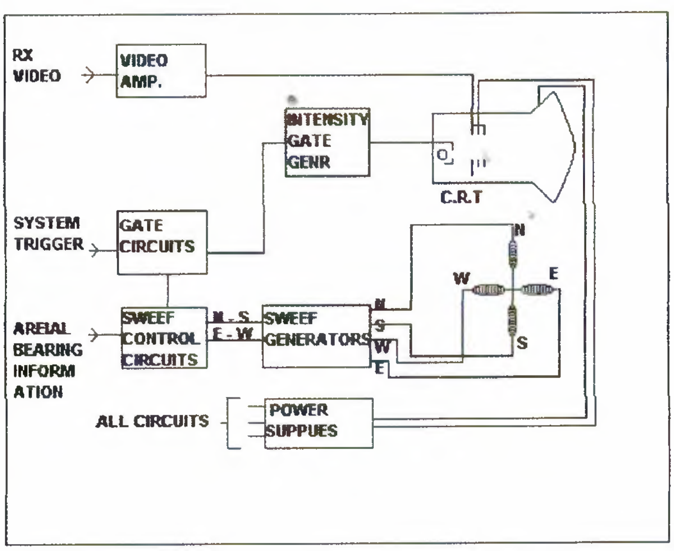
2.2 "A" SCOPE INDICATOR :

2.2 "A" SCOPE INDICATOR :



Figure(2.2): Type A-scope

This form of display will only gives an indication of range and echo amplitude it gives no positional data at all. This display is not used these days except for displaying range in some tracking radars.



Figure(2.3): basic P.P.I display

Three inputs are required for P.P.I. display. A trigger pulse, from the master Timing units, fires all the timing circuits within the display. The pulse starts the time base generation circuits to produce the deflection wave forms used to drive the spot from the centre of the CRT to the edge. The received Video output is used to intensity modulate this trace (normally the brilliance level is adjusted so that the trace minimum signal is just visible, system noise will modulate this, and give a speckled appearance).The aerial rotational information is also fed in so that the display can give accurate bearing data. The display will give range and bearing of the target from the aerial head. Range can be indicated using fixed markers known as CAL rings. Each echo return causes a ` bright up ` to occur at the instantaneous position of the cathode ray on the tube face, true echoes can be detected in the presence of the background noise by the following Means:

a) each echo is ` painted ` at the same position on the tube face (at the same range) in each PRF, and So will appear at higher intensity than noise. (The persistence of the tube causes integration). Note that as the beam sweeps past a target there are a number of returns inside the beam width all painted at the same tube face position, unlike noise.

b) Noise occurs at random time intervals while the cathode beam is being deflected across the tube face. This causes random bright ups which are at a lower average intensity than echo returns since they do not integrate to the same extent.

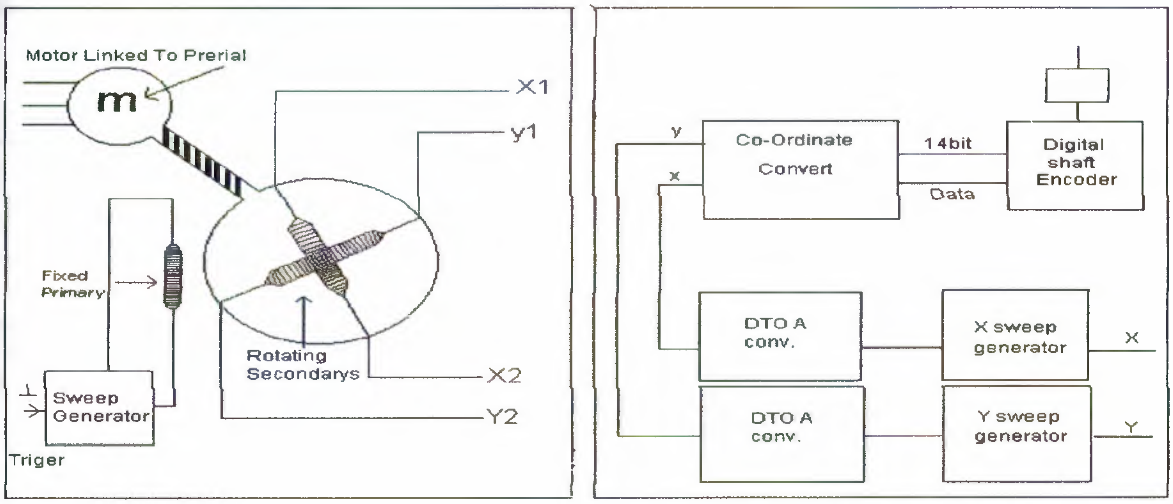
c) The time base rotates in synchronous with the aerial and ' plan ' position of all targets surrounding the radar is displayed. If the tube after glow or persistence is long enough then the bright up from a particular echo may last for up to 10 revolution of the antenna. If the target is moving then the bright

up will be formed into a ' track ' on the tube face indicating the previous heading of the target which is useful in a simple radar system, to overcome problem of ' missed ' paints , target moving in cluttered areas or in ' noisy ' environments.

Note that in a simple radar system clutter causes large areas of the P.P.I tube face to bright up and wanted target echoes which ' enter ' these areas cannot detected by the operator.

2.3 Resolver generated rotating time base :

the deflection coils are fixed; two sets of coils are used set at 90 degree to each other (X and Y coils) and sine and cosine waveforms fed to each. These are derived either from a rotating transformer and servo system or digitally from an encoder set on to the aerial using digital techniques to derive the waveforms.



Figure(2.4): Resolver Generated Rotating Time Base

2.4 early type of PPI :

The P.P.I display is only displaying the received echoes as they are received. Modern radar system need to provide the display operator controller with further information such as video maps showing air routes, prohibited areas, specially controlled air space etc. Video maps systems (early types)

A small CRT whose rotational deflection system was turned in synchronism with the aerial and trace intensity

Modulation is applied to the CRT. This rotating trace was then optically projected onto a slide. The slide was photographically prepared and contained the required maps etc. on it. Below the slide again on an optical system focused the slide onto a photo multiplier system. This changed the fluctuating light levels into electrical video signals. After suitable amplification this video was electronically mixed with the radar video and fed to the P.P.I., which would now display radar returns and maps etc. The problem with this that the video map system has to be very accurately set up and carefully maintained as circuit drift etc. could move the maps. The other disadvantage is that the maps cannot easily be changed thus for several different maps, each must have its own Projection system.

To make a change physically to a map means a new slide has to be prepared which could take days. The slides are also very prone to damage, being made from optical glass (a photographic plate similar to the type

Used in early cameras).

