NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

Surveillance Radar

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Student: bashar jalal

(20011822)

Supervisor: Assoc. Prof. Dr. Sameer Ikhdair

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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 of a target, a continuous indication of the rate of change of target position is also available.

INTRODUCTION

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

In 1888 Heinrich Hertz showed that the invisible electromagnetic waves radiated by suitable electrical circuits travel with the speed of light, and that they are reflected in a similar way. From time to time in the succeeding decades it was suggested that these properties might be used to detect obstacles to navigation, but the first successful experiment s, that of Tuve and Breit, made use of short repeated pulses of radiation, and this technique was employed in most of the developments of radar.

In practice we need to know more about the target than its distance; we must also determine its direction. Arranging an antenna system to project a suitable radiation pattern that can be rotated in azimuth or elevation does this. As may be deduced from what follows, a very great deal of ingenuity and engineering skill has been devoted to the design of radar antennas.

The first successful radar installations in Great Britainin the years 1935 to 1939 used wavelengths in the 6 to 15 m band, and required very large antennas. Other equipment developed later used wavelengths of 3 m and 1.5 m; and in 1940 the invention of a new from of generator, the cavity magnetron, at once made it practicable to employ wavelengths of 10 cm and even less. Nearly, all the radar developed at the National Research Council in 1942 and later was done at centimeters wavelengths. Universally referred to as microwaves.

In Chapter One, we present the fundamentals of radar system, radar pulse, omponents and target recognition which are accomplished by measuring the size and speed of the target. Further this is accomplished by observing the target with high resolution in one or more dimensions. The radar subsystems contain radar antenna, its components, and the factors affecting radar performance.

In Chapter Two we investigate the 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.

In Chapter Three we study the surveillance radar applications in Ercan Airport
Finally, we give our conclusions and remarks.

CHAPTER ONE

FUNDAMENTALS OF RADAR

1.1 Overview

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. A generation of adequate R.F. power is an important part of any radar system. So that the transmitter is selected for any particular application. There are two basic transmitter configurations used in radar. One is the self-exited oscillator exemplified by the magnetron and the other utilizes a low power level by one or more power amplifier tubes. The types of radar antenna are different from antenna used in communications. Radar antenna must generate beams with shaped directive patterns, which can be scanned, since the radar opened at VHF or the UHF bands use array antenna. At the microwave frequencies the parabolic reflector and microwave lenses are used. The special design, which this project contains, is a wide-band amplifier or video amplifier, since the RC-coupled voltage and current amplifiers possess flat frequency-response characteristics over range of frequencies. The region of uniform amplification must be wider than possible with simple circuits. They're 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 Basic Principle

Typical radar operates by radiating a narrow beam of electromagnetic energy into space from an antenna as in Figure 1.1.

The transmitted pulse, which has already passed the target, has reflected a portion of the radiated energy back toward the narrow antenna beam is scanned to search a region where targets are expected.

When the beam illuminates a target, it intercepts some of the radiated energy and reflects a portion back toward the radar system. Since most radar systems do not

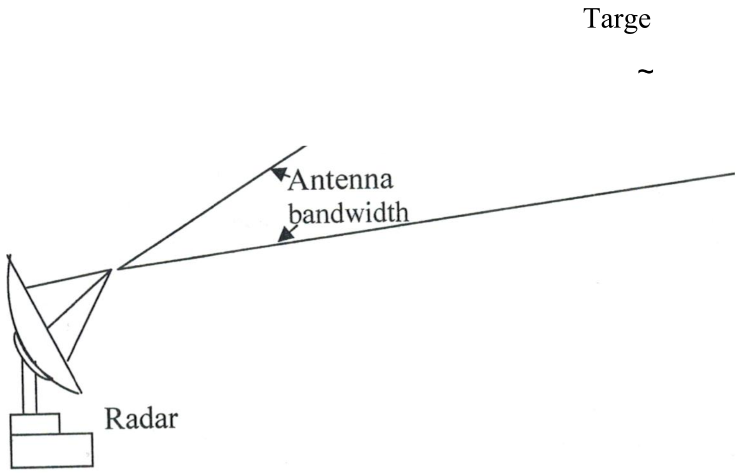

Figure 1.1 Principle of Radar Operation.

transmit and receive at the same time, a single antenna can be used on a time-shared basis for both transmitting and receiving.

A receiver attached to the output element of the antenna extracts the desired reflected signals and (ideally) rejects those that are of no interest. For example, a signal of interest might be the echo from an aircraft signal that are not of interest and might be echoes from the ground or rain, which can mask and interfere with the detection of the desired echo from the aircraft. The radar measures the location of the target in range and angular direction. Range is determined by measuring the total time it takes for the radar signal to make the round trip to the target and back as in Figure 1.2. The angular direction of a target is usually found from the direction in which the antenna points at the time the echo signal is received. Through measurement of the location of a target at successive instants tıme, its track can be determined. Once this information has been established, the get's location at a time in the future can be predicted, in much surveillance radar a ations, the target is not considered to be "detected" until its track has been ablished.

.1 Radar Pulse

The most common type of radar signal consists of a repetitive train of short--~tion pulses.

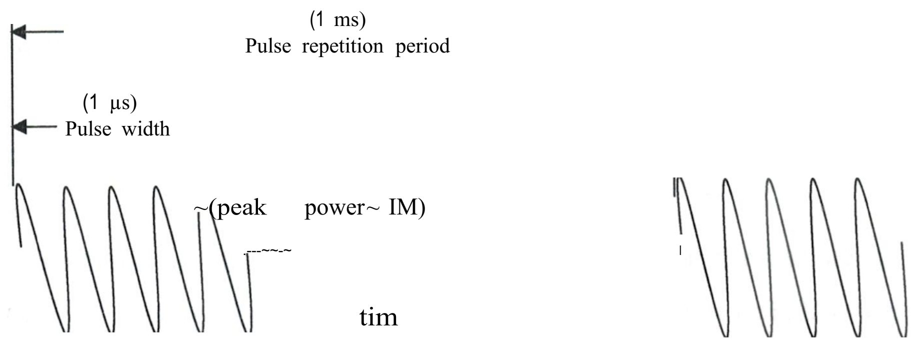

Figure 1.2 *A* typical pulse waveform transmitted by radar.

Figure 1.2 is a simple representation of a sine-wave pulse that might be generated by the transmitter of medium-range radar designed for aircraft detection. This sine wave in the Figure represents the variation with time of the output voltage of the transmitter. The numbers given in brackets in the Figure are only meant to be illustrative and are not necessarily those of any particular radar. They are numbers however, similar to what might be expected for a ground-based radar system with a range of about 50 to 60 nautical miles (or 90 to 110 kilometers), such as the kind used for air traffic control at airports. The pulse width is given in the Figure as one millionth of a second (one microsecond). It should be noted that the pulse is shown as containing only a few cycles of the sine wave; however, in a radar system. Having the values indicated, there would be 1,000 cycles within the pulse. In Figure 1.2 the time between successive pulses is given as one thousandth of a second (one millisecond), which corresponds to a pulse repetition frequency of lk Hz. The power of the pulse, called the peak power, is taken here to be lMW. Since pulse radar does not radiate continually, the average power is much less than the peak power. In this example, the average power is lKW. The average power, rather than the peak power, is the measure of the capability of a radar system. Radars have average powers from a few mill watts to as much as one or more megawatts, depending on the application.

A weak echo signal from a target might be as low as one trillionth of a watt (10^{-12} W). In short, the power levels in a radar system can be very large (at the transmitter) and very small (at the receiver).

Another example of the extremes encountered in a radar system is the timing. An air-surveillance radar one that is used to search for aircraft) might scan its antenna 360 degrees in azimuth in a few seconds, but, the pulse width might be about one microsecond in duration.

The range to a target is determined by measuring the time that a radar signal takes to travel out to the target and back. The range to the target is equal to cT/2, where *c* is the speed of propagation of radar energy, and T is the round-trip time as measured by the radar. From this expression, the round-trip travel of the radar signal is at a rate of 150 meters per microsecond. For example, if the radar to be 600 microseconds measured the time that it takes the signal to travel out to the target and back, then the range of the target would be 90 kilometers [1].

1.2.2 Components

Figure 1.3 shows the basic parts of a typical radar system. The transmitter generates the high-power signal that is radiated by the antenna. The antenna is often in the shape of a parabolic reflector, similar in concept to an automobile headlight but much different in construction and size. It also might consist of a collection of individual antennas operating together as a phased-array antenna.

