UNIT – 7

INTRODUCTION TO RADAR

Radar is an electromagnetic system for the detection and location of objects. It operates by transmitting a particular type of waveform, a pulse-modulated sine wave for example, and detects the nature of the echo signal.

Radar can be designed to see through those conditions impervious to normal human vision, such as darkness, haze, fog, rain, and snow. In addition, radar has the advantage of being able to measure the distance or range to the object.

An elementary form of radar consists of a transmitting antenna emitting electromagnetic radiation generated by an oscillator of some sort, a receiving antenna, and an energy-detecting device. or receiver.

A portion of the transmitted signal is intercepted by a reflecting object (target) and is reradiated in all directions. It is the energy reradiated in the back direction that is of prime interest to the radar.

The receiving antenna collects the returned energy and delivers it to a receiver, where it is processed to detect the presence of the target and to extract its location and relative velocity. The distance to the target is determined by measuring the time taken for the radar signal to travel to the target and back. The direction, or angular position, of the target may be determined from the direction of arrival of the reflected wave front.

The name radar reflects the emphasis placed by the early experimenters on a device to detect the presence of a target and measure its range. Radar is a contraction of the words radio detection and ranging. It was first developed as a detection device to warn of the approach of hostile aircraft and for directing antiaircraft weapons. Although a well-designed modern radar can usually extract more information from the target signal than merely range, the measurement of range is still one of radar's most important functions.

The most common radar waveform is a train of narrow, rectangular-shape pulses modulating a sine wave carrier. The distance, or range, to the target is determined by measuring the time ***TR*** taken by the pulse to travel to the target and return.

$$R = \frac{cT_R}{2} \qquad (1.1)$$

The factor 2 appears in the denominator because of the two-way propagation of radar. With the range in kilometers or nautical miles, and ***TR*** in microseconds, ***Eq.*** (1.1) becomes

$$R(\text{km}) = 0.15\,T_R(\mu s) \qquad \text{or} \qquad R(\text{nmi}) = 0.081\,T_R(\mu s)$$

Once the transmitted pulse is emitted by the radar, a sufficient length of time must elapse to allow any echo signals to return and be detected before the next pulse may be transmitted.

Therefore the rate at which the pulses may be transmitted is determined by the longest range at which targets are expected. If the pulse repetition frequency is too high, echo signals from some targets might arrive after the transmission of the next pulse, and ambiguities in measuring range might result. Echoes that arrive after the transmission of the next pulse are called second-time-around (or multiple-time-around) echoes. Such an echo would appear to be at a much shorter range than the actual and could be misleading if it were not known to be a ***second-time-around echo***. The range beyond which targets appear as second-time-around echoes is called the ***maximum unambiguous range*** and is

$$R_{unamb} = \frac{c}{2f_p} \tag{1.2}$$

Where fp = pulse repetition frequency, in Hz.

1.2 THE SIMPLE FORM OF THE RADAR EQUATION

The radar equation relates the range of a radar to the characteristics of the transmitter,receiver, antenna, target, and environment. It is useful not just as a means for determining the maximum distance from the radar to the target, but it can serve both as a tool for understanding radar operation and as a basis for radar design.

If the power of the radar transmitter is denoted by P,, and if an isotropic antenna is used (one which radiates uniformly in all directions), the ***power*** density (watts per unit area) at a distance ***R*** from the radar is equal to the transmitter power divided by the surface area ***4∏R2*** of an imaginary sphere of radius R

$$\text{Power density from isotropic antenna} = \frac{P_t}{4\pi R^2} \tag{1.3}$$

Radars employ directive antennas to channel, or direct, the radiated power ***Pt*** into some
particular direction. The ***gain*** G of an antenna is a measure of the increased power radiated in the direction of the target as compared with the power that would have been radiated from an isotropic antenna. It may be defined as the ratio of the maximum radiation intensity from the subject antenna to the radiation intensity from a lossless, isotropic antenna with the same power input.

$$\text{Power density from directive antenna} = \frac{P_t G}{4\pi R^2} \tag{1.4}$$

The target intercepts a portion of the incident power and reradiates it in various directions The measure of the amount of incident power intercepted by the target and reradiated back in the direction of the radar is denoted as the radar cross section , and is defined by the relation

$$\text{Power density of echo signal at radar} = \frac{P_t G}{4\pi R^2}\frac{\sigma}{4\pi R^2} \tag{1.5}$$

The radar cross section a has units of area. It is a characteristic of the particular target and is a measure of its size as seen by the radar. The radar antenna captures a portion of the echo power. If the effective area of the receiving antenna is denoted ***A.,*** the power *P,* received by the radar is

$$P_r = \frac{P_t G}{4\pi R^2}\frac{\sigma}{4\pi R^2} A_e = \frac{P_t G A_e \sigma}{(4\pi)^2 R^4} \tag{1.6}$$

The maximum radar range ***Rmax*** is the distance beyond which the target cannot be detected. It occurs when the received echo signal power *P,* just equals the minimum detectable signal ***Smin***

$$R_{\max} = \left[\frac{P_t G A_e \sigma}{(4\pi)^2 S_{\min}}\right]^{1/4} \tag{1.7}$$

This is the fundamental form of the radar equation.