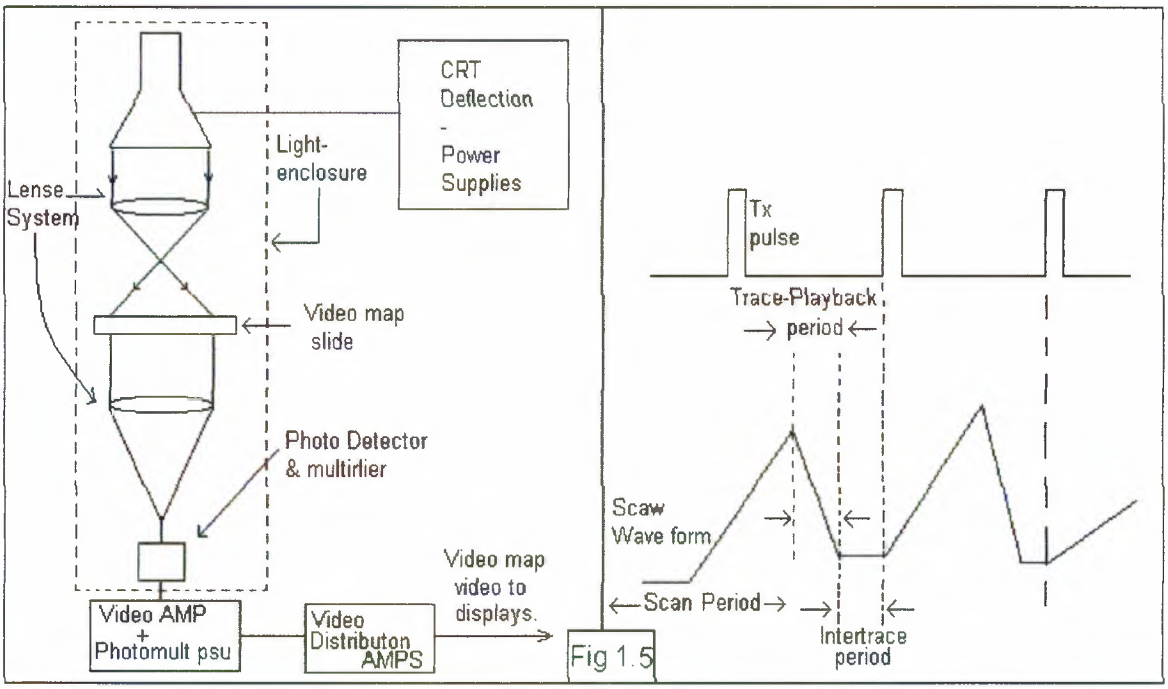


figure (2.5): Video Map Generation System

Today video maps are computer generated. The ma details are held in digital memory and loaded by means of flexible disc. The map can be changed readily by the operator using special software. The problem with this from of map generation is that the computer draws the map using vectors and bright-up signals; this does not readily lend itself to running with a standard PPI system but can be implemented in the intertrace period.

how Vector Drawn Video Map In Intertrace Period:

The electron beam can be moved around the face of the CRT very rapidly and high writing speeds can readily be achieved , Not all the interscan period can be used to write maps as a period has to be allowed every time the spot to move back to the centre of the CRT ready to start the next radar trace . The video bright up signal level has to be higher when using high writing speed to give the same level of brilliance on the screen. However with modern radar display system a large amount of extra data as well as maps is required to be displayed e.g. Primary plots secondary plots; trial plots aircraft idents, lights, emergency idents as well as system status messages. This cannot be accommodated in the limited intertrace period so some means of obtaining the extra display time needs to be found.

Since for a given target size, we expect a number of ' hits ' as the aerial beam scans through the target, so that on display is appears as fairly large ' blip ' of light, one or possibly two paints would not be missed . The time thus gained could be used to increase the amount of auxiliary data displayed on the screen.

In practice something like one scan in five ' stolen ' in this manner and ' scan stealing'

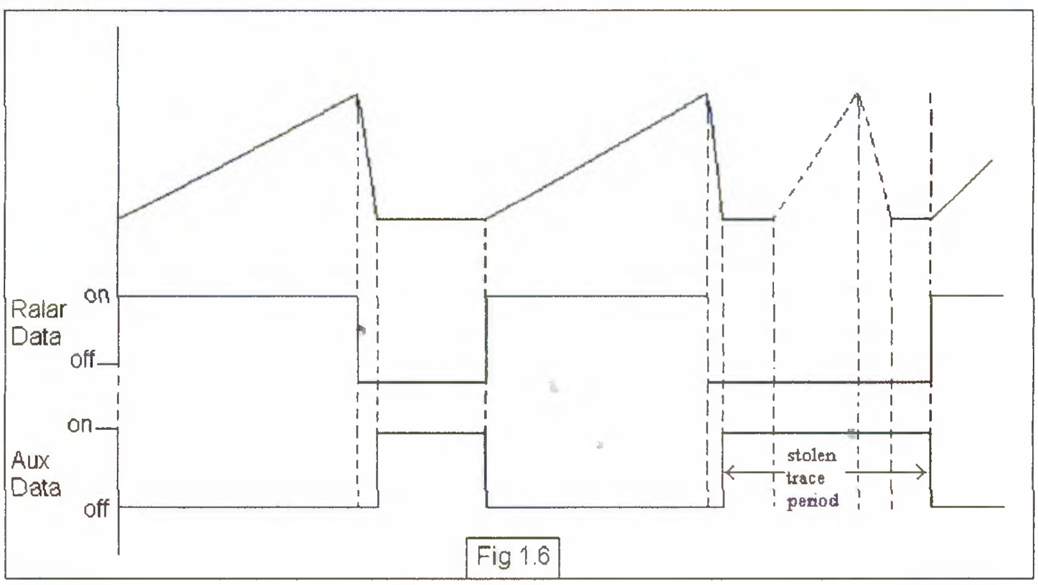


figure (2.6): Scan Stealing

The advent of high speed digital signal processing and the reduction of cost of high speed RAM has made digital storage of radar data a possibility. The radar data during the scan period is sampled a number of times and every time the radar returns are above a given limit, this fact is stored in a digital shift register. This data can be clocked out from the register at a faster clock rate during the next scan period. For this operate efficiently two shift registers are used, each on alternate scans, so that one is receiving radar data in whilst the other is clocking data out . At the end of that scan the registers change over and the data to the display in clocked out a much faster rate during the next period. This way of achieving a much increased time for auxiliary data displaying is known as " Retimed Video ". Usually the digital encoder information from the aerial is also Stored and used to generate the vector (direction) that the data is to be played out on the display.

From the above it can be seen that a large increase in time for aux data display has been gained and no radar data lost .

2.5 Computer Controlled Displays:

So far we have only considered a display covering the whole of the radar surveillance area. In practice this is seldom the case as when a number of displays and operator/controllers are used each is given a sector of total

Area to look after.

