ABSTRACT

The objective of the project is to simulate the real time Radar detection and tracking operations using MATLAB software. Radar system use modulated waveforms and directive antennas to transmit electromagnetic energy into a specific volume in space to search for targets. Objects (targets) within a search volume will reflect portions of this energy (radar returns or echoes) back to the radar. These echoes are then processed by radar receiver to extract target information such as range. Velocity, angular position, and other target identifying characteristics. The project mainly concentrates on the radar displays and different radar types to collect the information of the flying objects, such as the range, speed, distance, angles. The display types are A-scope, B-scope, C-scope, PPI, and RHI, which are used in modern radars. While others are either obsolete or are found only in very specialized applications. Signals displayed on these scopes can be raw video, synthetic video (detected video) or computer-generated symbols. The radar types consider in the project are CWT (Continuous Wave Transmission), Pulse, Doppler, and MTI (Moving Target Indicator). For each display, all the values related to the object are calculated in different patterns and graphs for the corresponding formulated values and angles.

CHAPTER I

INTRODUCTION

1.1 BACKGROUND

Radars are very complex electronic systems. The term radar is an acronym for the RAdio Detection and Ranging, and is used to describe systems that utilized electromagnetic energy to detect distant objects. It can be classified as ground based, air bone, space borne, or ship based radar systems. They can also be classified into numerous categories based on the specific radar characteristics, such as the frequency band and antenna type. Another classification is concerned with the mission and the functionality of the radar. This includes weather, acquisitions and search, tracking, track-while-scan, fire control, early warning, over the horizon, terrain following and are often called multifunction radars. Radars may also be classified by the type of waveforms they used, or by their operating frequency. Considering the waveforms first, radar can be Continuous Wave (CW) or Pulsed Radar (PR). CW radars are those that continuously emit electromagnetic energy, and use separate transmit and receive antennas. Unmodulated CW radars can be accurately measure target radial velocity (Doppler Shift) and angular position. Target range information cannot be extracted without utilizing some form of modulation. High frequency (HF) radars utilize the electromagnetic waves reflection off the ionosphere to detect targets beyond the horizon. Some examples include the United States Over The Horizon Backscatter (U.S.OTH/B) radar, which operates in the frequency range of 5-28MHZ, the U.S. Navy Relocatable Over The Horizon Radar (ROTHR), and the Russian Woodpecker radar. Very High frequency (VHF) and Ultra High frequency (UHF) bands are used for very long range Early warning Radars (EWR). Radar is an active device in that it carries its own transmitter and does not depend on ambient radiation, as do most optical and infrared sensors. Radar can detect relatively small targets at near or far distances and can measure their range with precision in all weather, which is its chief advantage when compared with other sensors.

1.2 BASIC RADAR

Radar systems, like other complex electronics systems, are composed of several major subsystems and many individual circuits. Although modern radar systems are quite complicated, you can easily understand their operation by using a basic block diagram of a pulse-radar system. The basic concept of radar is relatively simple even though in many instances its practical implementation is not. A radar operates by radiating electromagnetic energy and detecting the echo returned from reflecting objects (targets). The nature of the echo signal provides information about the target. The range, or distance, to the target is found from the time it takes for the radiated energy to travel to the target and back. The angular location of the target is found with a directive antenna (one with a narrow beamwidth) to sense the angle of arrival of the echo signal. If the target is moving, a radar can derive its track, or trajectory, and predict the future location. The shift in frequency of the received echo signal due to the Doppler effect caused by a moving target allows a radar to separate desired moving targets (such as aircraft) from undesired stationary targets (such as land and sea clutter) even though the stationary echo signal may be many orders of magnitude greater than the moving target. With sufficiently high resolution, a radar can discern something about the nature of a target's size and shape. Radar resolution may be obtained in range or angle, or both. Range resolution requires large bandwidth. Angle resolution requires (electrically) large antennas. Resolution in the cross-range dimension is usually not as good as the resolution that can be obtained in range. However, when there is relative motion between the individual parts of a target and the radar, it is possible to use the inherent resolution in Doppler frequency to resolve in the cross-range dimension. The cross-range resolution of a synthetic aperture radar (SAR) for imaging a scene such as terrain can be explained as being due to resolution in Doppler, although a SAR is usually thought of as generating a large "synthetic" antenna by storing received signals in a memory. The two views—Doppler resolution and synthetic antenna—are equivalent. Resolution in the Doppler domain is a natural way to envision the cross-range resolution achieved by the inverse synthetic aperture radar (ISAR) used for the imaging of a target.

Radar is an active device in that it carries its own transmitter and does not depend on ambient radiation, as do most optical and infrared sensors. Radar can detect relatively small targets at near or far distances and can measure their range with precision in all weather, which is its chief advantage when compared with other sensors. The principle of radar has been applied from frequencies of a few megahertz (HF, or high-frequency region of the electromagnetic spectrum) to well beyond the optical region (laser radar). The particular techniques for implementing radar differ greatly over this range of frequencies, but the basic principles remain the same.

Radar was originally developed to satisfy the needs of the military for surveillance and weapon control. Military applications have funded much of the development of its technology. However, radar has seen significant civil applications for the safe travel of aircraft, ships, and spacecraft; the remote sensing of the environment, especially the weather; and law enforcement and many other applications. Figures 1.1 show us the basic principle of Radar.