Antenna theory gives the relationship between the transmitting gain and the receiving effective area of an antenna as

$$G = \frac{4\pi A_e}{\lambda^2} \tag{1.8}$$

Since radars generally use the same antenna for both transmission and reception, Eq. (1.8) can be substituted into Eq.

(1.7), first for ***A,*** then for G, to give two other forms of the radar equation

$$R_{max} = \left[\frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 S_{min}}\right]^{1/4} \tag{1.9}$$

$$R_{max} = \left[\frac{P_t A_e^2 \sigma}{4\pi \lambda^2 S_{min}}\right]^{1/4} \tag{1.10}$$

These three forms (Eqs. 1.7, 1.9, and 1.10) illustrate the need to be careful in the interpretation of the radar equation.

1.3 RADAR BLOCK DIAGRAM AND OPERATION

The operation of a typical pulse radar may be described with the aid of the block diagram shown in Fig. 1.2. The transmitter may be an oscillator, such as a magnetron, that is "pulsed" (turned on and on) by the modulator to generate a repetitive train of pulses. The magnetron has probably been the most widely used of the various microwave generators for radar.

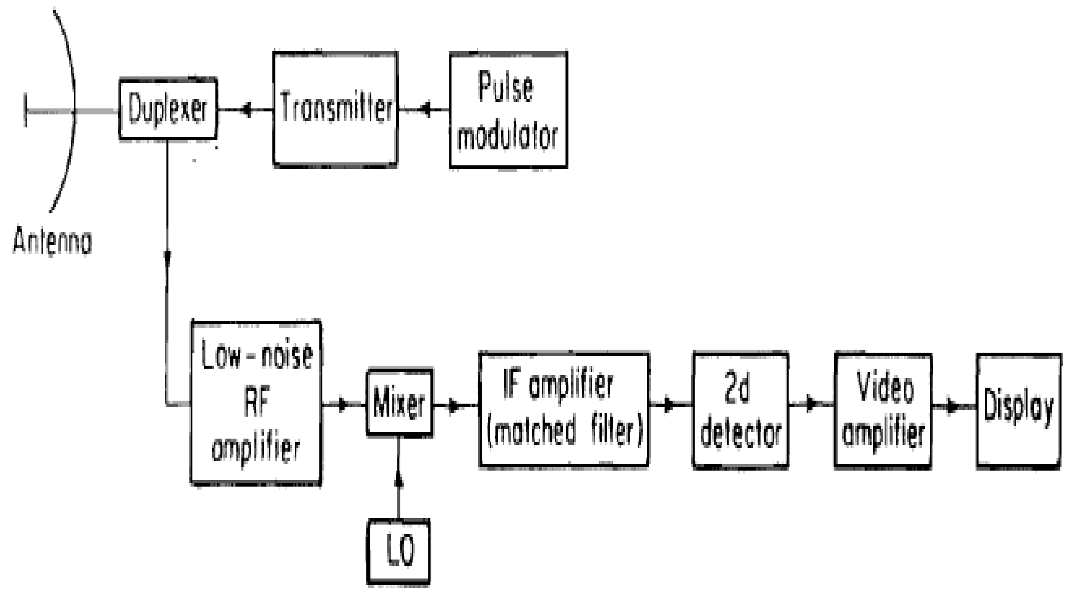

Figure 1.2 Block diagram of a pulse radar.

The waveform generated by the transmitter travels via a transmission line to the antenna, where it is radiated into space. A single antenna is generally used for both transmitting and receiving. The receiver must be protected from damage caused by the high power of the transmitter. This is the function of the duplexer. The duplexer also serves to channel the returned echo signals to the receiver and not to the transmitter. The duplexer might consist of two gas-discharge devices, one known as a TR (transmit-receive) and the other an ATR (anti-transmit-receive). The TR protects the receiver during transmission and the ATR directs the echo signal to the receiver during reception. Solid-state ferrite circulators and receiver protectors with gas-plasma TR devices and/or diode limiters are also employed as duplexers.

The receiver is usually of the super heterodyne type. The first stage might be a low-noise **RF** amplifier, such as a parametric amplifier or a low-noise transistor. However, it is not always desirable to employ a low-noise first stage in radar. The receiver input can simply be the mixer stage, especially in military radars that must operate in a noisy environment.