The duplexer permits ultimate transmission and reception with the same antenna, it is a fast-acting switch that protects the sensitive receiver from the high power of the transmitter. The receiver selects and amplifies the weak radar echoes so that they can be displayed on a television-like screen for the human operator or be processed by a computer. The signal processor separates the signals reflected by the target (e.g., echoes - om an aircraft) and from unwanted echo signals (the clutter from land, sea, rain, etc). It - not unusual for these undesired reflections to be much larger than desired target echoes, in some cases more than one million times larger. Large clutter echoes from stationary objects can be differentiated from small echoes for a moving target by noting the shift in the observed frequency produced by the moving target. This phenomenon is called the Doppler frequency shift (Figure 1.3)

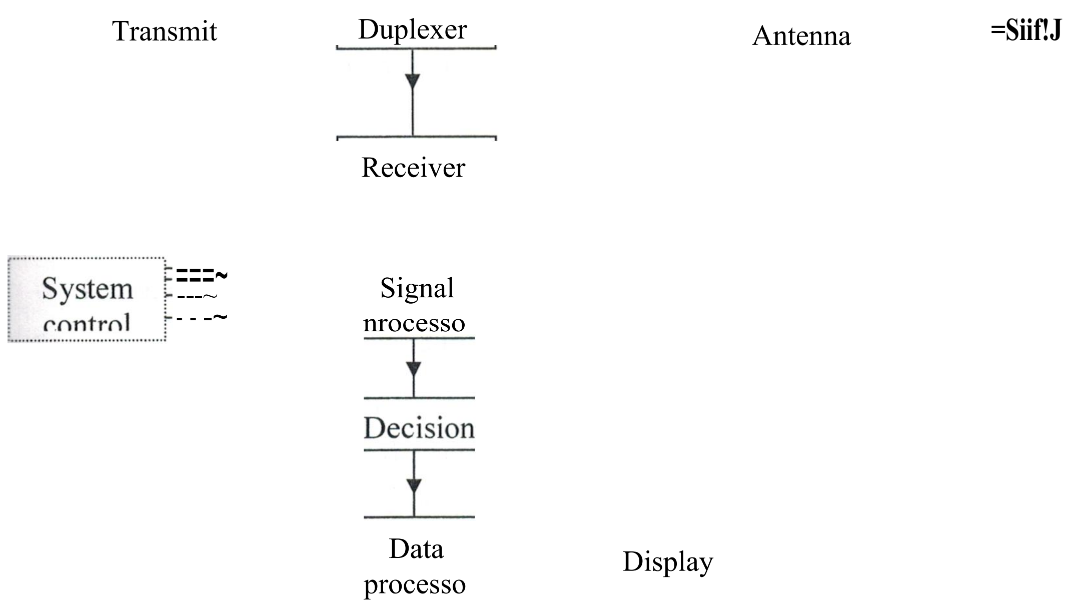

Figure 1.3 Basic Parts of a Radar System

At the output of the receiver a decision is made as to whether or not a target echo is present. If the output of the receiver is larger than a predetermined value, a target is assumed to be present [2].

Once the a target is present and its location has been determined, the track of the target can be obtained by measuring the target location at different times. During the early days of radar, target tracking was performed by an operator marking the location of the target "blip" on the face of a cathode-ray tube (CRT) display with a grease pencil. Manual tracking has been largely replaced by automatic electronic tracking, which can process a much greater number of target tracks than can an operator who can handle only a few simultaneous tracks. Automatic tracking is an example of an operation performed by a data processor. The type of signal waveform transmitted and the associated received-signal processing in a radar system might be different depending on the type of target involved and the environment in which it is located. An operator can select the parameters of the radar to maximize performance in a particular environment. Alternatively, electronic circuitry in the radar system can automatically analyze the environment and select the proper transmitted signal, signal processing, and other radar parameters to optimize performance. The box labeled "system control" in Figure 1.3 is intended to represent this function. The system control also can provide the timing and reference signals needed .to permit the various parts of the radar to operate effectively as an integrated system.

1.2.3 Target Information

The ability to measure the range to a target accurately at long distances and to operate under adverse weather conditions are radar's most distinctive attributes. There are no other devices that can compete with radar in the measurement of range. The range accuracy of simple pulse radar depends on the width of the pulse, the shorter pulse, the better accuracy. Short pulses; require wide bandwidths in the receiver and transmitter. Radar with a pulse width of one microsecond can measure the range to an accuracy of a few tens of meters or better. Some special radars can measure to an accuracy of a few centimeters. The ultimate range accuracy of the best radars is limited not by the radar system itself, but rather by the known accuracy of the velocity at which electromagnetic waves travel.

Almost all radars use a directive antenna, i.e., one that directs its energy in a narrow. The direction of a target can be found from the direction in which the antenna is beam pointing when the received echo is at a maximum. A dedicated tracking radar-one that follows automatically a single target so as to determine its trajectory-generally has a narrow symmetrical "pencil" beam. Such a radar system can determine the location of the target in both azimuth angle and elevation angle. Aircraft-surveillance radar generally employs an antenna that radiates a "fan" beam, one that is narrow in azimuth (about 1 or 2 degrees) and broad in elevation. A fan beam allows only the measurement of the azimuth angle.

Radar can extract the Doppler frequency shift of the echo produced by a moving target by noting how much the frequency of the received signal differs from the frequency of the signal that was transmitted. A moving target will cause the frequency of the echo signal to increase if it is approaching the radar or to decrease if it is receding from the radar. For example, if a radar system operates at a frequency of 3 GHz and an aircraft is moving toward it at a speed of 400 knots (740 Km/hr), the frequency of the received echo signal will be greater than that of the transmitted signal by about 4.1 KHz. The Doppler frequency shift in hertz is equal to $3.4 f_0 v_r$, where f_0 the radar frequency in GHz and v_r *is* the radial velocity in knots.

Since the Doppler frequency shift is proportional to radial velocity, a radar system that measures such a shift in frequency can provide the radial velocity of a target. The Doppler frequency shift also is used to separate moving targets from stationary ones (land or sea clutter) even when the undesired clutter power might be much greater than the power of the echo from the targets. A form of pulse radar that uses the Doppler frequency shift to eliminate stationary clutter is called either moving target indication (MTI) radar or a pulse Doppler radar, depending on the particular parameters of the signal waveform [3].

The above measurements of range, angle, and radial velocity assume that the target is like a point. Actual targets, however, are of finite size and can have distinctive shapes. The range profile of a finite-sized target can be determined if the range resolution of the radar is small compared to the target's size in the range dimension. Some radar can have resolutions smaller than one meter, which is quite suitable for determining the radar size and profile of many targets of interest.

The resolution in angle that can be obtained with conventional antennas is poor compared to that which can be obtained in range. It is possible, however, to achieve good resolution in angle, or cross range, by resolving in Doppler frequency if the radar is moving relative to the target, the Doppler frequency shift will be different for different parts of the target. Thus the Doppler frequency shift can allow the various parts of the target to be resolved. The resolution in cross range derived from the Doppler frequency shift is far better than achieved with a narrow-beam antenna. It is not unusual for the cross-range resolution otained from Doppler frequency to be comparable to that obtained in the range ensıon.

ross-range resolution obtained from Doppler frequency, along with range resolution, is ae basis for synthetic aperture radar (SAR). SAR produces an image of a scene that is similar to, but not identical with, an optical photograph. One should not expect the image seen by radar "eyes" to be the same as that observed by optical ones. Each provides ~.tterent information. Radar and optical images differ because of the large difference in ·-=- frequencies involved, optical frequencies are approximately 100,000 times higher ızan radar frequencies.

ae SAR can operate from long range and through clouds of other atmospheric effects aat limit optical and infrared imaging sensors. The resolution of a SAR image can be ade independent of range, an advantage over passive optical imaging, where the esolution worsens with increasing range. Synthetic aperture radars that map areas of the Earth's surface with resolutions of a few meters can provide information about the nature : the terrain and what is on the surface.

SAR operates on a moving vehicle, such as an aircraft or spacecraft, to image stationary object or planetary surfaces. Since relative motion is the basis for the Doppler resclution, high resolution (in cross range) also can be accomplished if the radar is stationary and the target is moving. This is called inverse synthetic aperture radar 1SAR). Both the target and the radar can be in motion with ISAR.

1.2.4 Target Recognition

Radar can distinguish one kind of target from another (such as a bird from an ircraft), and some systems are able to recognize specific classes of targets. Target recognition is accomplished by measuring the size and speed of the target and by observing the target with high resolution in one or more dimensions. Propeller or jet engines modify the radar echo from aircraft and can assist in target recognition. The flapping of the wings of a bird in flight produces a characteristic modulation, which can be used to recognize that a bird is present or even to identify one type of bird from another.

.3 Developments

.1 Early Experiments

Serious developmental work on radar began in the 1930s, but the basic idea of adar had its origins n the classical experiments on electromagnetic radiation conducted -.· 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 . Iaxwell. Maxwell had formulated the general equations of the electromagnetic field, zetermining that both light and radio waves are examples of electromagnetic waves ~overned by the same fundamental laws but having widely different frequencies. ..laxwell's work led to the conclusion that radio waves can be reflected from metallic ıjects and refracted by a dielectric medium just like light waves. Hertz demonstrated zaese properties in 1888, using radio waves at a 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 of and ship navigation device," based on the principles demonstrated by Hertz, was issued in several countries to Christian Hulsmeyer, a German engineer. Hulsmeyer built his invention and demonstrated it to the German navy, but failed to arouse any interest. There vas 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 prompted the major countries of the world to look for a 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 [3].

1.3.2 First Military Radars

During the 193 0s, efforts to use radio echo for aircraft detection were initiated :ndependently and almost simultaneously in several countries that were concerned with tne 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 of World War II in 193 9.

