NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

Airport Surveillance Radar

Graduation Project
EE- 400

Student: Mohammed AlSaadi (20021028)

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 ofthe 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 :frequencyofthe reflected wave (Doppler Effect) is a measure of the target's relative (radial) velocity and may he used to distinguish moving targets :from stationary objects. in radars, which continuously track the movement ofa target, a continuous indication of the rate of change of target position is also available.

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INTRODUCTIONS

We had thought to do our work on the radar system, and then we searched for the important part on this subject which is the airport surveillance radar(ASR), ASR is considered as one of the most common and important parts in the communication system. in modem tim.es, radar is used in wide variety of applications including air tra:ffic control, defense, meteorology, and even mapping, radar is "radio detecting and ranging". An electromagnetic sensor used for detecting, locating, tracking, and identifying objects of various kinds at considerable distances, it operates by transmitting electromagnetic energy toward objects, commonly referred to as targets, and then observing the echoes returned from them. The target may be a.ircraft, ships, spacecraft, automotive vehicles, and astronomical bodies, or even birds, insects; and raindrops,
Radar can not only determine the presence, loca.tion, and velocity of such objects but can sometimes obtain their size and shape as well. What distinguishes radar from optical and infrared sensing devices is its ability to detect faraway objects under all weather conditions and to determine their range with precision.

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

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

The project is divided into four chapters and conclusion:
Chapter one presents of some Basic Radar Principles, Radio wave frequency and wavelength, Radio Wave Polarization, phase interference, and Propagation, Radio System Basics, Antenna Basics, A simple Pulse. Radar System, Band Radar and types of BandRadar.

Chapter two, presents the various types of radar systems such as (ASR), Weather Radar (WR), Pulsed Radar System (PRS), CW Radar, Pulse Doppler Radar, Pulse-Compression Radar, Synthetic Aperture Radar (SAR), 3-D Radar.

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

Chapter four, covers the radar systems in Ercan Airport, we also explain the operation and the basic elements of the radar systems; used in Ercan Airport further, we present some important systems related with Ercan's radar to make the operation of the ATC easier.

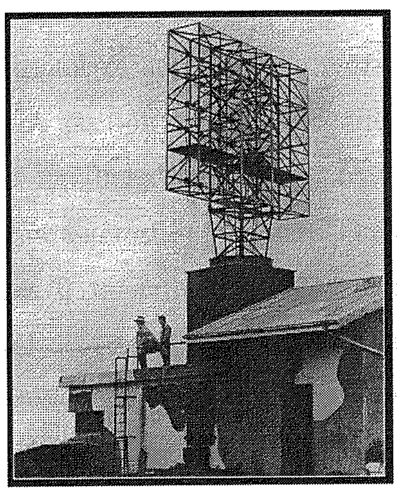
Finally, in the conclusion we part present the important comments related to this project.

CHAPTERONE

HISTORY OF RADAR

1.1 Overview

Radar systems (Radio Detection and Ranging) were developed in the 1942s mainly by the armed forces. Radar is an active remote sensing system which means that it provides its own source of energy to produce an image. Thus, it does not require sunlight (as do optical systems) and data can be acquired either by day or by night. Furthermore, due to the specific wavelength of radar cloud cover can be penetrated without any effect on the imagery.



Figuer 1.1: show An Army CD Radar at North Head circa 1942.

Using a radio transmitter and a reciever. The transmitter sends out a high frequency radio wave. Ifthe radio wave hits another object (a plane ora ship) it will reflect back to the reciever. By gauging the time it tak.es for the wave to return and the amount ofthe radio wave which returns to the reciever, the position and size ofthe plane or ship can be projected onto a radar screen. If a lot ofthe signal is bounced back then they are close to the object. If only a little bit of the signal is bounced back then they are far from the object. If only a little bit of the wave returned that means the object is smaller. If a lot of the radio wave returns that means the object is larger.