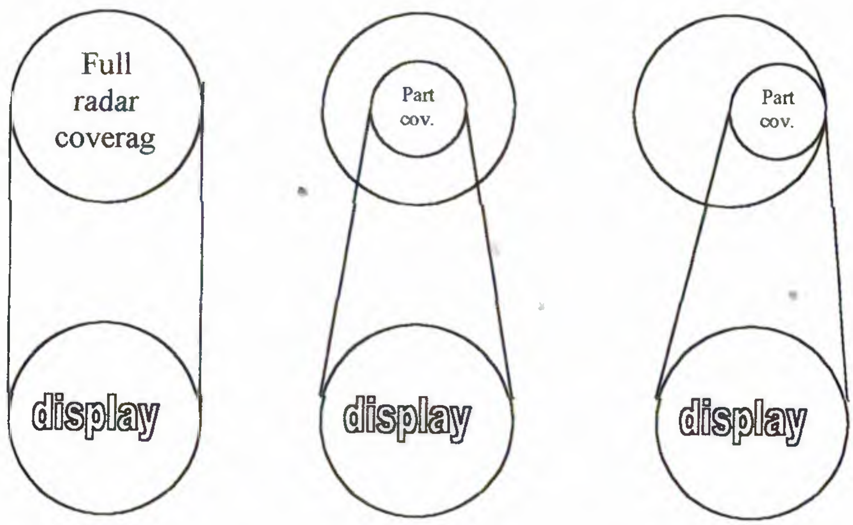


figure (2.7): Display Areas

In the case of an operator using his display data as (b) or (c) then he will experience eyestrain as the display

Data presentation is poor In the case of (b) where only a limited range is used to fill the display, all that happens electronically is that the gain of the deflection amplifiers is increased thus the spot takes less time to travel from centre to edge of display .

To the operator however the brilliance level will have dropped as writing speed has risen. So he will turn up signal gain to compensate, however any echo ' blips ' range rings, map lines will all be correspondingly wider.

With the trace rotating at the standard rate (the picture being nit too disimilar to normal) it is quite acceptable to the operator, If however the centre of the display is offset by means of the X and Y display shift controls and the

Range used reduced as in (c) then the operator has a problem, the screen is only updated once per aerial revolution and with the reduced range poorly defined data is displayed.

Using radar retiming techniques the sampling clock rate is increased and the playout time similarly reduced then the definition can be restored to short range displays (b) similarly if the start of the sampling clock is delayed then the definition of the offset display can be improved (c) .

* Start of Sample Period and Sample Rate Varied:

In the above examples the radar head and display are co-sited however it is more normal practice to have the radar heads remoted from the displays and even more than one Radar feeding into overall area surveillance System.

This generates a bigger problem, as to make this combination possible, the radar data has to be positionally corrected for the new center.

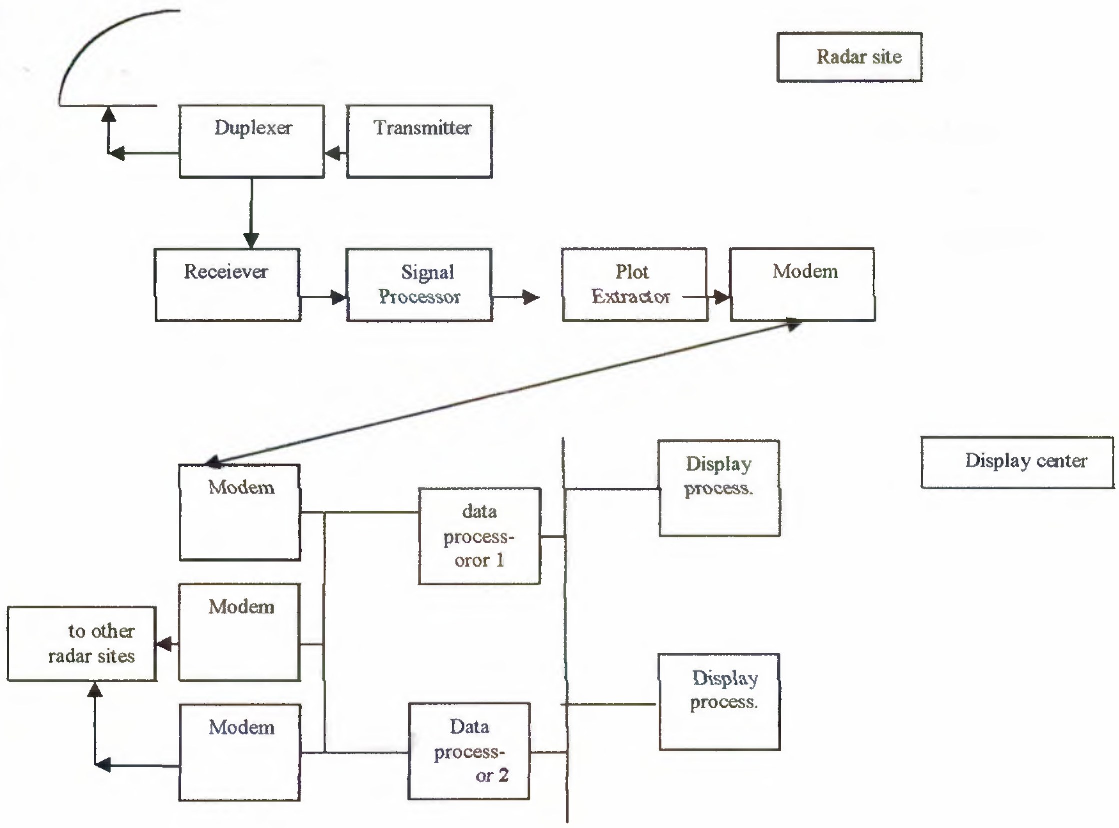
The radar data on the target is converted to polar co-ordinates X1 and Y1 these can then be sent to the display centre where the site offset can then be added so that the target can be displayed in respect of the Display Centre co-ordinates of range and bearing.

Data converted in this manner can be displayed from several radar at one display centre. To rapidly achieve this, co-ordinate conversion digital computer are used. The Radar data can be passed to the display centre and all the processing carried out there. Or part of the processing carried out at the radar, where the processor will send back just plot data on the echoes.

This is then sent to the Centre where the co-ordinate conversion takes place in the main Radar Display processor (RDP). The data on all targets within the system area is held and update with RDP.

This processor also generates target tracks and the auxiliary data for each plot, the data is then read out from the RDP by a display processor (as per actual Radar Display).

This processor interrogates the RDP and extracts all the data for the area the display is covering in digital from, and from that information generates the actual display picture.
The operator can instruct the processor to alter range scan size, or call for different map, or only show targets above given flight levels by means of a keyboard takes the form of a standard kerty keyboard plus a series of dedicated keys . The operator also has a rolling ball to move markers or the display.
The outputs forms the rolling ball, in the form of X and Y co-ordinate values, are read by the processor software, and move the selected character around the display area,
Often associated with the display processor and display is a secondary display. This takes the form of a TV Type display and is used to provide information messages, tote board of flights etc, etc .If that display is fitted with a touch-mask then this screen can be used to input data into the system to control it.
The commands appear as words on the screen and the operator touches the command required.
This will interrupt a series of X and Y Infra Red beams, this is decoded and sent to the processor as an instruction character. Another version of this display uses capacitive coupling between the operators fingers and etched areas of the screen, this is decoded and fed back to the processor in similar manner.
Thus a modern radar system will look like.



Figure(2.8): Display centre

The data from radar plot extractors (usually two) is fed modem units .These convert the digital data to Frequency shifted data suitable for transmitting over long distances either over puone lines or radio links.

At the display centre the modems decode the data back into digital form which is fed to the Display Processor, where the data is assembled into a radar picture for the area to be controlled.