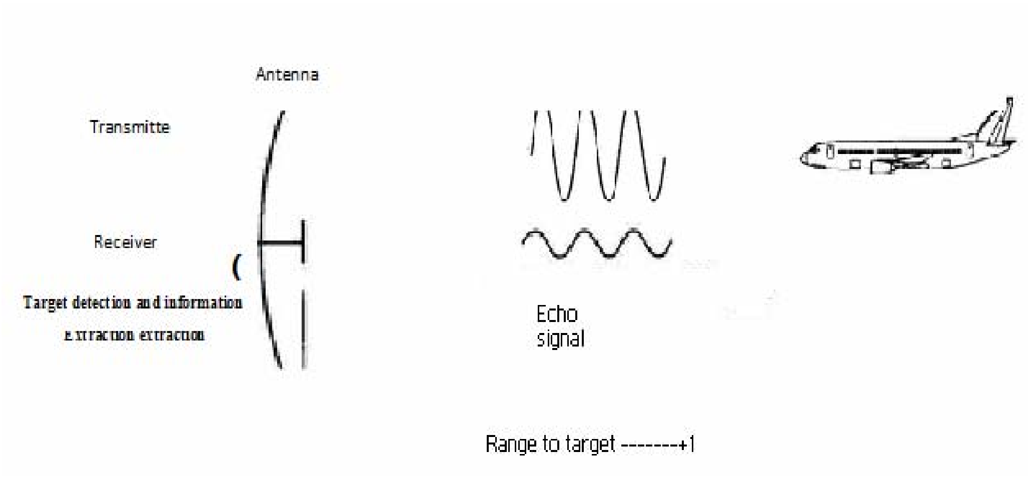

Figure 1.1 Basic Principle of Radar

1.3 DISSERTATION OBJECTIVE

The objectives of the project are:

- Study the radar systems and how radar works.

- Study the radar display types and how the information received by radar can be displayed.

- Develop a simulation of the real time Radar detection and tracking operations, using "MATLAB" software.

1.4 Thesis Layout.

The thesis is organized as follows:

Chapter 1: The basic concepts of what is the radar.

Chapter 2: The introduction history and sub-system of radars.

Chapter 3: Object Detection Using Radar, we will present the details of types of displays; types of radar developed using MATLAB.

Chapter 4: The full details of the system including simulator development, project design, coding; flow charts and the description of functions used in MATLAB.

Chapter 5: Conclusion and potential future works.

CHAPTER II

RADAR SYSTEM

2.1 INTRODUCTION

The basic concept of radar is relatively simple even though in many instances its practical implementation is not. A radar operates by radiating electromagnetic energy and detecting the echo returned from reflecting objects (targets). The nature of the echo signal provides information about the target. The range, or distance, to the target is found from the time it takes for the radiated energy to travel to the target and back. The angular location of the target is found with a directive antenna (one with a narrow beamwidth) to sense the angle of arrival of the echo signal. If the target is moving, a radar can derive its track, or trajectory, and predict the future location. The shift in frequency of the received echo signal due to the doppler effect caused by a moving target allows a radar to separate desired moving targets (such as aircraft) from undesired stationary targets (such as land and sea clutter) even though the stationary echo signal may be many orders of magnitude greater than the moving target. With sufficiently high resolution, a radar can discern something about the nature of a target's size and shape. Radar resolution may be obtained in range or angle, or both. Range resolution requires large bandwidth. Angle resolution requires (electrically) large antennas. Resolution in the cross-range dimension is usually not as good as the resolution that can be obtained in range. However, when there is relative motion between the individual parts of a target and the radar, it is possible to use the inherent resolution in doppler frequency to resolve in the cross-range dimension. The cross-range resolution of a synthetic aperture radar (SAR) for imaging a scene such as terrain can be explained as being due to resolution in doppler, although a SAR is usually thought of as generating a large "synthetic" antenna by storing received signals in a memory. The two views—doppler resolution and synthetic antenna—are equivalent. Resolution in the doppler domain is a natural way to envision the cross-range resolution achieved by the inverse synthetic aperture radar (ISAR) used for the imaging of a target.

2.2 RADAR BLOCK DIAGRAM

The basic parts of a radar system are illustrated in the simple block diagram of Fig. 2.1. The radar signal, usually a repetitive train of short pulses, is generated by the transmitter and radiated into space by the antenna. The duplexer permits a single antenna to be time-shared for both transmission and reception. Reflecting objects (targets) intercept and reradiate a portion of the radar signal, a small amount of which is returned in the direction of the radar. The returned echo signal is collected by the radar antenna and amplified by the receiver. If the output of the radar receiver is sufficiently large, detection of a target is said to occur. A radar generally determines the location of a target in range and angle, but the echo signal also can provide information about the nature of the target. The output of the receiver may be presented on a display to an operator who makes the decision as to whether or not a target is present, or the receiver output can be processed by electronic means to automatically recognize the presence of a target and to establish a track of the target from detections made over a period of time. With automatic detection and track (ADT) the operator usually is presented with the processed target track rather than the raw radar detections. In some applications, the processed radar output might be used to directly control a system (such as a guided missile) without any operator intervention.