Although a receiver with a low-noise front-end will be more sensitive, the mixer input can have greater dynamic range, less susceptibility to overload, and less vulnerability to electronic interference.

The mixer and local oscillator (LO) convert the RF signal to an intermediate frequency **(IF).** A " typical" IF amplifier for an air-surveillance radar might have a center frequency of 30 or 60 MHz and a bandwidth of the order of one megahertz. After maximizing the signal-to-noise ratio in the IF amplifier, the pulse modulation is extracted by the second detector and amplified by the video amplifier to a level where it can be properly displayed, usually on a cathode-ray tube (CRT). Timing signals are also supplied to the indicator to provide the range zero. Angle information is obtained from the pointing direction of the antenna.

1.4 RADAR FREQUENCIES

Conventional radars generally have been operated at frequencies extending from about 220 **MHz** to 35 **GHz,** a spread of more than seven octaves. The place of radar frequencies in the electromagnetic spectrum is shown in Fig. 1.4. Some of the nomenclature employed to designate the various frequency regions.

Early in the development of radar, a letter code such as S, X, L, etc., was employed to designate radar frequency bands. Although its original purpose was to guard military secrecy, the designations were maintained, probably out of habit as well as the need for some convenient short nomenclature. This usage has continued and is now an accepted practice of radar engineers.

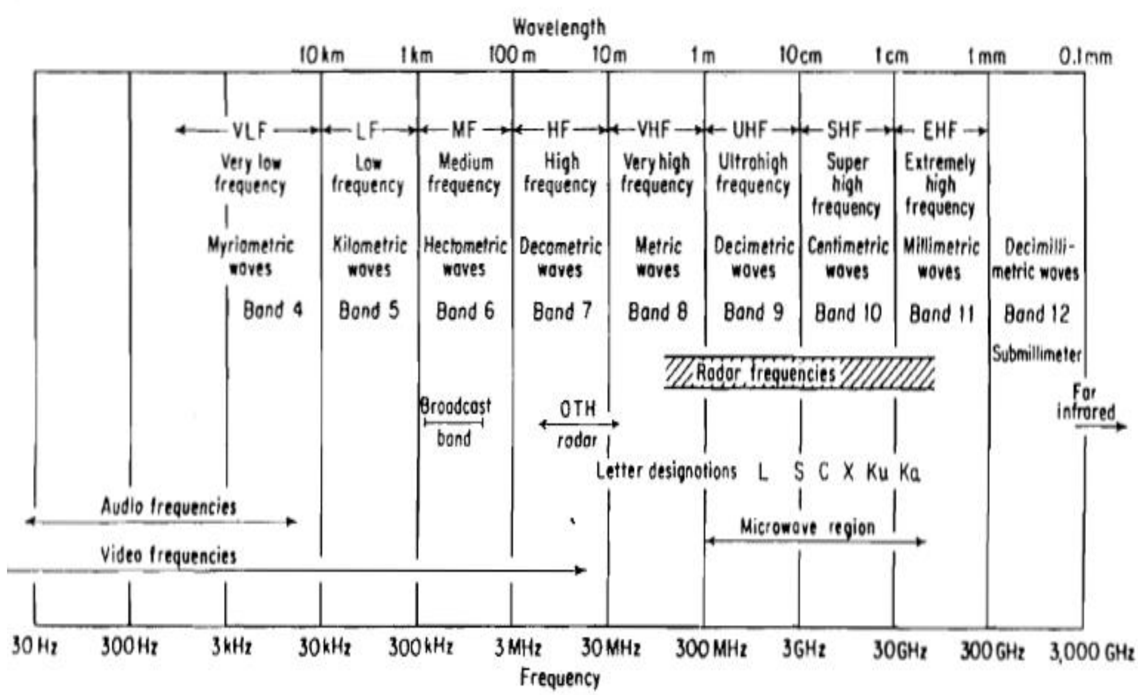

Figure 1.4 Radar frequencies and the electromagnetic spectrum.

Table 1.1 Standard radar-frequency letter-band nomenclature

Band designation	Nominal frequency range	Specific radiolocation (radar) bands based on ITU assignments for region 2
HF	3-30 MHz	
VHF	30-300 MHz	138-144 MHz 216-225
UHF	300-1000 MHz	420-450 MHz 890-942
L	1000-2000 MHz	1215-1400 MHz
S	2000-4000 MHz	2300-2500 MHz 2700-3700
C	4000-8000 MHz	5250-5925 MHz
X	8000-12,000 MHz	8500-10,680 MHz
K_u	12.0-18 GHz	13.4-14.0 GHz 15.7-17.7
K	18-27 GHz	24.05-24.25 GHz
K_a	27-40 GHz	33.4-36.0 GHz
mm	40-300 GHz	

1.5 RADAR DEVELOPMENT PRIOR TO WORLD WAR I1

Or

ORIGIN OF RADAR

Heinrich Hertz, in 1886, experimentally tested the theories of Maxwell and demonstrated the similarity between radio and light waves. Hertz showed that radio waves could be reflected by metallic and dielectric bodies.