This process is similar to a bat's use of echo-location to locate insects in the dark. The only difference is that echo-location uses sound waves as opposed to the radio waves sent out by the radar.

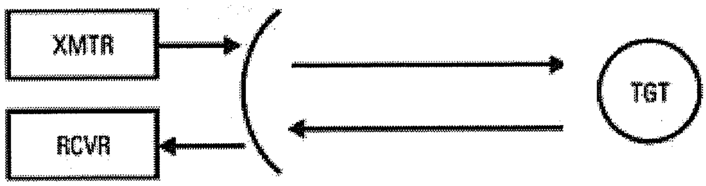


Figure 1.2: Basic Radar Function

An elementary form of radar consists of a transmitting antenna emitting electromagnetic radiation generated by an oscillator of some sort, a receiving antenna, and an energy-detecting device, or receiver. A portion of the transmitted signal is intercepted by a reflecting object (target) and is reradiated in all directions. It is the energy reradiated in the back direction that is of prime interest to the radar. The receiving antenna collects the :refinanced 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 forthe tadar signalto 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 be used to distinguish moving targets from stationary objects. in radars which continuously track the movement ofa target, a continuous indication of the rate of change of target position is available. The name radar reflects the emphasis placed by the early experimenters on a device to detect the presence of a target and measure its range. Radar is a contraction of the words radio detection and ranging. It was first developed as a detection device to warn of the approach of hostile aircraft and for directing antiaircraft weapons. Although well-designed modem radar can usually extractors information from the target signal than merely range, the measuftment of range is still one of radar's most important functions. There seem to be no other competitive techniques which can measure range as well or as rapidly as can radar. The most common radar waveform is a train of narrow, rectangular-shape pulses modulating a sine wave carrier. The distance, or range, to the target is determined by measuring the time TR taken by the pulse to travel to the target and return. Since electromagnetic energy propagates at the speed of light c =3 x 10^8 *mis,* the range R is

$$R = \frac{cT_R}{2} \tag{1.1}$$

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

$$R(Km) = 0.15TR\ (\mu\ S) \text{ or } R(nmi)=0.081\,TR(\mu\ S) \tag{1.2}$$

Each microsecond of round-trip travel time corrt::spoiıdstô ā. distance of 0.081 nautical mile, 0.093 statute mile, 150 meters, 164 yards, or 492 feet.

ünce the transmitted pulse is emitted by the radar, a sufficient length of time must elapse to allow any echo signals to return and be detected before the next pulse may be transmitted. Therefore the rate at which the pulses may be transmitted is determined by the longest range at which targets are

Expected. If the pulse repetition frequency is too high, echo signals from some targets might arrive after the transmission of the next pulse, and ambiguities in measuring range might result. Echoes that arrive after the transmission of the next pulse are called second-time-around (or multiple-time-around) echoes. Such an echo would appear to be at a much shorter range than the actual and could be misleading if it were not known to be a second-time-around echo.

The range beyond which targets appear as second-time-around echoes is called the maximum unambiguous range and is

$$R_{unamb} = \frac{c}{2f_p} \qquad (1.3)$$

Where/p = pulse repetition frequency, in Hz. A plot ofthe maximum unambiguous range as a function ofpulse repetition frequency is