These processors also check each plot coming in and assemble 'tracks' thus processors can ignore the odd noise plot that has come through the system, thus if a plot is missed due to whatever reason the processor will insert the plot in its new expected position . Indicate that this is a predicted track by changing the displayed character.

These processors will extract the secondary radar data and convert this to height information which can be displayed adjacent to the target and also the flight information.

The processor will compare thin data with the manually Flight delay input via the system Data, Terminal and where matches are found then the flight number will also be displayed alongside the target .All of this information is stored in the memory of the Processors. The display processors will interrogate the main processors and extract the data for the area they are interested in, put into their own memory. Then construct X, Y and modulation information from that digital data to drive the spot on the CRT screen to give the desired display.

3. RADAR ANTENNAS

3.1 INTRODUCTION:

The main purpose of the radar antenna is to act as a transducer between free space propagation and guided wave propagation. The function of the antenna during transmission is to concentrate the radiated energy into a shaped beam which points in the desired direction contained echo signal and delivers it to the receiver.

The large apertures required for long range detection result in narrow beam width one of the prime characteristics of radar. The advantages of microwave frequencies for radar application are that apertures of relatively small physical size but large interms of wave length can be obtained conventionally.

High gain antennas with narrow band width are quite practical at microwave propagation frequencies radar antenna must generate beams with shaped directive patterns which can be scanned at microwave frequencies.

The type of antenna normally used in radar applications differs in general from antenna used for communication. The parabolic reflector which is well known in optics is extensively employed, which is often used in radar and different types of antenna of which characteristics can be directly used.

3.2 ANTENNA PARAMETERS:

3.2.1 Directive Gain:

A measure of the ability of an antenna to concentrate energy in particular direction is called the gain. For an antenna gain is found as two types, one is the directive gain which is sometimes called the directive gain for transmitting antenna is defined as:

Gd = max. Radiation intensity / average radiation intensity

Where the radiation intensity is the power per unit solid angle radiated in direction of the power or power per unit area plotted as a function of angle is called a power pattern.

The radiation intensity pattern of rectangular apertures can often be written as the product of the radiation intensity pattern in the two coordinates for instance.

i.e. $P(\theta,\varphi) = P(\theta,\varphi).\ P(\theta,\varphi)$

Since the average radiation intensity over a solid angle or 4π radius is equal to the power radiated divided by 4π .

$G_d = 4\pi$ max . Radiation intensity per unit of solid angle / average radiation intensity from isotropic source with same input.

3.2.2 POWER GAIN:

The power gain is one of the antenna gains which are more appropriate for use in radar equation which is denoted in the above chapter. The power gain is obtained when we used total input power instead of radiated power which is given by:

Power gain = max .radiation intensity from subject antenna /
Radiation intensity from isotropic source with same input

i.e.

$$G_p = 4\pi I\ (\theta,\varphi)\ /\ \text{total input power}$$

3.2.3 EFFECTIVE APPARTURE:

It is defined as the projection of the antenna on the plane perpendicular to the direction of propagation and if we assume that:

G = the gain for antenna.

Ae = the effective area.

λ = the wave length.

ρ a = the aperture efficiency.

A= physical area of antenna.

3.2.4 POLARIZATION:

The direction of polarization of an antenna is defined as the direction of electric field vector.

Types of polarization:

i- Elliptical polarization

ii- Circular polarization

iii- Linear polarization.

Most radar antennas are linearly polarized (where the electric field is changed in amplitude with time but constant direction), that is the direction of electric field is either vertical or horizontal.

3.2.5 ANTENNA EFFECIENCY:

The aperture efficiency is a measure of the gain of the antenna relative to the gain of a similar antenna with a uniform aperture distribution.

3.2.6 EFFECTIVE LENGTH:

It is defined as the current I (0) at all points along its length and radius, the same field strength as the actual antenna in the direction perpendicular to its length.

i.e.

$$L_{(eft)} = 1/ I(0) \int I(z) \quad dz$$

$$L_{(eft)\,Trans} = L_{(eft)Rec}$$

3.2.7 BEAM SHAPE:

The most commonly used in radar are pencil beam and fan beam.

1. pencil beam: with using what is necessary to measure continuously the angle position of a single target of both a zmith and elevation as in the case of target tracking radar for control of the weapons of missile guidance.

2.Fan beam: are suitable for search radar because the large number of resolution cells it has been to scan. A fan beam is shape pattern is used with one broad dimension, while there is narrow of fan beam of 1° and 45 ° in elevation is required to scan 360° in azimuth.

3.2.8 SIDE LOBE:

Low side lobes are generally desired for radar applications. If the side lobe is large, there would be reduction in the main beam energy with a consequent lowering of maximum gain. If the side lobe is too high strong echo signals can enter the receiver and appear as false targets. This is the effect for side lobe on the directive gain for the antenna.

3.3 TYPES OF TRADITIONAL ANTENNA:

There are different types of antenna that is used for micro wave frequency range such as:

3.3.1 PARABOLIC REFELCTION:

For radar system technique, parabolic antenna is the most wildly used because having dimension are many times those of the operating wave's length. It has narrow beam pattern and so very high directive properties. The design of the principle reflector is illustrated as shown in figure 1.

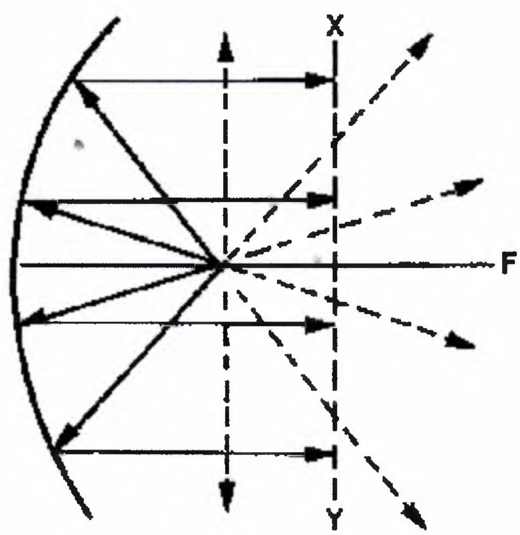


figure (3.1) : parabolic reflector.

3.3.1.1 Truncated Parabolic :

View B of figure 3-19 shows a horizontally truncated parabolic. Since the reflector is parabolic in the horizontal plane, the energy is focused into a narrow horizontal beam. With the reflector truncated, or cut, so that it is shortened vertically, the beam spreads out vertically instead of being focused. Since the beam is wide vertically, it will detect aircraft at different altitudes without changing the tilt of the antenna. It also works well for surface search radars to overcome the pitch and roll of the ship.

