# NEAR EAST UNIVERSITY

## Faculty of Engineering

Department of Electrical and Electronic Engineering

# Airport Surveillance Radar

Graduation Project
EE-400

Student: Hazem-Mohammed Abushaban

(20000522)

Supervisor: Assoc. Prof. Dr. Sameer Ikhdair

Nicosia - 2005

# ACKNOWLEDGMENTS

First at all I would like to thank Allah Almighty who gave me the strength to complete this project.

Also I would like to thank my Supervisor Assoc. Prof. Dr. Sameer Ikhdair for his valuable advice and belief in my work and my self over the course of this Graduation Project.

I would like to thank all our Stuff in the Near East University, Faculty of Engineering especially my Advise Mr. Özgür Özerdem, the Dean of the Faculty Prof. Fakhreddtin Madedov, and the vice president of the University Assoc Prof. Dr. Şenol Bektas.

I would like to thank my father Mohammed Abushaban and my family who have supported, and sponsored me through out my life and encouraged me in every aspect of my life. What I am today is because of them, the greatness of my father is unable to be explained in words.

Finally I thank al my friends in the Near East University especially Rami Matar.

I dedicate to all people mintioned above.

# ABSTRACT


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,

An elementary form of radar consists 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 usual method of measuring the direction of arrival is with narrow antenna beams. If relative motion exists between target and radar, the shift in the carrier frequency of the reflected wave (Doppler Effect) is a measure of the target's relative (radial) velocity and may he used to distinguish moving targets from stationary objects. In radars, which continuously track the movement ofa target, a continuous indication of the rate of change of target position is also available.

# TABLE OF CONTENTS

INTRODUCTIONS

We had thought to do our work on the radar system, and then we search for the important part on this subject is airport surveillance radar is one of the most common and important parts in the same parts in the communication system..

In modern times, radar is used in wide variety of applications including air traffic control, defense, meteorology, and even mapping, radar is "radio detecting and ranging", an electromagnetic sensor used for detecting, locating, tracking, and identifying objects of various kinds at considerable distances, it operates by transmitting electromagnetic energy toward objects, commonly referred to as targets, and observing the echoes returned from them. The target may be aircraft, ships, spacecraft, automotive vehicles, and astronomical bodies, or even birds, insects, and raindrops.
Radar can not only determine the presence, location, and velocity of such objects but can sometimes obtain their size and shape as well. What distinguishes radar from optical and infrared sensing devices is its ability to detect faraway objects under all weatlıer coıiditioiıs andto deteiiriine their ringe with precision.

Radar is an "active" sensing device in that it has its own source of illumination (a transmitter) for locating targets. In certain respects, it resembles active sonar, which is used chiefly for detecting submarines and other objects underwater; however, the acoustic waves of sonar propagate differently from electromagnetic waves and have different. properties. Radar typically operates in the microwave region of the electromagnetic spectrum namely, at frequencies extending from about 400 MHz to 40 GHz. It has, however, been used at lower frequencies for Iong-range applications.

Surveillance radara device which, by measuring the time interval between transmission and reception of radio pulses and correlating the angular orientation of the radiated antenna beam or beams in azimuth and/or elevation, provides information on range, azimuth, and/or elevation of objects in the patlı of the transmitted pulses.

Surveillance radars are divided into two general categories. Airport surveillance radar (ASR) and air route surveillance radar (ARSR). Surveillance radars scan through 360 degrees of azimuth and present target information on a radar display located in a tower

(ATCT) or center (ARTCC). This information is used independently or in conjunction with other navigational aids in the control of air traffic.

The project is divided in to four chapters and conclusion,

Chapter one studies the radar fundamentals, radar system description, components of a radar system, factors affecting radar performance, radar development, major applications of radar.

Chapter two, present the type of radar, by studies many difference radar systems such as Airport Surveillance Radar, Weather radar, Pulsed Radar System, CW Radar, Pulse Doppler Radar, Pulse-Compression Radar, Synthetic Aperture Radar (SAR), 3-D Radar.

Chapter three present the airport surveillance radar, primary surveillance radar, secondary surveillance radar and we explain the radar's role in the air traffic control showing the advantages and the disadvantages of the airport radar.

Chapter four, which is radar systems in Ercan Airport, in this chapter we explain the operation and the basic elements of the radar systems used in Ercan Airport then we present some important systems have related with Ercan's radar to make the operation of the ATC easier.

Finally, the conclusion section presents the .important .results obtained -within the project.

# CHAPTERONE

# FUNDAMENTALS OF RADAR

## 1.1 General Introduetion

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. üne 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 patteriis 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. There for 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. 2 Learning Objectives

Leaming objectives are stated at the beginning of each chapter. These leaming objectives serve as a preview of the information you are expected to leam 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 leamed 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

## 1.3 Introduetien **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 ofa 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 seme degree,' depending on freqtiency.'1t permitsfadat' systenistô 'determine tlie 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 berter than those early versions .

Modem 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 .

## 1.4 Basic Radar Coneepts

The electronics principle on which radar operates is very similar to the principle of sound-wave reflection. If you shout in the direction ofa 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 lmown. Radar uses electromagnetic energy pulses in much the same way, as shown in figure 1.1. The radio-frequency energy is transmitted to and reflects from the reflecting object. A small portion of the energy is reflected and returns to the radar set. This returned energy is called an ECHO, just as it is in sound terminology. Radar sets use the echo to determine the direction and distance of the reflecting object.

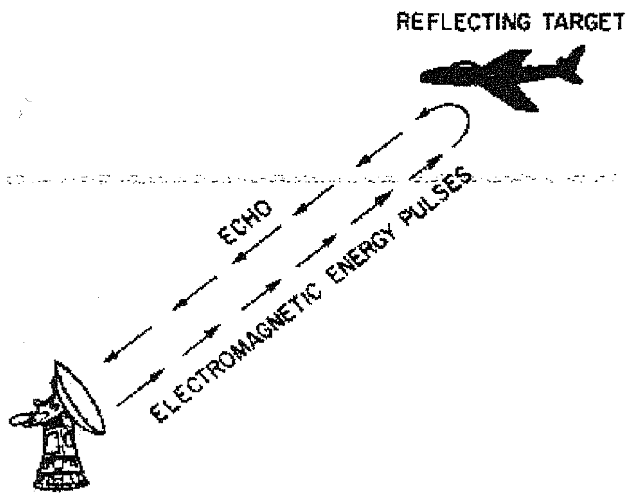



Figure 1.1 Radar echo.

Note: the terms target, return, echo, contact, object, and reflecting object are used interchangeably throughout this module to indicate a surface or airborne object that has been detected by a radar system .

Radar systems also have some characteristics in common with telescopes. Both provide only a limited field of view and require reference coordinate systems to define the positions of detected objects. If you describe the location of an object as you see it through a telescope, you will most likely refer to prominent features of the landscape. Radar requires a more precise reference system. Radar surface angular measurements are normally made in a clockwise direction from true north, as shown in figure 1.2, or from the heading line of a ship or aircraft. The surface of the earth is represented by an imaginary flat plane, tangent (or parallel) to the earth's surface at that location. This plane is referred to as the horizontal plane. All angles in the up direction are measured in a second imaginary plane that is perpendicular to the horizontal plane .

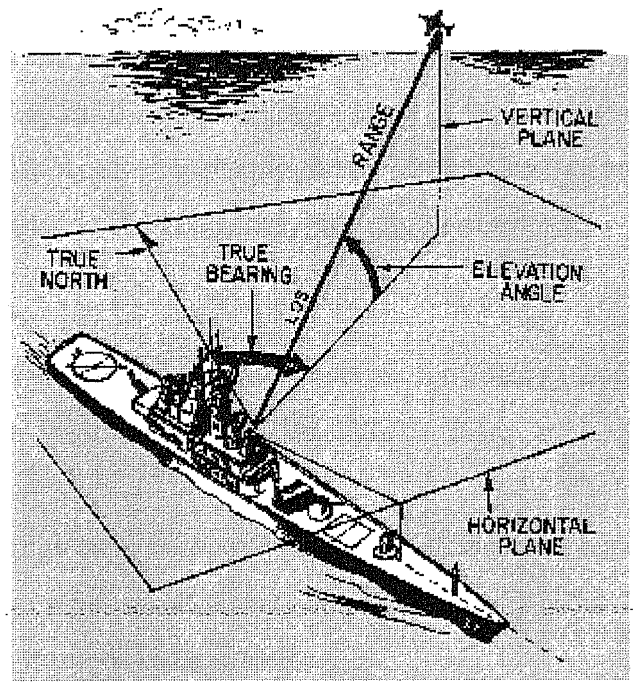



Figure **1.2** Radar reference coordinates.

This second plane is called the vertical plane. The radar location is the center of this coordinate system. The line from the radar set directly to the object is referred to as the line of sight (loss). The length of this line is called range. The angle between the horizontal plane and the loss 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 .

1.5 Radar System Deseripüon

1.5.1 Background Informarion

Again the radar stands for:

- 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 ofa monostatic radar system. Monostatic means that the receiver and transmitter are in the same place.
- A radar system achieves its purpose is by firstly transmitting a signal from its antenna .This signal is in the form of an electromagnetic wave bounces of the target and proceeds to the receiver antenna of the radar system .
- The "bouncing" off the target changes some of the parameters of the transmitted signal and the receiver measures these changes and extracts the information about the target, i.e. its speed, size, heading, position ete.

Radar used for:

- Radar il used to gain information about the surrounding area.
- For example what is the weather like, is there an aircraft, ship, tank ete 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 (Airbome Waming And Control System) is an example of an airbome supervisory role of radar. There are many other application of radar system.

### 1.5.2 The Parts ofa Radar System

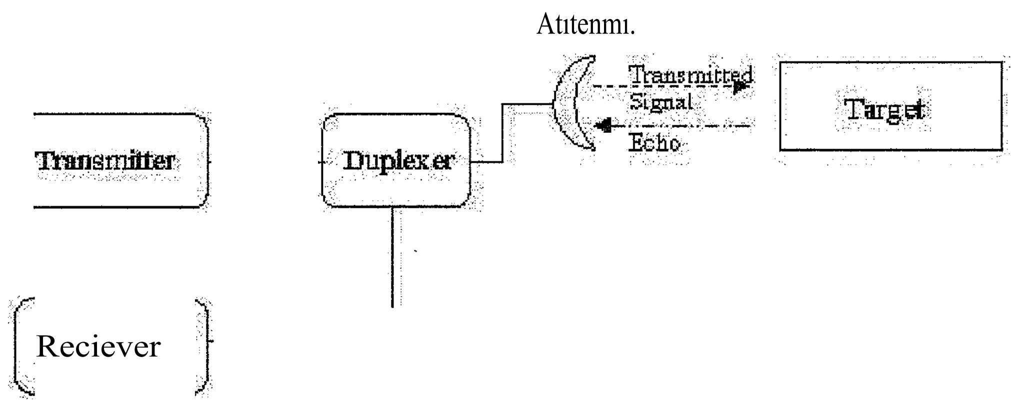



Figure 1.3 Radar blocks.

- 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 patlı back to the antenna.
- The receiver measures the parameters changes caused on the transmitted signal by the target.

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

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

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

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

### 1.5.3 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 ete., 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

### 1.5.4 Ditferent Radar System Set-ups

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

## 1.6 Components ofa Radar System

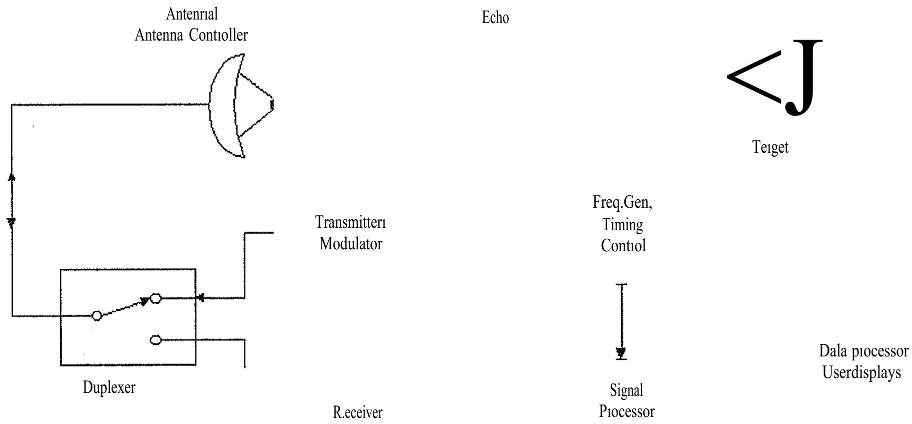



Figure 1.5 Block diagram ofa Monostatic Single Antenna Radar System.

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

### 1.6.1 Frequeney 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 :functionsrelate to the time of transmission
- It controls the system's parameters and passes them to the other modules

### 1.6.2 Transmitter

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

### 1.6.3 Modulator

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

1.6.4 Duplexer

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

1.6.5 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 ofthe transmission medium.
- Is usually steered so that the antenna can search or track in maying directions .

};6.6 Antenna Controller

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

1.6.7 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.

1.6.8 Signal Proeessor

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.

### 1.6.9 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 rietting. 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.

### 1.6.10 Displays

Thedisplay. 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 .

## 1.7 Factors Mfecting Radar Performance

The performance of a radar system can be judged by the following: (1) the maximuın rai:ıge at which it can see a target ofa 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.

### 1.7.1 Transmitter Power and Antenna Size

The maximuın range ofa 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.

### 1.7.2 Reeeiver Noise

The sensitivity ofa radar receiver is determined by the unavoidable noise that appears at its input, At microwave radar frequencies shown in appendix 4, the noise that limits delectability 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 applicaiion ofthe 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 delectability of weak signals by using what radar engineers call a "matched filter which is a filter that maximizesthe 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.