The first observation of the radar effect at the U.S. Naval Research Laboratory (NRL) in ashington, 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 aused 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.

1.4 Radar Subsystems

Figure 1.3 shows the major subsystems that make up a typical radar system. These subsystems are described in greater detail here.

1.4.1 Antennas

A widely used from of radar antenna is the parabolic reflector, the principle of which is shown in cross section in Figure 1.4(A). A horn antenna or other small antenna is placed at the focus of the parabola to illuminate the parabolic surface of the reflector. After being reflected by this surface, the electromagnetic energy is radiated as a narrow beam. A parabolic, which is generated by rotating a parabola about its axis, forms a symmetrical beam called a pencil beam. A fan beam, one with a narrow beam width in azimuth and a broad beam width in elevation, can be obtained by illuminating an asymmetrical section of the parabolic. An example of an antenna that produces a fan beam is shown in the photograph.

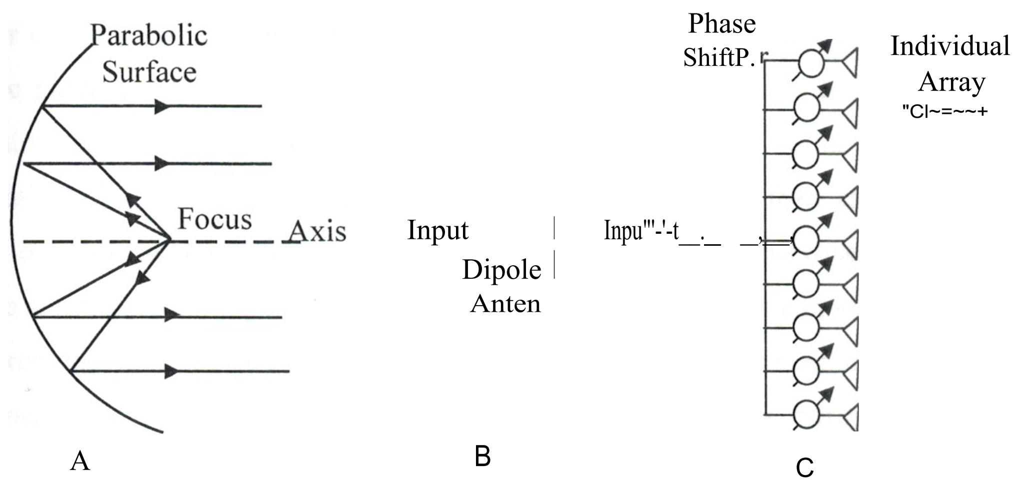

Figure 1.4 Radar antennas. (A) A parabolic reflector antenna in which the energy radiated from the focus is reflected from the parabolic surface as a narrow beam. (B) A dipole antenna. (C) A phased-array antenna composed of many individual radiating elements.

The half-wave dipole Figure 1.4(8), whose dimension is one-half of the radar wave length, is the classic type of electromagnetic antenna. A single dipole is not of much use for radar, since it produces a beam width too wide for most applications. Radar requires a narrow beam (a beam width of only a few degrees) in order to concentrate its energy on the target and to determine the target location with accuracy. Combining many individual dipole antennas so that the signals radiated or received by each elemental dipole are in unison or in step can form such narrow beams [4].

The ,phase shifters at each radiating antenna-element shift the phase of the signal, so that all signals received from a particular direction will be in step with one another. Similarly, all signals radiated by the individual elements of the antenna will be in step with one another in some specific direction. Changing the phase shift at each element alters the direction of the antenna beam. An antenna of this kind is called an electronically steered phased array. It allows rapid changes in the position of the beam without moving large mechanical structures. In some systems, the beam can be changed from one direction to another within microseconds.

The individual radiating elements of a phased-array antenna need not be dipoles; various other types of antenna elements also can be used. For example, slots cut in the side of a wave guide are common, especially at the higher microwave frequencies. In radar that requires a one-degree, pencil-beam antenna, there might be about 5,000 individual radiating elements. The phased-array radar is more complex than radar systems that employ reflector antennas, but it provides capabilities not otherwise available. Since there are many control points in a phased-array, the radiated beam can be shaped to give a desired pattern to the beam. Controlling the shape of the radiated beam is important when the beam has to illuminate the air space where aircraft are found but not illuminate the ground, where clutter echoes are produced Another example is when the stray radiation (called antenna side lobes) outside the main beam of the antenna pattern must be minimized.

The electronically steered phased-array is attractive for applications that require large antennas or when the beam must be rapidly changed from one direction to another Satellite surveillance radars and ballistic missile detection radars are examples that usually require phased-arrays The U.S. Army's Patriot battlefield air-defense system and the U.S. Navy's Aegis system for ship air-defense also depend on the electronically steered phased-array antenna

The phased-array antenna is also used without the phase shifters in Figure 1.4(C). The beam is steered by the mechanical movement of the entire antenna. Antennas of this sort are preferred over the parabolic reflector for airborne applications, in land-based air-surveillance radars requiring multiple beams, and in applications that require ultra antenna side lobe radiation.

1.4.2 Transmitters

The transmitter of a radar system must be efficient, reliable, not too large in size and weight, and easily maintained, as well as have the wide bandwidths and high power that are characteristic of radar applications. In MT, pulse Doppler, and CW applications, the transmitter must generate noise-free, stable transmissions so that extraneous (unwanted) signals from the transmitter do not interfere with the detection of the small Doppler frequency shift produced by weak moving targets.

It was observed earlier that the invention of the magnetron transmitter in the lasted 1930s resulted in radar systems that could operate at the higher frequencies known as microwaves. The magnetron transmitter has certain limitations, but it continues to be widely used-generally in low-average-power applications such as ship navigation radar and airborne weather-avoidance radar. The magnetron is a power oscillator in that it self-oscillates when voltage is applied. Other radar transmitters usually are power amplifiers in that they take low-power signals at the input and amplify them to high power at the output. This provides stable high-power signals, as the signals to be radiated can be generated with precision at low power.

The klystron amplifier is capable of some of the highest power levels used in radar. It has good efficiency and good stability. The disadvantages of the klystron are that it is usually large and it requires high voltages (e.g. about 90 kilovolts for one megawatt of peak power). At low power the instantaneous bandwidth of the klystron is small, but the klystron is capable of large bandwidth at high peak powers of a few megawatts.

The traveling-wave tube (TWT) is related to the klystron. It has very wide bandwidths at low peak power, but, as the peak power Levels are increased to those needed for radar, its bandwidth decreases. As peak power increases, the bandwidths of the TWT and the klystron approach one another.

Solid-state transmitters, such as the silicon bipolar transistor, are attractive because of their potential for long life, ease of maintenance, and relatively wide bandwidth. An individual solid-state device generates relatively low power and can be used only when the radar application can be accomplished with low power (as in short-range applications or in the radar altimeter). High power can be achieved, however, by combining the outputs of many individual solid-state devices.

While the solid-state transmitter is easy to maintain and is capable of wide-band operation, it has certain disadvantages. It is much better suited for long pulses (ms) than for the short pulses (μs). Long pulses can complicate radar operation because signal processing (such as pulse compression) is needed to achieve the desired range resolution. Furthermore, long-pulse radar generally requires several different pulse widths: a long pulse for long range and one or more shorter pulses to observe targets at the ranges masked when the long pulse is transmitting. Every kind of transmitter has its disadvantages as well as advantages. In any particular application, the radar engineer must continually search for compromises that give the results desired without too many negative effects that cannot be adequately accommodated.

1.4.3 Receivers

Like most other receivers, the radar receiver is a classic super heterodyne. It has to filter the desired echo signals from unwanted clutter signals and receiver noise that interfere with detection. It also must amplify the weak received signals to a level where the receiver output is large enough to actuate a display or a computer. The technology of the radar receiver is well established and seldom sets a limit on radar performance.

The receiver must have a large dynamic range in situations where it is necessary to detect weak signals in the presence of very large. Clutter echoes by recognizing the Doppler frequency shift of the desired moving targets. Dynamic range can be loosely described as the ratio of the largest to the smallest signals that can be handled adequately by a receiver without distortion. A radar receiver might be required to detect signals that vary in power by a million to one-and sometimes much more.

In most cases, the sensitivity of a radar receiver is determined by the noise generated internally at its input. Because it does not generate much noise of its own, a transistor is usually used as the first stage of a receiver.

1.4.4 Signal and Data Processors

The signal processor is the part of the receiver that extracts the desired signal and rejects clutter. Doppler filtering in MTI radar or in a pulse Doppler system is an example. Most signal processing is performed digitally with computer technology. Digital processing has significant capabilities in signal processing not previously available with analog methods. Without digital methods many of the signal processing techniques found in today's high performance radars would not be possible. Digital processing also has made practical data processing, such as required for automatic tracking. Pulse ompression (described below in Pulse-compression radar) is sometimes included under signal processing. It too benefits from digital technology, but analog processors (e.g. surface acoustic wave delay-lines) are used rather than digital methods when pulse compression must achieve resolutions of a few meters or less.