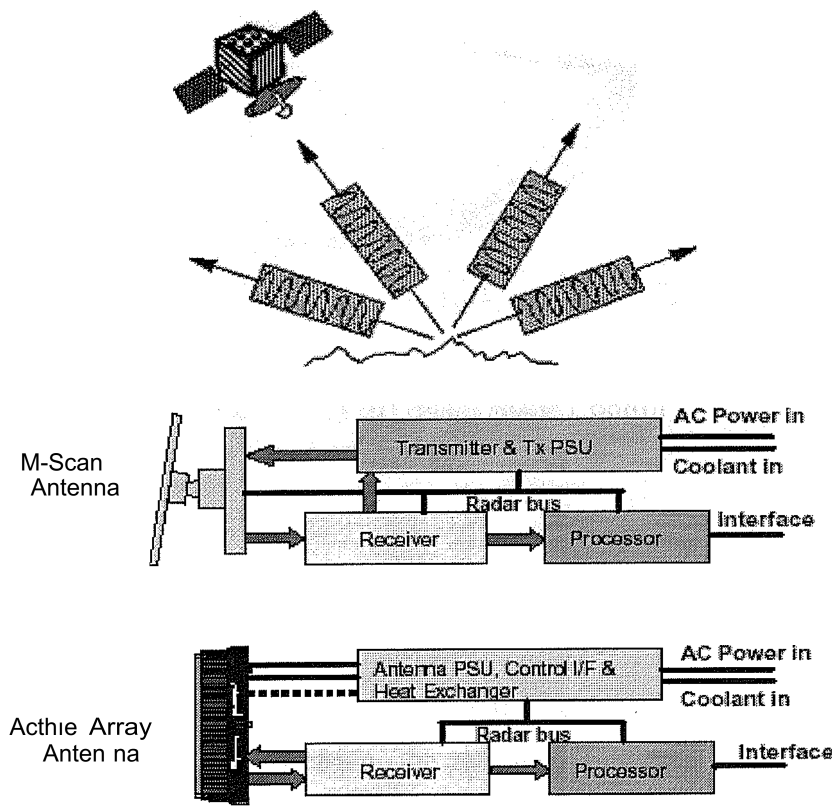


Figure 1.3 Radar concept transformation m Radar concept transformation m-scan to scan toAESA

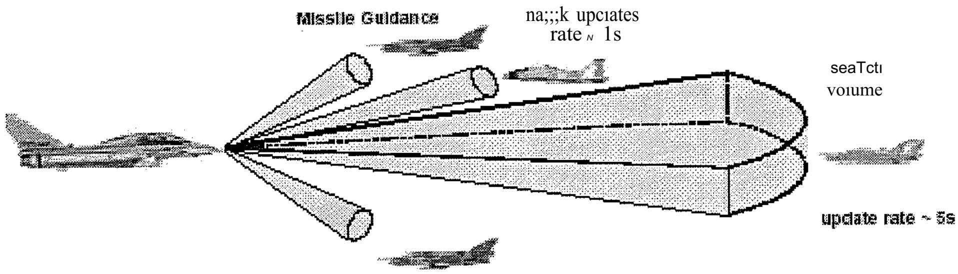


Figure 1.4 (a) AESA Independent Search and Track AESA lndependent Search and Track Regime

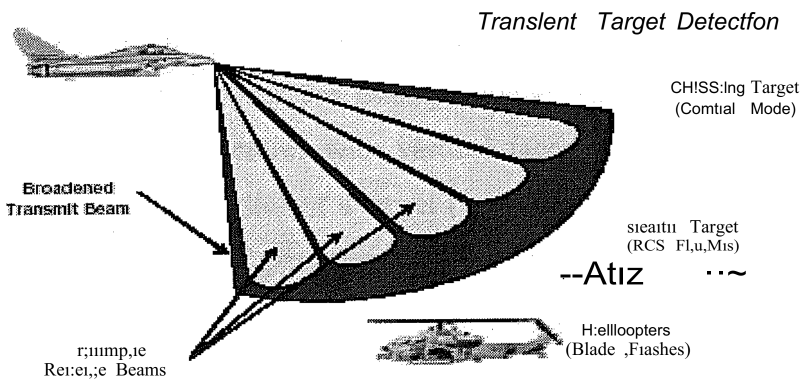


Figure 1.4 (b) Beam shape Control

1.2 **Some** Basic **Radar** Principles

Radar is based on the transmission and reception of pulses in a narrow beam in the cm bands of the electromagnetic spectrum; the returning echoes are then recorded, taking into consideration their strength, time interval and phase. The power received by the antenna on board :from each radar pulse transmitted is directly connected with the physical characteristics of the target through the backscattering coefficient.