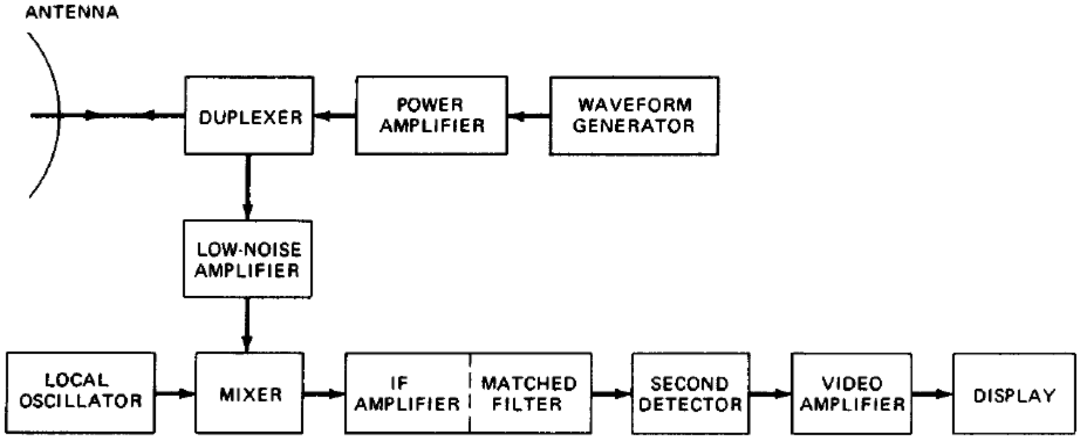

Fig 2.1 Simple block diagram of radar employing a power amplifier transmitter and a superheterodyne receiver.

The operation of the radar is described in more detail, starting with the transmitter. The transmitter generates powerful pulses of electromagnetic energy at precise intervals. The required power is obtained by using a high-power microwave oscillator (such as a magnetron) or a microwave amplifier (such as a klystron) that is supplied by a low-power RF source. Transmitters not only must be able to generate high power with stable waveforms, but they must often operate over a wide bandwidth, with high efficiency and with long, trouble-free life.

The duplexer acts as a rapid switch to protect the receiver from damage when the high-power transmitter is on. On reception, with the transmitter off, the duplexer directs the weak received signal to the receiver rather than to the transmitter. Duplexers generally are some form of gas-discharge device and may be used with solid-state or gas-discharge receiver protectors. A solid-state circulator is sometimes used to provide further isolation between the transmitter and the receiver.

The receiver is almost always superheterodyne. The input, or RF, stage can be a low-noise transistor amplifier. The mixer and local oscillator (LO) convert the RF signal to an intermediate frequency (IF) where it is amplified by the IF amplifier. The signal bandwidth of superheterodyne receiver is determined by bandwidth of its IF stage. The IF amplifier is followed by a crystal diode, which is traditionally called the second detector or demodulator. Its purpose is to assist in extracting the signal modulation from the carrier. The combination of IF amplifier, second detector, and video amplifier act as an envelope to pass the pulse modulation (envelope) and reject the carrier frequency. In radars that Doppler shift of the echo signal, the envelope detector is replaced by a phase detector, which is different from the envelope detector shown. The combination of IF amplifier and video amplifier is designed to provide sufficient amplification, or gain, to raise the level of the input signal to a magnitude where it can be seen on a display, such as a cathode-ray tube (CRT), or be the input to a digital computer foe further processing. At the output of the receiver a decision is made whether or not a target is present. The decision is based on the magnitude of the receiver output. If the output is larger enough to exceed a predetermined threshold, the decision is that a target is present. If it does not cross the threshold level is set so that the rate at which false alarms occur due to noise crossing the threshold (in the absence of signal) is below some specified, tolerable value. This is fine if the noise remains constant, as when receiver noise dominates. If, on the other hand, noise is external to radar (as from unintentional or from deliberate noise jamming) or if clutter echoes (from the natural environment) are larger than the receiver noise, the threshold has to be varied adaptively in order to maintain the false alarm rate at a constant value. This is accomplished by a constant false alarm rate (CFAR) receiver. Radar usually receiver many echo pulses from a target. The process of adding these pulses together to obtain a greater signal-to-noise ratio before the detection decision is made is called integration. The integrator is often found in the video portion of the receiver. The signal processor is that part of the radar whose function is to pass the desired echo signal and reject unwanted signals, noise, or clutter. The signal processor is found in the receiver before the detection is made. The matched filter mentioned previously, is an example of a signal. Another example is the doppler filter that separates desired moving targets (whose are shifted in frequency due to the Doppler effect) from undesired stationary clutter echoes.

Some radars process the detected target signal further, in the data processor, before displaying the information to an operator. An example is an automatic tracker, which uses the locations of the target measured over a period of time to establish the track (or path) of the target. Most modern air-surveillance radars and some surface-surveillance radars generate target tracks as their output rather than simply display detections. Following the data processor, or the decision function if there is no data processor, the radar output is displayed to an operator or used in a computer or other automatic device to provide some further action. The signal processor and data processor are usually implemented with digital technology rather than with analog circuitry. The analog-to-digital (A/D) converter and digital memory are therefore important in modern radar system. In some sophisticated radars in the past, the signal and data processors were larger and consumed more power than the transmitter and were a major factor in determining the overall radar system reliability; but this should not be taken as true in all cases.