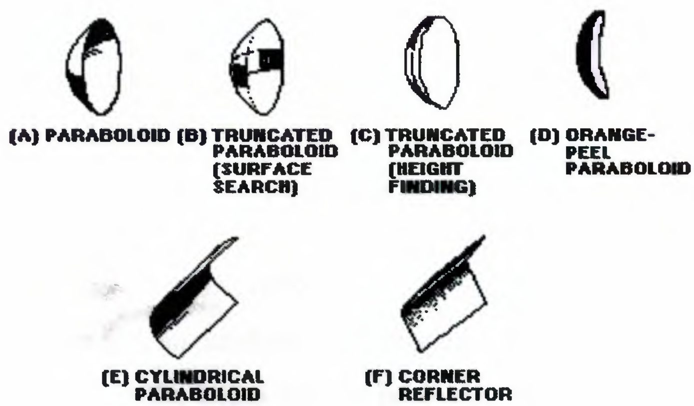


Figure 3.2 : Reflector shapes

The truncated parabolic reflector may be used in height-finding systems if the reflector is rotated 90 degrees, as shown in view C. Because the reflector is now parabolic in the vertical plane, the energy is focused into a narrow beam vertically. With the reflector truncated, or cut, so that it is shortened horizontally, the beam spreads out horizontally instead of being focused. Such a fan-shaped beam is used to determine elevation very accurately.

3.3.1.2 Orange-Peel Parabolic :

A section of a complete circular paraboloid, often called an ORANGE-PEEL REFLECTOR because of its shape, is shown in view D of figure 3-19. Since the reflector is narrow in the horizontal plane and wide in the vertical, it produces a beam that is wide in the horizontal plane and narrow in the vertical. In shape, the beam resembles a huge beaver tail. This type of antenna system is generally used in height-finding equipment.

3.3.1.3 Cylindrical Paraboloid :

When a beam of radiated energy noticeably wider in one cross-sectional dimension than in the other is desired, a cylindrical paraboloidal section approximating a rectangle can be used. View E of figure 3-19 illustrates this antenna. A parabolic cross section is in one dimension only; therefore, the reflector is directive in one plane only. The cylindrical paraboloid reflector is either fed by a linear array of dipoles, a slit in the side of a waveguide, or by a thin waveguide radiator. Rather than a single focal point, this type of reflector has a series of focal points forming a straight line. Placing the radiator, or radiators, along this focal line produces a directed beam of energy. As the width of the parabolic section is changed, different beam shapes are obtained. This type of antenna system is used in search and in ground control approach (GCA) systems

3.3.2 SCANNING FEED REFLECTOR:

The beam reduced by a simple parabolic reflector can be scanned over limited angle by posting the feed. However the beam cannot be scanned too far without en countering serious deterioration of the antenna radiation pattern because of increasing coma and astigmatism. The antenna impedance changes with changes at feed position. Hence scanning a simple parabolic antenna by scanning the feed is possible, but is generally limited in angle because of the deterioration in the antenna pattern after scanning but a few beam widths off axis.

3.3.3 CASSEGRAIN ANTENNA:

The cassegrain principle is widely used in telescope design to obtain high magnification and allow a convenient rear location for the observer. Its application to microwave reflector antennas permits a reduction in the axial dimensions of the antenna, just as in optics. It also permits greater flexibility in the design of the feed system and eliminates the need for long transmission lines.

Figure(3.3) : cassegrin antenna.

A better radiation pattern with lower side lobes can be obtained by using the CASs grain antenna, the feed is located at the vertex of the parabolic reflector and sub reflector is located in front of the parabola between the vertex and the focus. Parallel rays coming from a target, are reflected by the parabola as a convergent beam on re – reflected by the hyperbolic sub reflector, converging at the position of the feed.

If a dipole is used as the source of radiation, there will be radiation from the antenna into space (dotted lines in figure 3-17) as well as toward the reflector. Energy that is not directed toward the paraboloid has a wide-beam characteristic that would destroy the narrow pattern from the parabolic reflector. This occurrence is prevented by the use of a hemispherical shield (not shown) that directs most radiation toward the parabolic surface. By this means, direct radiation is eliminated, the beam is made sharper, and power is concentrated in the beam. Without the shield, some of the radiated field would leave the radiator directly. Since it would not be reflected, it would not become a part of the main beam and thus could serve no useful purpose. The same end can be accomplished through the use of a PARASITIC array, which directs the radiated field back to the reflector, or through the use of a feed horn pointed at the paraboloid.

The radiation pattern of a parabola contains a major lobe, which is directed along the axis of revolution, and several minor lobes, as shown in figure 3-18. Very narrow beams are possible with this type of reflector. View A of figure 3.3 illustrates the parabolic reflector.

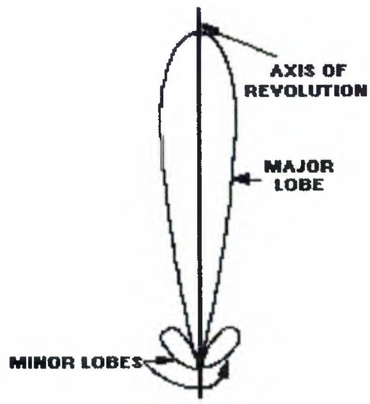


Figure 3.4 :- Parabolic radiation pattern.

3.3.4 Yagi-Uda antennas:

Physical description :

A Yagi-Uda antenna is familiar as the commonest kind of terrestrial TV antenna to be found on the rooftops of houses. It is usually used at frequencies between about 30MHz and 3GHz, or a wavelength range of 10 metres to 10 cm. (There are some obsessional amateur radio enthusiasts who construct Yagi-Uda antennas for the 80 metre wavelength band. This is rather impractical as spacing them from the ground by more than half a wavelength is difficult.) The rod lengths in a Yagi-Uda are about a half wavelength each, and the spacings of the elements are about 1/3 of a wavelength. This puts the overall sizes of Yagi-Udas in the ranges

freq	transverse dimension (lambda/2)	length 3 elements	length 5 elements	length 15 elements
30MHz	5 metres	6 metres	13 metres	47 metres

100MHz	1.5 metres	1.8 metres	3.9 metres	14 metres
300MHz	50 cm	60 cm	1.3 metres	4.7 metres
1GHz	15 cm	18 cm	39 cm	1.4 metres
3GHz	5 cm	6 cm	13 cm	47 cm

From this table one can get a very good idea of the approximate frequency of the link by looking at the antenna from afar.

A diagram of a 7 element Yagi-Uda layout is given here:-

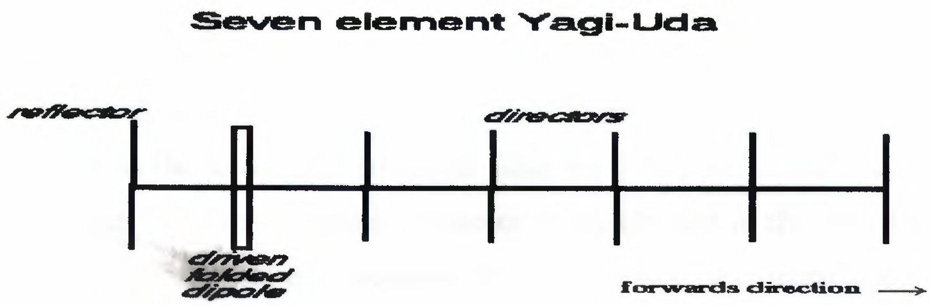


figure (3.5): seven segment yagi

There are three kinds of elements (or rods) mounted on a longitudinal connecting bar or rod. It doesn't matter if this connecting rod conducts, as it is orientated at right angles to the currents in the elements, and to the radiating electric fields; it supports little or no current, and does not contribute to the radiation. It does not matter what it is made of other than that it should have good structural properties. If it is made of conducting metal as are the elements, it can be connected electrically to the directors and to the reflector (but not to the driven element) without disturbing any of the properties of the antenna.