### 1.7.3 Target Size

The size ofa 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 sectiorı and is given in units of area ($m^2$). 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 meter in area will produce a radar cross section of about 1 $Km^2$ ata frequency of 3GHz (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 ofa square meter even though its projected area is also one square meter. Theoretically, this value does not depend to a great extent on the size ofthe 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, a sphere with a projected area of one square meter hasa radar cross section of one square meter.

Commercial aircraft might have radar cross sections from about 10 to 100 $m^2$, 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 meters, since some small general-aviation aircraft can be of'this value. For comparisontlre radar cross section ofa man-has "b-een--'- measured at microwave frequencies to be about one square meter. A bird can have a cross section of 0.01 $m''$. 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 target:

Theradar cross section of an aircraft and most other fargets of practicalinterest is nota constant but; rather, fluctuate 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.)

### 1.7.4 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 ofa 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 po l arization 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 air weather, most radars use linear polarization, i.e., the direction of the field is fixed).

### 1.7.5 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 weTL Th'.e\lecreiise in. deiisity -Of ihe" Earthı's ab:n6.splıere .wltll " : 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 coider regions. Ducts can sometimes extend the range of airborne radar, but· on other oc~asfons 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 ofa nuisance than a help. Loss of radar energy, when propagation is through the clear atmosphere or rain, is usually in significant for systems operating at microwave frequencies.

### 1.7.6 Interference

Signals from nearby radars and other transmitters can be strong enough to enter radar when propagation is through the clear atmosphere or rain, is usually insignificant for systems operating at microwave frequencies receiver and produce spurious responses. Well-trained operators are not often deceived by interference, though they may find ita nuısance. Interference is not as easily ignored by automatic detection and tracking systems, however, and so some method is usually needed to recognize and remove interference pulses before they enter the automatic detector and tracker of radar.

### 1.7.7 Electronie Countermeasures

The purpose of hostile electronic countermeasures (ECM) is to deliberately degrade the , effectiveness of military radar. ECM can consist of (1) noise jamming that enters the receiver via the antenna and increases the noise level at the input of the receiver , (2) false target generation, or repeater jamming, by which hostile jumpers introduce additional signals into the radar receiver in an attempt to confuse the receiver into thinking they are real target echoes, (3) chaff, which is an artificial cloud consisting ofa large number of tiny metallic retl ecting strips that create strong echoes over a large area to mask the presence of real target echoes or to create confusion, and (4) decays, which are small, inexpensive air vehicles or other objects designed to appear to the radar as if they were real targets. Military radars are also subject to direct attack by conventional weapons or oy·antiradıaHôii-mıssıles ~ARMs) th.at use radar -transriiissıôristo; find the target and home on it.

Military radar engineers have developed various ways of countering hostile ECM and maintaining the ability ofa radar system to perform its mission. It might be noted that a military radar system can o:ften accomplish its mission satisfactory even though its performance in the presence of ECM is not what it would be if such measures were absent.

## 1.8 Developments

### 1.8.1 Early Experiments

Serious developmental work on radar began in the 1930s, but the basic idea of radar had its origins n the classical experiments on electromagnetic radiation conducted by the German physicist Heinrich Hertz during the late 1880s. Hertz set out to verify experimentally the earlier theoretical work of the Scottish physicist James Clerk Maxwell. Maxwell had formulated the general equations of the electromagnetic field, determining that both light and radio waves are examples of electromagnetic waves Govemed by the same fundamental laws but having widely different frequencies.

Maxwell's work led to the conclusion that radio waves can be reflected from metallic objects and refracted by a dielectric medium just like light waves. Hertz demonstrated these properties in 1888, using radio waves ata wavelength of 66 centimeters (which corresponds to a frequency of about 455 MHz).

The potential utility of Hertz's work as the basis for the detection of targets of practical interest did not go unnoticed at the time. In 1904 a patent for "an obstacle detect or and ship navigation device," based on the principles demonstrated by Hertz, was issued in several countries to Christian Hulsmeyer, a Germai:ı engineer. Hulsmeyer built his invention and demonstrated it to the German navy, but failed to arouse any interest. There was simply no economic, social, or military need for radar until the early 1930s when a long-range military bomber capable of carrying large payloads was developed. This prohıpted the major countries ofthe world to look fora means with which to detect the approach of hostile aircraft.

Most of the countries that developed radar prior to World War II first experimented with other methods of aircraft detection, These, included listening for the acoustic noise of aircraft engines and detecting the electrical noise from their ignition. Researchers also experimented with infrared sensors. None of these, however, proved to be effective.

### 1.8.2 First Military Radars

During the 1930s, efforts to use radio echo for aircraft detection were initiated independently and almost simultaneously in several countries that were concemed with the preventing military situation and that already had practical experience with radio technology. The United States, Great Britain, Germany, France, the Soviet Union, Italy, and Japan all began experimenting with radar within about two years of one another and embarked, with varying degrees of motivation and success, on its development for military purposes. Most of these countries had some form of operational radar equipment in military service at the start ofWorld War II in 1939.

The first observation ofthe radar effect at the U.S. Naval Research Laboratory (NRL) in Washington, D.C., was made in 1922. NRL researchers positioned a radio transmitter on one shore of the Potomac River and a receiver on the other. A ship sailing on the river caused fluctuations in the intensity of the received signals when it passed between the transmitter and receiver. (Today, such a configuration would be called biostatic radar.) In spite of the promising results of this experiment, U.S. Navy officials were unwilling to sponsor further works.

## 1.9 Areas of Application

Over the years, radar has found many and varied uses for both civilian and military purposes. A sampling of some of the more significant applications is given here.

### 1.9.1 Military

Radar originally was developed to meet the needs of the military, and it continues to have significant application for military purposes. It is used to detect aircraft, missiles, artillery and mortar projectiles, ships, land vehicles, and satellites. In addition, radar controls, guides, and fuzzes weapons, allows one class of target to be distinguished from another, aids in the navigation of aircraftand ships, performs reconnaissance, and determines the damage caused by weapons to targets. The importance of radar in modem warfare is bome out by weapons to targets. The importance of radar in modem warfare is bome out by the many measures designed to negate its effectiveness modem warfare is bome out by the many measures designed to negate its effectiveness (in addition to direct attack, which is an option for any military target of value). Attempts to .degrade military radar capabilityinclude electronic warfare (jamming, deception, chaff, decoys, and interception of radar signals), antiradiation missiles that home on radar transmissions, reduced radar cross-section targets to make detection more difficult (stealth), and high-power microwave energy transmissions to degrade or burn out sensitive receivers. A major objective of military radar development is to insure that a radar system can continue to perform its mission in spite of the various measures that attempt to degrade it.

### 1.9.2 Air Traffic Control

Radar supports air traffic control by providing surveillance of aircraft and weather in the vicinity of airports as well as en route between airports. In the United States and elsewhere, airport surveillance radar (ASR) is employed at most major airports. It is designed to detect corrımercial aircraft and general aviation aircraft, as well as precipitation, in the area around an air terminal. A larger system, the air route surveillance radar (ARSR), tracks aircraft en route. It has a range of about 200 nautical miles. Many major airports also employ airport surface detection equipment (ASDE), which is high-resolution radar that provides the airport controller with the location and movement of ground targets within the airport, including service vehicles and taxiing aircraft. The location of dangerous weather phenomena such as "downbursts" (downward blasts of air associated with storms that have been identified as a major cause öf fatal weather-related aircraft accidents) can be pinpointed with a specially configured terminal Doppler weather radar (TDWR) located near airports. Radar also has been used to "talk down" pilots to safe landings in adverse weather conditions. This is called ground-controlled approach (GCA) by the military.

### 1.9.3 Remote Sensing

one of the early applications of remote sensing involved the observation of rainfall the --- radaririeasüremerit "ot the radial "ve'iôcity "of precıpitatıôrt°(from the Doppler frequency shift) in conjunction with the strength of the reflected signals (reflectivity) can indicate the severity of storms, as well as provide other important information for reliable weather forecasting.

Astronomers have made radar observations of meteors, auroras, and certain planets. Synthetic .aperture radars on orbiting spacecraft have mapped the surface of Venus beneath the ever-present cloud cover that blocks observation at optical wavelengths .. Space-based radar systems have measured the Earth's geoids and ocean roughness. An important application of imaging radar from either aircraft or spacecraft is the surveillance of sea ice; information about pack ice distribution and con concentration is used to route shipping in cold-weather regions.

Radar has even been used to study the movement of bird and insects at distances and under conditions where visual observation would not be possible.

### 1.9.4 Aircraft Navigation

The radar altimeter measures the height of an airplane above the local terrain, Doppler navigation radar determines the plane's own speed and direction, and high-resolution radar mapping of the ground contributes to its navigation. Radars carried aboard aircraft also provide information about the location of dangerous weather so that it can be avoided. Military aircraft can fly at low altitudes with the aid of terrain-avoidance and terrain-following radars that warn of obstacles.

### 1.9.5 Ship Safety

Small, relatively simple radar systems on board ships aid in piloting and collision avoidance. Similar radars on land provide harbour surveillance.

### 1.9.6 Space Applieations

Radars have been used in space for rendezvous, docking, and landing of spacecraft. Since size and weight are important in space, the same equipment is used on a timeshared basis aboard the U.S. space Shuttle both as radar to allow rendezvous with (and sometimes retrieve) other spacecraft and asa two-way <lata link to relay satellites t~at _col1}lll_pri~~t~, ~iJp_ W()ll?:1. _syıt_i9~:)3e~_i~es pro~!4i11gremote sensing of_Earth's surface, radar carried by orbiting spacecraft is able to monitor rainfall over the oceans. Large Iand-based radar systems permit the detection and tracking of satellites and space debris.

### 1.9.7 Law Enforcement

·The familiar police radar is a relatively simple, low-power continuous-wave systern that measurement the speed of vehicles by detecting the Doppler frequency shift introduced in the echo signal by a moving vehicle. The Doppler shift is directly proportional to the radial speed of the vehicle. Radar also has been used in security systems for intrusion detection; it can "sense" the movement of people attempting to penetrate a protected area.

### 1.9.8 Instrumentation

Surveyors may make use of special radars to measure distances. CW radars are used to measure speed in certain industrial applications. The sensor does not make contact with the object whose speed is to be determined. Instrumentation radars are employed at missile test ranges for precision tracking of targets.

## 1.10 Radar.Appfications by Frequency

Each radar application seems to have a particular frequency band to which it is best suited. The various types of application found at the different radar frequency bands are surveyed below. The frequency letter-band nomenclature used here is that approved by the institute of (IEE standard 521-1984). These letter bands also are recognized by the U.S. Department ofDefense and are listed in its index of Specification and Standards.

### 1.10~1 HF (3 to 30 MHz)

Although the first British radar system, Chain Home operated in the HF band, it is ordinarily not a dood frequency region for radar. Antenna beamwidths are very wide, the available bandwidths are narrow, the spectrum is crowded with other users, and the extemal noise is high. There is, nevertheless, an important application for radar in this band-namely, long-range radar, which takes advantage ofrefraction by the ionosphere to extendranges by an order of magnitude greater than can be obtained by ground-based microwave aircraft deteetion radars. The ionosphere is a region 'of ionized gases produced by solar radiation at altitudes from about 80 to 400 kilometers or higher. The ions bend radio wave enough to retum to Earth at considerable distances.

### 1.10.2 VHF (30 to 300 MHz)

For reasons similar to those cited above, this frequency band is not too popular for radar. However, very long-range radars for either aircraft or satellite detection can be built at the VHF band more economically than at higher frequencies. Radar operations at such frequencies are not bothered by rain clutter or insects, put auroras and meteors produce large echoes that can interfere with target detection.

### 1.10.3 UHF (300 to 1,000 MHz)

Military airbome early waming (AEW) radars operate in the UHF band to detect aircra:ft in the midst of clutter. This is a good frequency range for detecting extraterrestrial targets (e.g., satellites and missiles), since large antennas and high power are readily obtained for this application.

1.9.4 L Band (1,000 to 2,000 MHz)

This is the preferred frequency band for long-range (200 nautical miles) air surveillance radar, such as the air-traf:fic control systems used to track aircraft en route between airports. It also is a band of interest for military space surveillance and missile detection because it is not as susceptible to nuclear blackout effects as radar systems that operate at the lower frequencies .

1.10.5 S band (2 to 4 GHz)

Medium-range (50 to 60 nautical miles) airport surveillance radars are well suited for this band. It is the preferred frequency band for long-range weather observation radars. Military *)3D* radars that determine elevation angle as well as range and azimuth angle are often in S band, but they may also be at L band. Frequencies lower than S band are good for long-range surveillance, since large power, large antennas, and good moving target detection are betler there than at high :frequencies.Frequencies greater than S band are,preferred.for. extracting targetinformation, as in tracking radars and weapon control systems. Therefore, when a single frequency must be used for surveillance and information extraction, S band can be a compromise.

1.10.6 C Band (4 to 8 GHz)

Single-frequency phased-array radars that must perform both surveillance and weapon control for air defense operate at these frequencies as well as at S band. This frequency region is well suited for long-range, precision-tracking radars.

1.10.7X Band (8 to 12 GHz)

This is a band :frequentlyused for shipboard civil marine radar, tracking radar, airbome weather-avoidance radar, systems for detecting mortar and artillery projectiles, and police speed meters. Most synthetic aperture radars operate at X band, the exceptions are some remote-sensing SARs that are designed for lower frequencies.

1.10.8 K Band (12 to 40 GHz)

Radars at this frequency band are usually of short range, because it is difficult to obtain the large antennas and large power necessary for long-range applications. This band has been used for airbome radar and for short-range Airport Surface Detection (ASDE).

1.10.9 Milfimeter Waves (40 to 300 GHz)

Although there has been much interest in exploring the potential of radars at millimeter wavelengths, it has not been practical for most applications because of high attenuation even in the "clear" atmosphere. It is difficult to use millimeter-wave radar for anything other th~n short range (a few kilometers) within the atmosphere. For deployment in outer space where there is no atmosphere to attenuate these frequencies, millimeter wave radar, however, can be considered.