2.3 RADAR SUBSYSTEM

Basic parts of a typical radar system. The transmitter generates the high-power signal that is radiated by the antenna. The antenna is often in the shape of a parabolic reflector, similar in concept to an automobile headlight but much different in construction and size. It also might consist of a collection of individual antennas operating together as a phased-array antenna. In a sense, an antenna acts as a “transducer” to couple electromagnetic energy from the transmission line to radiation in space, and vice versa. The duplexer permits alternate transmission and reception with the antenna; in effect, it is a fast-acting switch that protects the sensitive receiver from the high power of the transmitter.

The receiver selects and amplifies the weak radar echoes so that they can be displayed on a television-like screen for the human operator or be processed by computer. The signal processor separates the signals reflected by target (*e.g.* echoes from an aircraft) from unwanted echo signals (the clutter from land, sea, rain, etc.). It is not unusual for these undesired reflections to be much larger than desired target echoes, in some cases more than one million times larger. Larger clutter echoes from stationary objects can be differentiated from small echoes moving target by noting the shift in the observed frequency produced by moving target. The type of signal waveform transmitted and associated received-signal processing in a radar system might be different depending on type of target involved and the environment in which it is located. An operator can select the parameters of the radar to maximize performance in a particular environment. Alternatively, electronic circuitry in the radar system can be automatically analyze and select the proper transmitted signal, signal processing and other radar parameters to optimize performance. The system control also can provide timing and reference signals needed to permit the various parts of the radar to operate effectively as an integrated system.

2.3.1 Transmitters

The system surrounding the transmitter is made is made up of three main elements: the oscillator, the modulator, and the transmitter itself. The transmitter supplies energy to the antenna in the form of high-energy electrical signal. The antenna then sends out electromagnetic radar waves as the passes through it.

2.3.1.1 Local Oscillators

Most radar receivers use a 30- or 60-MHz inter- mediate frequency. A highly important factor in receiver operation is the tracking stability of the local oscillator, which generates the frequency that beats with the incoming signal to produce the IF. For example, if the local oscillator frequency is 3000 MHz, a frequency shift of as much as 0.1 percent would be a 3-MHz frequency shift. This is equal to the bandwidth of most receivers and would cause a considerable loss in gain. Bandwidth is the inverse of the pulsewidth, with a wider bandwidth for narrow pulses. In receivers that use crystal mixers, the power required of the local oscillator is small, only 20 to 50 milliwatts in the 4000-MHz region. Because of the very loose coupling, only about 1 milliwatt actually reaches the crystal. Another requirement of a local oscillator is that it must be tunable over a range of several megahertz to compensate for changes in both the transmitted frequencies and its own frequency. It is desirable that the local oscillator have the capability of being tuned by varying its voltage. Because the reflex klystron meets these requirements, it is used as a local oscillator in some radar receivers. As the local oscillator in a microwave receiver, a reflex klystron need not supply large amounts of power, but it should oscillate at a frequency that is relatively stable and easily controlled. The need for a wide electronic tuning range suggests the use of a voltage mode of a high order. However, if a mode of an excessively high order is selected, the power available will be too small for local oscillator applications, and a compromise between wide range and power is necessary. Also, the use of a very- high-order mode is undesirable because the noise output of a reflex klystron is essentially the same for all voltage modes. Thus, the closer coupling to the mixer required with high-order, low-power modes increases the receiver noise figure. Usually, the 1-3/4- or 2-3/4-voltage mode is found suitable. Since the modes are not symmetrical, the point of operation is usually a little below the resonant frequency of the cavity. This makes possible tuning above the operating frequency to a greater degree than if the precise resonant frequency is used. In practice, the reflex klystron is used with an automatic frequency-control circuit. Since the repeller voltage is effective in making small changes in frequency, the AFC circuit is used to control the repeller voltage to maintain the correct intermediate frequency. It should be noted that the coarse frequency of oscillation is determined by the dimensions of the cavity, and there is, on most reflex klystrons, a coarse frequency adjustment, which varies the cavity size. Reflex klystrons are also used as drivers for RF power amplifier klystrons. When they are used as drivers, the frequency and the amplitude stability are much more critical. Any variation in driver frequency is reproduced in the power amplifier output and, thus, on the target echo signal. This frequency-modulation (FM) variation can result in degraded Doppler track- ing and velocity computations. If the FM deviation is large enough or if the driver is not operated at the peak of a mode, then amplitude variations will occur. This amplitude modulation (AM) may be very small in magnitude on the driver signal, but after a gain of 30 dB or more in the power amplifier, the magnitude can be considerable. Both FM and AM signals are undesirable and are classified as noise. Therefore, extra care in tuning and maintenance of the power supplies is required to mini- mize FM and AM noise generation.

2.3.1.2 The Modulator

The next stage of a radar system is modulator. It is the heart of the radar system and generates all the necessary timing pulses (triggers) for use in the radar and associated systems. Its function is to ensure that all subsystems making up the radar system operate in a definite time relationship with each other and that the intervals between pulses, as well as the pulses themselves, are of the proper length.

2.3.1.3 The Transmitter

The radar system's transmitter increases the power of the oscillator. The transmitter amplifies the power from the level of about 1 watt to as much as 1 megawatter, or 1 million watts. Radar signals have such high power levels because so little of the original signal comes back in the return.

2.3.2 Receivers

The receiver accepts the weak RF echoes from the antenna system and routes them to the indicator as discernible video signals. Because the radar frequencies are very high and difficult to amplify, a superheterodyne receiver is used to convert the echoes to a lower frequency, called the intermediate frequency (IF), which is easier to amplify.