The three types of element are termed the *driving element*, the *reflector(s)* and the *director(s)*. Only the driving element is connected directly to the feeder; the other elements couple to the transmitter power through the local electromagnetic fields which induce currents in them. The driving element is often a folded dipole, which by itself would have a driving point impedance of about 300 ohms to the feeder; but this is reduced by the shunting effect of the other elements, so a typical Yagi-Uda has driving point impedance in the range 20-90 ohms.

The maximum gain of a Yagi-Uda is limited to an amount given approximately by the gain of a dipole (1.66 numerical) times the total number of elements. Why is the power gain proportional to the total number of elements? Well, in an end-fire array of N elements the gain is proportional to N. Consider N isotropic sources, all phased such that the field contributions in the end-fire direction from each element all add up in phase in the far field. The field strength (E-field or H-field) of the sum of the phasors will be N times the field from a single element, so the radiated power density, which is proportional to the square of the fields, will be N^2 times larger. However, the total POWER delivered to the N elements will be N times larger than that delivered to a single element, so the power gain in the far field is (N^2)/N = N . Now this argument becomes suspect when the radiation resistance of an element in the array is different from the radiation resistance of an isolated element, for it is the currents in the elements which contribute to the far field strengths. In a longish Yagi-Uda, however, the end elements will not see a very different environment for the addition of an element in the middle of the directors, and the elements in the middle of the directors are not much affected by how long the array may be. Thus, as a rough "rule of thumb", the factor N (which is empirically about right) may be justified theoretically.

Thus, a single element has maximum gain 1.66 = 2.2dBi, a driving element with a single reflector has maximum gain 3.3 (numerical) or 5.2dBi, a three element antenna consisting of a single director, driving element, and reflector has maximum gain about 5 (numerical) or 7dBi and a 15 element Yagi-Uda with 13 directors has maximum gain about 25 (numerical) or 14dBi. There may be compromises in the design to achieve the required front/back ratio, driving point impedance, and bandwidth, so the gains may be somewhat less than these numbers in a practical antenna.

At a meeting of the RSGB at Sandown Park Racecourse on 21 Feb 1999 I looked at a stand advertising a 9 element Yagi-Uda antenna with a stated gain of "11.4 dBd" or 11.4dB over the gain of a single dipole. We note that the array factor for this antenna is limited to the number of elements, in this case 9, and so we would expect the maximum gain to be 10log[10]9 or 9.54 dBd. If we add the gain of the dipole elements over isotropic as about 2.2dBi we are limited in gain to at most 11.8 dBi. So we deduce that the people advertising this antenna were either misinformed, or they didn't appreciate the difference between dBd and dBi.

Of course, a naive comparison between a simple dipole antenna and a Yagi-Uda just substitutes one for the other, and then the "gain" may be measured from some field strength measurements on boresight. However, since the radiation resistances will be different, and recalling that the definition of relative gain is the ratio of radiated power levels in a certain direction produced by two antennas having the same TOTAL ACCEPTED INPUT POWER, there is a potent source of confusion here. This is because the antenna is connected via a feeder to a transmitter whose output level may be determined in terms of the voltage at its terminals. Thus for the same transmitter and feeder, the accepted powers for the two antennas may be quite different. If one assumes they are the same, one makes an error in deducing the gain figure from the field strength measurements.

To broadband a Yagi-Uda, sometimes the individual elements are split into two in an approximation to a primitive "biconical antenna". An example is shown here; this shows part of a UHF television receive Yagi-Uda to cover a fractional bandwidth of around 30 percent. It is horizontally polarised.

3.4 TYPES OF FEEDERS:

3.4.1 HALF WAVE DIPOLE:

These types suffer from two major limitations that are given as the following:

1. The dipoles radiates uniformly in a plane normal to its length and radiate no energy in the direction of its length.
2. The efficiency of the simple dipole feed can be increased by making the energy radiated in the direction of the reflector element placed behind the excited reflector element placed behind the dipole to reflect the energy towards the parabolic.

3.4.2 THE OPEN ENDED WAVE GUIDE:

Most of the energy directed in the forward direction and the phase characteristics is usually good if radiating in the proper made. A circular parabolic might be fed by a circular open-ended wave guide operating in the TE11 made and thus for rectangular.

3.4.2 WAVE GUIDE HORN :

:This is used when more directivity is required than can be obtained with a simple open-ended wave guide. Some forms of wave guide horn may be used. The wave guide horn is probably the most popular methods of feeding a parabolic for radar applications. The resonant half wave dipole and wave guide horn can be arranged to feed the parabolic as shown in figure.

This series of high power waveguide horns are capable of withstanding 500 Watts CW. They utilize a cast and dip brazed polarizer section coupled to a cast, flared, circular horn, to achieve a constant 3 db beamwidth and minimum gain of 17.0 dbic with a low axial ratio of 2.0 db maximum at boresight. Available as right-hand or left-hand circular polarized.

FIGURE(3.6) : horn feeder

3.5 Radar Technology Antennas :

Antennas are devices which determine the shape of a radar's beam. Upon transmission, they direct the transmitter's energy into a selected area of the surrounding space. Upon reception they collect the signals from out of the air .

Note: There is concern that this entry might lose some readers somewhere in all its 'technese' language. If so, then please, at least take a look at the very last chapter !

3..5.1 The Basic Principle:

In general, a single radiation source distributes power equally and provides an omnidirectional pattern (comparable with throwing a stone into a silent pond, which yields waves which propagate evenly into all directions). If a second radiation source is added then the waves emanating from them will produce an interference pattern. There are directions where the waves add to each other, and others where they cancel each other out (comparable with throwing two stones simultaneously). In other words, the contributions will combine such that there's a single direction where they all add constructively (this is the 'maximum', or 'main lobe'), there are directions where there are just as many positive contributions as there are negative ones (these areas are known as 'nulls' in the pattern) and there are areas where the intensity of the resultant wave takes on some intermediate value (these areas are called 'sidelobes'). If you are familiar with the Huygens principle of superposing waves then this effect shouldn't be anything new .

The precise shape of such an interference pattern depends on the amount of radiation sources and the spacing between them, and can be calculated using some rather complicated mathematical concepts. But the basic principle is this: the more radiation sources are added and combined into a linear arrangement, the narrower and stronger the main lobe will get. The sidelobes will not vanish nor become weaker in relation to the main lobe, but there will be more of them and they are closer to each other. Every lobe is separated from its neighbour by a null. A polar diagram (that is, an antenna pattern viewed from somewhere above) of a typical antenna pattern looks quite like a bundle of baseball clubs of different sizes :

x main lobe

xxxxx

xxxxxxx

xxxxxxx null

xxxxxxx

xxxxx

xxxxx

xxxxx sidelobe

xx xxxxx xx

xxxx xxx xxxx

xxxx xxx xxxx

xxx xxx xxx null

xx xxx xx

xx x xx

xx x x x xx

xxxxxxxx-O-xxxxxxxx sidelobe

xx x xx

x

xxx null

x xxx

rear lobe

Figure(3.7) radiation pattern

If a narrow beam is desired then more radiation sources are called for. A higher amount of sources directly translates into a bigger antenna. Big antennas have their disadvantages as they are bulky and heavy, they may not fit into a small platform like an aircraft or a satellite, and wind forces can pose a severe problem if they are mounted on ground installations .

