NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

General Radar

Graduation Project
EE- 400

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ABDELKAREEM AL-SAKARNEH

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CHAPTER ONE

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 .

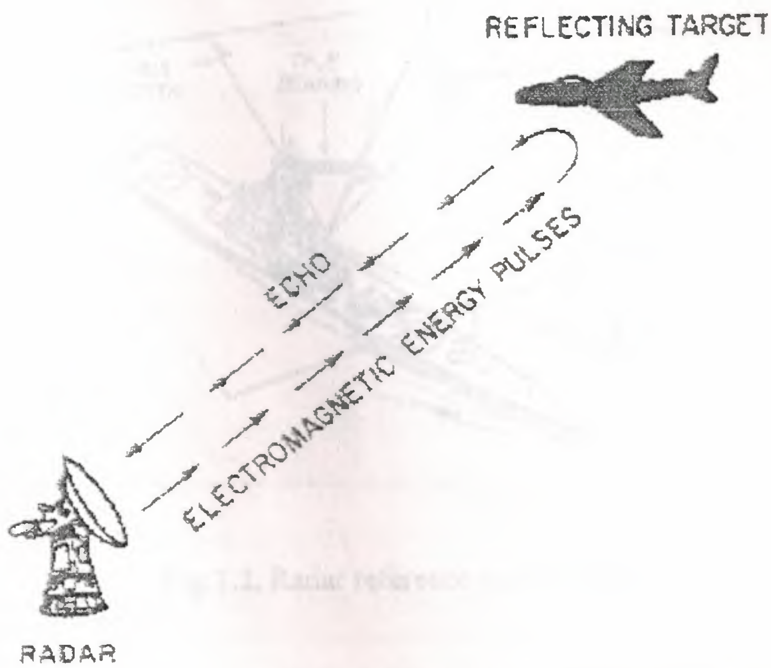


Fig.1.1. Radar echo.

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 .

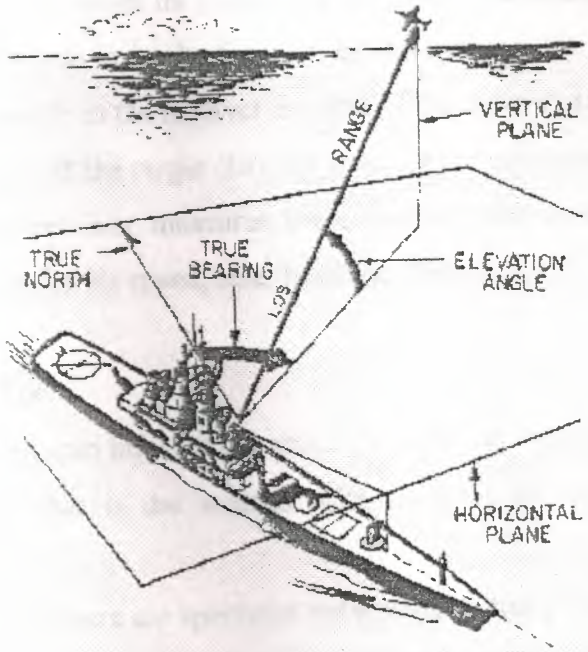


Fig.1.2. Radar reference coordinates.

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 mono-static radar system. Mono-static 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 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 examples of an airborne supervisory role of radar. There is many other application of radar system.

1.4.2 The parts of a Radar System

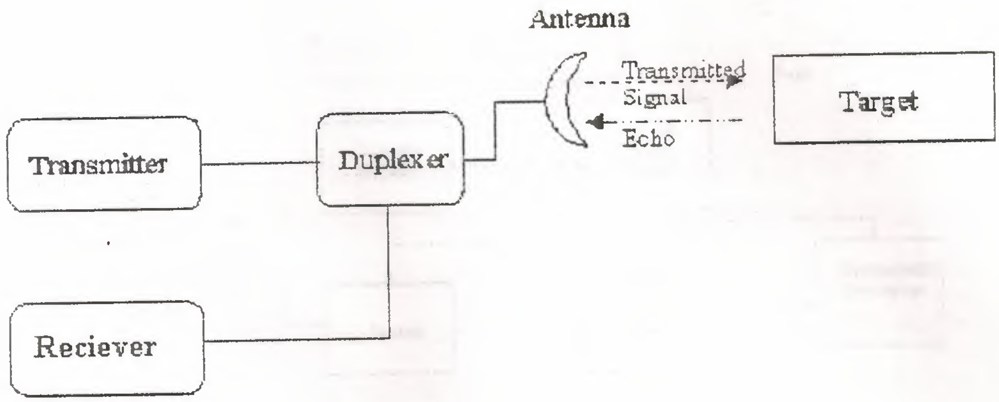


Fig.1.3. Radar Block Diagram

- 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,

1.5 Components of a Radar System

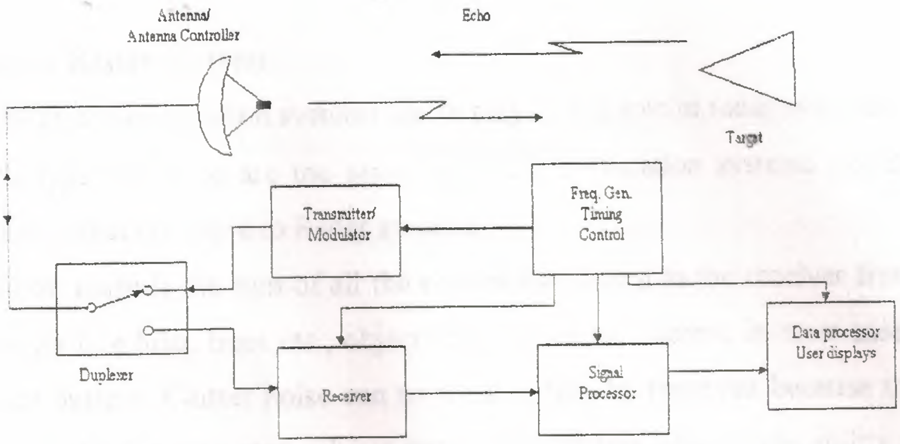


Fig .1.5. Block diagram of a Mono-static Single Antenna Radar System

- 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

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 Setups

Most radar systems have the transmitter and receiver in the same location, monotonic 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, this 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.

1.5.2 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 mono-static 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 many 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:

$$\frac{\sigma G P_t}{4\pi r^2} \tag{1.1}$$

where

□ is the back scattering cross section of the target.

NOTE: □ is not necessarily equal to the geometrical cross section.

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

$$\frac{\sigma G P_t}{\left(4\pi r^2\right)^2} \tag{1.2}$$

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

$$P_r = \frac{A_e \sigma G P_t}{\left(4\pi r^2\right)^2} \tag{1.3}$$

where: $[P_r]$ in watts

A_e = effective area of the antenna

What are typical values of these quantities?

$P_t \sim 10^5$ W

r ~ 100 km

G ~ 40 dB

□ ~ 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:

$$G = \frac{4\pi A_e}{\lambda^2} \quad \text{or} \quad A_e = \frac{G\lambda^2}{4\pi} \tag{1.4}$$

so substituting (1.4) into (1.3) 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.

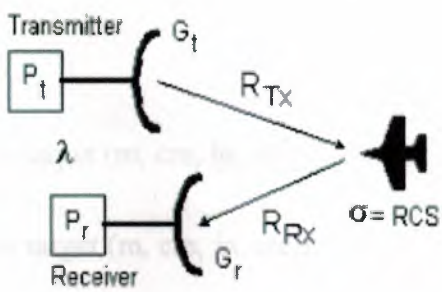


Fig. 1.5. Bi-static (Tx and Rx in different locations)

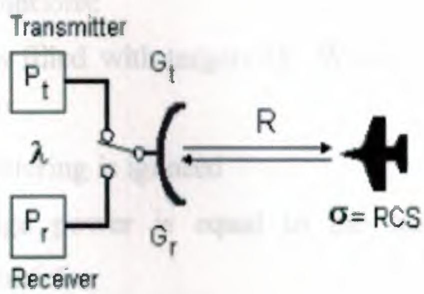


Fig.1.6. Mono-static (Tx and Rx in same location)

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:

$$\overline{P}_r = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 R^4} \tag{1.5}$$

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

For multiple targets, (1.5) can write as:

$$\overline{P}_r = \frac{P_t G^2 \lambda^2}{(4\pi)^3} \sum_i \frac{\sigma_i}{R_i^4} \tag{1.6}$$

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

Fig.1.7. Reflection from Target

then (1.6) can be written as:

$$\overline{P}_r = \frac{P_t G^2 \lambda^2}{(4\pi)^3} \sum_i \sigma_i \tag{1.7}$$

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

Hence the sum in (1.7) can be written as:

$$\sum_i \sigma_i = \left(\sum_i \frac{\sigma_i}{unitvolume} \right) totalvolume \tag{1.8}$$

where the total volume is the volume of the pulse.