1.10.10 Laser Radar

Laser- radars which operate at infrared and .optical frequencies also suffer -frem attenuation by the atmosphere, especially in bad weather, and therefore are of limited utility. Laser radar systems, however, have been used for precision range-finding in weapon control and for distance measuring in surveying. They also have been considered for use on board spacecraft to probe the nature ofthe atmosphere.

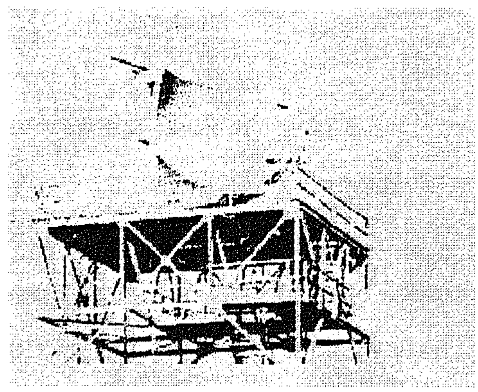
# CHAPTERTWO

# TYPES OF RADAR

## 2.1. Introduetion

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 modem radar systems, At the end of this section, we will briefly discuss radar applications by the radio frequency bands used.

## 2.2. Airport Surveillanee Radar



Flgure 2.1 Airports Surveillance Radar.

This is a medium-range radar system capable of reliably detecting and tracking aircraft at altit~des below 25,000-:feetand within 40 to 60 nautical miles of the airport where it is located. Systems of this type have been installed at more than 100 major airports throughout the United States. The ASR-9 is designed to be operable at least 99.9 percent of the time, which means that the system is down less than 10 hours per year. This high availability is attributable to reliable electronic components, a 'built-in test' to search for failures, remote monitoring, and redundancy (i.e., the system has two complete channels except for the antenna; when one channel must be shut down for repair, the other continues to operate). The ASR-9 is designed to operate unattended with no maintenance personnel at the radar site. A number of radar units can be monitored and controlled from a single location. When trouble occurs, the fault is identified anda maintenance person dispatched for repair.

Echoes from rain that mask the detection of aircraft are reduced by the use of Doppler filtering and other techniques devised to separate moving aircraft from undesired clutter. It is important for air-traffic controllers to recognize areas of severe weather so that they can direct aircraft safely around, rather than through, rough or hazardous conditions. The ASR-9 hasa separate receiving channel that recognizes weather echoes and provides their location to air traffic controllers. Six different levels of precipitation intensity can be displayed, either with or without the aircraft targets superimposed.

The ASR-9 system operates within S band from 2.7 to 2.9 GHz. Its klystron transmitter has a _P,eak power of 1.3 megawatts, a pulse width of 1 microsecond, and an antenna with a ho;izontal beam width of 1.4 degrees that rotates at 12.5 revolutions per minute (4.8-second rotation period).

The reflector antenna shown in the photograph is a section of a paraboloid. It is 16.5 feet wide and 9 feet high. Atop the radar (riding piggyback) is a lightweight planar array 'anteniia for the air-traffic-control radar-beacon system. Itsdiinerisioiis are-Z6feefby '.5'.2 - feet. ATCRBS is the primary means for detecting and identifying aircraft equipped with a transponder.that can reply to the ATCRBS interrogation. The ATCRBS transmitter, which is independent of the radar system and operates at a different frequency, radiates a coded interrogation signal. Aircraft equipped with a suitable transponder can recognize the interrogation and send a coded reply at a frequency different from the interrogation frequency. The interrogator might then ask the aircraft, by means of other coded signals, to automatically identify it self and to report its altitude. ATCRBS only works with cooperative targets (i.e., those with an operational transponder).

## 2.3. CW Radar

The CW radar gun, which operates on the homodyne principle, is low powered 1OmW 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.

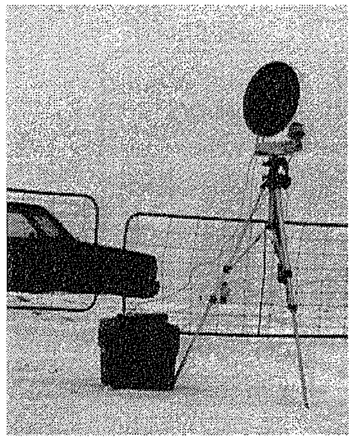


Figure 2.2 CW Radar.

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 joumal bearings for azimuth and elevation. The operator steers the antenna assembly manually. The whole system is attached to the bed ofa small truck.

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

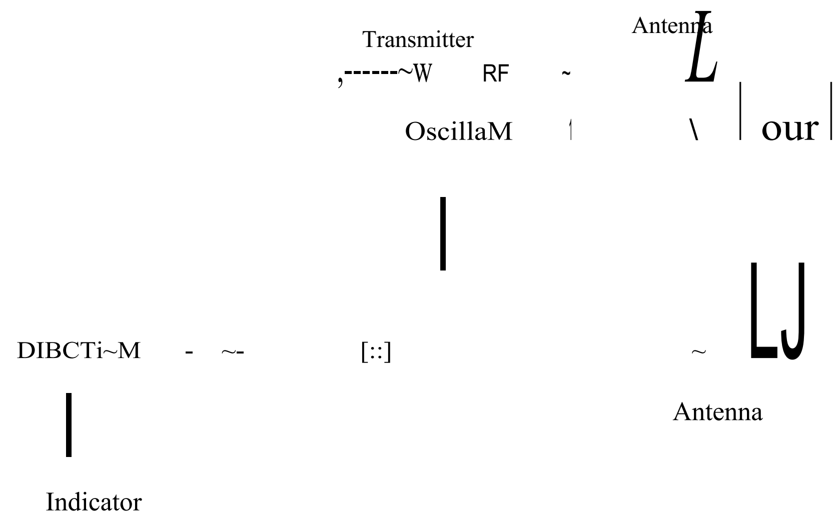



Figure 2.3 Continuous wave radar components.

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.

## 2.4 Pulsed Radar System

### 2.4.1 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:

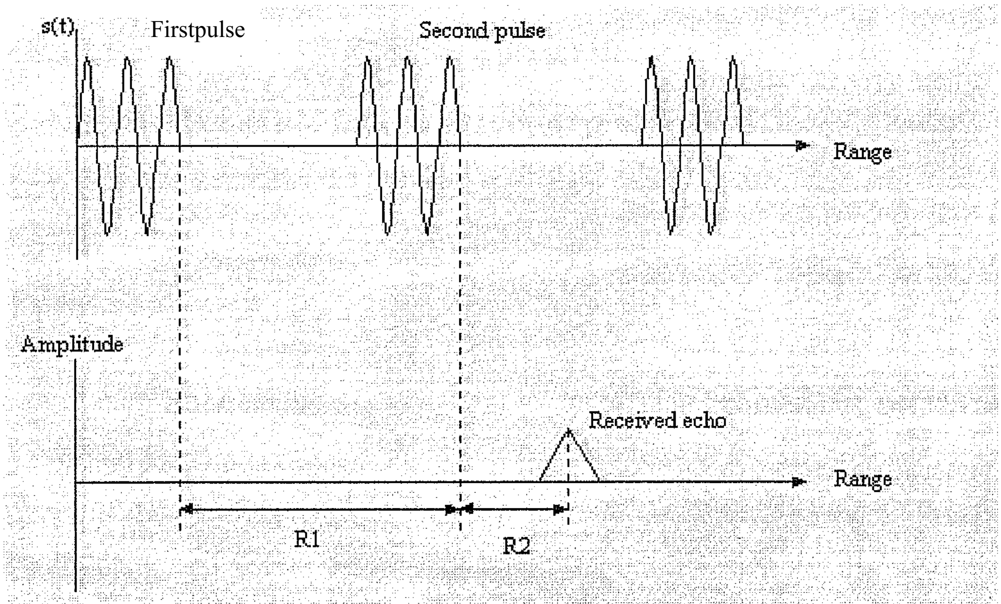
$$R = C \frac{Dt}{2} \qquad (2.1)$$

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, Rınax, which the pulsed radar system can detect a target.
Theinverse of the IPP is the pulse repetition frequency (PRF).
Another factor, apart from Rınax, 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 _fu~r.yfo.ı:~ nxe.4s. tç, have, _on(r_-3:114 only O}J-~ı> sharp s., reference point.

## 2.4.2 Range Ambiguity

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




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

Figure 2.4 Range Ambiguity.

If for instance the target echo was detected 0.000005 seconds after a pulse, and the IPP is 0.0006. Rınax for this system is therefore 90km. The echo could therefore have come from arange of750m or 90.75km.

It is thereforethe-Il'P or-the ,PRF thatdetermines theamount 0frange-ambiguity.

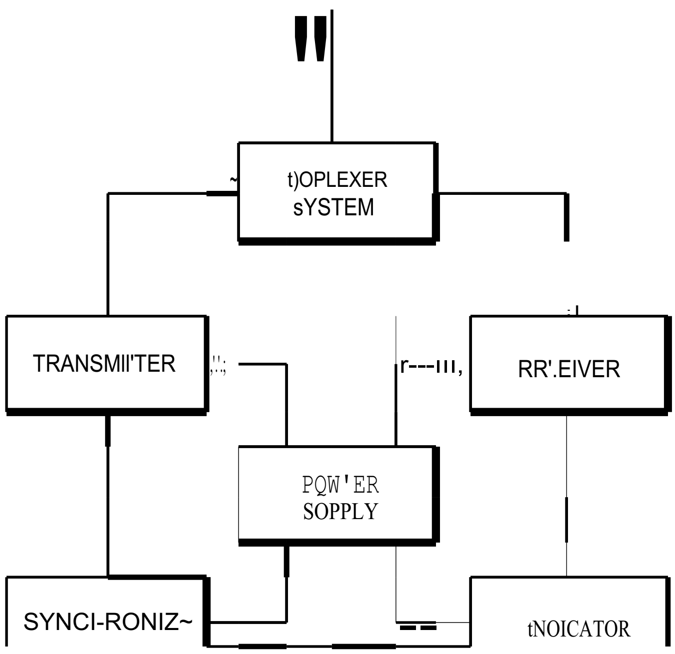



Figure 2.5 Pulse radar.

- 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 Rınax.

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

### 2.4.3 Range Resolutton

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

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

## 2.5 Over the Horizon Radar (0TH)

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 -theIine-cf-sigbtproblem there is- great-interestinusing 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 0TH radar as it is the most common.

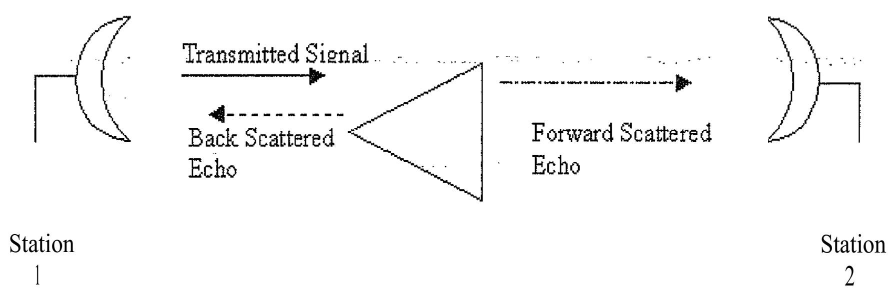



Figure 2.6 0TH Radar.

0TH radar may either work using back scattering, like most conventional radar systems, or using forward scattering.

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

Most 0TH 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 0TH 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 0TH 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 0TH radar system set-up near Alice Springs which monitors northem Australia.

### 2.5.1 Case Study – WARF OTH Radar

WARF stands for Wide Aperture Research Facility.

Uses ofthe WARF facility include:

- The continued study of 0TH radar systems
- Detection of ships and aircraft.
- Observations of the state of the ocean.
- Study of the ionosphere.
- Features ofthe WARF facility include:

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

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

## 2.6 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 ofa 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 ofa second (1 microsecond), and the time between -pulses isgiven as one-thousandth ofa 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 ofthe waveform during the pulse; in reality, a system like this could have 1,000 cycles ofthe 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 usedto measure the capability of aradar system, is much lowerthan the peakpower, "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.

## 2.7 Moving Target Indication (MTI) Radar

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

## 2.8 Pulse Doppler Radar (With High Pulse Repetitien Frequeney)

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 hasa 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 -deteetions. Cenvetsely..pulse.Doppler, .with its high PRF, -yields unambiguous radial velocity measurements but highly ambiguous range readings. Range in pulse Doppler is sometimes resolved by the transmission of multiple waveforms with different prfs.

## 2.9 Pulse Doppler Radar (With Medium Pulse Repetitien Frequeney)

Tlii~ type ofpulse Dopplerradaroperates ata lower .PRF(lO kHz, for example) then tlıe high-prf systems, and it yields ambiguities in both range and Doppler shift measurements. It is, however, better for detecting aircraft with low closing speeds than is high-prf pulse Doppler. An aircraft-mounted medium-prf pulse Doppler radar might have to use as many as seven or eight different prfs to obtain accurate target information.

## 2.10 High-Range-Resolutton 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 ofa meter, and they can profile a target and measure its length in the range dimension.

## 2.11 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 raiige. Pulse compression solves this problem by transmitting a long, high-energy pulse that is modulated in either frequency or phase. The modulation allows the pulse to be compressed in the receiver, thus achieving the range resolution of short-pulse transmission with longer pulses.

## 2.12 Synthetic Aperture Radar (SAR)

With conventional pulse radars, the resolution in range is much berter 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 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.

### 2.13 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 short-pulse or pulse-compression radar for ranging, a two-dimensional, high-resolution image of the target can be obtained.

### 2.14 Side-Looking Airborne Radar (SLAR)

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

### 2.15 Bistatie Radar

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

### 2.16 Traeking 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 patlı, or trajectory, and to predict its future position. Single-target tracking radar provides target location almost continuously, with a typical tracking radar measuring target location at a rate of ten times per second.

## 2.17 Scatterometer Radar

This type of radar measures back:scatteraccurately 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 back:scatterfor that area on the ground darker areas in the image represent low backscatter, brighter areas represent high backscatter. A useful rule-of-thumb in analyzing radar images is that the higher or brighter the backscatter on the image, the rougher the surface being imaged.