Any metallic object and every square centimetre of a metallic structure can act as a source, once it is illuminated with an electromagnetic wave of proper wavelength. Therefore, a dish antenna can be treated like an arrangement of a vast amount of radiating sources which are fed not from a wire but from the primary illuminating element. In consequence, it is the active area or aperture which determines antenna beamwidth .

3..5.2 Construction:

Elements of radar antennas exhibit a huge variety of shapes, for example :

- monopole and dipole rods (the 'big brothers' of a walkie-talkie's telescopic antenna).
- Yagi elements (like they are used for terrestrial TV reception).
- horns and dishes of all imaginable sizes ,
- bars like those to be seen on your sea-going 18m-yacht ,
- spirals which could as well have been taken out of an old sofa,

and a multitude of other shapes. In fact, almost any structure made from metal can be turned into an antenna. The only precondition is that some feature of it bears dimensions which are equal to a quarter of the wavelength (or an integer multiple thereof) which is used. However, it takes some rather complicated equations to make a good antenna element. Apart from metal structures, lenses and mirrors can be used like they are used for shaping beams in the optical part of the electromagnetic spectrum .

3.5.3 Antenna technology Types :

An important distinction must be made between antennas with a single source of illumination, and arrays. The former consist of the illuminating element and a reflector which is shaped such that the radar beam gets its desired form .

3.5.3.1 Array Antennas:

Arrays consist of a multitude of identical radiating elements which are fed from a single transmitter through a network of radio frequency lines or waveguides1. In order to understand how an array antenna works, the basic wave superposition principle which was outlined above must be applied twice: the radiating elements can be thought of as consisting of radiation sources whose contributions are added in order to yield the directional pattern of the device. An array is a group of such elements, and its directional pattern is determined by, err..., superposing the superposition results once again. Hence, the shape of the beam is determined by the properties of the individual elements, plus the power distribution among the elements and the geometric details of their arrangement .

Arrays and single feed antennas produce a beam which can only be moved in space by either moving the reflector, the feeder or the whole construction .

3.5.3.2 Phased Arrays:

Phased Arrays additionally contain delay elements in the feeding structure. By controlling these delay elements, phased array antennas are capable of moving the beam position in space without moving any mechanical part. The term 'phased array' originates from the fact that, when considering sinusoidal signals such as electromagnetic waves, a time delay can be translated as a shift of the phase of the signal. Actually, many phased arrays are using phase shifting devices rather than delay lines .

<table>
<tr><th colspan="2">How a phased array antenna works</th></tr>
<tr><td>Case 1: no time delay:

El1 <)) |
El2 <)) |
El3 <)) | ---------->
El4 <)) | beam direction
El5 <)) |
The wave front is in parallel to the array face.</td><td>Case 2: with time delay (Element 5 transmits first):

El5 <))
El4 <)))
El3 <))) /
El2 <)) /
El1 <)) /
.) /
The wave front is at an angle to the array face.</td></tr>
</table>

Even more sophisticated, complicated and expensive are Active Phased Arrays which feature as many transmitters as they have radiating elements. Their main advantage over (ordinary) phased arrays is an economical one: transporting electromagnetic waves through cables or waveguides is subject to severe attenuation losses. If each antenna element has its own transmitter attached to it then the radio frequency (RF) energy is being created in place and the heavy RF plumbing can be omitted .

3.5.4 Figures of Merit :

Antennas are characterised by their beamwidth, sidelobe level, gain and the beam shape. These parameters are explained below .

3.5.4.1 Beamwidth:

The most prominent property of an antenna is its beamwidth. A narrow beam is desirable in most cases because:

- transmitting through a wide beam distributes the energy over too big an area.
- receiving through a wide beam collects more noise which later on competes with target returns .

But narrow antenna beams come at a price because beamwidth is related to antenna size as explained above. As a rule of thumb, the beamwidth can be calculated as

$$\text{beamwidth (degrees)} = \frac{51 * \text{wavelength (metres)}}{\text{length of structure (metres)}}$$

Hence, in order to achieve a beamwidth of 2°, the required length of the antenna structure in the corresponding dimension is somewhere around

- 0.099metres (9.9 centimetres) for an Automotive Radar (77GHz)
- 0.765 metres for a tracking radar (10GHz)
- 7.65 metres for an air traffic control (ATC) radar (1GHz)
- 51metres for an air surveillance radar (150MHz)
- 1.53 kilometres for an Over The Horizon radar (5MHz)

If the requirement calls for a pencil beam then the formula above must be applied separately to the horizontal and vertical antenna dimensions .

3.5.4.2 Sidelobe Level :

The sidelobe level --sometimes called 'peak sidelobe level'-- is the difference2 between the power measured in the main lobe and the power measured in the strongest sidelobe of the antenna pattern. An average sidelobe level is sometimes calculated but really isn't an important number. The design goal is to have low sidelobe levels, and a good antenna features some -40dB3 which equates to a factor of 10,000 between the power in the main lobe and the strongest sidelobe .

Low sidelobes are important for two reasons :

- The Signal Processing will simply assume that any return was obtained through the main lobe. If the antenna receives some strong echo through a sidelobe then this echo will be displayed with the correct range value, but at an azimuth which corresponds to the current main lobe direction. This type of misreading can severely impede air traffic safety, even if measures like Side Lobe Suppression are taken .
- 'Injecting' false targets through a radar antenna's sidelobes is one of the various methods of Electronic Combat. Presented with a wealth of 'ghost' targets, an anti-aircraft system would have a hard job sorting the true ones out .

If the radiating elements of an antenna are all transmitting the same power then some mathematical analysis shows that there is only one fixed relation, with no way to improve sidelobe levels. This relation says that the strongest sidelobe is 13.1dB below the mainlobe (ie, the signal power in the sidelobe is roughly 1/20 of that in the mainlobe) and that is it. 13.1dB is nothing that a radar operator would accept .

The work-around is to play with the power distribution along the antenna aperture (ie, have the elements radiate at different power levels, with the most powerful elements located towards the centre of the aperture). Doing this in a systematic approach involves some examination of higher order polynomials, the Fourier transform and other areas of advanced mathematics (which won't be done here). The outcome is that the sidelobe level can be improved by applying an aperture tapering function, of which several are available. They all have one thing in common: the sidelobes can be reduced by several orders of magnitude, but at the price of a wider main beam. In consequence, the aperture area needs to be further increased in order to compensate for this .