Thus, (1.8) can be written as:

$$\sum_i \sigma_i = \left(\sum_i \frac{\sigma_i}{unitvolume} \right) \pi \frac{R^2\theta^2 h}{8} \tag{1.9}$$

Substituting (1.9) into (1.7) gives:

$$\overline{P}_r = \left(\frac{P_t G^2 \lambda^2 \theta^2 h}{512\pi^2 R^2} \right) \sum_i \sigma_i \tag{1.10}$$

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

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.

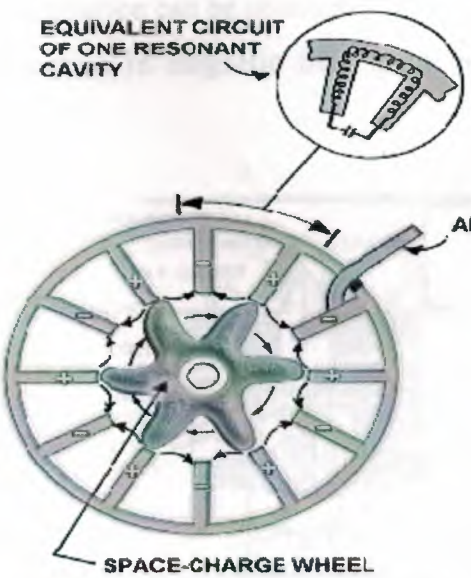


Figure 7-5 Electrons form a rotating pattern.
(Wagner / Gallawa)

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 multiuse 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.

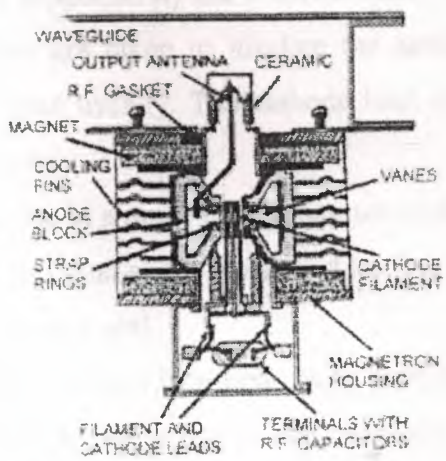


Figure 1 Sectional view of a typical magnetron (Courtesy of Michael S. Wagner)

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.

His 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 multi-cavity magnetron have iron pole faces built into them with the iron bode 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 (2).

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.

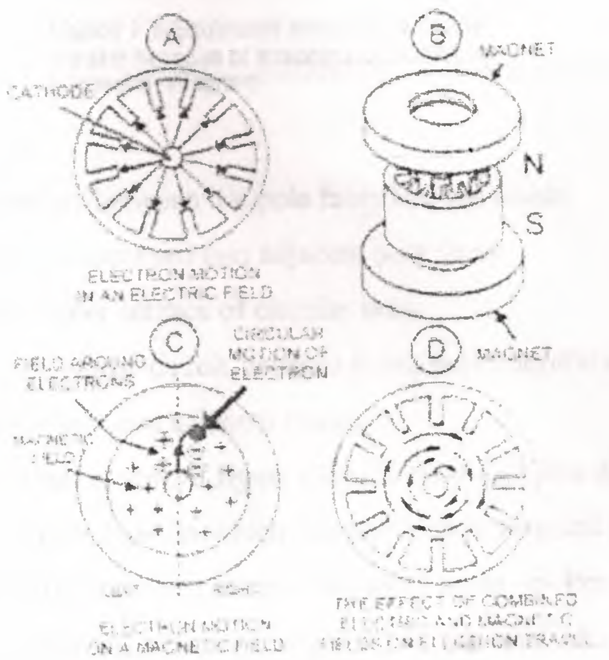


Figure 3 Electron motion in a magnetron tube (Courtesy of Michael S. Wagner)

1.8.2.3 Resonant properties of multi-cavity 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 in figure (3).

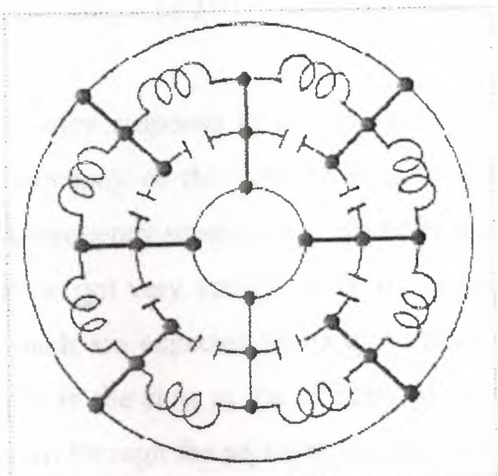


Figure 7-6 Equivalent circuit of cavities in parallel because of strapping. (Courtesy of Michael S. Wagner)

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 $-\pi$- 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:

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

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:

$$W_2 = 1/1-\cos(2\pi n/N).\ 2/(\acute{\omega}_1)^2 + 1/(\acute{\omega}_2)^2 \qquad (1.11)$$

Where:

$\Omega_1 = 1/\sqrt{M_1 C_1}$,

$\Omega_2 = 1/\sqrt{M_1 C_2}$

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.

Multi-cavity 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 Magnetron 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 geotechnical 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 vapors 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 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.

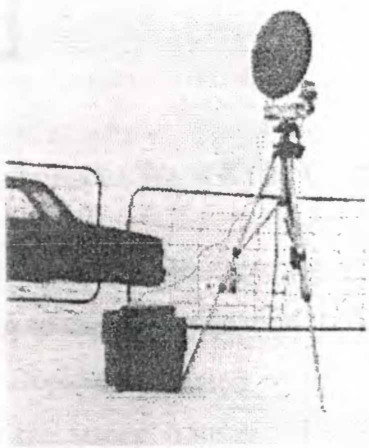
Two probe options mean that the system is suited to work in a wide range of liquids from light hydrocarbons to water-based slurries at temperatures up to 200°C pressure up to 50bar and lengths from 60 to 610cm. Approvals include CENELEC intrinsically safe FM/CSA intrinsically safe and explosion proof.

1.9 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, and 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.

1.9.1 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.

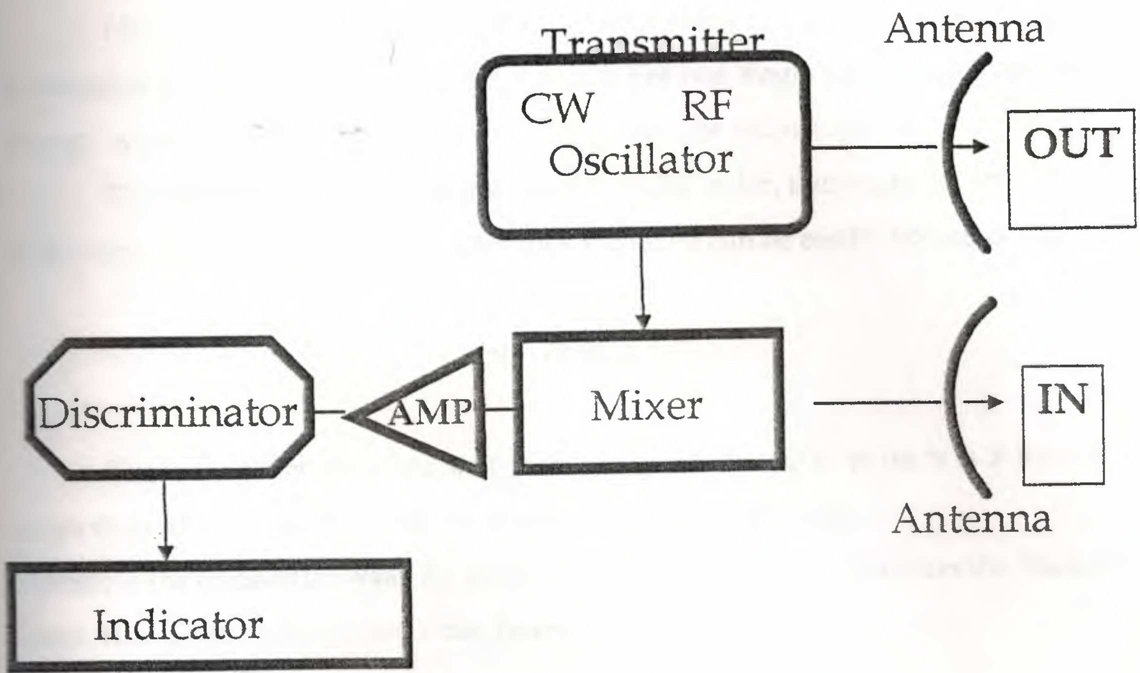


Fig.1.8 Continuous Wave Radar Components.

The following applet allows you to calculate the signal to noise ratio of a received radar signal according to the radar equation. 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.

1.9.2 Pulsed Radar System

1.9.2.1 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:

$$R = C.\ D t / 2$$

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.

1.9.2.2 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.