1.4.5 Display

The cathode-ray tube has been the traditional means of displaying the output of a radar system. Although it has its limitations, the CRT has been the preferred technology ever since the early days of radar. The CRT has undergone continual improvement that has made it even more versatile.

Plan position indicator, or PPI is a map like presentation in polar coordinates of range and angle. The CRT screen is dark (other than for slight noise background) except when echo signals are present. The PPI is called an intensity-modulated display because the intensity of the electron beam of the CRT is increased sufficiently to excite the phosphor of the screen whenever an echo signal is present. The PPI is the most common form of display in use with radar. Another variety, the B-scope, is also an intensity-modulated display that presents the same information and the same coordinates as the PPI but in rectangular rather than polar format. In still another format, the A-scope, the received signal amplitude is displayed as the vertical coordinate and the range as the horizontal coordinate. The A-scope is called an amplitude-modulated display because echo signals are indicated by the increased amplitude (the vertical coordinate) on the CRT. The A-scope is not a suitable display for surveillance radar that must search 360 degrees in azimuth, but it is used for tracking radars and in experimental radars when examining the nature of the echo signal is important.

Practical radar displays have been two dimensional, yet most radar provides more information than can be displayed on the two coordinates of a flat screen. Co lour coding of the intensity-modulated signal on the PPI is sometimes used to provide additional information about the echo signal. Co lour has been employed, for example, to indicate the strength of the echo. Doppler weather radars good use of co lour coding to indicate on a two-dimensional display the rain intensity associated with each echo shown. They also ilize co lour to indicate the radial speed of the wind, the wind shear, and other formation relating to severe storms. The PPI displays targets as if seen in a horizontal lane. On the other hand, a range-height indicator, or RHI, is an intensity-modulated display that presents the echoes that appear in a vertical plane, e.g., a vertical cut through ..... e cloud of a severe storm.

The radar display has benefited from the availability of digital technology. Digital memory allows the radar to store data from an entire scan period (usually one rotation of the radar antenna) and present the information to the operate of all at once (as in the case of a television-type monitor) rather than display targets only when they are actually vithin the antenna beam. This allows the operator to view the entire scene all the time and to manipulate the output to display the type of target information of most interest.

Modern surveillance radars rarely display the output of a radar receiver without further processing (raw video). When automatic detection of targets is employed in a radar system, the rejection of unwanted echoes such as land or sea clutter, the addition of the radar pulses received from a target, and the decision as to whether a target is present or not are all performed electronically without assistance from a human operator. The display then shows only detected targets without the background noise. This has been called a "cleaned-up" display or processed video. When automatic tracking is performed electronically (in a digital data processor), only processed target tracks are displayed and no individual target detections are indicated. The speed of a target and its direction of travel can be indicated on the CRT by the length of the line defining the track and its orientation. Near each target track on the display, alphanumeric information can be entered automatically to indicate information that is known about the target. For example, when the air-traffic-control radar-beacon system (ATCRB S) is used in conjunction with air-surveillance radar, the alphanumeric data on the display can indicate the flight number of the aircraft and its altitude.

1.4.6 Antenna Directivity and Aperture Area

The directivity of the antenna is

$$D = \frac{4\pi A}{\lambda^2} \qquad (1.1)$$

Where *A* ?is the radar carrier wavelength. Aperture inefficiency is due to the antenna illumination factor.

The common form of the radar range equation uses power gain rather than directivity. Antenna gain is equal to the directivity divided by the antenna losses. In the design and analysis of modem radars, directivity is a more convenient measure of performance because it permits designs with distributed active elements, such as solid-state phased arrays, to be assessed to permit direct comparison with passive antenna systems.

Beam-width and directivity are inversely related; a highly directive antenna will have a narrow beam-width. For typical design parameters,

$$D = \frac{10^7}{\theta_{az}\theta_{cl}} \qquad (1.2)$$

Where *Baz* and *Bcl* are the radar azimuth and elevation beam-widths, respectively, in mill radians.

1.5 Factors Affecting Radar Performance

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

1.5.1 Transmitter Power and Antenna Size

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

1.5.2 Receiver Noise

The sensitivity of a radar receiver is determined by the unavoidable noise that appears at its input. At microwave radar frequencies shown in appendix 6, 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 application of the basic engineering principle that the "best" performance that can be obtained might not necessarily be the solution that best meets the needs of the user.

The receiver is designed to enhance the desired signals and to reduce the noise and other undesired signals that interfere with detection. The designer attempts to maximize the delectability of weak signals by using what radar engineers call a "matched filter which is a filter that maximizes the signal-to-noise ratio at the receiver output. The matched filter has a precise mathematical formulation that depends on the shape of the input signal and the character of the receiver noise. A suitable approximation to the matched filter for the ordinary pulse radar, however, is one whose bandwidth in hertz is the reciprocal of the pulse width in seconds.

1.5.3 Target Size

The size of a target as "seen" by radar is not always related to the physical size of the object. The measure of the target size as observed by radar is called the radar cross section and is given in units of area (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 at a 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 of a 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 of the cone or the cone angle. Thus the flat plate and the cone-sphere can have radar cross sections that differ by a million to one even though their physical projected areas are the same.

The sphere is an unusual target in that its radar cross section is the same as its physical cross section area (when its circumference is large compared to the radar wavelength). That is, a sphere with a projected area of one square meter has a 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 comparison, the radar cross section of a man has been measured at microwave frequencies to be about one square meter. A bird can have a cross section of 0.01 m^2. 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:

The radar cross section of an aircraft and most other targets of practical interest is not a 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.)

1.5.4 Clutter

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

1.5.5 Atmospheric Effects

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

1.5.6 Interference

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

1.5.7 Electronic 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 of a large number of tiny metallic retlecting 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

·entional weapons or by ant radiation missiles (ARMs) that use radar transmissions to - the target and home on it.

.itary radar engineers have developed various ways of countering hostile ECM and · taining the ability of a radar system to perform its mission. It might be noted that a itary radar system can often accomplish its mission satisfactory even though its ormance in the presence of ECM is not what it would be if such measures were csernt.

CHAPTER TWO

SURVEILLANCE RADAR

2.1 Introduction

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 path Surveillance radar a device which, by measuring the time interval between 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.

1. ASR is designed to provide relatively short-range coverage in the general 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.

2.2 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.

eliable maintenance and improved equipment have reduced radar system failures to a -5ligible factor. All of the DFW RADAR facilities have components duplicated-one ·:crating and another, which immediately takes over when a malfunction occurs to the imary component.

_„ characteristics of radio waves are such that they normally travel in a continuous ight 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, etc.; 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't.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 return. 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 airborne 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 _;" 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 :-revent his issuing traffic information. The controller's first priority is given to establishing vertical, lateral, or longitudinal separation between aircraft flying IFR under -.. e control of ATC. [5]

2.3. 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, scans in synchronism with the 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 returns and both are displayed on the same radarscope.
- Transponder. This airborne 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 return.
- Radarscope. The radarscope used by the controller displays returns from both the primary radar system and the ATCRBS. These returns, 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.

.\ 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 .
.,ormally only one code will be assigned for the entire flight. The ARTCC computer on tne basis 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 alternative 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.

2.4. 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.

2.5. Secondary Surveillance Radar (SSR)

Secondary surveillance radar provides, after processing of data 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.

2.6 Problems with Primary Radar

As you can see from the previous slides:

1. Rain makes targets difficult to see.
2. Birds can show a return 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.

2.7. SSR helps us Sort it out

All the transponder equipped aircraft have numbers. Even the ones without primary returns! 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 numbers are assigned by controllers, and mean different things in different airspace.

In this example,

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

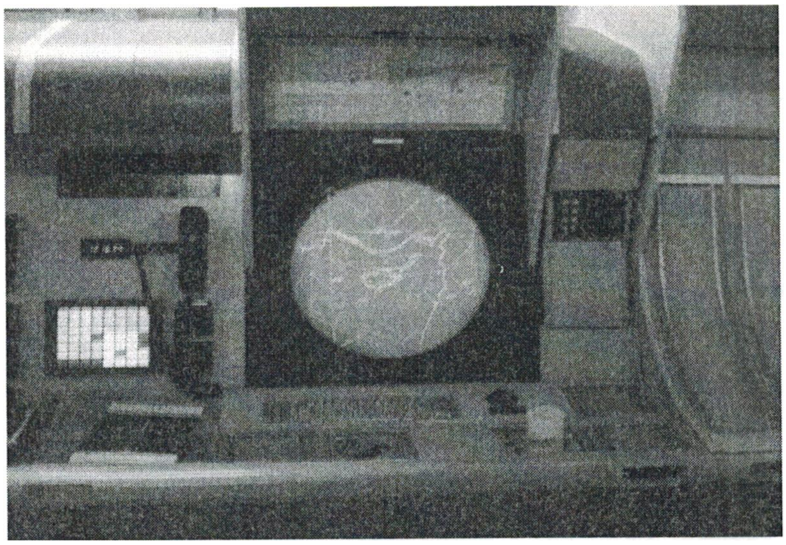

Figure 2.1 Monitor of SSR shows the targets.