## 2.l8 Track-While-Scaıı Radar

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

## 2.19 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 azimııth angle and has either fixed multiple beams in elevation or a pencil beam that is scanned up and down to measure the elevation angle.

## 2.20 Eleetronically Scanned Phased-Array Radar

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

## 2.21 Frequency-Modulated Continueus-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 altemation in frequency. This means that the frequency of the retuming echo signal will differ from the signal then being transmitted. The difference between the two frequencies is proportional to the range of the target, so the measurement of the frequency difference allows range to be determined. Phase modulation of CW signals has also been used to obtain range measurements. The most common form of FM-CW radar is the radar altimeter used in aircraft to determine height above the ground.

## 2.22 Weather radar

### 2.22.1 Introdnetion

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 intemal and extemal use. Radar and satellite pictures are an essential tool for the meteorologist on duty and are of use in research also. For the public these radar pictures have become familiar from for example the weather forecasts presented in the evening news .

### 2.22.2 Weather Radar Working

As it tums, 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 strength 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 rainsha:ft, and can also penetrate to measure other rain areas beyond .

2.22.3 Technical Aspeets

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 .

| Tecbnical data | Measurement |
|---|---|
| .ı\ntennadiameter | 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 | 250KW |
| Average transmitter power | 300W |

# CHAPTER TBREE

# AIRPORT SURVEILLANCE RADAR

## 3.1 Introduction

Surveillance radar a device which, by measuring the time interval between transmission and reception of radio pulses and correlating the angular orientation of the radiated antenna beam ·or beams in azimuth and/or elevation, provides information on range, azimuth, and/or elevation of objects in the patlı of the transmitted pulses.

Surveillance radars are divided into two general categories. Airport surveillance radar (ASR) and air route surveillance radar (ARSR). Surveillance radars scan through 360 degrees of azimuth and present target information on a radar display located in a tower (ATCT) or center (ARTCC). This information is used independently or in conjunction with other navigational aids in the control of air traffic.

L. ASR is. designed to provide relatively .short-range coverage... in .the, generalı. vicinity of an airport and to serve as an expeditious means of handling terminal area traffic through observation of precise aircraft locations on a radarscope. The ASR can also be used as an instrument approach aid. The DFW terminal radar approach control (TRACON) facility provides radar coverage with four ASR-9 installations.

2. ARSR is a long-range radar system designed primarily to .provide a- display .of aircraft locations over large areas. The Fort Worth air route traffic control center (ZFW ARTCC) provides radar coverage with a total of 9 long range radar installations, 2 radar beacon only sites and one ASR-9 installation.

## 3.2 Airport Surveillance Radar (ASR)

Approach control radar used to detect and display an aircraft's position in the terminal area. ASR provides range and azimuth information but does not provide elevation data. Coverage of the ASR can extend up to 60 miles. The DFW terminal area is blanketed with four ASR-9 facilities.

Reliable maintenance and improved equipment have reduced radar system failures to a negligible factor. All of the DFW RADAR facilities have components duplicated-one operating and another, which immediately takes over when a mal:function occurs to the primary component.

The characteristics of radio waves are such that they normally travel in a continuous straight line unless they are:

1. "Bent" abnormal atmospheric phenomena such as temperature inversions; the bending of radar pulses, often called anormalous propagation or ducting, may cause many extraneous blips to appear on the radar operator' s display if the beam has been bent toward the ground or may decrease the detection range if the wave is bent upward. It is difficult to solve the effects of anomalous propagation, but using beacon radar and electronically eliminating stationary and slow moving targets by a method called moving target indicator (MTI) usually negate the problem.
2. Reflected or attenuated by dense objects such as heavy clouds, precipitation, ground obstacles, mountains, ete.; radar energy that strikes dense objects will be reflected and displayed on the operators scope thereby blocking out aircraft at the same .rage and .greatly .weakening or completely .eliminating. the. display of targets at a greater range. Again, radar beacon and MTI are very effectively used to combat ground clutter and weather phenomena, and a method of circularly polarizing the radar beam will eliminate some weather returns. A negative characteristic of MTI is that an aircraft flying a speed that coincides with the canceling signal of the MTI (tangential or "blind" speed) may not be displayed to the radar controller.
3. Screened by high terrain features. Relatively low altitude aircraft will not be seen if they are screened by mountains or are below the radar beam due to earth curvature. The only solution to screening is the installation of strategically placed multiple radars which has been done in some areas.
4. There are several other factors which affect radar control. The amount of reflective surface of an aircraft will determine the size of the radar retum. Therefore, a small light airplane or a sleek jet fighter will be more difficult to see on radar that a large commercial jet or military bomber. Here a gain, the use of radar beacon in invaluable if the aircraft is equipped with an airbome transponder. All radars in the lone star SMO have the capability to interrogate MODE C and display altitude information to the controller from appropriately equipped aircraft. Just a quick note here.

The controllers' ability to advise a pilot flying on instruments or in visual conditions of his proximity to another aircraft will be limited if the unknown aircraft is not observed on radar, if no flight plan information is available, or if the volume of traffic and workload prevent his issuing traffic information. The controller' s first priority is given to establishing vertical, lateral, or longitudinal separation between aircraft flying IFR under the control of ATC.

## 3.3. Air Traffic Control Radar Beacon System (ATCRBS)

The ATCRBS, sometimes referred to as secondary surveillance radar, consists of three main components:

- Interrogator. Primary radar relies on a signal being transmitted from the radar antenna site and for this signal to be reflected or "bounced back" from an object (such as an aircraft). This reflected signal is then displayed as a "target" on the controller's radarscope. In the ATCRBS, the interrogator, a ground based radar beacon transmitter-receiver, seans -in-· -synchronism -withthe primary- radar-'and- transmits discrete radio signals which repetitiously request all transponders, on the mode being used, to reply. The replies received are then mixed with the primary retums and both are displayed on the same radarscope.
- Transponder. This airbome radar beacon transmitter-receiver automatically receives the signals from the interrogations being received on the mode to which it is· set. These replies are independent of; and .much stronger than a primary radar retum.
- Radarscope. The radarscope used by the controller displays retums from both the primary radar system and the ATCRBS. These retums, called targets, are what the controller refers to in the control and separation of traffic.
- The job of identifying and maintaining of primary radar targets is a long and tedious task for the controller. Some of the advantages of ATCRBS over primary radar are:
  * Reinforcement of radar targets
  * Rapid target identification.
  * Unique display of selected codes.

A part of the ATCRBS ground equipment is the decoder. This equipment enables the controller to assign discrete transponder codes to each aircraft under his control .

Normally only one code will be assigned for the entire flight. The ARTCC computer on the hasis of the National Beacon Code Allocation Plan makes assignments. The equipment is also designed to receive MODE C altitude information from the aircraft.

It should be emphasized that aircraft transponders greatly improve the effectiveness of radar system.

Center Radar Automated Radar Terminal System (ARTS) Processing (CENRAP) was developed to provide an altemative to a non-radar environment at terminal facilities should an Airport Surveillance Radar (ASR) fail or malfunction. CENRAP send aircraft radar beacon target information to the ASR terminal facility equipped with ARTS procedures used for the separation of aircraft may increase under certain conditions when a facility is utilizing CENRAP because radar target information updates at a slower rate than the normal ASR radar. Radar services for VFR aircraft are also limited during CENRAP operations because of the additional workload required to provide services to-IFR aircraft.

## 3.4. Primary Surveillance Radar (PSR)

Primary surveillance radar detects and provides both range and bearing information of an aircraft within its effective coverage. In Hong Kong, depending on the application, the coverage is within 80 nautical miles for approach control and within 200 nautical miles for en-route control purpose.

## 3.5. Secondary Surveillance Radar (SSR)

Secondary surveillance radar provides, after processing of <lata transmitted by the aircraft, the range, bearing, altitude and identity (Callsign) of an aircraft. The coverage can reach 250 nautical miles. A SSR can provide more useful information than Primary Surveillance Radar (PSR) but is subject to the proper functioning of the aircraft's transponder. To provide the best radar picture with a continuous display of aircraft targets, the SSR is usually paired with a PSR for air traffic control operation.

## 3.6 Problems with Primary Radar

As you can see from the previous slides:

1. Rain makes targets difficult to see.
2. Birds can show a retum that looks like an aircraft.
3. Some aircraft do not show up at all.
4. Clutter from other information makes aircraft difficult to see.

Secondary Surveillance Radar helps to solve these problems.

## 3.7. SSR helps us Sort it out

All the transponder equipped aircraft have numbers. Even the ones without primary retums! Birds and alien spacecraft do not have numbers.

The numbers have meaning:

1. 1200 means that the aircraft is navigating on its own under Visual Flight Rules, and not talking to a controller.
2. Other numbersare assigned by controllers, and mean differenrthings in different airspace.

In this example,

- odd numbers mean arrivals,
- Even numbers mean departures.

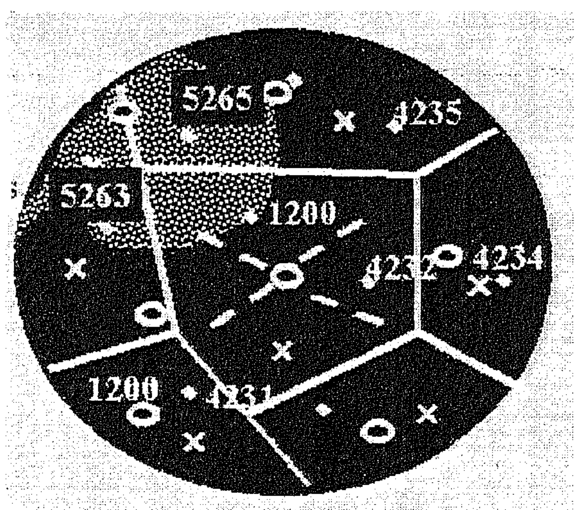



Figure 3.1 Monitor of SSR shows the targets.

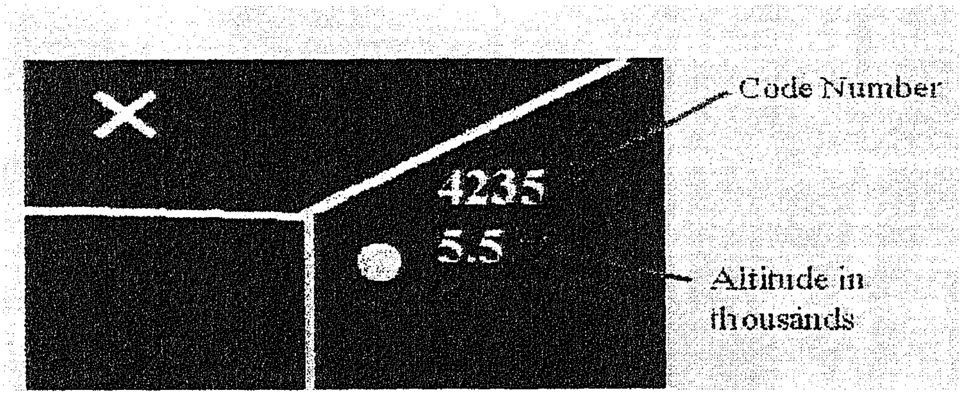



Figure 3.2 Monitor of SSR show the altitude of the plane.

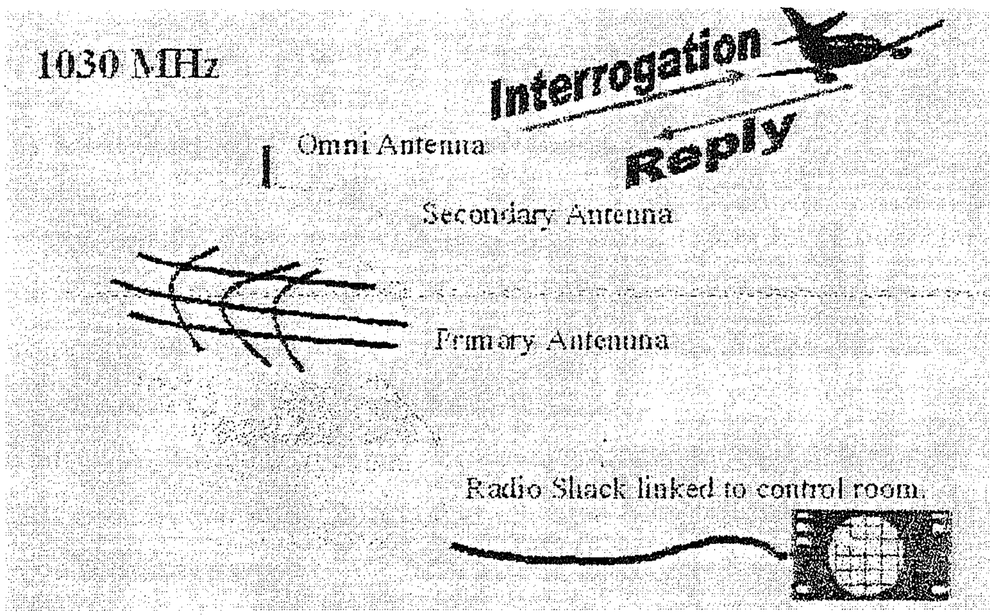



Figure 3.3 The ground system.