In 1903 a German engineer by the name of Hulsmeyer experimented with the detection of radio waves reflected from ships. He obtained a patent in 1904 in several countries for an obstacle detector and ship navigational device.

Marconi recognized the potentialities of short waves for radio detection and strongly urged their use in 1922 for this application. In a speech delivered before the Institute of Radio Engineers.

In the autumn of 1922 A. H. I'aylor arid L. C. Young of tile Naval Research Laboratory detected a wooden ship using a CW wave-interference radar with separated receiver and transmitter. The wavelength was 5 m.

The first application of the pulse technique to the measurement of distance was in the basic scientific investigation by Breit and Tuve in 1925 for measuring the height of the ionosphere.

The first experimental radar systems operated with CW and depended for detection upon the interference produced between the direct signal received from the transmitter and the doppler-frequency-shifted signal reflected by a moving target. This effect is the same as the rhythmic flickering, or flutter, observed in an ordinary television receiver, especially on weak stations, when an aircraft passes overhead. This type of radar originally was called CW wave interference radar.

The first detection of aircraft using the wave-interference effect was made in June, 1930, by L. **A.** Hyland of the Naval Research Laboratory. The early CW wave-interference radars were useful only for detecting the ***presence*** of the target. The problem of extracting target-position information from such radars was a difficult one and could not be readily solved with the techniques existing at that time. **A** proposal was made by NRL in 1933 to employ a chain of transmitting and receiving stations along a line to be guarded. for the purpose of obtaining some knowledge of distance and velocity.

The United States Army Signal Corps also maintained an interest in radar during the early 1930s.In 1939 the Army developed the SCR-270, a long-range radar for early warning. The attack on Pearl Harbor in December, 1941, was detected by an SCR-270, one of six in Hawaii at the time.

By June, 1935, the British had demonstrated the pulse technique to measure range of an aircraft target. This was almost a year sooner than the successful NRL experiments with pulse radar.

1.6 APPLICATIONS OF RADAR

Radar has been employed on the ground, in the air, on the sea, and in space. Ground-based radar has been applied chiefly to the detection, location, and tracking of aircraft or space targets.

Shipboard radar is used as a navigation aid and safety device to locate buoys, shore lines, and other ships. as well as for observing aircraft. Airborne radar may be used to detect other aircraft, ships, or land vehicles or it may be used for mapping of land, storm avoidance, terrain avoidance, and navigation. In space, radar has assisted in the guidance of spacecraft and for the remote sensing of the land and sea.

The major user of radar, and contributor of the cost of almost all of its development, has been the military: although there have been increasingly important civil applications, chiefly for marine and air navigation.

1. ***Air Traffic Control (A T C):*** Radars are employed throughout the world for the purpose of
safely controlling air traffic en route and in the vicinity of airports. Aircraft and ground
vehicular traffic at large airports are monitored by means of high-resolution radar.

2.Aircraft Navigation: The weather-avoidance radar used on aircraft to outline regions of precipitation to the pilot is a classical form of radar. Radar is also used for terrain avoidance and terrain.

3. Ship Safety: Radar is used for enhancing the safety of ship travel by warning of potential collision with other ships, and for detecting navigation buoys, especially in poor visibility. Automatic detection and tracking equipments (also called plot extractors) are commercially available for use with such radars for the purpose of collision avoidance. Shore-based radar **of** moderately high resolution is also used for the surveillance of harbors as an aid to navigation.

4.Space: Space vehicles have used radar for rendezvous and docking, and for landing on the moon. Some of the largest ground-based radars are for the detection and tracking of satellites. Satellite-borne radars have also been used for remote sensing.

5.Remote Sensing: Remote sensing with radar is also concerned with Earth resources, which includes the measurement and mapping of sea conditions, water resources, ice cover, agriculture, forestry conditions, geological formations, and environmental pollution. The platforms for such radars include satellites as well as aircraft.

6. Law Enforcement: The wide use of radar to measure the speed of automobile traffic by highway police, radar has also been employed as a means for the detection of intruders.

7.Military: The traditional role of radar for military application has been for surveillance, navigation, and for the control and guidance of weapons.

RECOMMENDED QUESITONS ON UNIT- 7

1. With the help of a block diagram, explain the operation of a radar system.

2. Derive radar range and equation.

3. Derive the radar equation. Discuss the effects of each parameter on the maximum detection range of the radar.

4.Write short notes of origin of radar

5.Wrtie any five important applications of Radar.

6. Write the frequency band designation of Radars