The value of this backscatter coefficient (corresponding to grey values in optical images) is basically dependent on three factors:

- the surface roughness,
- the surface humidity,
- the wavelength ofthe radar.

A surface is considered as being rough in the radar sense if its structure or shape has dimensions which are an appreciable fraction of the incident radar wavelength. For example, gravel surfaces exhibit stronger scatter than smooth clays. Another example of the effect of surface roughness can be observed when looking at the difference between water surfaces with and without waves. Over water surfaces which are not moved by wind effects, almost no energy is scattered back to the antenrıa, which means that this area appears dark. Land surfaces are usually rougher (higher backscatter) than water surfaces as they contain structures with vertical faces and comers. Moisture content influences the electrical properties ofa target (soil, vegetation, ete.) and the backscatter increases with humidity. A wet ground surface is characterised by a stronger backscatter than a dry one having the same roughness. The importance of both factors is also dependent on the chosen wavelength. A given surface may appear smooth at a wavelength of 25 cm (S band) and rough at 5 cm (C band). Furthermore, the longer the wavelength the higher the penetration capabilities. Thus, a 100 cm wave (P band) penetrates vegetation better than a 3 cm (X band wave) one. Furthermore, a distinction can be made between active systems (radar) and passive systems (radiometers), as well as non-imaging systems (scatterometers, altimeters) and imaging systems (synthetic or real aperture radar, scanning scatterometers). For example, the radar instrument mounted on ERS is a SAR (Synthetic Aperture Radar) which means that the antenna is made to appear longer than it really is by exploiting the relative movements between the platform and the Earth with complex processing. Through this, a higher resolution can be achieved. Moreover, both the polarization and the incidence angle play a very important role in the detection ofa target with the radar instrument.

1.2.1 Radio Wave Frequency and Wavelength

Radar is a variant of radio technology and shares many of the same basic concepts. It is useful to discuss fundamental concepts of radio operation to provide a hasis for discussing fundamental concepts of radar operation.

Late in the 19th century, researchers discovered that ifan altemating electric current were run through a wire or rod, it emitted an invisible form of radiation that could generate an altemating electric current in a separate wire or rod. This invisible radiation was quickly realized to be a form of "electromagnetic radiation", a disturbance of electric and magnetic fields that propagated through space. Electromagnetic radiation is in the form of waves, conceptually similar to the waves set up by shaking a rope up and down, and \propagating at a speed of 300,000,000 meters per second (186,000 miles per second).

The waves could be generated at varying "frequencies", defined by the number of cyclical variations of the wave that passed through a plane every second. Frequencies were once measured in "cycles per second (CPS)", but now are universally defined in terms of "hertz (Hz)", after Heinrich Hertz, a pioneering radio researcher. The frequencies of electromagnetic radiation are usually large numbers, and so it is useful,to use "metric prefixes"

The full range of :frequencies of electrornağnetic tadiatiorı is kııown as the "electromagnetic spectrum". Radio waves örıly take up part of this Spectrum, generally involving kilohertz, megahertz, or gigahertz radio emissions, Above about 300 GHz, electromagnetic radiation moves into a region of the spectrum known as "infrared"; and then with increasingly higher frequencies into the region of visible light that we can see with our eyes; and finally into energetic radiation defıned as the "ultraviolet", "X-ray", and (at the very highest :frequencies)"gamına ray" regionsofthe spectrum. Puta little bit more simply, radio waves are the same thing as visible light, both being forms of electromagnetic radiation. The only difference is that radio waves have lower frequencies. Incidentally, electromagnetic waves are entirely different from sound waves, which are mechanical disturbances propagating through the air, water, or a solid medium.

The two kinds of waves can be confused because very low frequency electromagnetic waves are sometimes said to be at "audio" frequencies, and of course electromagnetic waves can be used to transmit audio waves, as turning on a household radio shows.