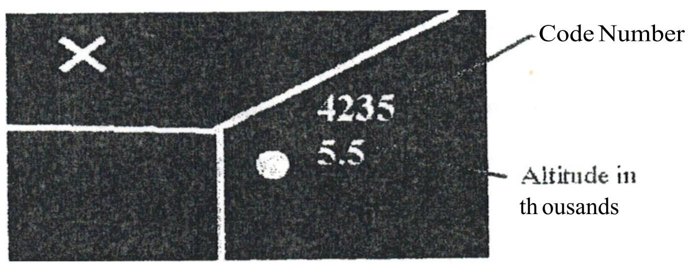

Figure 2.2 Monitor of SSR show the altitude of the plane.

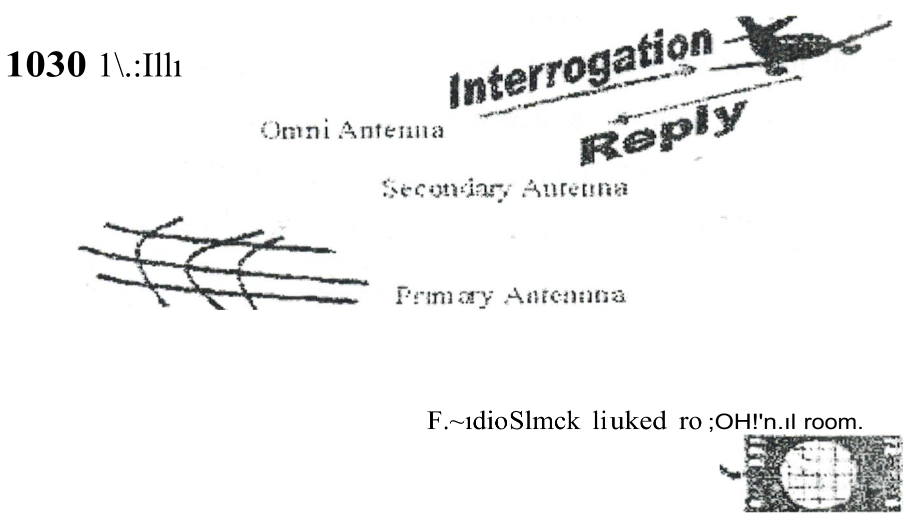

Figure 2.3 The ground system.

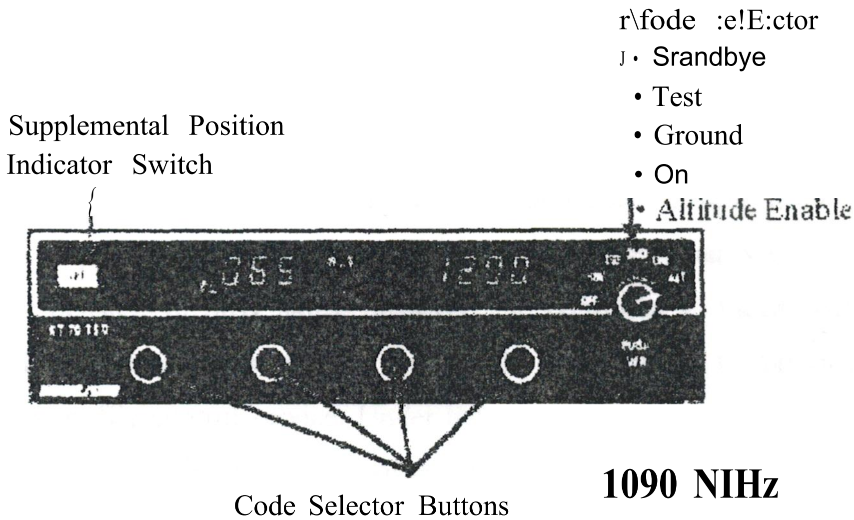

Figure 2.4 The airborne system.

2.8 Why it's Difficult to Provide Low-Level Radar Coverage?

Radio waves usually travel in straight line, they cannot detour round obstacles which curtail their line of travel : radar-like all other radio-based systems, therefore a line-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.

2.9 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 tum off course followed by a return 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 response 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 overage 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 apacity of that controlled airspace. However radar is limited to a range of about 200nm. On land, it is usually possible to install a sufficient number of radar sites to provide full radar coverage, particularly as aircraft climb away from the earth's surface and obstacle interference. But it is impossible 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.

2.10 Multi Radar Tracking

These days, in many busy areas, radar coverage is so comprehensive that several radar returns are generated for each aircraft. In reality, radar bias (the radar signal may be weekend by distance, weather conditions or other interference) or systematic error between radars means 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 from the radar providing the strongest signal and translate that into a target on the air traffic control display.

Today, multi radar tracking collate the signal data from all the relevant radars, calculate the strength of each return, and using all this information, define the aircraft's precise position.

2.11 Precision Approach Radar

At airports where it is not possible to install an (instrument Landing System) or ILS, but it may be necessary to offer a precision approach capability, ICAO recommends the use of (Precision Approach Radar) (PAR). In these circumstances, 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, giving the controller both azimuth and elevation views of the aircraft on approach. The controller will then talk to the pilot giving minute navigation 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.

2.12 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 specified region 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. Once a transponder has responded to all-call interrogation will reply. Once 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 S is claimed to improve overall surveillance accuracy by a factor of up 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 information 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.

2.13 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 data 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 often 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.

2.14 AN/SPS-49 Very Long-Range Air Surveillance 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. External 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 firm track and improved maneuver detection. This is done using unique signal processing techniques originated and tested by the Radar Division of NRL using 6.1 and 6.2 office of Naval Research (ONR) funds.

The AN/SPS-49(V) radar is a narrow beam, very long range, 2D air search radar that primarily supports the AAW mission in surface ships. The radar is used to provide 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 return (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[6]

- Table of frequency band

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
Antenna 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

2.15 Upgrading 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 of the 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 of the South, as the radar installation is known at Eglin, remains the nation's primary space surveillance radar because of unsurpassed power and coverage.

The AN/FPS-85 is a valued asset to the U.S. Air Force, but one with an aging technology base that must be supported into the future. For example, the on-site maintenance crew repairs an average of 17 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 concern for the Electro explosive devices, such as ejection seats and munitions.

CHAPTER THREE

APLICATION IN ERCAN AIRPORT

3.1 Radar Systems in Ercan Airport

radar systems in Ercan Airport (The Main Airport in Northern 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.

3.1.1 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 of light 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

$$R = ct/2 \tag{3.1}$$

Where R is the range, $c = 3.0 \times 10^8$ *mis* 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.

3.1.2 SSR

The principle of secondary surveillance radar is different than the prımary 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.

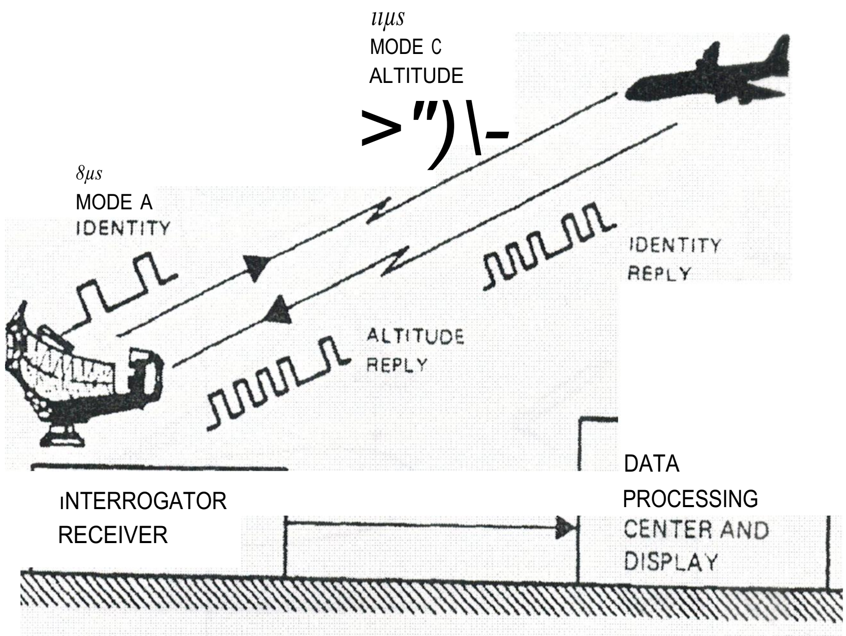

Figure 3.1 The basic principles for the operation of the SSR system in Ercan Airport

3.1.2.1 SSR Performance and Limitations

The attached document contains part of annex 10 of the convention of(1 NC 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
- For an 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 path figure 3.2
- Interrogation by coming from other SSR system figure 3.3
- Replies coming from aircrafts closely spaced figure 3.4 in heaving traffic areas.