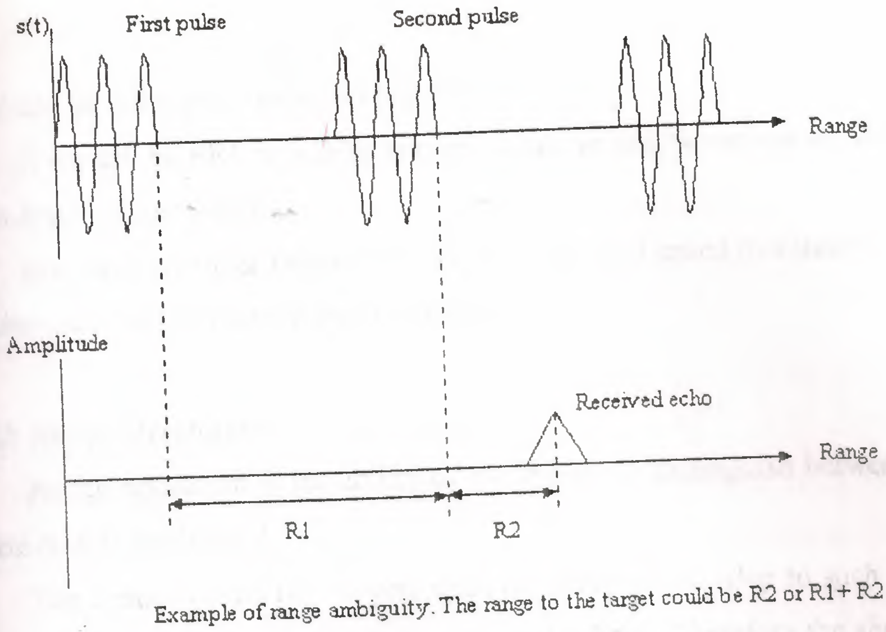


Fig.1.9. Rang Ambiguity.

If for instance the target echo was detected 0.000005 seconds after a pulse, and the IPP is 0.0006. R_{max} 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.

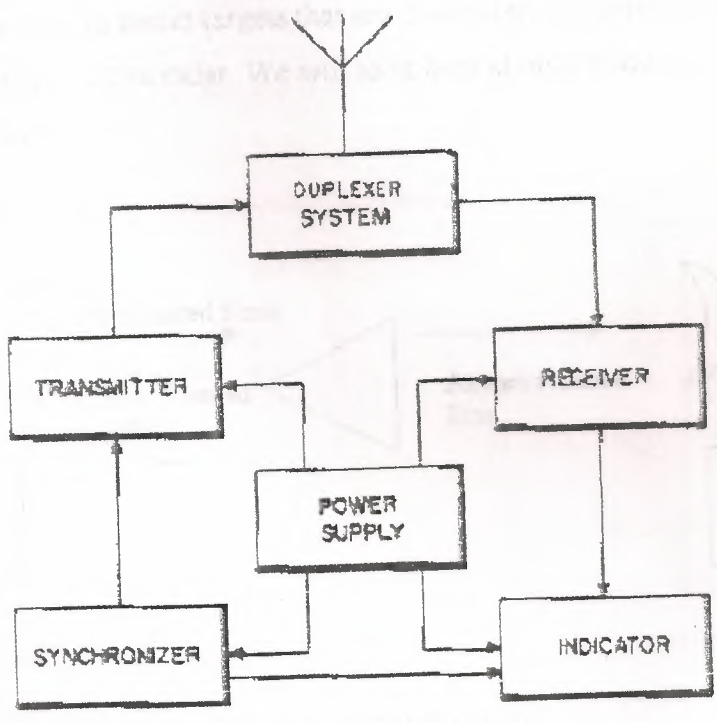


Fig.1.10. pulse radar

- 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 R_{max}.

But there are other factors like antenna rotational speed that limit the PRF value. Therefore we can not remove the problem entirely.

1.9.2.3 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.

1.9.3 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.

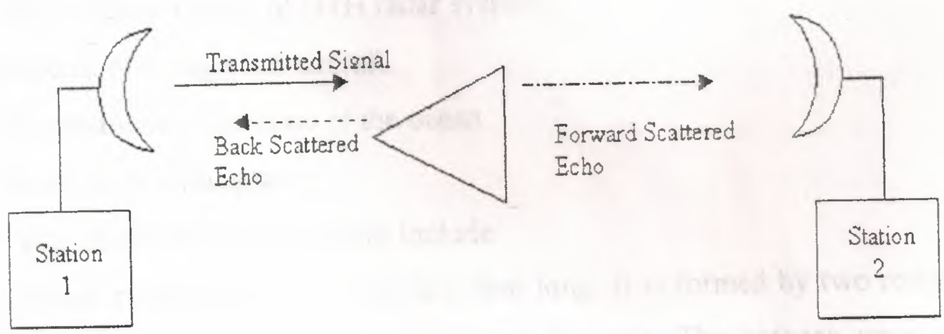


Fig.1.11. OTH RADAR

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

Back scattering has already been discussed. Forward 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.

1.9.3.1 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

1.9.4 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 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. Air surveillance radar might have pulse duration of one microsecond, while other types of radar can have equivalent pulse widths a thousand times smaller, in the nanosecond range.

1.9.5 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.

1.9.6 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.

1.9.7 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.

1.9.8 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.

1.9.9 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.

1.9.10 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 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.

1.9.11 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.

1.9.12 Side-Looking Airborne Radar (SLAR)

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

1.9.13 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.

1.9.14 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.

1.9.15 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.

1.9.16 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, ADT radar usually displays tracks or vectors of the targets that reveal both their direction and speed.

1.9.17 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.

1.9.18 Electronically Scanned Phased-Array Radar

This is really just a special antenna and not 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.

1.9.19 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 rangé measurements. The most common form of FM-CW radar is the radar altimeter used in aircraft to determine height above the ground.

1.9.20 Weather radar

1.9.20.1 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 .

1.9.20.2 How does 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 rains haft, and can also penetrate to measure other rain areas beyond .

1.9.20.3 Technical aspects

The main units in 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

1.10 Electronic Warfare and Radar Systems

There are two basic forms of electronic warfare:

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

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

ECM methods can be broken up into two broad categories:

- Noise Jamming. These 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.

NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

General Radar

Graduation Project
EE- 400

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ABDELKAREEM AL-SAKARNEH

TABLE OF CONTENTS

CHAPTER ONE
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 .

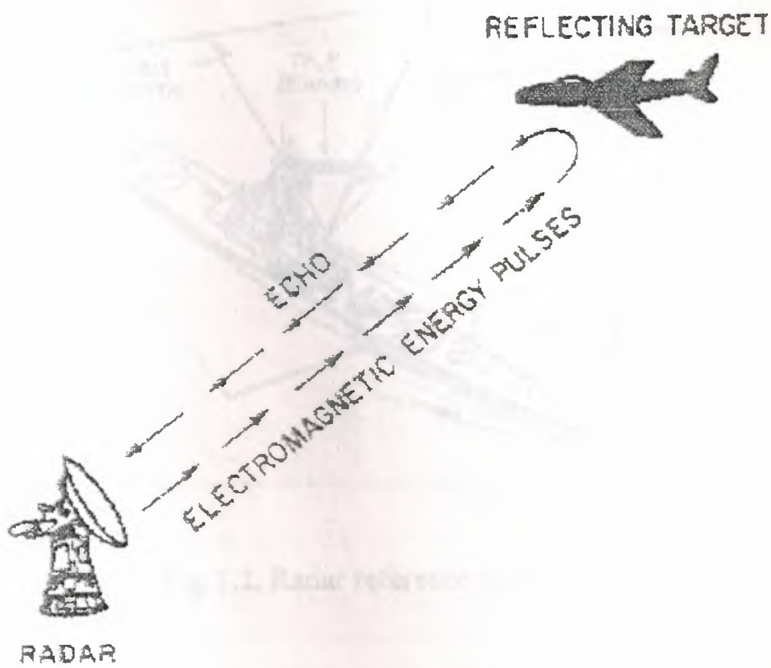


Fig.1.1. Radar echo.

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 .

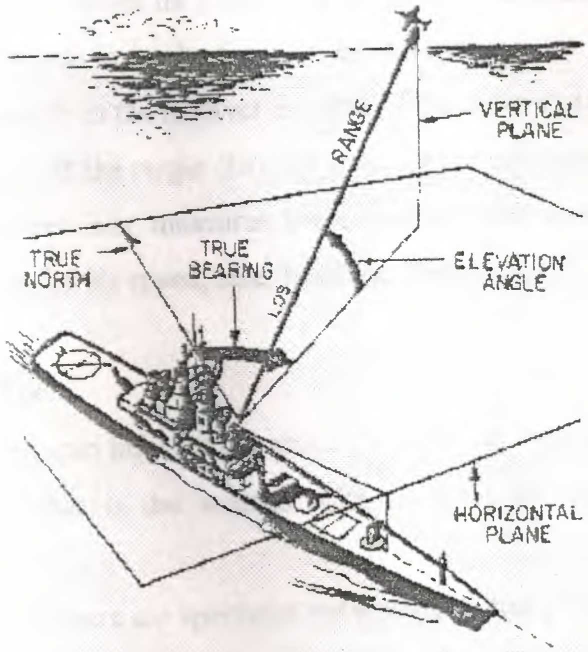


Fig.1.2. Radar reference coordinates.