This document focuses only on radio waves. Sometimes it is easier to talk about radio waves in terms of their "wavelength" in meters instead of their frequency. There is a simple relationship between the wavelength and frequency ofa wave:

$$\textit{wavelenght} = \frac{\textit{wave propagation speed}}{\textit{frequency}} \qquad (1.4)$$

Since the propagation speed ofelectfotrı.ağıiefic t~diation in fr.ee space is 300,000,000 meters per second, then for electrôri:ıağıieticfadi~tiô'ri\thiss:

wavelength = 300,000,000Ifreque11.cy

If frequency is given in megahertz, th.is sinıplifies to:

wavelength = 300 / frequency

Various frequency / wa:velength fatıges, or "bands", have been defined for radars, with general classes of equipment usually ôperating in one ör a few bands. The band nam.es, with the frequency / waveleneth corresnônding to the Iow eıid of each band, The VLF through UHF band definitions were inherited from radio engineering. The bands above UHF don't follow a clear order, which apparently was partly by intent, as a security measure. The K band originally included the Ku and Ka bands, but it turned out that the center portion of the K-band was üseless föt füösütn.ïli.tatypo.rpösesas .water vapor in the atmosphere soaked up radio waves in that range. The portion of the K-band "above" the absorption range became the "Ka-band", while the portion "under" the absorption range became the "Ku-band".

Just to make things more confusing, different band definitions are used in other electronic ::fields. Radio engineers retain the ELF through UHF definitions, but take the UHF band up to 3 GHz, and then cover the higher frequencies with the "Super High Frequency (SHF)" band from 3 to 30 GHz, covering the centimetric / microwave region, and then the "Extremely High Frequency (EHF)" band from 30 to 300 GHz, covering the millimeter wave region.

Electronic countermeasures systems are defined by a band scheme entirely different from the radar and radio scheme, with the bands much more conveniently arranged from "A" to "M" in order of increasing frequency. Oddly, there isn't a one-to-one correspondence between the countermeasures bands and the radar bands, and though there was some interest at one time at applying the more rational countermeasures scheme to radar, it wasn't practical.

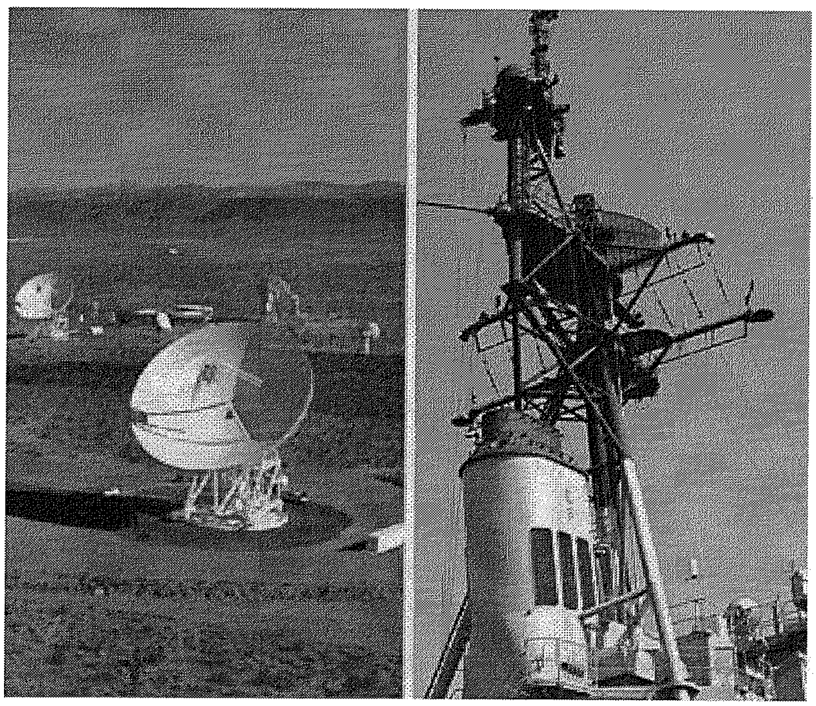


Figure 1.5: band scheme entirely different from the radar and radio scheme

1.2.2 Radio Wave Polarization, Phase, Interf erence, and Propagation

As electromagnetic radiation is a wave phenomenon, it has certain characteristics associated with waves, such as "polarization", "phase", and "wave interference".