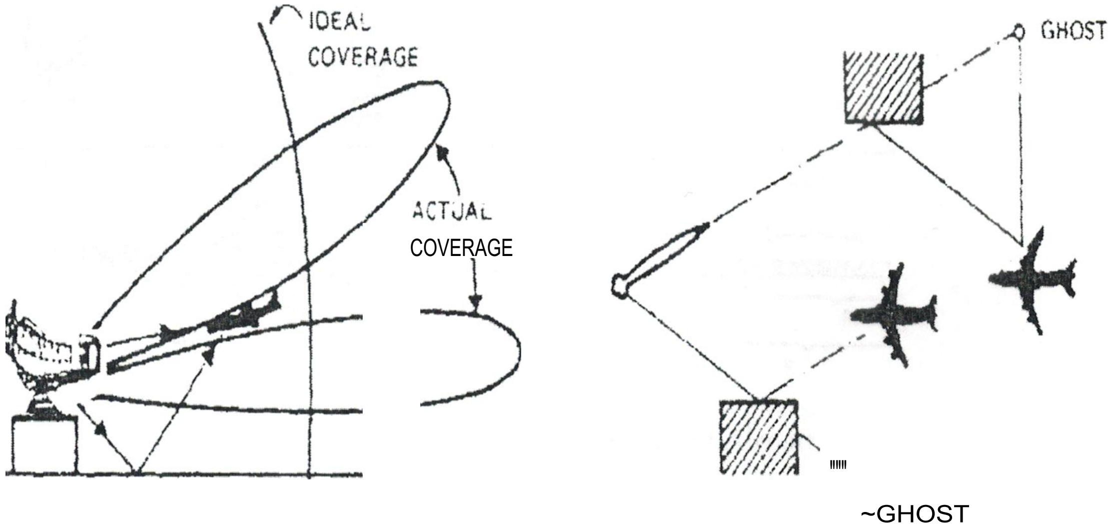

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Figure 3.2 Reflection influence on SSR coverage in Ercan Airport

Figure 3.3 SSR & PSR receiver

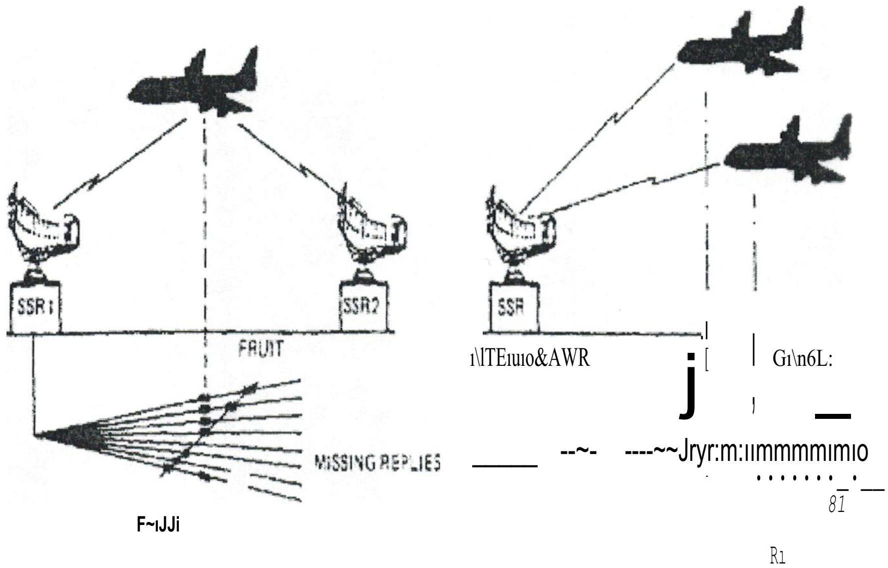
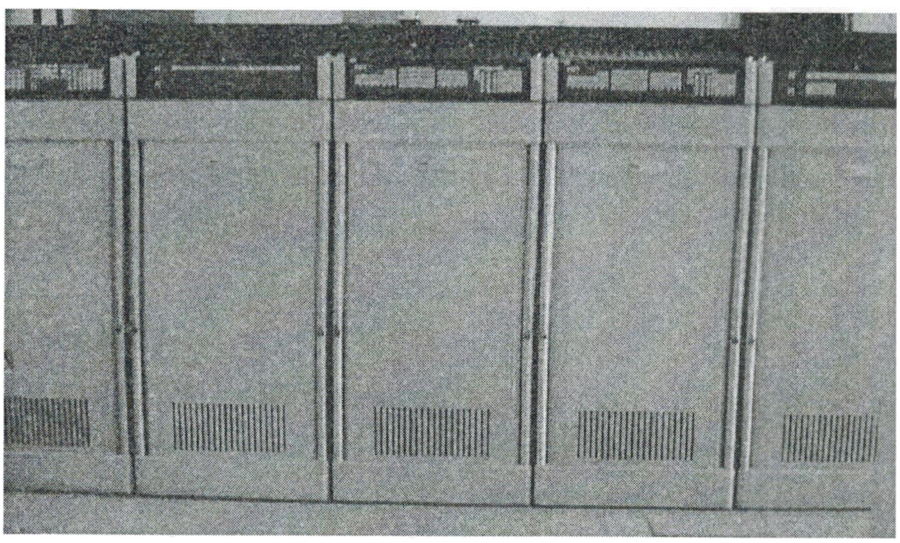
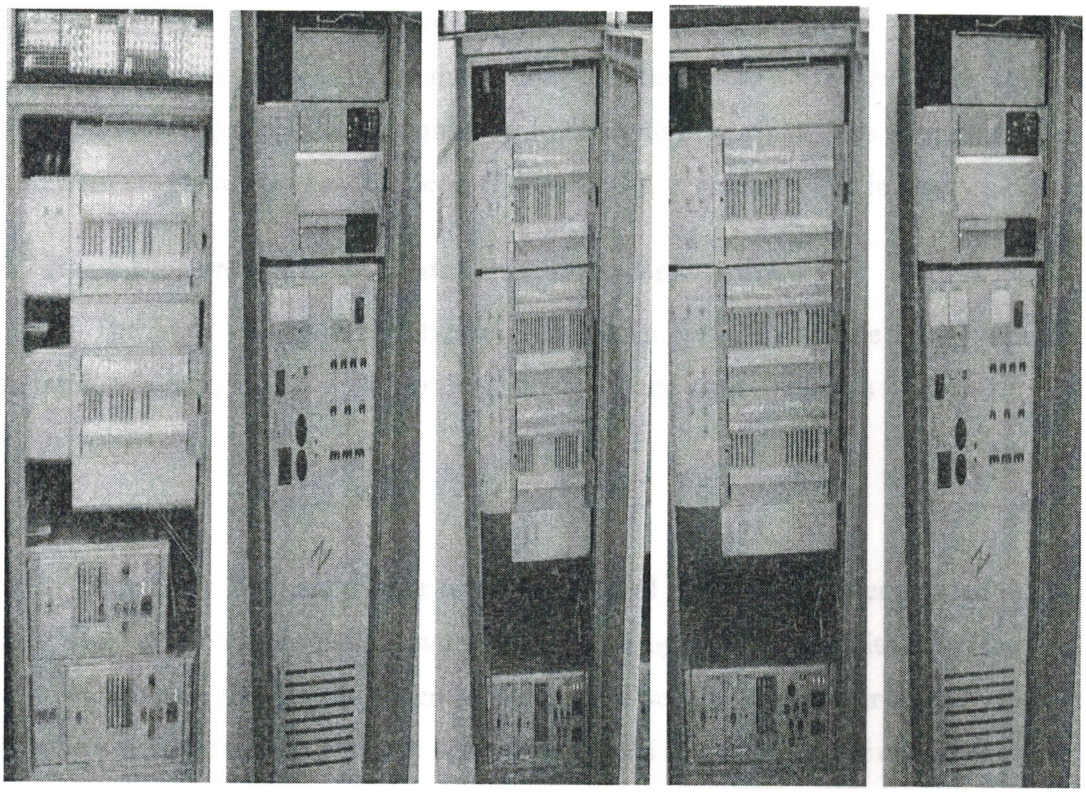


Figure 3.4 SSR Interferences Ercan Airport



- The machine room



(a) **(b)** **(c)** **(d)** **(e)**

a) Secondary surveillance radar . **b)** Power of secondary surveillance radar . **c)** Primary surveillance radar channel (A).d) Primary surveillance radar channel (B). e) Power of primary surveillance radar.

3.1.3 MRT and MCT

MRT means Multi Radar Tracking,

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

3.1.4 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 way.

3.2 Basic Elements of Pulse Radar Systems in Ercan Airport

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

3.2.1 Timer

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 of the proper length .The timer may be a separate unit by it self or it maybe included is the transmitter or receiver.

3.2.2 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.