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 mono-static radar system. Mono-static 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 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 examples of an airborne supervisory role of radar. There is many other application of radar system.

1.4.2 The parts of a Radar System

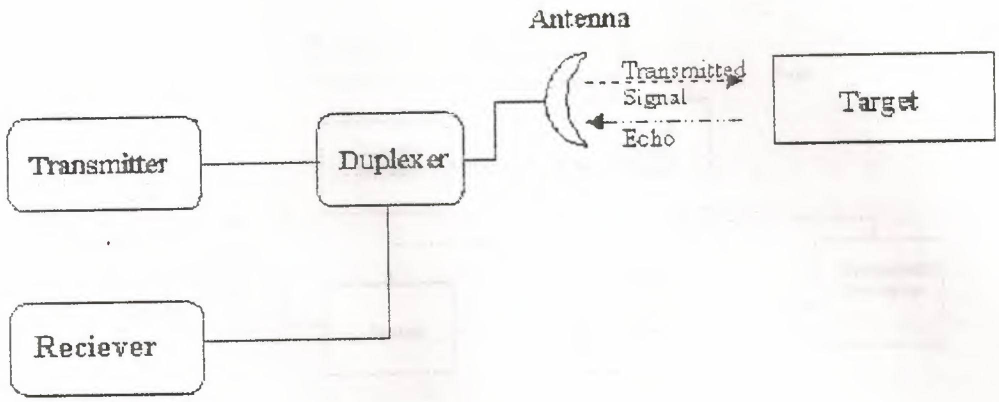


Fig.1.3. Radar Block Diagram

- 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,

1.5 Components of a Radar System

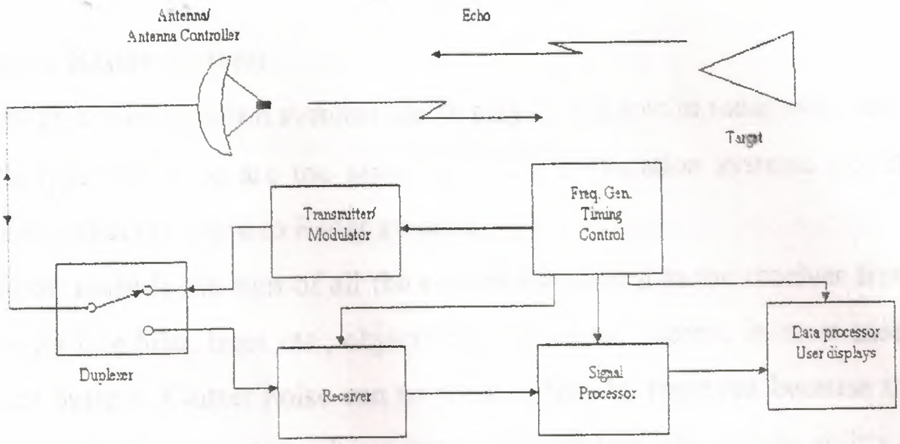


Fig .1.5. Block diagram of a Mono-static Single Antenna Radar System

- 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

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 Setups

Most radar systems have the transmitter and receiver in the same location, monotonic 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, this 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.

1.5.2 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 mono-static 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 many 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:

$$\frac{\sigma G P_t}{4\pi r^2} \qquad (1.1)$$

where

□ is the back scattering cross section of the target.

NOTE: □ is not necessarily equal to the geometrical cross section.

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

$$\frac{\sigma G P_t}{\left(4\pi r^2\right)^2} \tag{1.2}$$

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

$$P_r = \frac{A_e \sigma G P_t}{\left(4\pi r^2\right)^2} \tag{1.3}$$

where: $[P_r]$ in 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

□ ~ 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:

$$G = \frac{4\pi A_e}{\lambda^2} \quad \text{or} \quad A_e = \frac{G\lambda^2}{4\pi} \tag{1.4}$$

so substituting (1.4) into (1.3) 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.

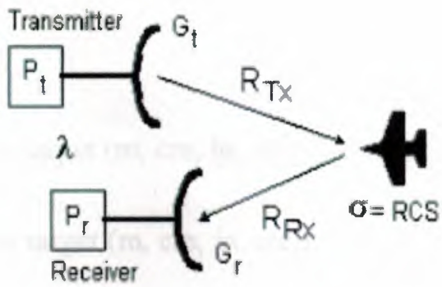


Fig. 1.5. Bi-static (Tx and Rx in different locations)

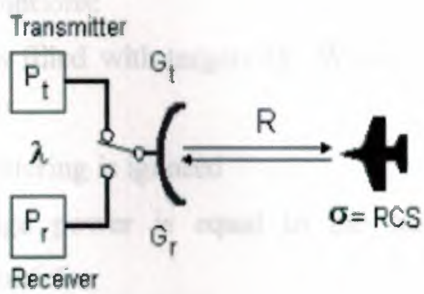


Fig.1.6. Mono-static (Tx and Rx in same location)

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:

$$\overline{P}_r = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 R^4} \tag{1.5}$$

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

For multiple targets, (1.5) can write as:

$$\overline{P}_r = \frac{P_t G^2 \lambda^2}{(4\pi)^3} \sum_i \frac{\sigma_i}{R_i^4} \tag{1.6}$$

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

Fig.1.7. Reflection from Target

then (1.6) can be written as:

$$\overline{P}_r = \frac{P_t G^2 \lambda^2}{(4\pi)^3} \sum_i \sigma_i \tag{1.7}$$

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

Hence the sum in (1.7) can be written as:

$$\sum_i \sigma_i = \left(\sum_i \frac{\sigma_i}{unitvolume} \right) totalvolume \tag{1.8}$$

where the total volume is the volume of the pulse.

Thus, (1.8) can be written as:

$$\sum_i \sigma_i = \left(\sum_i \frac{\sigma_i}{unitvolume} \right) \pi \frac{R^2\theta^2 h}{8} \tag{1.9}$$

Substituting (1.9) into (1.7) gives:

$$\overline{P}_r = \left(\frac{P_t G^2 \lambda^2 \theta^2 h}{512\pi^2 R^2} \right) \sum_i \sigma_i \tag{1.10}$$

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

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.

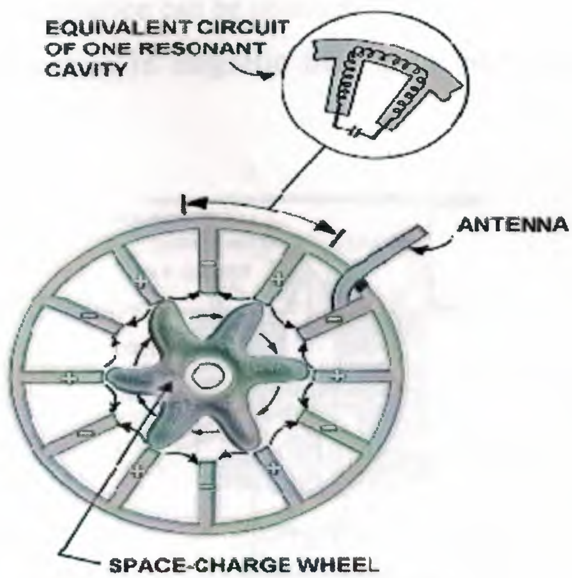


Figure 7-5 Electrons form a rotating pattern.
(Wagner / Gallawa)

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 multiuse 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.

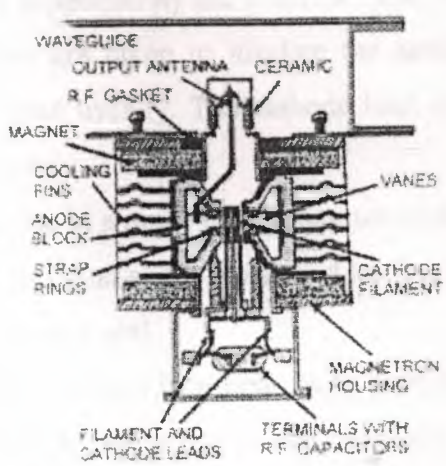


Figure 1 Sectional view of a typical magnetron
(Courtesy of Michael S. Wagner)

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.

His 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 multi-cavity magnetron have iron pole faces built into them with the iron bode 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 (2).

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.