The oscillations of an electromagnetic wave occur back and forth across the direction of the wave's propagation. This means that the wave has a certain "polarity". lf the wave's oscillations are up and down, the wave is said to be "vertically polarized"; if they are back and forth, the wave is said to be "horizontally polarized". Of course, the wave could also be polarized at any angle between those two extremes. The concepts of "phase" and "wave interference" are a bit trickier to explain. Suppose you have a tank of water, and are using some sort of vibrating element to generate waves. lf you stick another vibrating element in the water operating at the same vibration rate and same intensity, it will generate waves of the same frequency and height (or "amplitude"), but the peak:s and valleys of the waves generated by the second vibrating element will not necessarily coincide with those ofthe first. in other words, they won't have the same "phase".

The phase of the two sets of waves could be matched up, with the peak:s and valleys of both coinciding; or they could be completely out of phase, with the peak:s of one coinciding with the valleys of the other and the reverse, a condition known as "antiphase"; or they could have a phase difference anywhere between those two extremes.

The really interesting thing is that the two sets of waves add to each other. lfthe two sets of waves are exactly in phase, they add up into a single set of waves of twice the amplitude of one of the sets of waves. lf they are exactly antiphase, they cancel out, and the water in the tank is smooth. lf they are between those two extremes, the addi tive effect is intermediate. This phenomenon is known as "interference".

Radi o waves also have phase and can interfere. A single transmission may go from point A to point B by various paths. For example, one patlı may be a straight line, while another may be a long patlı due to a reflection or "bounce" off a mountain. Such "multipath effects" cause the "ghosting" sometimes seen on TV transmissions, with a faint image slightly offset from the main image.

They can also cause "phase delays" that seem to alter the direction of the beam by interference. Controlled interference effects can be used to deliberately shift the direction ofa. radio beam, a scheme known as "electronic steering" and discussed later. üne final comment before moving on to radio and radar technology: radio waves generally propagate over a line-of-sight, weakening with distance, as anybody who's driven from town to town in a car with a radio realizes, with the music fading out as one town is left behind, and becoming stronger as another town is approached.

Thc radio waves can propagate through the sky or over the ground, and as noted can often propagate by multiple paths. At night, radio waves can bounce off the ionospheric layer in the upper atmosphere, allowing them to propagate over the horizon, if in a somewhat unpredictable fashion. Such "ionospheric bounce" tends to work betler at lower frequencies. Anybody's who's ever played around with a broadcast radio receiver late at night knows remote stations can be picked up, sometimes over great distances.

Other atmospheric effects can interfere with radio signals. Higher frequencies can be blocked by heavy rainstorms or snowstorms, and lightning can thrown "noise" into radio transmissions. Partide flows from eruptions on the Sun can cause massive disruptions of radio communications. There-Isalso a variable ·background of radio noise fröm human sources that can cause unwaııted föterfe:terice.

Radio waves vary in their interactions with solid ınatter. 1{adjo waves, Iike light, can be absorbed or reflected by matter. Metals and water, for exaınple, tend to reflect radio waves, while soils tend to absorb them. Also as with light, radio reflections can be "specular", as ifbounced off a mirror, or "diffuse", as ifbounced off a rough and uneven surface. lf radio waves can penetrate a material, the penetration is greater at longer wavelengths. Radio wave can penetrate buildings well enough, and very long wavelength can even penetrate a good depth through the sea or into the ground. Very short wavelengths are strongly attenuated and have limited range.