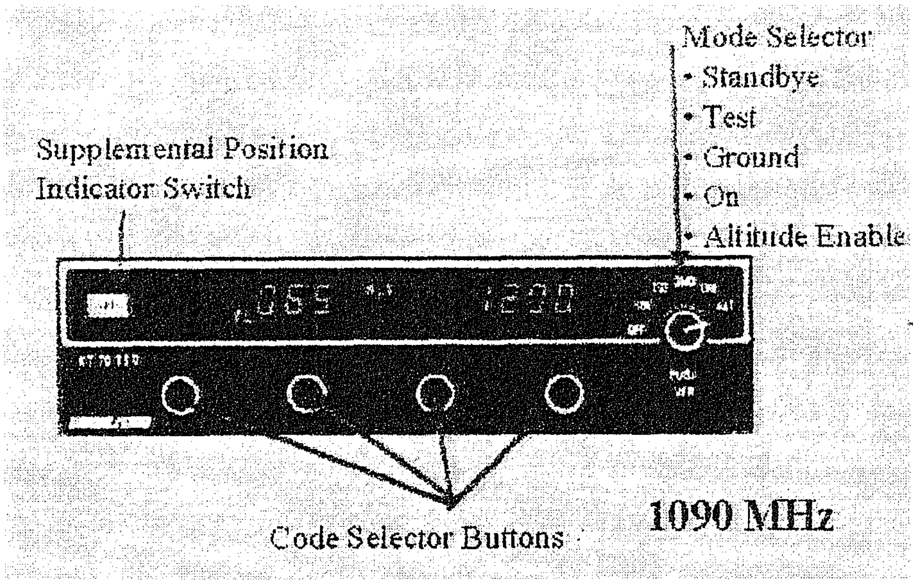



Figure 3.4 The airbome system.

## 3.8 Why it's Diffieult to Provide Low-Level Radar Coverage?

Radio waves usually travel in straight line, they cannot detour round obstacles which curtail -theirIine of travel :-radar-like all-other radio-based- systems, therefore a Iine-of- sight instrument and vulnerable to screening by mountains or even - if the aircraft is flying low enough- by the earth's curvature.

An aircraft flying behind a mountain, for example would not be visible to radar, but as soon as it climbed above the mountain or emerged from behind it, the aircraft would once again appear as a target on the radar screen. The higher the aircraft, the greater the radar ranges. In-mountainous regions it is, therefore, difficult-to provide low level radar overage which is why airports like Kathmandu in Nepal, which are difficult to fly into even under the best conditions, cannot be made safer with the introduction of radar or indeed other line-of-sight navigational aids.

## 3.9 The Radar's Role in the ATC

The biggest drawback with primary radar is that it can only highlight targets within its range: it cannot positively identify those targets or their altitude. The controller must paint a three-dimensional picture in his mind so that he knows the identification of each target, its altitude (as reported by the pilot), where it is going, how fast it is going and whether it is likely to conflict with any of the other targets on the screen.

If in doubt about a particular target's identity, the controller can request that aircraft to undertake a specific man oeuvre, such as a turn off course followed by a retum to course. By watching which target on his screen makes a momentary detour from course, the controller can pinpoint exactly which aircraft it is. It is a system that works well in areas of low traffic density. In busy skies, however, the controller is faced with a screen crowded with one-dimensional targets for which he is trying to provide a three-dimensional air traffic control service. Under those conditions, identifying man oeuvres becomes more hazardous and some from of positive target identification is essential.

The answer is secondary surveillance radar. Unlike primary radar, which does not require the aircraft to carry any respons~ equipment, secondary radar is an interrogative system: it transmits a signal to the aircraft to which the aircraft replies with coded transmission. The aircraft must therefore be equipped with response equipment, known as a transponder.

In order to identify a target, the ground controller will ask that aircraft to transponder or 'squawk' an assigned code number which immediately highlights a target on the controller's screen, identifying it as that particular aircraft. If the aircraft is equipped with what is known as a Mode C transponder, the altitude of that aircraft will appear as an unidentified target.

These days, most radar data is collected in a computer processing system which extracts the relevant aircraft information and discards the clutter of echoes generated by terrain or weather to create a much cleaner radar display showing all targets and, where relevant, identifying labels.

In busy airspace, or in the vicinity of terminal areas, primary and secondary radar sensors are generally mounted together to ensure that controllers are a ware not only of all transponder equipped aircraft in their sector, but also any traffic operating without transponders, for upper level en route surveillance, longer range secondary surveillance radar is generally used alone because there is less traffic control density and few, if any, aircraft operate in those sectors without transponders. Like its primary counterpart, secondary radar is a line of sight tool and range restricted. Where full secondary radar coverage is available, it is possible to reduce the separations required between aircraft and, therefore make more efficient use of the available airspace, thereby increasing the capacity of that controlled airspace. However radar is limited to a range of about

200nm. On land, it is usually possible to install a sufficient nuınber of radar sites to provide :full radar coverage, particularly as aircraft cliınb away froın the earth's surface and obstacle interference. But it is iınpossible to provide radar cover over the :full expanse of the world' s oceans and it is rarely viable to provide :full cover in the depth inaccessible terrain such as vast deserts.

3.10 Multi Radar Traeking

These .days, in ınany busy areas, radar coverage is so coınprehensive that several radar returns are generated for each aircraft. In reality, radar bias (the radar signal ınay be weekend by distance, weather conditions or other interference) or systeınatic error between radars ıneans that each radar data will give a slightly different position reading. The radar data will give a slightly different position reading. The radar data processor will, therefore, select the reading froın the radar providing the strongest signal and translate that into a target on the air traffic control display.

Today, ınulti radar tracking collate the signal data froın all the relevant radars, calculate the strength of eacli rettim;·and i.ısing all thisinformation, define üie ·aircraft' s precise position.

3.11 Precision Approach **Radar**

At airports where it is not possible to install an (instruınent Landing Systeın) or ILS, but itmaybe n~cessaty to offer aprecisionapproach capability,JCı'\O recommends the use of (Precision Approach Radar) (PAR). In these circuınstances, a local controller literally talks the aircraft down on to the runway. Because it is expensive and rarely used, PAR is not widely applied

It involves the use of two radar pictures, gıvıng the controller both aziınuth and elevation views of the aircraft on approach. The controller will then talk to the pilot giving minuteııavigation instructions to get the aircraft established on the centerline and glide slope and keep it there for the entire descent. In order for the controller to give accurate instructions, he must have the elevation/height information include in the display. A straightforward azimuth or plan display. A straightforward azimuth or plan display would provide insufficient data.

3.12 Mode S

'Mode select', or 'Mode S' as it is more commonly known, is a system which enhances existing radar-based surveillance and provides an additional data link function. It has been developed in order to over come sensitivity of existing systems to synchronous grabble and a critical shortage of transponder codes. Existing system are unable to assign unique identity codes to more than 4,096 aircraft in any one region at any given time.Although all aircraft operating in a specifi.edregion have individual codes, those same codes have to be used by other aircraft operating in different region across the globe. An aircraft passing through several regions may therefore have to be assigned a new identity code as it passes from one region into another to avoid an identity conflict with an aircraft already operating in that region with the same code.
Mode S, however, is capable of recognizing up to 16 million unique codes, which means that every aircraft currently in existence could be assigned its own unique code when the Mode S transponder is installed. This code cannot be changed from the cockpit. Mode S codes are derived from the aircraft's registration number or other numbering scheme.

Another key feature of Mode S is that it can selectively interrogate individual aircraft even if several transponder- equipped aircraft are simultaneously within view of the ground sensor. A Mode S transponder. However, in order to pick up unknown aircraft, a sensor periodically broadcasts a Mode S 'all-call' interrogation. Any Mode S transponder which has not been specifically commanded to ignore all-call interrogation will reply. ünce a transponder has responded to all-call interrogation will reply. ünce a transponder has responded to all-call interrogation and been identified, the sensor will then instruct it to ignore all further all-call interrogations. Mode Sis claimed to improve overall surveillance accuracy by a factor ofup to four.

As it is datalink tool, mode S used the basic surveillance interrogation and replies to pass datalink message, taking advantage of the selective address to exchange more comprehensive data. As a result, air traffic controllers can receive on screen more information a bout the status of each aircraft interrogation than is currently possible with Mode A (identity) and Mode C (altitude).
In addition, using the Mode S datalink function, a pilot may access weather and flight information services, flight safety services, automated terminal irtformation services

(ATIS), initial connection services, and automated en route air traffic control connection mode services. ICAO as the secondary surveillance radar (SSR) standard of the future has adopted Mode S.

## 3.13 Displays

Display technology has made great-strides over the last few years, giving controllers a much clearer picture of the airspace they are controlling.

From .the early days of round horizontal monochrome displays, air traffic control authorities are increasingly switching to vertical square color screens.

Until the advent of SSR, all radar surveillance involved the use of primary sensors. The <lata generated by these sensors was displayed on round PPI (Plan Position Indicator) screens with a beam making a circular scan of the screen represent each revolution of the radar antenna, updating the echoes with every revolution. But, as well as picking up aircraft, the screen also displayed all other echoes generated by the radar and, as a result, the picture received by the controller was o:ften cluttered.

The advent of SSR and the use of transponders meant that it was at least possible positively to identify and label targets and, as display technology improved, to select the amount of additional information that was displayed on the screen. It was possible, for example, to screen out terrain and weather echoes, leaving just the active targets and giving controllers a much clearer picture.

## 3.14 AN/SPS-49-Very Long-Range Air Surveillanee Radar

The radar set AN/SPS-49 is an L-band, long-range, two-dimensional, air-search radar system that provides automatic detection and reporting of targets within its surveillance volume. The AN/SPS-49 performs accurate centroiding of target range, azimuth, amplitude, ECM level background, and radial velocity with an associated confidence factor to produce contact data for command and control systems. In addition, contact range and bearing information is provided for display on standard plan position indicator consoles. The AN/SPS-49 uses a line-of-sight, horizon-stabilized antenna to provide acquisition of low-altitude targets in all sea states, and also utilizes an upspot feature to provide coverage for high diving threats in the high diver mode. Extemal control of AN/SPS-49 modes and operation by the command and control system, and processing to identify and flag contacts as special alerts are provided for self-defense support. The AN/SPS-49 has several operational features to allow optimum radar performance: an automatic target detection capability with pulse Doppler processing and clutter maps, ensuring reliable detection in normal and severe types of clutter, an electronic counter-countermeasures capability for jamming environments; a moving target indicator capability to distinguish moving targets from stationary targets and to improve target detection during the presence of clutter and chaff; the medium PRF Upgrade (MPU) to increase detection capabilities and reduce false contacts; and Coherent Didelobe Cancellation (CSLC) feature.

The AN/SPS-49 long range 2-dimensional air surveillance radar used for early target detection. The long-range AN/SPS-49 radar operates in the presence of clutter, chaff, and electronic counter-measures to detect, identify, and control low-radar-cross-section threats traveling at supersonic speeds. AN/SPS-49 provides the front-end element for successful target identification, designation, and engagement with either long range (SM-1 or SM-2) missiles and/or short range local defense missiles. A key feature of the most recent version of the radar, the SPS-49A (V) 1 is single-scan radial velocity estimation of all targets allowing faster promotion to firın track and improved maneuver detection. This is done using unique signal processing techniques originated and tested by the Radar Division ofNRL using 6.1 and 6.2 office ofNaval Research (ONR) funds. The AN/SPS-49(V) radar is a narrow beam, very long range, 2D air search radar that pr~marilysupports the.AAW mission in surface ships. The radar is used to provi1e long range air surveillance regardless of severe clutter and jamming environments. Collateral functions include air traffic control, air intercept control, and antisubmarine aircraft control. It also provides a reliable backup to the three-dimensional (3D) weapon system designation radar.

The AN/SPS-49(V) radar operates in the frequency range of 850-942 MHZ. in the long-range mode, the AN/SPS-49 can detect small fighter aircraft at ranges in excess of 225 nautical miles. Its narrow beam width substantially improves resistance to jamming. The addition of coherent side lobe canceller (CSLC) capability in some AN/SPS-49(V) radars also provides additional resistance to jamming/interference by canceling the jamming/interference signals. The moving target indicator (MTI) capability incorporated in the AN/SPS-49 (V) radar enhances target detection of low-flying high speed targets through the cancellation of ground/sea retum (clutter), weather and similar stationary targets. In 12-RPM mode operation, this radar is effective for the detection of hostile low flying and POPUP!c targets. Features of this set include:

• Solid state technology with modular construction used throughout the radar, with the exception of the klvstron power amplifier and high power modulator tubes

• Digital processing techniques used extensively in the automatic target detection modification

• Performance monitors, automatic fault detectors, and built-in-test equipment, and automatic on line self test features

| | |
|---|---|
| Band | L |
| Frequency Band | 850 to 942 MHz,three selectable 30MHz bands, 48 discrete frequencies |
| Transmitting Power | 360 kW peak, 280 kW specified peak power,12-13 kW average power |
| Antenrta Parameters | Parabolic Reflector stabilized for roll and pitch, 7.3m/24 ft wide, 4.3ml 14.2 ft high |
| Range | 250nm |
| Minimum Range | 0.5 nmi |
| Frequency Selection | Fixed or frequency agile |
| Range Accuracy | 0.03 nmi |
| Azimuth Accuracy | 0.5 deg |
| PRF | 280, 800, 1000 pps. |
| Pulse width | 125 microseconds |

## 3.15 Upgradmg the Nation's Largest Space Surveillance Radar

Some of the custom electronics assemblies designed at SwRI for the AiN/FPS-85 radar transmitter unit upgrade are shown at left. Large-quantity production factors were considered during the design phase. For example, a microcontroller (upper left) with highly integrated features selected to minimize assembly complexity and parts count.

Southwest Research Institute is leading an engineering development effort to upgrade the reliability and performance ofthe U.S. Space Command's largest surveillance radar. The world's first large phased-array radar, the AN/FPS-85 was constructed in the 1960s at Eglin Air Force Base, Florida. Other large radars have been introduced since then, but the Grand Old Lady ofthe South, as the radar installation is known at Eglin, remains the nation's primary space surveillance radar because ofunsurpassed power and coverage. The AN/FPS-85 is a valued asset to the U.S. Air Force, but one with an aging teclınology base that must be supported into the :future. For example, the on-site maintenance crew repairs an average of l 7 radar transmitter units per day at an expense of $2 million annually, a figure that will rise as the vacuum tube market diminishes. Recognizing that maintenance costs could be reduced by reliability improvements, the Air Force contracted with SwRI in 992 to study ways of improving the installations transmitter array system. The AN/FPS-85 Phased Array Radar Facility is located in the Florida panhandle, near the city of Freeport, which is approximately 25 miles east of Eglin Air Force Base. A several mile no-fly zone surrounds the radar installation as a safety concem for the Electro explosive devices, such as ejection seats and munitions.