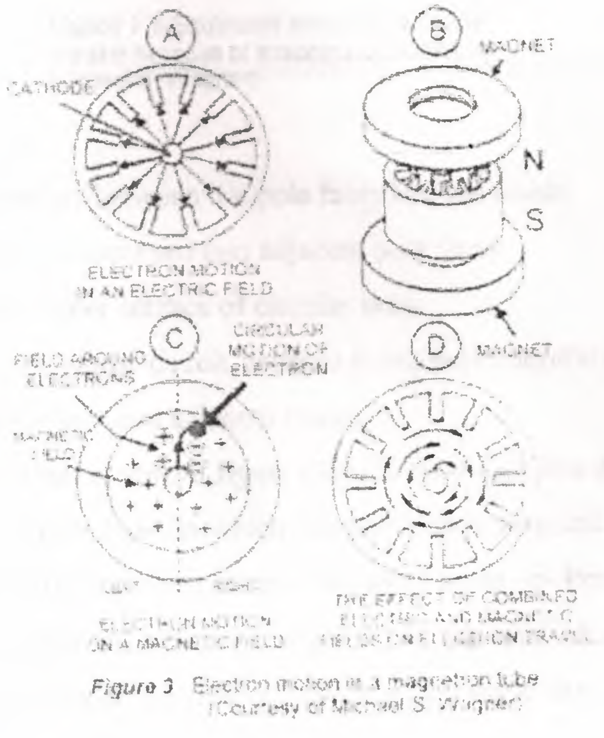


Figure 3 Electron motion in a magnetron tube (Courtesy of Michael S. Wagner)

1.8.2.3 Resonant properties of multi-cavity 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 in figure (3).

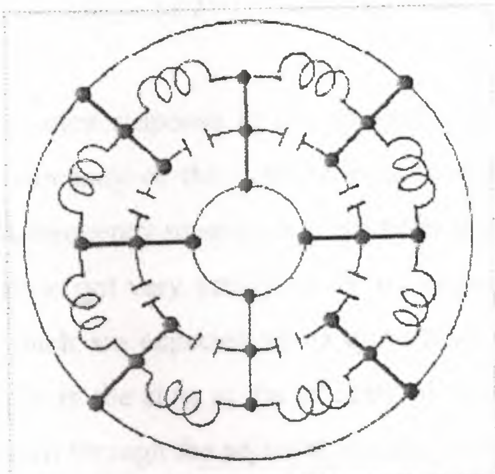


Figure 7-6 Equivalent circuit of cavities in parallel because of strapping. (Courtesy of Michael S. Wagner)

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 $-\pi$- 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:

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

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:

$$W_2 \;= 1/1-\cos(2\pi n/N).\; 2/ (\acute{\omega}_1)^{2} + 1/ (\acute{\omega}_2)^{2} \qquad (1.11)$$

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.

Multi-cavity 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 Magnetron 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 geotechnical 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 vapors 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 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.

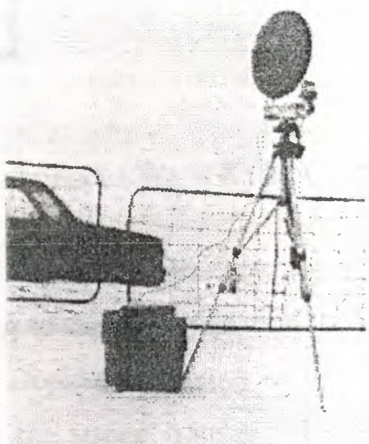
Two probe options mean that the system is suited to work in a wide range of liquids from light hydrocarbons to water-based slurries at temperatures up to 200°C pressure up to 50bar and lengths from 60 to 610cm. Approvals include CENELEC intrinsically safe FM/CSA intrinsically safe and explosion proof.

1.9 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, and 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.

1.9.1 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.

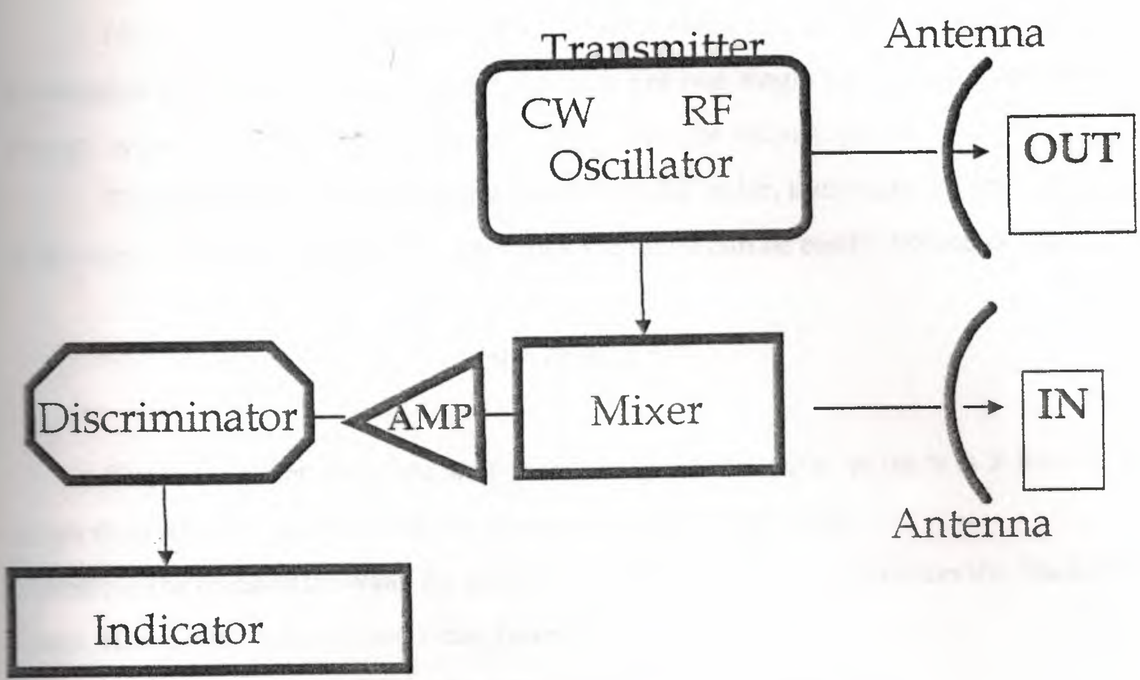


Fig.1.8 Continuous Wave Radar Components.

The following applet allows you to calculate the signal to noise ratio of a received radar signal according to the radar equation. 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.

1.9.2 Pulsed Radar System

1.9.2.1 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:

$$R = C. D t / 2$$

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.

1.9.2.2 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.

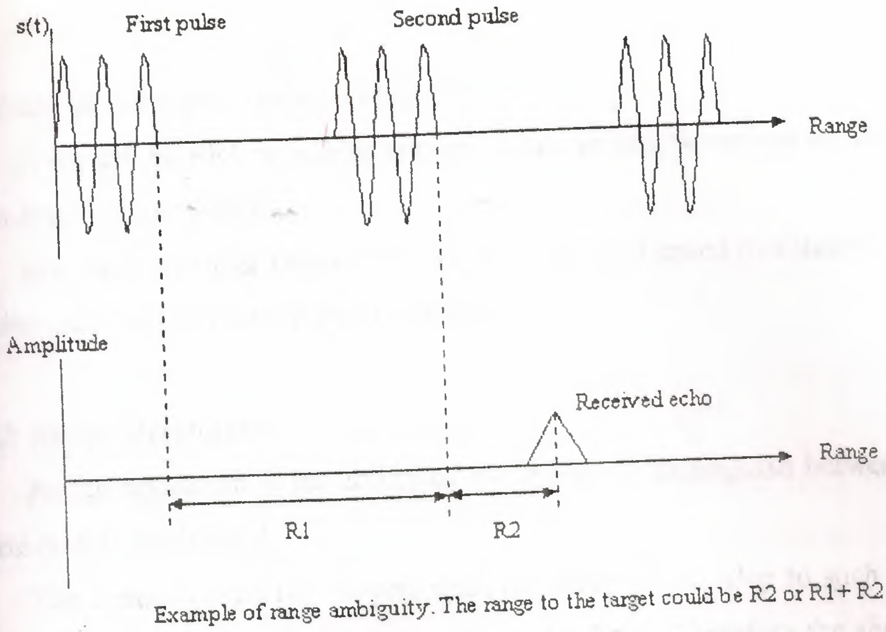


Fig.1.9. Rang Ambiguity.

If for instance the target echo was detected 0.000005 seconds after a pulse, and the IPP is 0.0006. R_{max} 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.

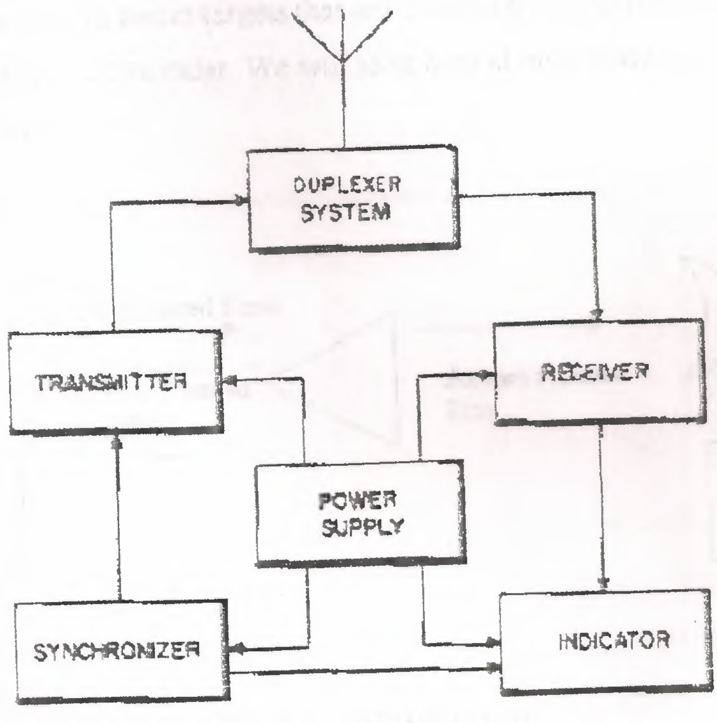


Fig.1.10. pulse radar

- 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 R_{max}.