2.3.2.1 The Duplexer

The duplexer acts as a rapid switch to protect the receiver from damage when the high-power transmitter is on. On reception, with the transmitter off, the duplexer directs the weak received signal to the receiver rather than to the transmitter. Duplexers generally are some form of gas-discharge device and may be used with solid-state or gas-discharge receiver protectors. A solid-state circulator is sometimes used to provide further isolation between the transmitter and the receiver.

2.3.2.2 Signal Processing

There has not always been general agreement as to what constitutes the signal-processing portion of the radar, but it is usually considered to be the processing whose purpose is to reject undesired signals (such as clutter) and pass desired signals due to targets. It is performed prior to the threshold detector where the detection decision is made. Signal processing includes the matched filter and the Doppler filters in MTI and pulse Doppler radar. Pulse compression, which is performed before the detection decision is made, is sometimes considered to be signal processing, although it does not fit the definition precisely.

2.3.2.2 Data Processing

This is the processing done after the detection decision has been made. Automatic tracking is the chief example of data processing. Target recognition is another example. It is best to use automatic tracking with a good radar that eliminates most of the unwanted signals so that the automatic tracker only has to deal with desired target detections and not undesired clutter.

When a radar cannot eliminate all nuisance echoes, a means to maintain a constant false-alarm rate (CFAR) at the input to the tracker is necessary. The CFAR portion of the receiver is usually found just before the detection decision is made. It is required to maintain the false-alarm rate constant as the clutter and/or noise background varies. Its purpose is to prevent the automatic tracker from being overloaded with extraneous echoes. It senses the magnitude of the radar echoes from noise or clutter in the near vicinity of the target and uses this information to establish a threshold so that the noise or clutter echoes are rejected at the threshold and not confused as targets by the automatic tracker. Unfortunately, CFAR reduces the probability of detection. It also results in a loss in signal-to-noise ratio, and it degrades the range resolution. CFAR or its equivalent is necessary when automatic tracking computers cannot handle large numbers of echo signals, but it should be avoided if possible. When an operator is used to make the threshold decision, CFAR is not a necessity as in limited capacity automatic systems because the operator can usually recognize echoes due to clutter or to increased noise (such as jamming) and not confuse them with desired targets.

2.3.2.3 The Displays

The display for surveillance radar is usually a cathode-ray tube with a PPI (plan position indicator) format. A PPI is an intensity-modulated, maplike presentation that provides the target's location in polar coordinates (range and angle). Older radars presented the video output of the receiver (called raw video) directly to the display, but more modern radars generally display processed video, that is, after processing by the automatic detector or the automatic detector and tracker (ADT). These are sometimes called cleaned-up displays since the noise and background clutters are removed.

2.4 TYPES OF RADAR

Radar system may be categorized according to the function they perform (e.g. aircraft surveillance, surveillance, surface (ground or sea) surveillance, space surveillance, tracking, weapon control, missile guidance, instrumentation, remote sensing of the environment, intruder detection, or underground probing. They also may be classified, as in the listing below, on the basis of the particular radar technique they employ. It is difficult to give in only a few words precise and readily understandable descriptions of the many type of radar available. The following survey is necessarily brief and qualitative.

2.4.1 Simple pulse radar

This is by far the most widely used technique and constitutes what might be termed “conventional” radar. All but the last two techniques outlined below employ a pulse waveform; however, they have additional features that give an enhanced performance as compared to simple radar.

2.4.2 Moving-target indication (MTI) radar

This is a form of pulse radar that uses the Doppler frequency shift of the received signal to detect moving target, such as aircraft, and to reject the large unwanted echoes from stationary clutter that do not have a Doppler shift. Almost all ground-based aircraft surveillance radar system use some form of MTI.

2.4.3 Airborne moving-target indication (AMTI) radar

An MTI radar in an aircraft encounters problems not found in a ground-based system of the same kind because the large undesired clutter echoes from the ground and the sea have sea have a Doppler frequency shift introduced by the motion of the aircraft carrying the radar. The AMTI radar, however, compensates for the Doppler frequency shift of the clutter, making it possible to detect moving targets even though the radar unit itself is in motion.

2.4.4 Pulse Doppler radar (with high pulse-repetition frequency)

As with the MTI system, the pulse Doppler radar is a type of pulse radar that utilizes the Doppler frequency shift of the echo signal to reject clutter and detect moving aircraft. However, it operates with a much higher pulse-repetition frequency (PRF) than the MTI radar. (A high-PRF pulse Doppler radar, for example, might have a PRF of 100 kHz, as compared to MTI radar with PRF of perhaps 300 Hz). The different of PRFs give rise to distinctly different behaviour. The MTI radar uses a low PRF in order to obtain an unambiguous range measurement. This causes the measurement of the target’s radial velocity (as derived from the Doppler frequency shift) to be highly ambiguous and can result in missing some target detections. On the other hand, the pulse Doppler radar operates with a high PRF so as to have no ambiguities in the measurement of radial velocity. A high PRF, however, causes a highly ambiguous range measurement. The true range is resolved by transmitting multiple waveforms with different PRFs.