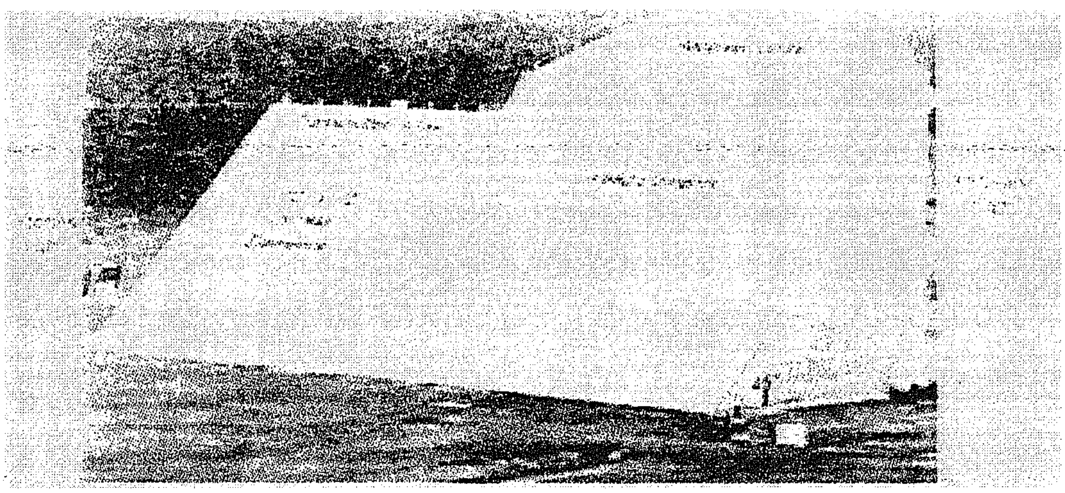


Figure 3.7 The AN/FPS-85 Phased Array Radar Facility in Florida,USA.

SwRI engineers determined that reliability, supportability, and reliability gains in the transmitter array system could be realized through modem design approaches that would replace high-power vacuum tubes with RF power transistor and integrated electronic technology. As the project progressed, new transmitter designs were developed, prototyped, and tested by modifying govemment-:fumishedradar transmitter units. The basic concept has been success:fully demonstrated, and a large four-year production effort to modify the :full transmitter array system is planned. The Air Force has endorsed the upgrade plan and is prepared to carry out the modification program with SwRI as the principle-engineering consultant.

# CHAPTER FOUR

# APLICATION iN ERCAN AIRPORT

## 4.1 Civil Aviation Department in Ercan Airport

!Name of the Governmental Organization: civil Aviation Department, Ministry of -Communication and works, Turkish Republic ofNorthem Cyprus (TRNC).

Number of the engineers employed in the company is four, three are electrical & electronic engineers and one mechanical engineer they are responsible to maintain the available systems for the continuity of airport facilities, they are responsible to manage the .technicians, also to make the work plane and they are responsible to prepare new project in order to improve Ercan Airport's facilities. There are 21 Technicians; 11 of whom are electrical & Electronics Technicians and the rest are mechanical technicians. The civil aviation in Northem Cyprus is responsible for Geçitkale Airport, which is the secondAirport in Northem Cypms. Cyprus. Turkish Civil Aviation was established in 20/7/1974 it's head quarters is in Capital City Lefkoşa (Nicosia), 23 km west of Ercan Airport. The Director of the Department is Mr. Orbay Kılıçç. The address is Telephone No 0392 2283666, Civil Aviation Department, Lefkoşa, and MersinlO, TURKEY.

## 4.2 Radar Systems in Ercan Airport

radar systems in Ercan Airport (The Main Airport in Northem Cyprus) is consisting of Primay Survellance Radar (PSR), Secondary Surveillance Radar (SSR), Multi Radar Tracking (MRT), Multi Channel Tracking (MCT), Associated modern, Common Display System (CDS) and Digital System (DDS) the last two for monitoring.

### 4.2.1 PSR

Primary Surveillance Radar (PSR) it has 60 nmi. The transmitter of PSR, since a pass of about one Mw for Duration about one micro second through the magnetron this pass travels in the air with speed oflight 162 000 nmi/s, when it hits the targets i.e. the plane it reflects back and the receiver of our system detect the echo and true the formula of

$$R= Ct/2 \qquad (4.1)$$

Where R is the range, C is the speed of light and t is the time between the transmission of signal and receiving of the echo, it calculates the range of the plane the purpose of PSR is detection and ranging only.

4.2.2 SSR

The principle of secondary surveillance radar is different than the primary surveillance because it needs the assistant of the plane to detect the target.

The transmitter of SSR sends two passes in two different modes 3A, and mode C that ask the plane who are you? And what high are you?, the transponder in the plane detects these signals and answers in pre determent model, the receiver of SSR detects and processing this reply. Lock at the figure.

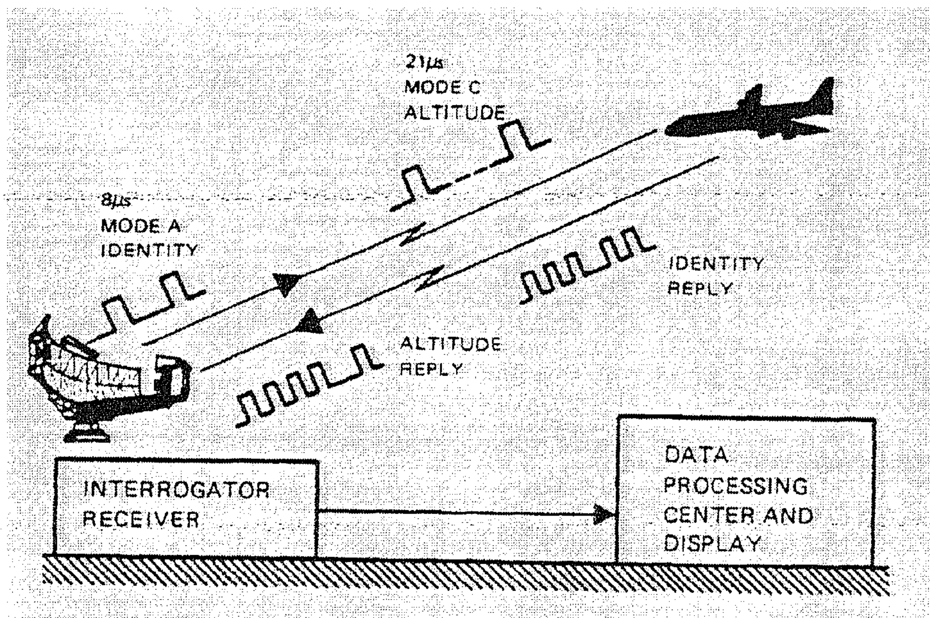



Figure 4.1 The basic principles for the operation ofthe SSR system in Ercan Airport

4.2.2.1 SSR Performanee and Limitations

The attached document contains part of annex 10 of the convention of(l N C A) and it gives specifications and recommendations of for SSR to which the SSR must add here

- Detection the aircraft position without to use necessarily the decoding equipment;
- Identification of the aircraft height code; I
- To identify, when it is requested, a signal aircraft from the reply of special pulse SPI (Special Pulse Identification);

- To indicate, immediatlyian aircraft in an emergency condition or with the radio communication system in trouble such performance must be available, typically with in following limits for all the conditions
- Up to 200 nautical miles ranges
- Up to an altitude of 30.480 meter (100.000) for elevation angles between .5 /45
- Foran azimuth angle of 360
- The advantages gamed from an SSR system are off set by the following problems
- Interrogation by antenna side lobes
- Interrogation by means multiple patlı figure 4.2
- Interrogation by coming from other SSR system figure 4.2
- Replies coming from aircrafts closely spaced figure 5.3 in heaving traffic areas.

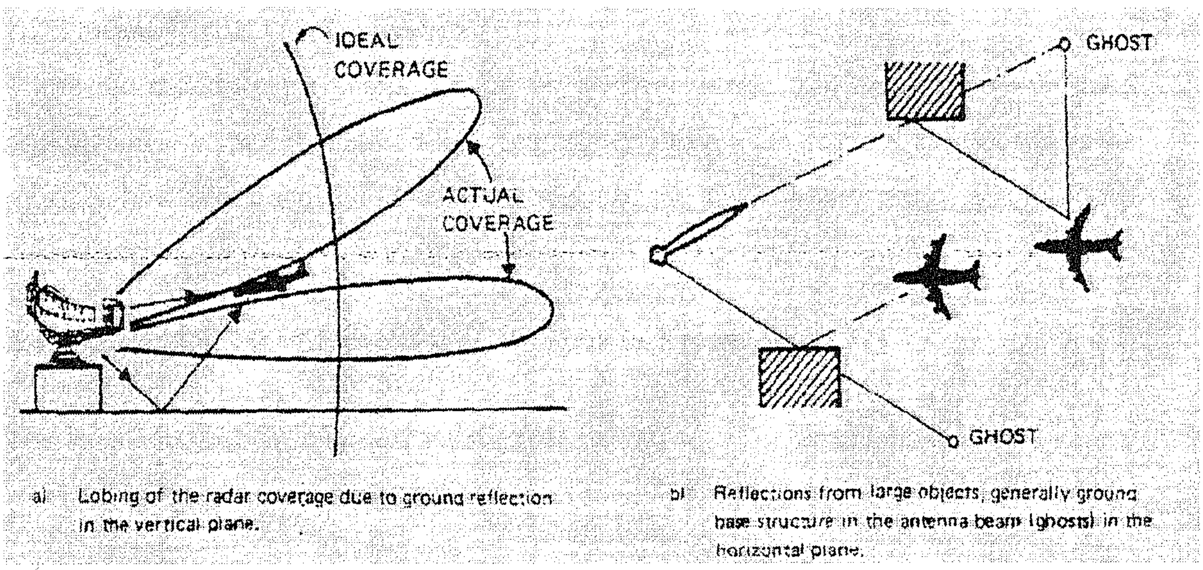



Figure 4.2 Reflectioİı influence on SSR coverage in Ercan Airport

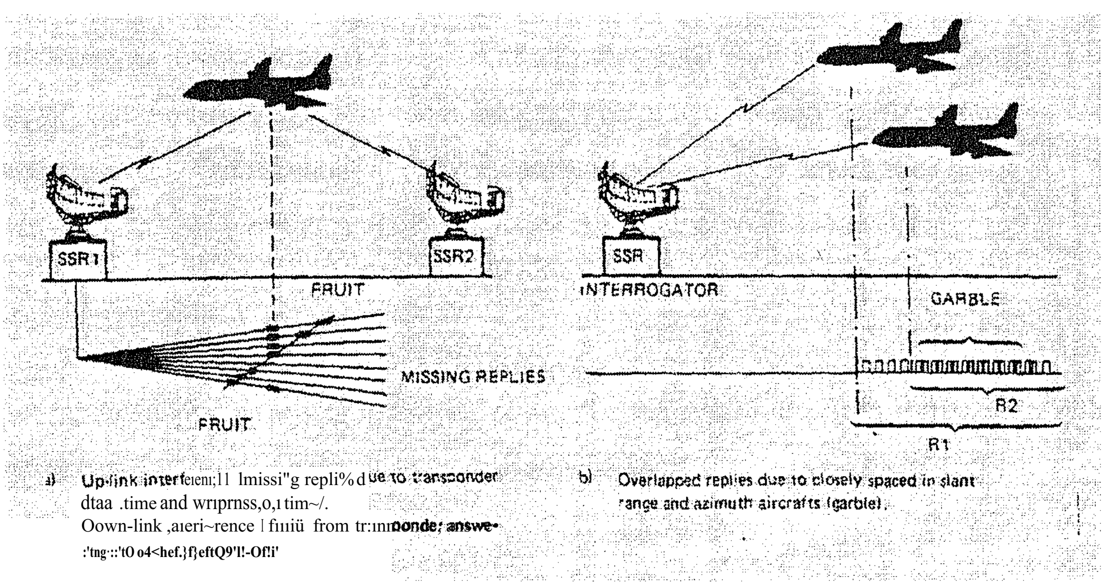



Figure 4.3 SSR Interferences Ercan Airport

### 4.3.3 MRT and MCT

MRT means Multi Radar Tracking,

MCT means Multi Channel Tracking Most of these are for processing and converting the <lata from PSR and SSR in form to send to DDS/CDs for the use of air traffic control.. Also MCT combines the <lata of SSR coming from Ermenek City (central of Turkey) to Ercan. Modems: these are used for transmission of <lata between Ercan Radar site, Ermenek SSR and the ATC Air Traffic Control center.

### 4.3.4 CDS and DDS

CDS means Common Display System

DDS means Digital Display System

These are monitoring systems for the air traffic controls rule it has many different access to able an easier control when a controller looks at his displays he sees where the plane is, how high the plane is, what the speed of the plane is, very easily, and in a very clear w.ay~c

## 4.4 Basic Elements of Pulse Radar Systems in Ercan Airport

The basic elementsin a typical pulse radar system are: The timer, modulator, antenna, receiver, indicator, transmitter, duplexer and rotary joint, as is shown in figure 4.4.

### 4.4.1Timer

The timer, or synchronizer is the heart of all pulse radar systems, it's function is insure that all circuits connected with radar system operate in a deifnite time relationship with each other, and that the interval between pulse is ofthe proper length .The timer may be a separate unit by it self or it maybe included is the transmitter or receiver.

### 4.4.2 Modulator

The modulator is usually a source of power for the transmitter it is controlled by the pulse from the timer, it sometimes is called the keyer.