But there are other factors like antenna rotational speed that limit the PRF value. Therefore we can not remove the problem entirely.

1.9.2.3 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.

1.9.3 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.

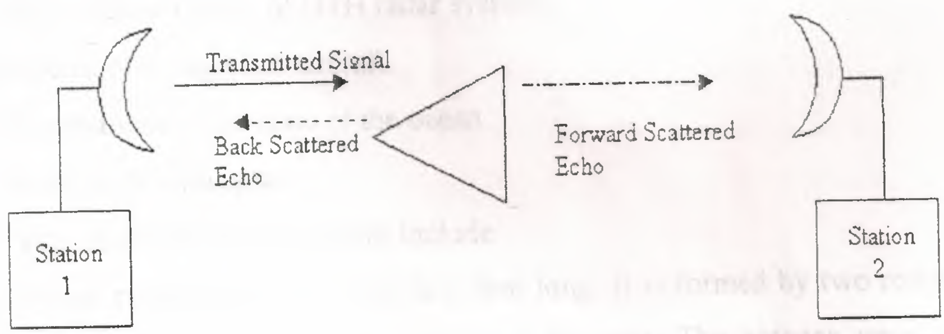


Fig.1.11. OTH RADAR

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

Back scattering has already been discussed. Forward 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.

1.9.3.1 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

1.9.4 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 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. Air surveillance radar might have pulse duration of one microsecond, while other types of radar can have equivalent pulse widths a thousand times smaller, in the nanosecond range.

1.9.5 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.

1.9.6 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.

1.9.7 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.

1.9.8 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.

1.9.9 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.

1.9.10 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 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.

1.9.11 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.

1.9.12 Side-Looking Airborne Radar (SLAR)

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

1.9.13 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.

1.9.14 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.

1.9.15 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.

1.9.16 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, ADT radar usually displays tracks or vectors of the targets that reveal both their direction and speed.

1.9.17 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.

1.9.18 Electronically Scanned Phased-Array Radar

This is really just a special antenna and not 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.

1.9.19 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 rangé measurements. The most common form of FM-CW radar is the radar altimeter used in aircraft to determine height above the ground.

1.9.20 Weather radar

1.9.20.1 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 .

1.9.20.2 How does 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 rains haft, and can also penetrate to measure other rain areas beyond .

1.9.20.3 Technical aspects

The main units in 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

1.10 Electronic Warfare and Radar Systems

There are two basic forms of electronic warfare:

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

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

ECM methods can be broken up into two broad categories:

- Noise Jamming. These 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.

1.10.1 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 reduce 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 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 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 neutralize 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 .

1.10.2 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.

1.10.3 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 side lobes
- 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 .

1.11SUMMARY

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 .

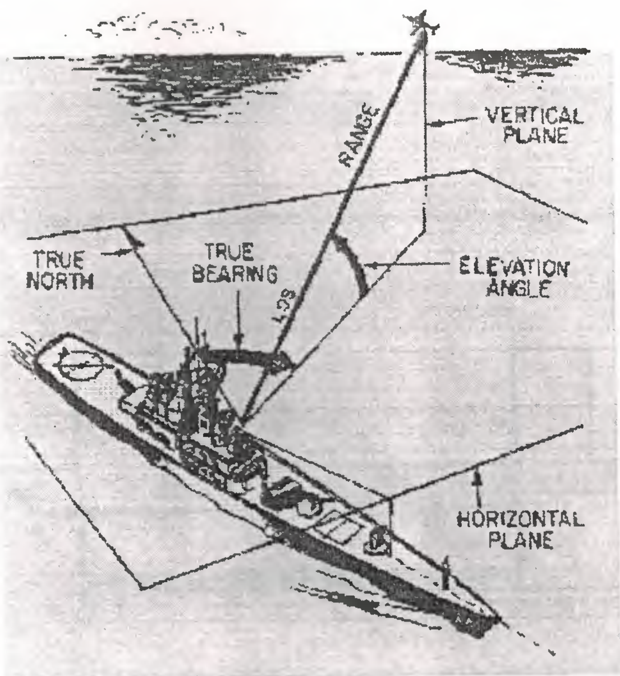


Fig.1.12. Range

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

$$\text{target range} = \frac{\text{elapsed time}}{12.36 \text{ microseconds per nautical mile}}$$

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 .

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

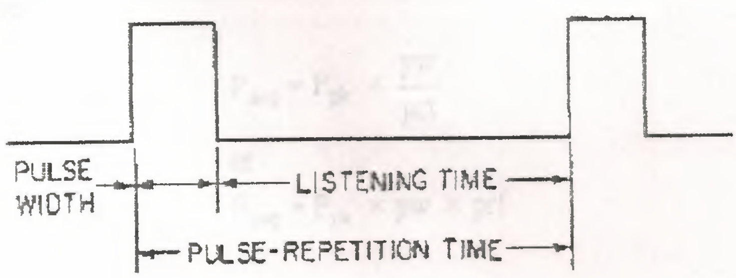


Fig.1.13. pulse time diagram

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

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

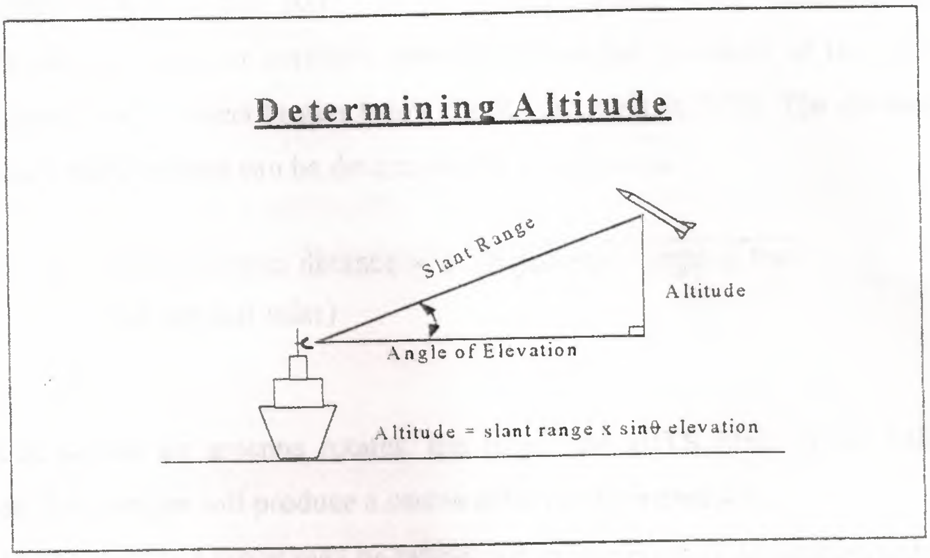


Fig.1.14. Determining altitude.

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 .

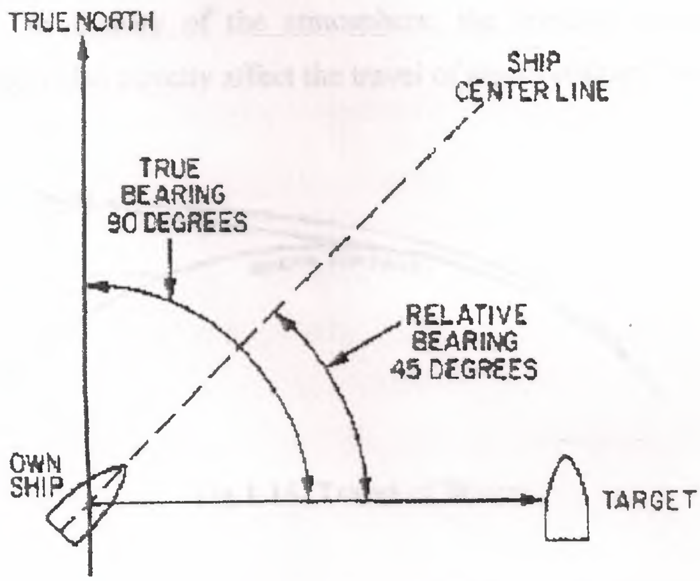


Fig.1.15. Bearing

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 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 wave-fronts traveling through the air. Under normal conditions, the wave-fronts increase uniformly in speed as altitude increases which cause 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 wave-fronts.

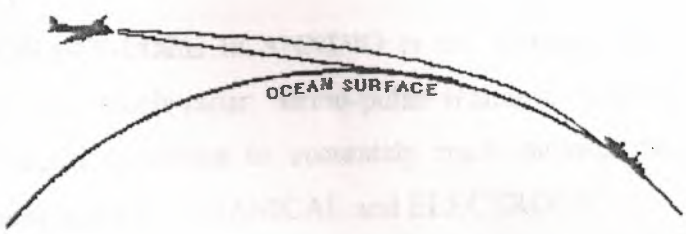


Fig.1.16. Travel of Waves

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 .