2.4.5 Pulse Doppler radar (with medium pulse-repetition frequency)

A modified form of pulse Doppler radar that operates at a lower PRF (10 KHz, for example) than the above-mentioned high-PRF pulse Doppler system has both range and Doppler shift ambiguities. It is, however, better for detecting aircraft with low closing speeds than high-PRF pulse Doppler radar (which is better for detecting aircraft with high closing speeds). An aircraft medium-PRF pulse Doppler radar might have to use seven or eight different PRFs in order to extract the target information ambiguities.

2.4.6 High-range-resolution radar

This type of radar uses a very short pulse with range resolution from several metres to a fraction of a metre. Such a radar can profile a target and measure its projected length in the range dimension.

2.4.7 Pulse-compression radar

The ability to generate very short pulses with high peak power (and high energy) is limited for practical reasons by voltage breakdown, or arcing. Thus, conventional high-range-resolution radars with short pulses often are limited in peak power and are not capable of operating at long ranges. Pulse compression overcomes this limitation by obtaining the resolution of a short pulse but with the energy of a long pulse. It does this by modulating either the frequency or the phase of a long, high-energy pulse. The frequency or phase modulation allows the long pulse to be compressed in the receiver by an amount equal to the reciprocal of the signal bandwidth.

2.4.8 Synthetic aperture (SAR)

The SAR was described above as utilizing resolution in Doppler frequency to provide the equivalent of cross-range (or angle) resolution. More often, it is regarded as a synthetic antenna generated by a moving radar. The effect of a large antenna is obtained by storing the echo signals in a storage medium, or memory, and processing a substantial number of the previously received echoes just as if they were received by a large antenna. This kind of radar is primarily used for mapping the Earth's surface. Although it is not obvious, the two different models used for describing a SAR--a synthetic antenna and Doppler-frequency resolution--are equivalent and produce the same results.

2.4. 9 Inverse synthetic aperture radar (ISAR)

As previously noted, an ISAR depends on target motion to provide the Doppler frequency shift between various parts of the target and the radar unit so as to obtain high resolution in cross range. A two-dimensional high-resolution image of a target can be obtained by using ISAR for cross-range resolution in conjunction with either a short pulse or pulse-compression radar for resolution in the range dimension.

2.4.10 Side-looking airborne radar (SLAR)

This variety of airborne radar employs a large side-looking antenna (*i.e.,* one whose beam is perpendicular to the aircraft's line of flight) and is capable of high range resolution. (The resolution in cross range is not as good as can be obtained with SAR, but it is simpler than the latter and is acceptable for some applications.) SLAR generates maplike images of the ground and permits detection of ground targets.

2.4.11 Imaging radar

Synthetic aperture, inverse synthetic aperture, and side-looking airborne radar techniques are sometimes referred to as imaging radars.

2.4.12 Tracking radar

A radar tracker is a component of a radar system, or an associated command and control system, that associates consecutive radar observations of the same target into tracks. It is particularly useful when the radar system is reporting data from several different targets or when it is necessary to combine the data from several different radars or other sensors.

2.4.13 Track-while-scan radar

This form of surveillance radar can provide tracks of all targets within its area of coverage by measuring the location of targets on each rotation of the antenna. Though called track-while-scan radar, it is more often known as automatic detection and tracking, or ADT. The output on a visual display from such a radar usually consists of the tracks of the targets (vectors showing direction and speed) rather than individual detections (blips). This type of tracking is suitable for surveillance radars, while continuous tracking is more appropriate for weapon control and instrumentation-radar applications.

2.4.14 3D radar

Conventional air-surveillance radar measures the location of a target in two dimensions--range and azimuth. The elevation angle, from which target height can be derived, also can be determined. The so-called 3D radar is an air-surveillance radar that measures range in a conventional manner but that has an antenna which is mechanically rotated about a vertical axis to obtain the azimuth angle of a target and which has either fixed multiple beams in elevation or a scanned pencil beam to measure its elevation angle. There are other types of radar (such as electronically scanned phased arrays and tracking radars) that measure the target location in three dimensions, but a radar that is properly called 3D is an air-surveillance system that measures the azimuth and elevation angles as just described.

2.4.15 Electronically scanned phased-array radar

An electronically scanned phased-array antenna can position its beam rapidly from one direction to another without mechanical movement of large antenna structures. Agile, rapid beam switching permits the radar to track many targets simultaneously and to perform other functions as required.

2.4.16 Continuous-wave (CW) radar

Since a CW radar transmits and receives at the same time, it must depend on the Doppler frequency shift produced by a moving target to separate the weak echo signal from the strong transmitted signal. A simple CW radar can detect targets, measure their radial velocity (from the Doppler frequency shift), and determine the direction of arrival of the received signal. However, a more complicated waveform is required for finding the range of the target.

2.4.17 Frequency-modulated continuous-wave (FM-CW) radar

If the frequency of a CW radar is continually changed with time, the frequency of the echo signal will differ from that transmitted and the difference will be proportional to the range of the target. Accordingly, measuring the difference between the transmitted and received frequencies gives the range to the target. In such a frequency-modulated continuous-wave radar, the frequency is generally changed in a linear fashion, so that there is an up-and-down alternation in frequency. The most common form of FM-CW radar is the radar altimeter used on aircraft to determine height above the ground. Phase modulation, rather than frequency modulation, of the CW signal has also been used to obtain range measurement.