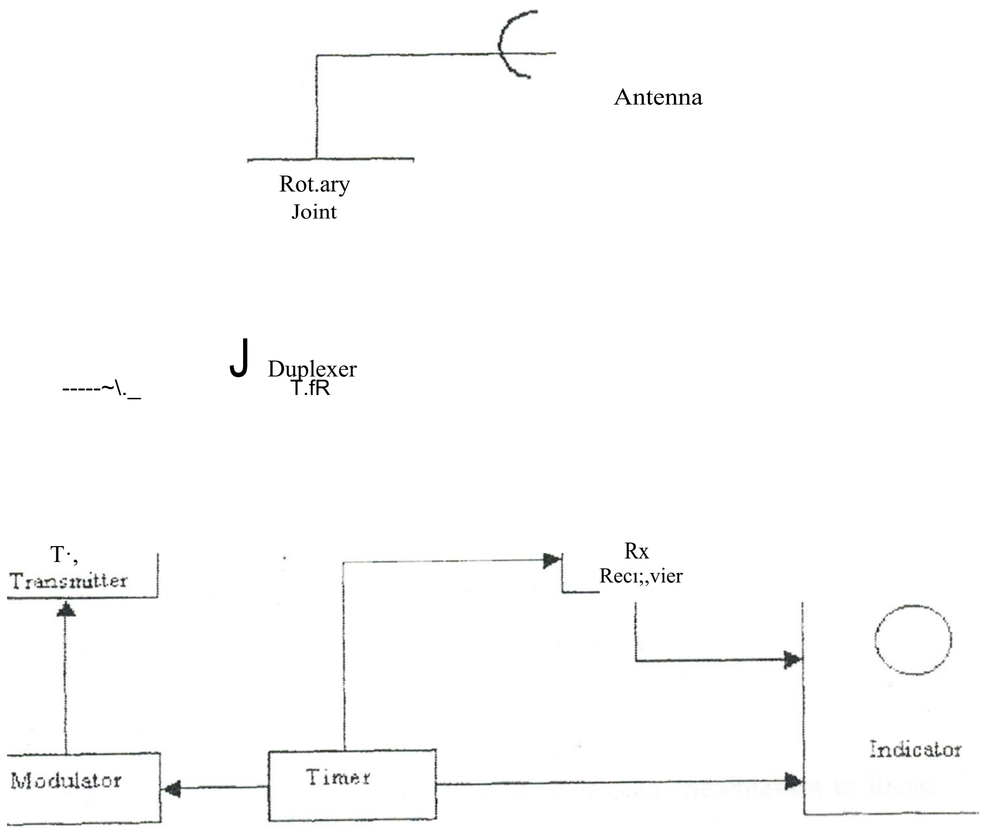


Figure 3.5 Basic elements of pulse systems radar in Ercan Airport

3.2.3 Transmitter

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

3.2.4 Antenna

The antenna is very directional in nature because it must obtain the angles of elevation and bearing of the target to obtain this directivity at centimeter wave lengths ordinary dipole antennas are used in conjunction with parabolic reflectors usually ,in order to same space and weight the same antenna is used for both transmitting and receiving when this system is used , some kind of switching device is required for connecting it to the transmitter 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.

3.2.5 Duplexer

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

3.2.6 Rotary joint

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

3.2.7 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.

3.2.8 Indicator

The indicator presents visually all the necessary information to locate the target on the indicator screen. The method of presenting the data depends on the purpose of the radar set. Since the spot (scans) 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 common types of scan used will be supplied.

3.3 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 this section we are going to present theses systems which used in Ercan Airport.

3.3.1 The Navigational Aids Systems in Ercan Airport

The purpose of navigation system is to ensure the safe, efficient transit of aircraft following established procedures. The elements which support the basic function of determining the position of aircraft are ground-based navaids, which 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.

3.3.1.1 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 of VOR 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

- Power supply
- Transmitter
- Modulator
- Electronic goniometric
- Antenna
- Monitor

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

3.3.1.2 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 identi l' 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

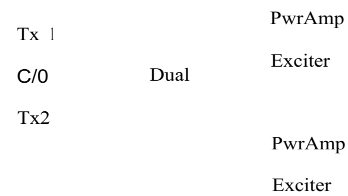


Figure 3.5 The NDB system

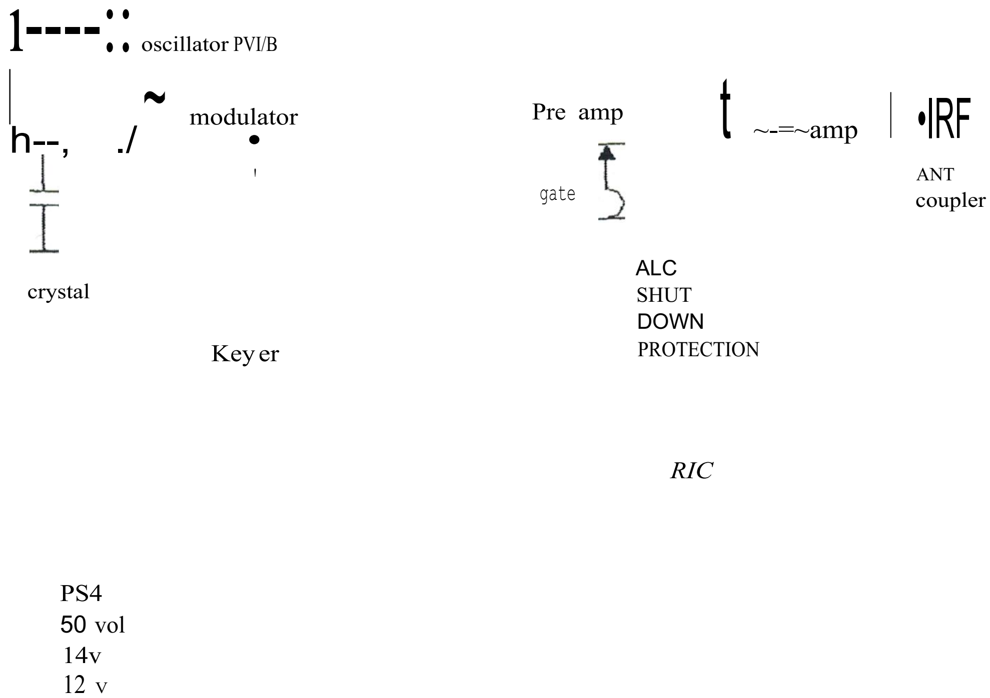


Figure 3.6 Block diagram ofNDB in Ercan Airport

3.3.1.3 DME

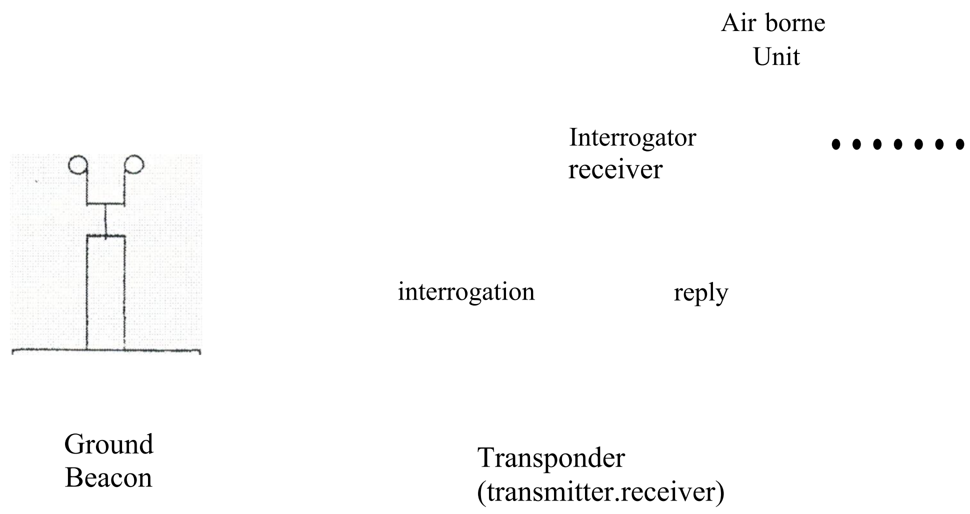


Figure 3.7 The DME system in Ercan Airport

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 of DME.

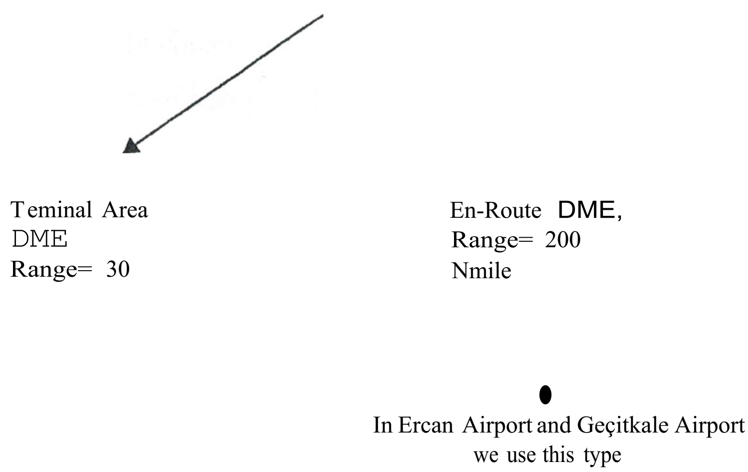


Figure 3.8 Types ofDME

Face standard FSD-15 is used in Ercan Airport and the Airsys Navigation FSD-45 is used in Getcitkale Airport, The working principle of DME:

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

M=t. C (3.2)