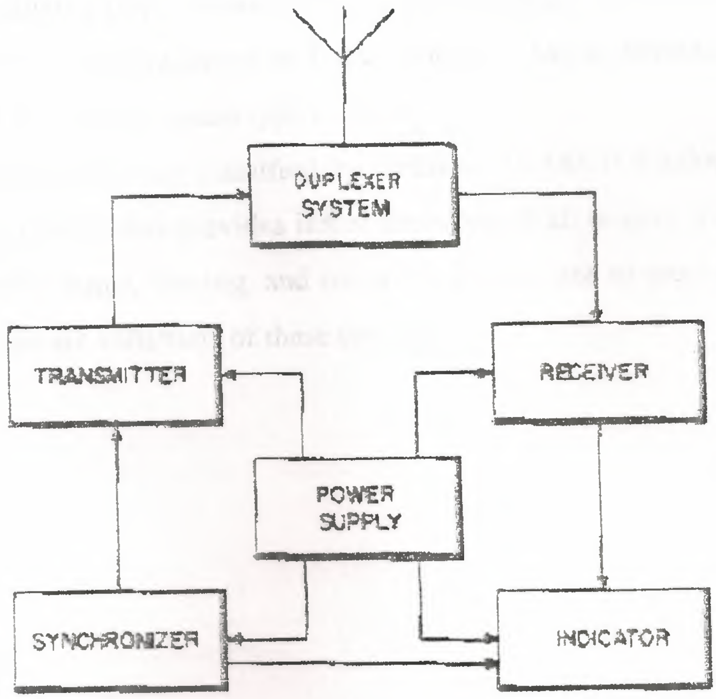


Fig.1.17. pulse radar system

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. Mono-pulse 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 .

CHAPTER TWO

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, a focusing system that attracts the cathode electron beam and

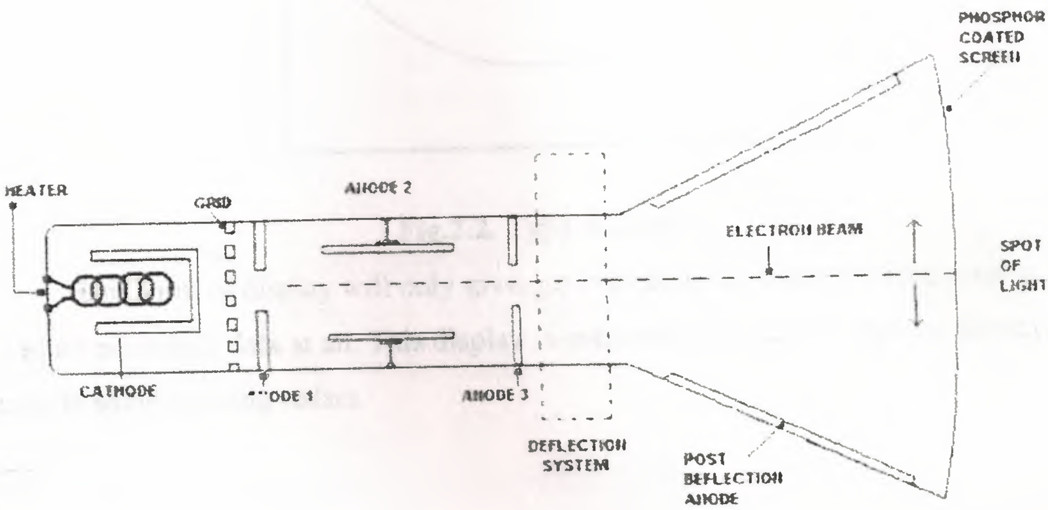


Fig.2.1. Display

focuses it into abeam of electrons. This beam is then deflected by either an electromagnetic or electrostatic deflection system and hits a phosphor coated screen. The speed that the electron beam 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

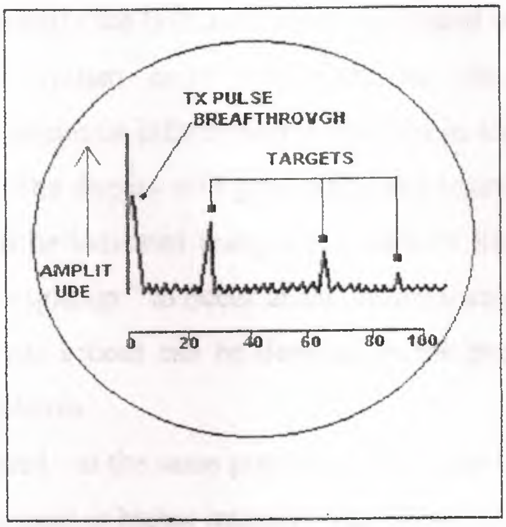


Fig.2.2. Type A-scope

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.

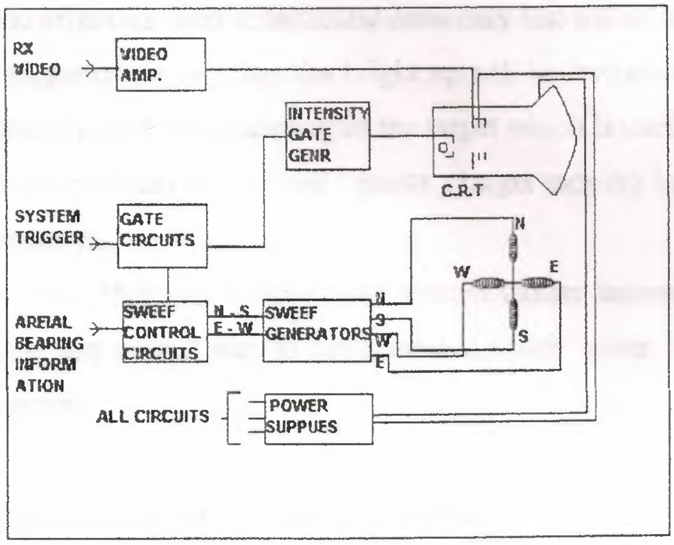


Fig.2.3. Basic P.P.I Display

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.

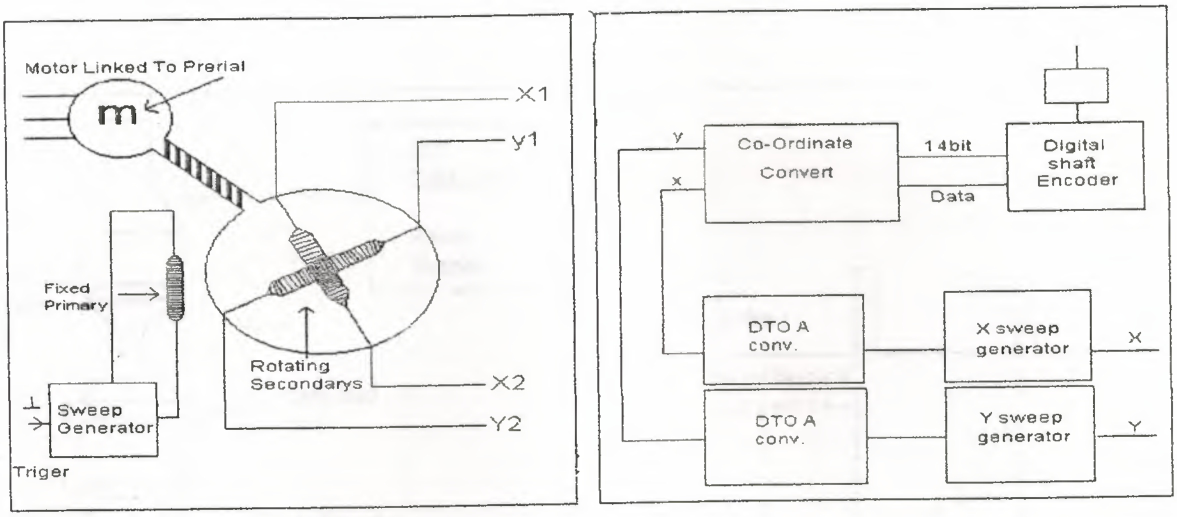


Fig.2.4. Resolver Generated Rotating Time Base

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).