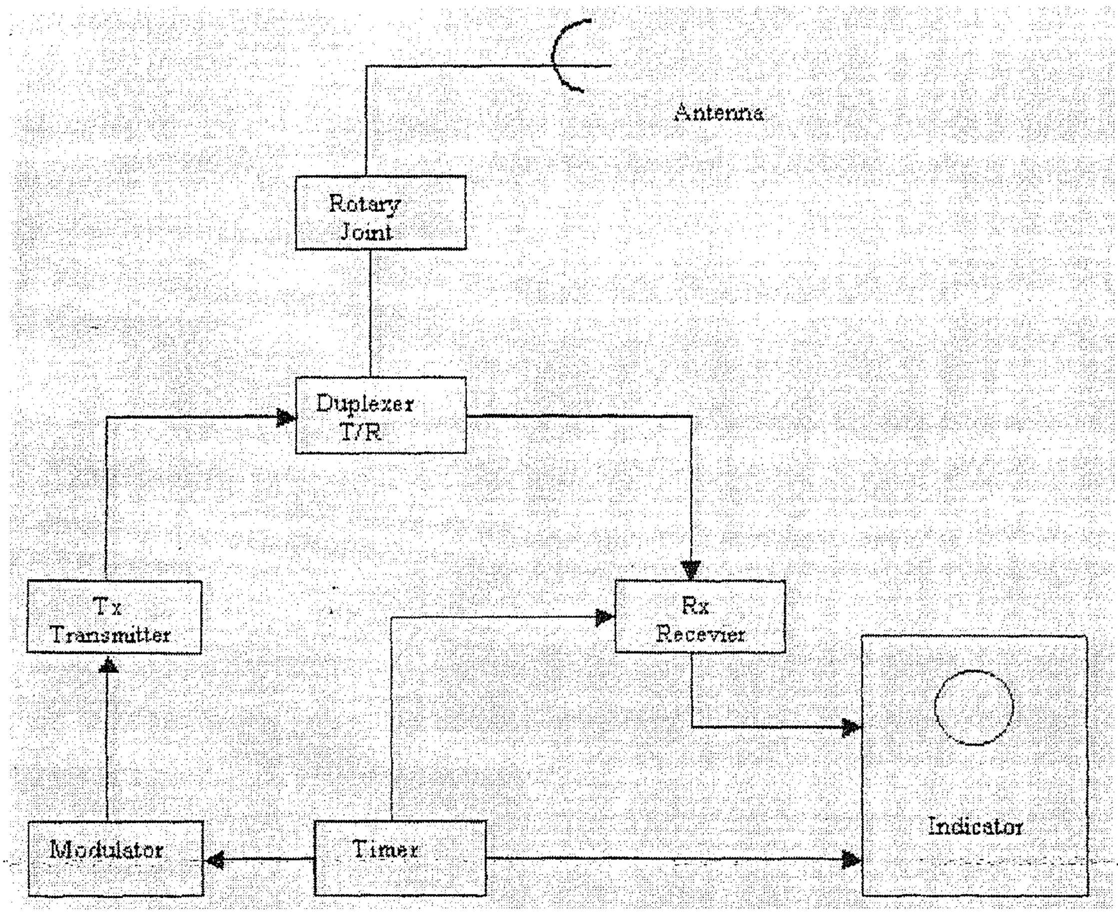



Figure 4.4 Basic elernents of pulse systerns radar in Ercan Airport

4.4.3 Transmitter

The transrnitter provider RF energy at an extrernely high power for a very short time. The frequency must to get many cycles in to the short pulse,

4.4.4 Antenna

The antenna is very directional in nature because it rnust obtain the angles of elevation and bearing of the target to obtain this directivity at centirneter wave lengths ordinary dipole antennas are used in conjunction with parabolic reflectors usually ,in order to sarne space and weight the sarne antenna is used for both transrnitting and receiving when this systern is used , sorne kind of switching device is required for connecting it to the transrnitter when a pulse is being radiated ,and to the receiver during the interval between pulse. Since the antenna only (sees) in one direction, it is usually rotated or Moved a bout to cover the area around the radar set this is called searching. The presence of targets in the area is established by this searching.

4.4.5 Duplexer

Such a device realized the antenna switching from transmitting phase to receiving phase enabling the patlı Transmitter-antenna and inhibiting tlıe patlı Antenna-receiver during radiation; vice versa during recetion.

4.4.6 Rotary joint

This device allows the transorming of the RF energy between the fixed part and the turntableone oftlıe RF system.

4.4. 7 Receiver

The receive in radar equipment is primarily a super-hetero dyne receiver. İt is usually quite senitive. When pulsed operation is employed. it must be capable of accepting signals in a bandwidth of one to ten mega cycles.

4.4~8 .Indteamr-

Tlıe indicator presents visually all the necessary information to locate tlıe target on the indicator screen. The method of presenting tlıe data depends on the purpose of the radar set. Since tlıe spot (seans) the indicator screen to present the data, the method of presentation is often reflexes to as the type of scan, in the following sub paragraphs a brief description on the most commorı types of scan used will be supplied.

4.5 Important Aviation System has Related with Airport Surveillance Radar in Ercan Airport

There is also important aviation systems have related with radar, to make the Air traffic control easier, in tlıis section we are going to present tlıeses systems wlıich used in Ercan Airport.

4.5.1 The Navigational Aids Systems in Ercan Airport

The purpose of navigation system is to ensure tlıe safe, efficient transit of aircraft following establislıed procedures. Tlıe elements which support tlıe basic function of determining tlıe position of aircraft are ground-based navaids, wlıich support en route and approach navigation, and landing at airports. The surveillance function, needed to provide Air Transit Services, is based on primary and secondary surveillance radar sensors to perform en route and approach air traffic control. Navigational aids systems in Ercan Airport consist of VOR, NDB and DME.

#### 4.5.1.1 VOR

VOR is (Very High Frequency (VHF) Omni-directional Radio Range), each VOR equipment has a name of three characters and identification in morse code the VOR station have different frequencies, if two VOR station will use the same frequency they should have 500 miles difference. What is the job ofVOR equipment?

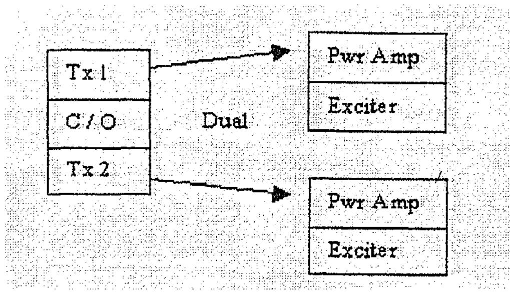
It has a global radio lines transmission; there are 360 radials 0 degree is adjusted to magnetic north. The frequency of VOR equipment is between 108 MHz- 117.95 MHz, VOR equipment consists of solid state plug in modules, 220 VAC is converted to 40 vdc, 12 vdc and 24 vdc by transformer. There are mainly six parts in VOR equipment

1- power supply
2~ transmitter
3- modulator
4- electronic goniometric
5- antenna
6- monitor

The VOR Frequencies in Ercan Airport (ECN) is 117.00 MHz, and in Geçıtkale Airport (GKE) is 114.3 MHz.

#### 4.5.1.2 NDB

NDB is Non Directional Beacon, it is a radio transmitter NDB frequency range is between (200 - 800 kHz), the frequency of Ercan Airport is 290 kHz. It can be identified by a Morse code signal that it emits at frequent intervals, it offers no tracking guidance and most aircrafts are fitted with an Automatic Direction Finder (ADF) to identil' the direction of the beacon from the aircraft. NDB's are usually used in the vicinity of airports as an aid to locating the airport itself




Flgure 4.5 The NDB system

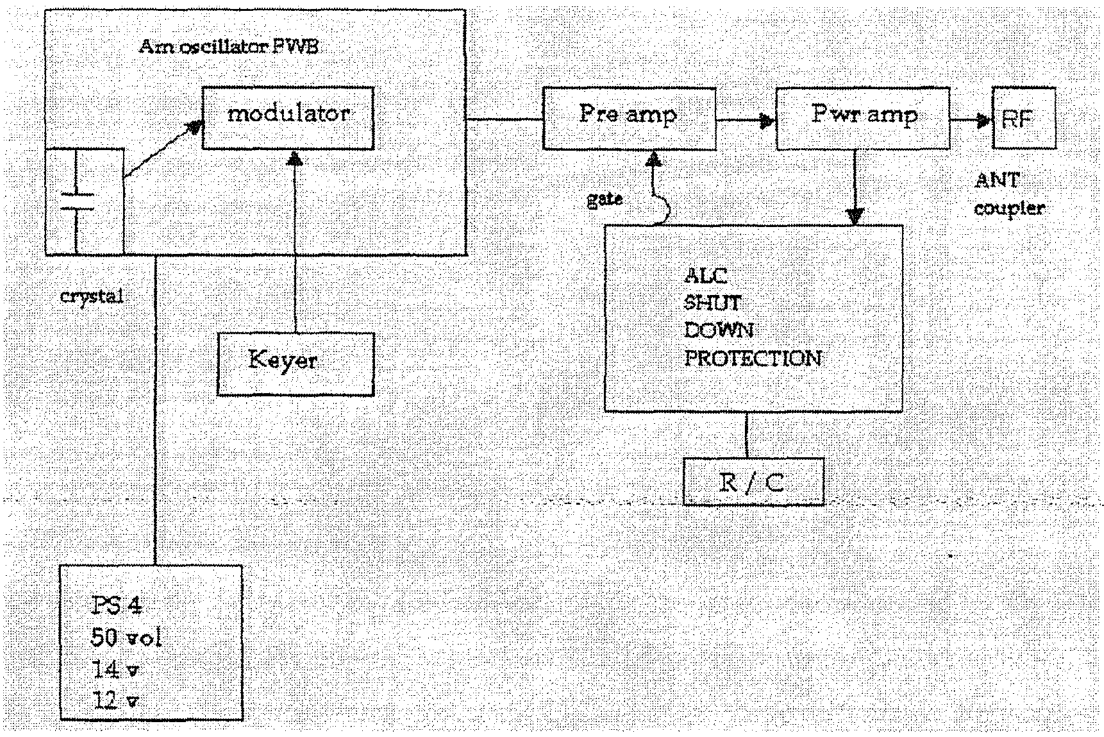



Figure 4.6 Block diagram ofNDB in Ercan Airport

4.5.1.3 DME

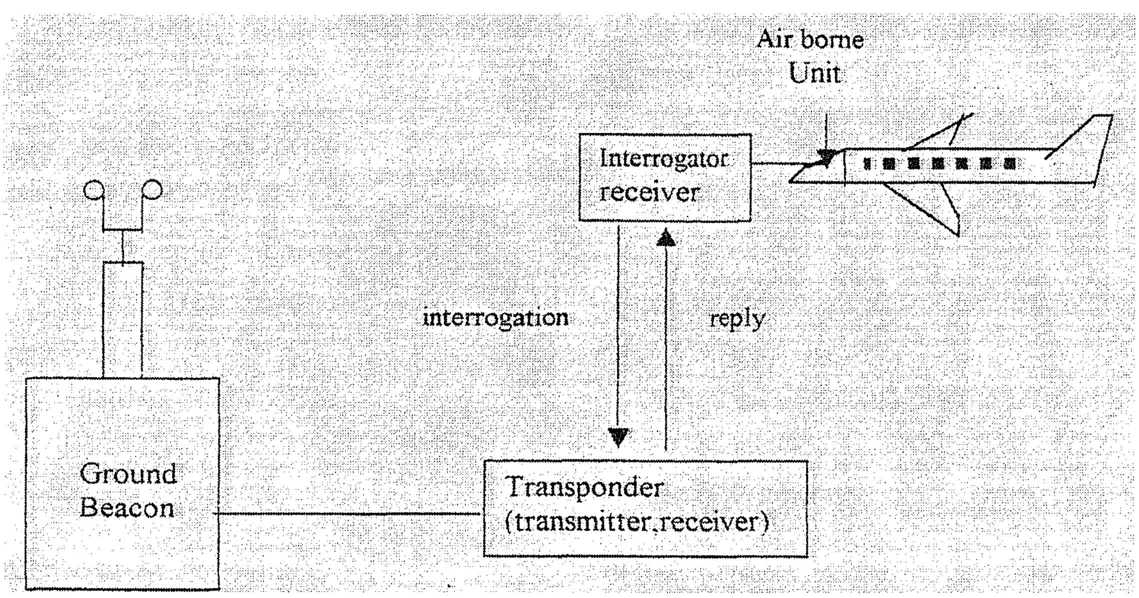



Figure 4.7 The DME system in Ercan Airport

DME is Distance Measuring Equipment, DME is a frill-duplex VHF system, full duplex means transmission and reception can be realized at the same time, in DME the frequency is different for every airport, for usage purpose there are two types ofDME.

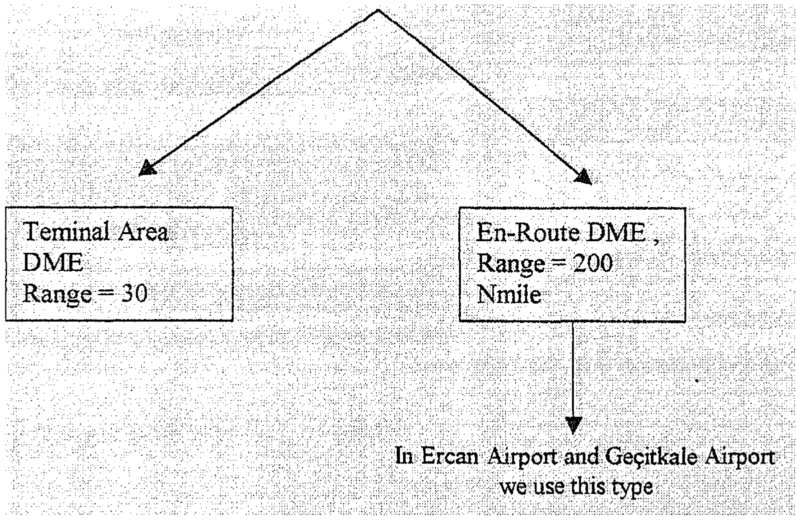



Figure 4.8 Types ofDME

Face standard FSP:-lŞ is used in ErcanAirport and the Airsys .Navigation fŞPd_~js used in Getcitkale Airport, The working principle ofDME:

The interrogator / receiver in airbome unit sends the interrogation signal to the DME ground beacon, then the ground beacon sends a reply signal to the air bome unite, the air bome unit then calculates the distance using the time difference between the interrogation and reply signals by using the formula,

$$M=t.\ C \qquad (4.2)$$

Mis the distance, t the time and c is the velocity ofthe light Parts ofDME ground beacon.