2.5 FACTORS AFFECTING RADAR PERFORMANCE

The performance of a radar system can be judged by the following: (1) the maximum range at which it can see a target of a specified size, (2) the accuracy of its measurement of target location in range and angle, (3) its ability to distinguish one target from another, (4) its ability to detect the desired target echo when masked by large clutter echoes, unintentional interfering signals from other "friendly" transmitters, or intentional radiation from hostile jamming (if a military radar), (5) its ability to recognize the type of target, and (6) its availability (ability to operate when needed), reliability, and maintainability. Some of the major factors that affect performance are discussed in this section.

2.5.1 Transmitter power and antenna size.

The maximum range of a radar system depends in large part on the average power of its transmitter and the physical size of its antenna. (In technical terms, this is the power-aperture product.) There are practical limits to each. As noted before, some radar systems have an average power of roughly one megawatt. Phased-array radars about 100 feet in diameter are not uncommon; some are much larger. Likewise, mechanically scanned reflector antennas about 100 feet or larger in size can be found. There are specialized radars with (fixed) antennas, such as some HF over-the-horizon radars and the U.S. Space Surveillance System (SPASUR), that extend more than one mile.

2.5.2 Receiver noise

The sensitivity of a radar receiver is determined by the unavoidable noise that appears at its input. At microwave radar frequencies, the noise that limits detectability is usually generated by the receiver itself (i.e., by the random motion of electrons at the input of the receiver) rather than by external noise that enters the receiver via the antenna. The radar engineer often employs a transistor amplifier as the first stage of the receiver even though lower noise can be obtained with more sophisticated devices. This is an example of the application of the basic engineering principle that the "best" performance that can be obtained might not necessarily be the solution that best meets the needs of the user. The receiver is designed to enhance the desired signals and to reduce the noise and other undesired signals that interfere with detection. The designer attempts to maximize the detectability of weak signals by using what radar engineers call a "matched filter," which is a filter that maximizes the signal-to-noise ratio at the receiver output. The matched filter has a precise mathematical formulation that depends on the shape of the input signal and the character of the receiver noise. A suitable approximation to the matched filter for the ordinary pulse radar, however, is one whose bandwidth in hertz is the reciprocal of the pulse width in seconds.

2.5.3 Object size

The size of a target as "seen" by radar is not always related to the physical size of the object. The measure of the target size as observed by radar is called the radar cross section and is given in units of area (square metres). It is possible for two targets with the same physical cross sectional area to differ considerably in radar size, or radar cross section. For example, a flat plate one square metre in area will produce a radar cross section of about 1,000 square metres at a frequency of 3,000 megahertz (S band; see below) when viewed perpendicular to the surface. A cone-sphere (an object resembling an ice-cream cone) when viewed in the direction of the cone rather than the sphere could have a radar cross section one thousandth of a square metre even though its projected area is also one square metre. In theory, this value does not depend to a great extent on the size of the cone or the cone angle. Thus the flat plate and the cone-sphere can have radar cross sections that differ by a million to one even though their physical projected areas are the same. The sphere is an unusual target in that its radar cross section is the same as its physical cross section area (when its circumference is large compared to the radar wavelength). That is to say, a sphere with a projected area of one square metre has a radar cross section of one square metre. Commercial aircraft might have radar cross sections from about 10 to 100 square metres, except when viewed broadside, where it is much larger. (This is an aspect that is seldom of interest, however.) Most air-traffic-control radars are required to detect aircraft with a radar cross section as low as two square metres, since some small general-aviation aircraft can be of this value. For comparison, the radar cross section of a man has been measured at microwave frequencies to be about one square metre. A bird can have a cross section of 0.01 square metre. Although this is a small value, a bird can be readily detected at ranges of several tens of miles by long-range radar. In general, many birds can be picked up by radar so that special measures must usually be taken to insure that echoes from birds do not interfere with the detection of desired targets. The radar cross section of an aircraft and most other targets of practical interest is not a constant but, rather, fluctuates rapidly as the aspect of the target changes with respect to the radar unit. It would not be unusual for a slight change in aspect to cause the radar cross section to change by a factor of 10 to 1,000. (Radar engineers have to take this fluctuation in the radar cross section of targets into account in their design.)

2.5.4 Clutter

Echoes from land, sea, rain, snow, hail, birds, insects, auroras, and meteors are of interest to those who observe and study the environment, but they are a nuisance to those who want to detect and follow aircraft, ships, missiles, or other similar targets. Clutter echoes can seriously limit the capability of a radar system; thus a significant part of radar design is devoted to minimizing the effects of clutter without reducing the echoes from desired targets. The Doppler frequency shift is the usual means by which moving targets are distinguished from the clutter of stationary objects. Detection of targets in rain is less of a problem at the lower frequencies, since the radar echo from rain decreases rapidly with decreasing frequency and the average cross section of aircraft is relatively independent of frequency in the microwave region. Because raindrops are more or less spherical (symmetrical) and aircraft are asymmetrical, the use of circular polarization can enhance the detection of aircraft in rain. With circular polarization, the electric field rotates at the radar frequency. Because of this, the electromagnetic energy reflected by the rain and the aircraft will be affected differently, thereby making it easier to distinguish between the two. (In fair weather, most radars use linear polarization--*i.e.,* the direction of the field is fixed.)