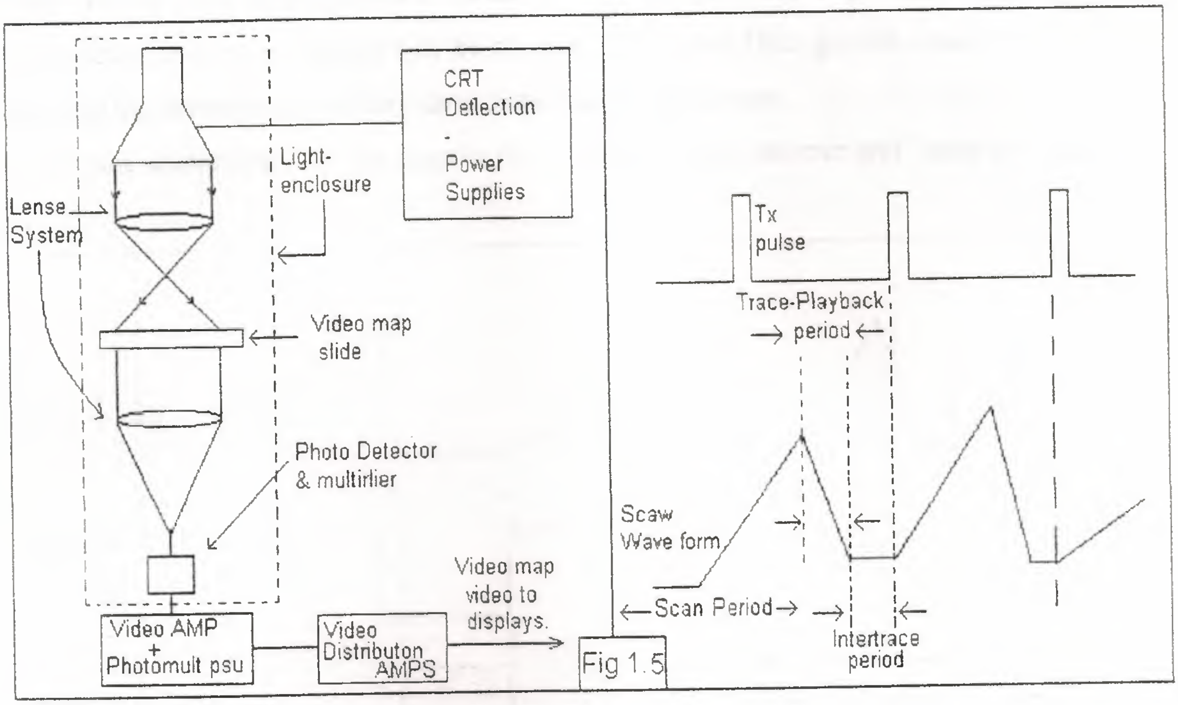


Fig.2.5. Video Map Generation System

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'

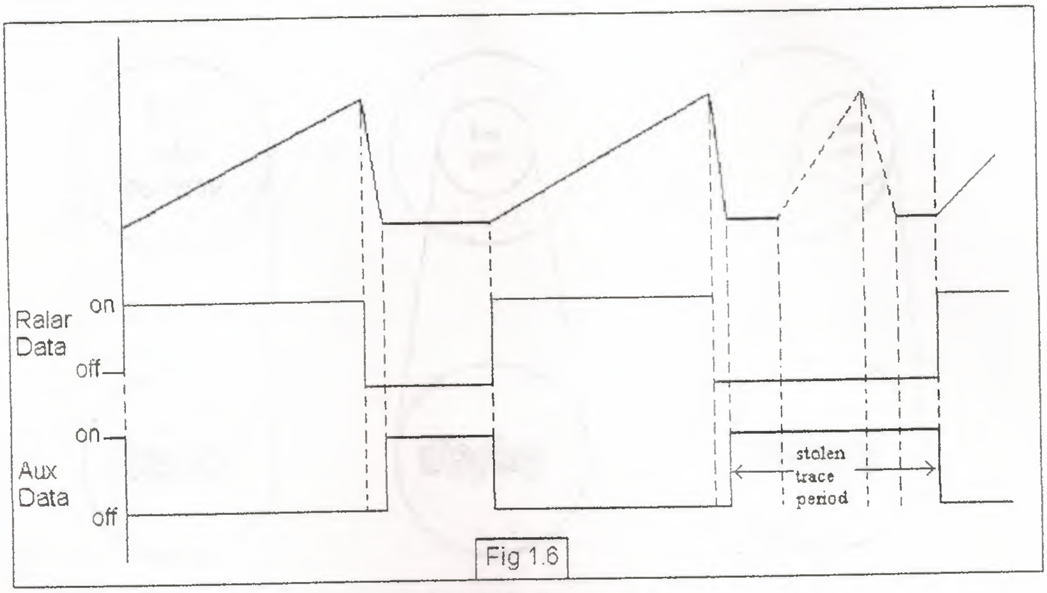


Fig.2.6. Scan Stealing

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.

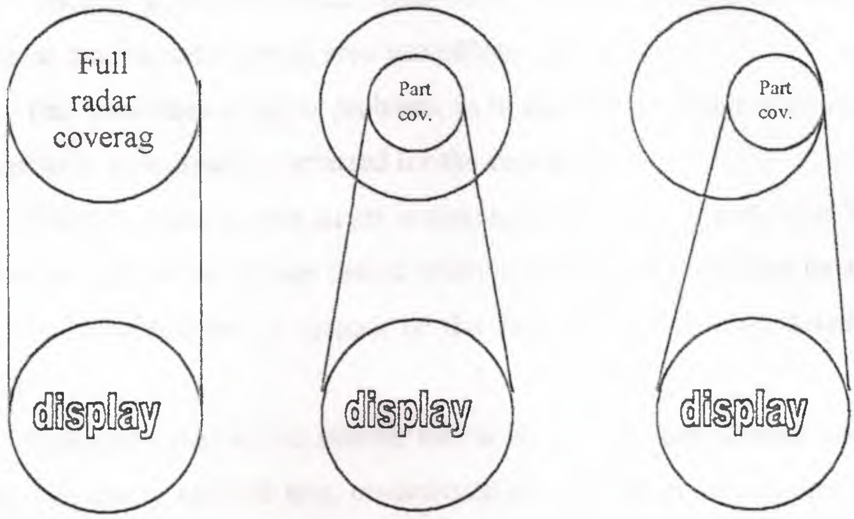


Fig.2.7. Display Areas

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 operator's 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.

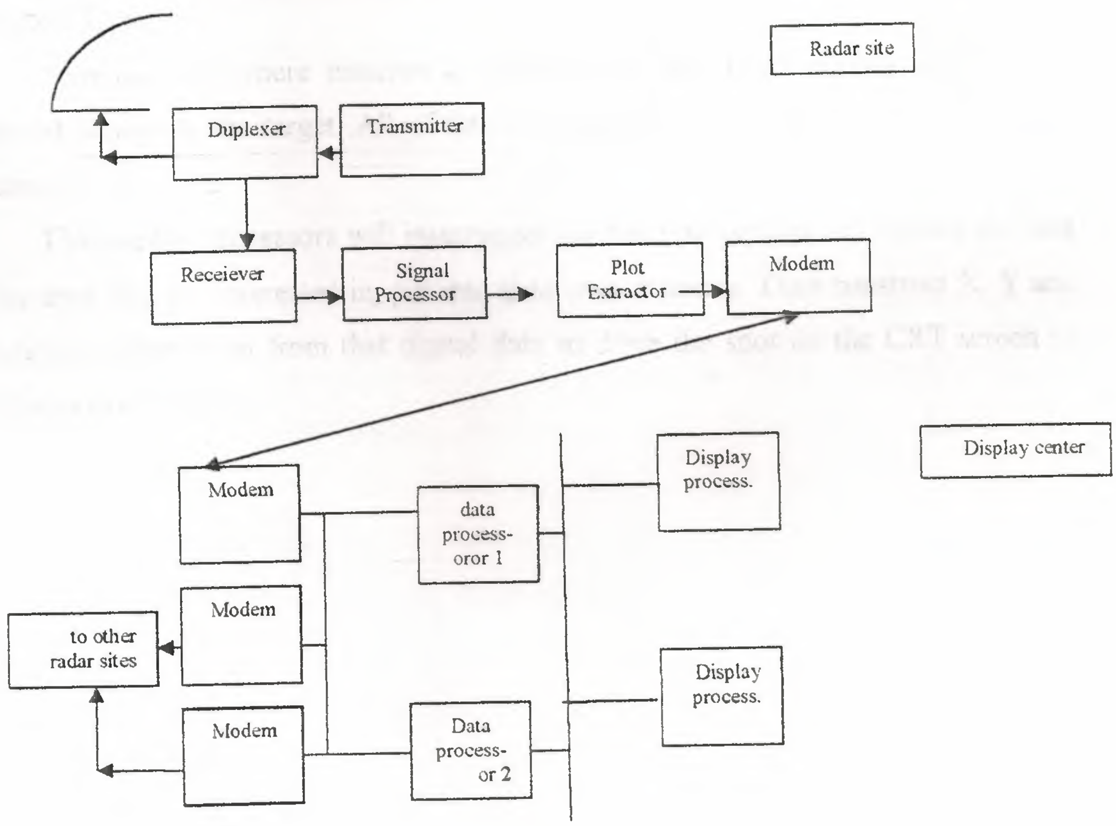


Fig.2.8. Display center

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.

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.

ATMOSPHERIC CONDITIONS affect the speed and direction of travel of electromagnetic wave-fronts traveling through the air. Under normal conditions, the wave-fronts increase uniformly in speed as altitude increases which cause 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 wave-fronts.

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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