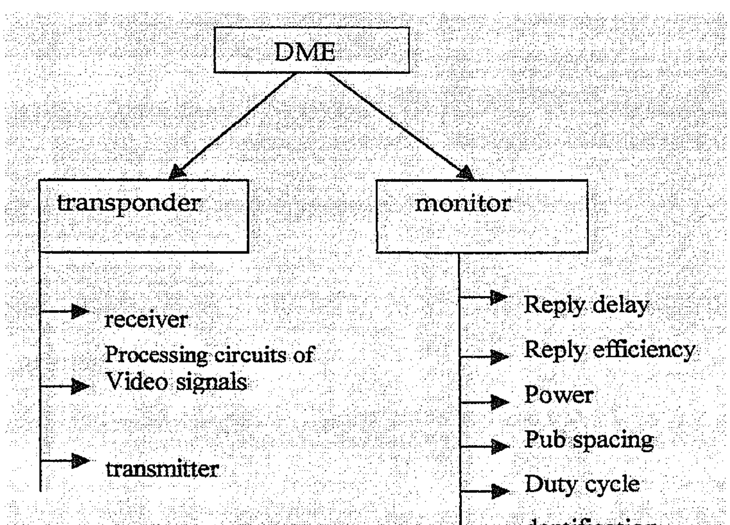
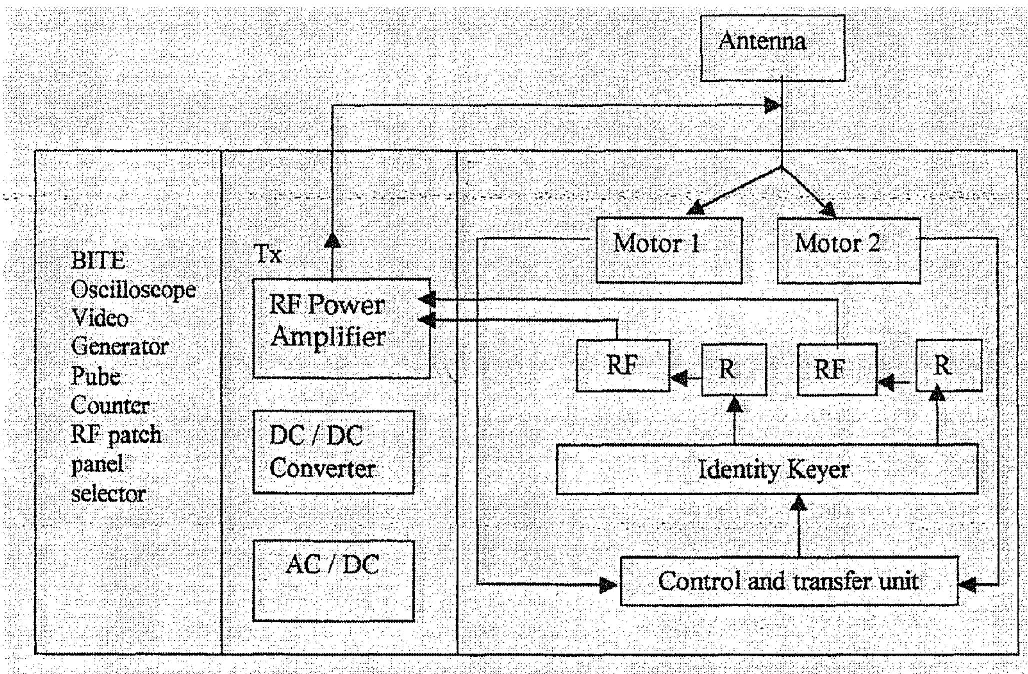



Figure 4.9 Parts ofDME ground beacon

The fnônitor system continuously checks if the pulses and all the transmission properties are correct. The frequency of Ercan DME is as below,

| Airport | Channel | Iaterrogation frequeney | Reply Frequency | Pulse Frequeney | VHF Channel |
|---|---|---|---|---|---|
| GKE | 90x | 1114 MHz | 1177MHz | 12 us | 114.3 MHz |
| GKE | 90y | 1114 MHz | 1051 MHz | 30 us | 114.3 MHz |
| ECN | 117x | 1141 MHz | 1024 MHz | 12 us | 117.0 MHz |
| ECN | 117y | 1141 MHz | 1078MHz | 30 us | 117.0 MHz |

See figure 4.10 the general diagram ofDME




Flgure 4.10 General Diagram ofDMEin Ercan Airport

4.5.2 VHF Voice Communieation System in Ercan Airport

VHF frequency in general 30 - 300 MHz in air navigation. 118 MHz - 136 MHz separated for air navigation.

In Ercan Airport, frequencies used (assigned for Ercan), I C A 0 assigns these frequencies.

| Frequeney | Function |
|---|---|
| 120. 2 MHz | Tower frequency |
| 126. 7 MHz | Air traffic control frequency |
| 126.9 MHz | Approach frequency |
| 121.5 MHz | Emergency frequency, it is same in all the airports ofthe world |
| 118. 1 MHz | Spare tower frequency (Gecitkale tower frequency) |

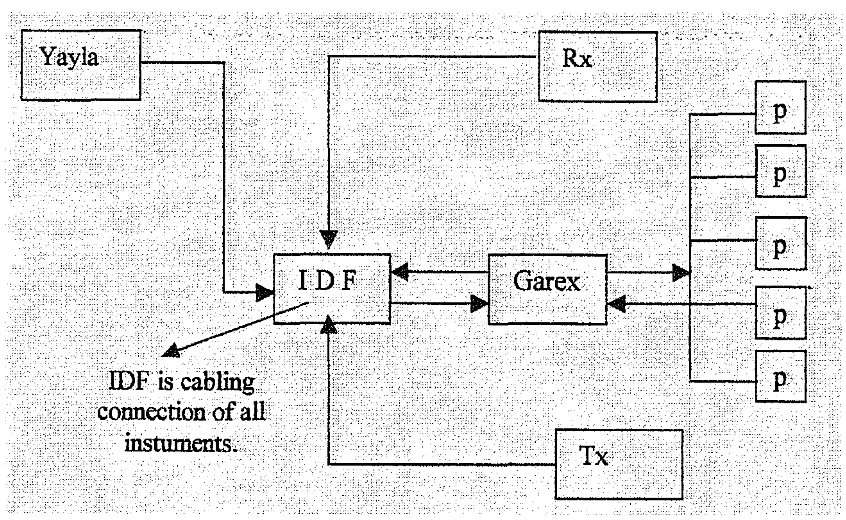
Local system situated in Ercan Airport for local frequency as,

| | |
|---|---|
| 120.2 MHz | 2 transmitters, 2 receivers |
| 126.7 MHz | 1 transmitter, I receiver |
| 126.9 MHz | I transmitter, I receiver |
| 121.5 MHz | 1 transmitter, I receiver |
| 118.1 MHz | 1 transmitter, 1 receiver |

Yayla station system situated in yayla over mountains,

| | |
|---|---|
| 126.7 MHz | 2 transmitters, 2 receivers |
| 126.9 MHz | -- "Ttransmitter.T'receiver' |
| 121.5 MHz | 1 transmitter, 1 receiver |

The system used in Yayla in order to have a greater coverage performance because they are situated over the mountains.




Figüre 4.11 Voice communication in Ercan Airport

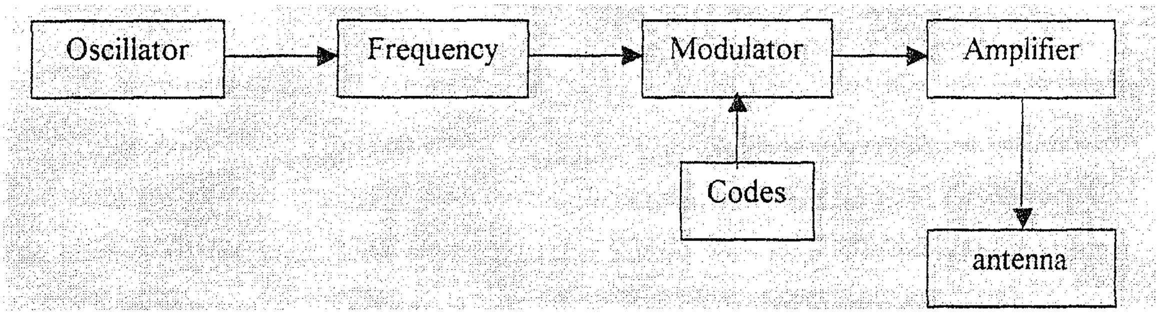



Figure 4.12 Simple block diagram of transmitter in voice communication

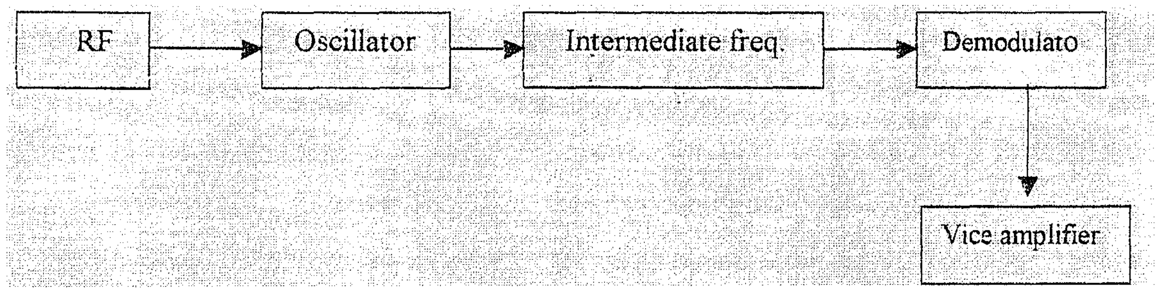



Figure 4.13 Simple block diagram of receiver in voice communication

4.5.2.1,Garex210

The main controlling and switching instrument for voice communication system. All the receivers, transmitter,position intercom telephone lines are all connected and controlled by garex system ( Brain of voice communication system ), it consist of two functional units , and many position cards and telephone cards and radio cards (7 position cards, 10 telephone cards and 10 radio card ) x 2., there is also a diagnostic card which mails the diagnostic of all the system and gives their information to the computer.

## 4.6 Summary

We can now understand the important of radar systems which include the SSR which inform the ATC room in Ercan about all the civil plans around Cyprus, as we mention that there are transponder in the plan resend the signal and inform Ercan the altitude and the identity of the plan, look at the figure 4.1 then we know the navigation systems which consist of three main parts DIVIE,VOR and NDB these systems make insurance for the plan ,so the pilot can know the altitude of the plan and its location . here come the VHF voice communication systems , which is very important also , the pilot can contact with the ATC room by this system by the frequencies assigned for Ercan by ICAO so here the employee in Ercan can tell the pilot what is his altitude as what is written in the radar monitor in the ATC room , the pilot of course will look at the transponder of DM.E to make insurance, the plan can lmow what is going on the space by contact Ercan and what is the speed of the other plans so the employee of ATC room here has big responsible to what happening in the air.

Pigure 4.14 The new ATC room in Istanbul, and its similar to ATC room in Ercan

# CONCLUSION

Most of the airports are using the secondary surveillance radar (SSR) to detect the plans and for the air traffic control (ATC), secondary surveillance radar provides, afler processing f <lata transmitted by the aircraft, the range, bearing, altitude and identity (call sign) of an aircrafl. The coverage can reach 250 nautical miles. A SSR can provide more useful information than Primary Surveillance Radar (PSR) but is subject to the proper functioning of the aircrafl's transponder. To provide the best radar picture with a continuous display of aircrafl targets, the SSR is usually paired with a PSR for air traffic control operation.

The future of radar does not lie in larger and more powerful systems, but rather in slightly smaller systems that are more agile, intelligent and difficult to detect because of the larger bandwidths that will be used. The resolution of radars, and the number of targets that can be tracked, can be expected to increase as large amounts of low-cost computer power become available.

We hope that this project has conveyed the mainideas and helped you to understand the underlying principles of the airport surveillance radar. We hope also that you have gained an appreciation of the importance of radar in many diverse areas, and sensed some of the excitement of working in this field.

## REFERENCES


[1] M. L. Skolnik, "Introduction to Radar Systems", McGraw-Hill, Inc., New York, NY, 1980.

[2] Y. Bar-Shalom "Multitarget-Multisensor Tracking: Advanced Applications", Artec House, Inc., Norwood,~MA, 1990.

[3] E.J. Chrzanowski, "Active Radar Electronic Countermeasures", Artec House, Inc., Norwood, MA, 1990.

[4] C.Sindey Burrus,Computer-Based Exercises for Signal Processing Using MATLAB, chapter 10 pages 317-329. Prentice Hall, Englewood Cliffs, NJ, 199.

[5] W. August, Rihaczek, "Principles of Hlgfi-resofution Radar", New York,McGraw Hill, 1969.

[6J Anne-Paylor, "AirTraffic ControtTodayôcTomorrôw", Btitish Council,UK, 1993.

[7] Kingsley and Quegan, "Understanding Radar Systems",Caınbridge, UK, 1992.

[8] Mustafa Sofi, "Radar System in Ercan Airport notes", (Jivil Aviation Department, Nicosia, 2000.

[9J Associate Prof Dr Sameer Ikhdair , Notes of Electromagnetic 1,2~ Notes of radar system 1999, 200 L

[10] Hovanessian S.A., "Radar system Design and Analysis", Dedham MA, Artech House, 1984.