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

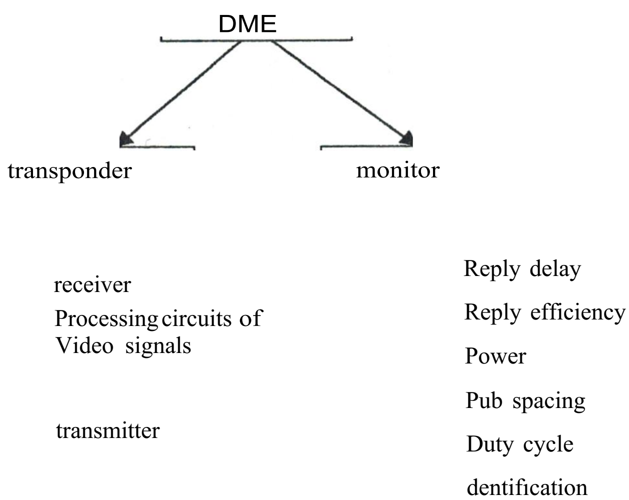


Figure 3.9 Parts ofDME ground beacon

The monitor system continuously checks if the pulses and all the transmission properties are correct. The frequency of Ercan DME is as below,[7]

Airport	**Channel**	**Interrogation frequency**	**Reply Frequency**	**Pulse Frequency**	**VHF Channel**
GKE	90x	1114 MHz	1177 MHz	12 us	114.3 MHz
GKE	90y	1114MHz	1051 MHz	30 us	114.3 MHz
ECN	117x	1141 MHz	1024 MHz	12 u,s	117.0 MHz
ECN	117y	1141 MHz	1078MHz	30 us	117.0 MHz

- **See figure 3.10 the general diagram of DME:**

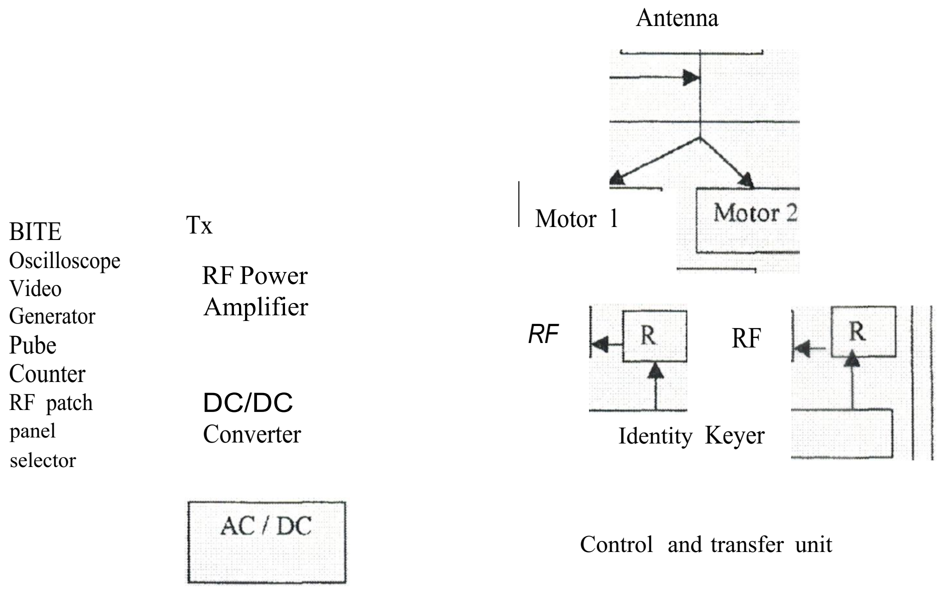


Figure 3.10 General Diagram of Dillin Ercan Airport

3.3.2 VHF Voice Communication 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.

Frequency	**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 of the 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	1 transmitter	1 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.

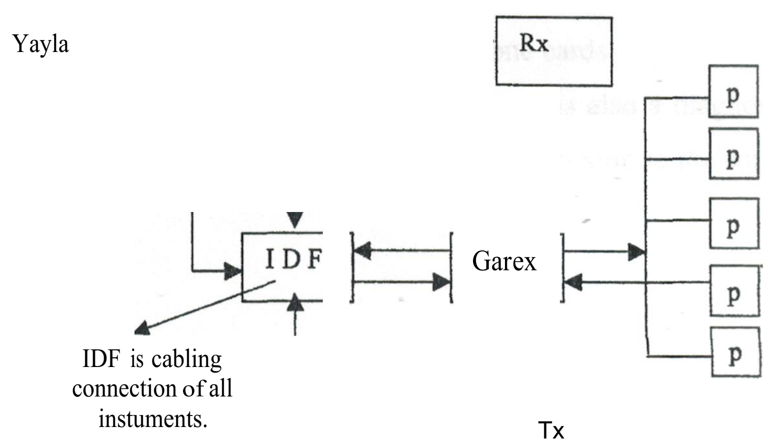


Figure 3.11 Voice communication in Ercan Airport

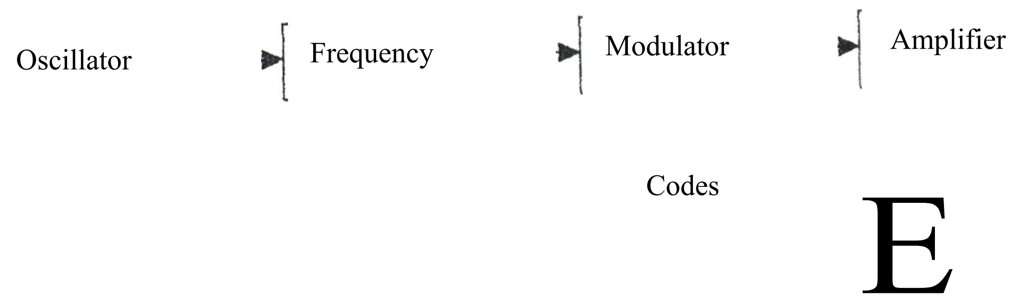


Figure 3.12 Simple block diagram of transmitter in voice communication

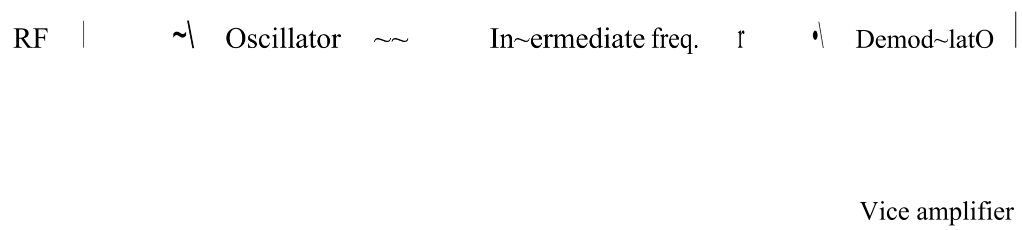


Figure 3.13 Simple block diagram of receiver in voice communication

3.3.2.1 Garex 210

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.[8]

3.4 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 DlVIE,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 know 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.

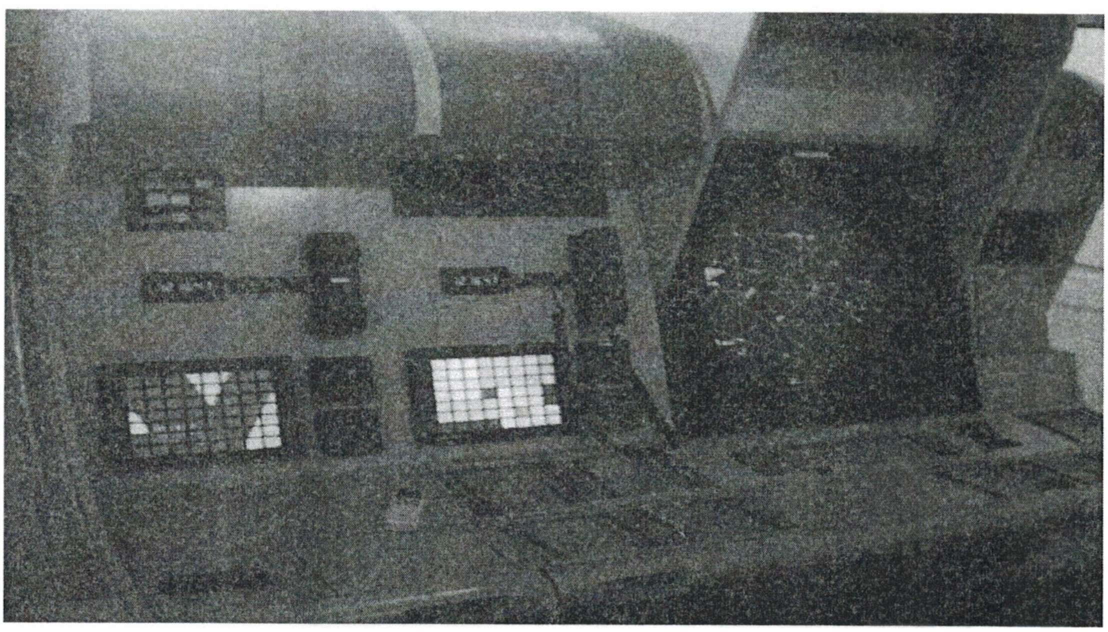


Figure 3.14 The ATC room in Ercan

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, after processing f data transmitted by the aircraft, the range, bearing, altitude and identity (call sign) 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.

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.

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