3.5.4.3 Antenna Gain :

This number is best defined as the answer to a certain question4: How many times more power would be needed in order to achieve a given amount of power in the main beam direction if a truly omnidirectional antenna was used rather than the antenna in question? If the answer was '42 times more' then the antenna is said to have a gain of 42. Antenna gains on the order of 10,000 are quite common, but low frequency radars may have to cope with 20 or even less .

3.5.5 Beam Shapes :

The most common beam shapes found in radars are fan beam and pencil beam. Radar warning receivers and intercept equipment used in Electronic combat are using sector beams (which essentially are fan beams which have been extended to cover some dozen degrees of azimuth and elevation simultaneously). There is no such thing as the 'ideal' beam shape, as this is depending on the application in question .

Selecting a Beam Shape - An Example

It has been pointed out that there is a fixed relation between an antenna's aperture and the width of the beam. Air surveillance radars are usually built with beamwidths of around 1°, and less beamwidth isn't desirable because scanning a given area requires much more time when a narrow beam is used. This is easy to explain with a (somewhat constructed) example :

Assume an Air Traffic Control (ATC) radar with a phased array antenna and a 1°x1° pencil beam. It takes 360 horizontal beam positions to scan a full circle at a certain elevation angle, and there are, say, 45° of elevation to be examined5. This yields 360 x 45 = 16200 positions for hemispherical coverage. With a design range of 150km, the pulse repetition times becomes 1ms. Let's assume that a single pulse does the job of finding all the targets in a given direction, hence the time for a full scan is 16200 x 1ms = 16.2 seconds. That is, a space position will be re-visited roughly four times a minute. If the beamwidth were only 0.5°x0.5° then there were twice as many azimuth and elevation positions, and the time for one scan would be more than one minute. One minute is a long time, and no air traffic controller can live with an air picture that is that old .

Now, assume a conventional reflector antenna with a fan beam of 1° azimuth x 45° elevation: its peculiarity is that it covers all elevations of interest at the same time. Still assuming that a single pulse per beam position is sufficient, this radar has performed a full scan after visiting 360 x 1 (azimuth x elevation) positions, which amounts to 360 x 1ms = 0.36 seconds. Thus, this radar is able to update the whole operator's screen three times a second. Of course, owing to the fan shaped beam this radar cannot distinguish between low-flying and high-flying objects. But, as an ATC radar is considered here, flight level information can be obtained from an aircraft's ATC transponder (see Primary and Secondary Radar) .

3.5.5.1 Beam Shape Agility:

In general, an antenna's beam shape is determined during the development phase and remains fixed. But sophisticated phased arrays are capable of switching beam shapes during operation. The easiest way of doing this is to simply switch off a part of the elements and to redirect transmitter power into the rest. As an example, assume an array of 100x100 elements which have a beamwidth of (10° azimuth) x (30° elevation) if taken as individuals .

- In full operation, the beam is a pencil beam of, say, 2°x2° which was achieved by combining those 100x100 elements into an array and using a proper amplitude taper. 2°x2° is a pencil beam which is quite suitable for tracking a target whose position is known from some previous examinations .

- Now switch off half of the elements along the horizontal and vertical axis. This decreases the active antenna length and width and the beam widens up to become 4°x4°. This wider pencil beam is useful for searching a target which went missing in a previous tracking phase, or if its coordinates were handed over from a less accurate surveillance radar .

- Now switch off all the rows apart from one. The horizontal dimension of the aperture remains the same, hence the azimuth beam width remains at 2°. The beamwidth in elevation is determined only by the properties of the radiating elements and was assumed to be 30°. This 2°x30° fan beam is advantageous for target search in a stand-alone application .

- Finally, switch off all the columns apart from one. The result is a tilted fan beam of 10°x2°. This beam shape could be used for guarding against low flying aircraft which appear closely above the horizon .

Last but not least, a modern phased array antenna has a feature called 'Null Steering' in its inventory. Somewhere in those complicated polynomial equations there are parameters which allow the position of an antenna diagram's nulls to be varied, with only minor impact on the position of the main lobe. By playing around with these parameters, a radar can simply make itself 'blind' in directions where hostile jammers are located. After having sent a message to a long range missile system, that is .

3.5.6 Miscellaneous :

A common misconception is to believe there was a relation between antenna size and transmitter power. Apart from some minimum required size to prevent sparking, there isn't any. If you see a 'big' antenna then the only conclusions possible are that it either

- operates on a low frequency,
- features a very narrow beam,
- or both.

Just to repeat the point: there are two factors which lead to huge antennas: frequency and beamwidth. First, if you're using some low transmitter frequency (ie, large wavelength) then a quarter of the wavelength may still amount to some 10m as the size of a single antenna element. Second, if a narrow beam is required then it takes either a 'king size' dish or hundreds and thousands of array elements to achieve the goal .

1. Waveguides are hollow metal tubes which basically work like the optical fibers used in today's telecommunication networks.

2. on a logarithmic scale
3. wot, no 'Decibel' entry.
4. Noooh, not what you might be thinking now!
5. Usually, around 30° elevation coverage is asked for, but applications like anti ballistic missile defence are going for full elevation coverage.

CONCLUSION

Our objective to study radar and know its performance and its ability detection of targets, because radar receiver is very sensitive can detect small echo from the targets and determine its locations and the accurate angle from radar center.

Radar systems are also classified by function. SEARCH RADAR continuously scans a volume of space and provides initial detection of all targets. TRACK RADAR provides continuous range, bearing, and elevation data on one or more specific targets. Most radar systems are variations of these two types .

Also we study the different types of radar which has different specifications; also radar as we have seen can be used as air traffic control radar and weather radar and so many applications in our life.

Also we find the main part in transmitter radar which is magnetron and how it works to transfer to antenna high power with high frequency output, and see the modes of its operation.

We have seen the types of displays and how it's developed from the past and how we can get synchronization between the rotating antenna and scanning beam on screen.

Finally see the types of antenna which give the high directivity of radiation pattern to give radar system very high resolution between the targets.

So radar system can be used in many application with high performance and this can be achieved by the hole system parts stability.

ATMOSPHERIC CONDITIONS affect the speed and direction of travel of electromagnetic wavefronts traveling through the air. Under normal conditions, the wavefronts increase uniformly in speed as altitude increases which causes the travel path to curve downward. The downward curve extends the radar horizon as shown in the illustration. The density of the atmosphere, the presence of water vapor, and temperature changes also directly affect the travel of electromagnetic wavefronts

Radar systems that detect only range and bearing are called TWO-DIMENSIONAL (2D) radars. Radars that detect height as well as range and bearing are called THREE-DIMENSIONAL (3D) RADARS .

The target RESOLUTION of a radar system is its ability to distinguish between targets that are very close together .

The major components in a typical PULSE RADAR SYSTEM are shown in the illustration. The SYNCHRONIZER supplies the timing signals to coordinate the operation of the entire system. The TRANSMITTER generates electromagnetic energy in short, powerful pulses. The DUPLEXER allows the same antenna to be used to both transmit and receive. The RECEIVER detects and amplifies the return signals. The INDICATOR produces a visual indication of the range and bearing of the echo .

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