2.5.5 Atmospheric effects

As was mentioned, rain and other forms of precipitation can cause echo signals that mask the desired target echoes. There are other atmospheric phenomena that can affect radar performance as well. The decrease in density of the Earth's atmosphere with increasing altitude causes radar waves to bend as they propagate through the atmosphere. This usually increases the detection range at low angles to a slight extent. The atmosphere can form "ducts" that trap and guide radar energy around the curvature of the Earth and allow detection at ranges beyond the normal horizon. Ducting over water is more likely to occur in tropical climates than in colder regions. Ducts can sometimes extend the range of airborne radar, but on other occasions they may cause the radar energy to be diverted and not illuminate regions below the ducts. This results in the formation of what are called radar holes in the coverage. Since it is not predictable or reliable, ducting can in some instances be more of a nuisance than a help. Loss of radar energy, when propagation is through the clear atmosphere or rain, is usually insignificant for systems operating at microwave frequencies.

2.6 RADAR TO AN OBJECT

The most common radar signal, or waveform, is a series of short duration, somewhat rectangular-shaped pulses modulating a sine wave carrier. (This is sometimes called a pulse train.) The range to a target is determined by the time TR it takes is determined by the time TR it takes the radar signal to travel to the target and back. Electromagnetic energy in free space travels with the speed of light, which is **c=** $\mathbf{3x10^8}$ **m/s.** Thus the time for the singal to travel to a target located at a range **R** and returns back the back is 2R/c. The range to target is then

$$\mathbf{T}= \frac{cT_R}{2} \qquad \mathbf{(2.1)}$$

With the range in Kilometers or in nautical miles, and **T** in microsecond, Eq. (2.1)

R (Km) = 0.15 T_R (μs) or R (nmi) = 0.081 T_R (μs)

$$G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi \rho_a A}{\lambda^2}$$

Ae=Antenna effective aperture
Smin = Minimum detectable signal
σ= Radar cross section of the target
Power density at range *R* from an isotropic antenna= $\frac{Pt}{4\pi R^2}$

Power density at range *R* from an directive antenna= $\frac{Pt\ G}{4\pi R^2}$

2.7 MAXIMUM UNAMBIGUOUS RANGE

The maximum unambiguous range, Rmax, corresponds to half the distance electromagnetic energy can travel between pulses (since the energy needs to travel to the target and back). The pulse repetition frequency (PRF) is a measure of how frequently the pulses are transmitted. If c is the speed of light (taken as $3x10^{8}$ $m{\cdot}s^{-1}$), then

$$\mathbf{R\ max} = \left[\frac{c}{(2xPRF)}\right] \qquad \mathbf{(2.2)}$$

2.8 Radar Waveforms

The typical radar utilizes a pulse waveform, an example of which is shown in fig.2.3. the peak power in this example is Pt = 1 MW, pulse width T = 1μs, and pulse repetition period T_p= 1ms = 1000 μs. (the number shown were chosen for a medium-range air-surveillance radar.) the pulse repetition frequency fp is 1000Hz, which provides a maximum unambiguous range of 150Km, or 81nmi. The average power (Pav) of a repetitive pulse-train waveform is equal to $\frac{Pt\ T}{Tp}$

So the average power in this case is = 1 KW. The duty cycle of a radar waveform is defined as the ratio of the total time the radar is radiating to the total time it could have radiated, which is T/Tp = Tfp, or its equivalent Pav/Pt. in this case the duty cycle is 0.001. the energy of the pulse is equal to PtT, which is 1 J (joule). If duty cycle is 0.001. The energy of the pulse is equal a signal of 10^{-12}W. the echo would be 180 dB below the level of the signal that was transmitted. A short-duration pulse waveform is attractive since the strong transmitted. A short-duration pulse waveform is attractive strong transmitter signal is not attractive since received. With a pulse width T of 1 μs. The waveform extends in space over a distance cT=300 m. two equal targets can be recognized as being resolved in range when they are separated a distance half this value, or CT/2. The factor of one-half results from the two-way travel of the radar wave. For example, when T=1 μs, two equal size targets can be resolved if they are separated by 150m.

A very long pulse is needed for some long range. A long pulse, however, has poor resolution in the range dimension. Frequency or phase modulation can be used to increase the spectral width of a long pulse to obtain the resolution of a short pulse. This is called pulse compression. Continuous wave (CW) waveforms have also been used in radar. Since they have to receive while transmitting, CW radars depend on the Doppler frequency shift of the echo single, caused by a moving target, to separate in the frequency domain the weak echo signal from the large transmitted signal and the echoes from fixed clutter (land, sea, or weather), as well as to measure the radial velocity of the target. Simple CW radar does not measure range. It can obtain range, however, by modulating the carrier with frequency or phase modulation. An example is the frequency modulation (FM – CW) waveform used in the radar altimeter that measures the height (altitude) of an aircraft above the earth.

Pulse radars that extract the Doppler frequency shift are called either moving target indication (MTI) or pulse Doppler radars, depending on their particular values of pulse repetition frequency and duty cycle. MTI radar has a low PRF and a low duty cycle. A pulse Doppler radar, on the other hand, has a high PRF and a high duty cycle. Almost all radars designed to detect aircraft use the Doppler frequency shift to reject the large unwanted echoes from stationary clutter.

It is very useful to trace out and track the information related to the space moving objects such as aircrafts and any other flying objects the system which we developed the simulation will track all the information related to the object such as what is the object, what is the speed

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