1.3 Radio System Basics

A radar system is basically an evolution of a radio system, and it is useful to define the basic elements of a radio system first. A radio system consists of a "transmitter" that produces radio waves and one or more "receivers" that pick them up, with both transmitter and receiver(s) fitted with antennas. The very earliest "wireless telegraphy" radio systems used a transmitter that simply generated a burst of radio energy by opening an electric circuit with a telegraph key and causing a spark. The radio waves propagated through space and set up an electric current in a receiving antenna, which in turn closed a relay switch, possibly using an "amplifier" circuit to boost the electrical signal. Messages were sent using Morse code.

The problem with this simple scheme is that the spark generated.waves over a wide and indiscriminate range of frequencies, with a single receiver picking up and mixing up transmissions from every transmitter in the line of sight.

The way to get around this problem is to fit each transmitter with a "variable oscillator", an electronic circuit that generates electrical signals at different frequencies, as set by a knob turned by the transmitter operator. Receivers are then fitted with a "variable filter", another electronic circuit that can be set by a knob turned by the receiver operator to block out all frequencies except one. This scheme alföws m.ultiple transmitters to operate in a given area withôutifiterference. The transmitter operatör sets 'the-transmitter oscillator to a given frequency; the receiver opetator sets the .receiver filter to the same frequency; and the transmitter operator uses a telegraph key to turn the output of an oscillator on and off, with the receiver operator picking up the output over the airwaves. The receiver will usually be fitted with a "detector" circuit to convert high-frequency signals into a direct-current signal to activate the relay switch. This is obviously the same concept that is used in tuning a voice radio to different channels, though a voice radio works somewhat differently from a radio telegraph. A voice radio also uses a variable oscillator. The voice ofa user is converted into an electrical waveform which is "mixed" with the output of the oscillator, shifting the voice signal up in frequency to that of the oscillator, and transmitted. The oscillator frequency is known as the "carrier" frequency, since it "carries" the voice signal.

The receiver has its own variable oscillator, tuned to the same carrier frequency, which is mixed with the received signal, a process that somewhat magically obtains the original voice waveform. The voice waveform is converted back into sound through a loudspeaker.

The process of converting a voice (or music or whatever) into an electrical signal is known as "modulation". There are two classic forms of modulation: "amplitude modulation (AM)", in which the electrical signal varies in amplitude along with variations in amplitude of the voice input; and "frequency modulation (FM)", in which the electrical signal varies in frequency along with variations in the amplitude of the voice input. The process of mixing and unmixing frequencies is known as "heterodyning". in many cases, heterodyning is used to translate a voice or other signal up to an "intermediate frequency", which is then heterodyned again to produce an output signal of even higher frequency. This is done because it gets more difficult to handle signals at higher frequencies, and this scheme, known as "superheterodyning", allows most of the handling to be performed at the intermediate frequency.

A traditional analog television signal is conceptually much the same as a voice radio. The TV sound track is transmitted with FM, while the basic visual signal, which is black and white, is transmitted by AM. There are various schemes used in different nations for overlaying color signals, but they are devious and irrelevant to this discussion.

Incidentally, transmitter output power is measured in watts, or (as far as radar is concemed) more usually kilowatts (kW, thousands of watts) and megawatts (MW, millions of watts). Receiver "sensititivity", or the ability of the receiver to amplify received signals, is determined in terms of "decibels", defined as:

$$\text{decibels} = 10 \log_{10} \left(\frac{\text{out\_power}}{\text{in\_power}} \right) \tag{1.5}$$

The ampli:ficationfactor is commonly referred to as "gain". Incidentally, a radio doesn't transmit or receive ona single frequency but ona range or band offrequencies. Although the details are beyond the scope of this simple document, the "bandwidth" is roughly proportional to the amount of information carried by the signal. A TV channel needs more bandwidth than a hi-fidelity tadio channel, for example, just as a hi-:fidelityradio channel needs more bandwidth than a low-:fidelityradio channel.

1.4 Antenna **Basics**

A transmitter needs an antenna to send its radio signal, and a receiver needs an antenna to pick up that radio signal. The design of these antennas is not trivial. The simplest form of antenna is the "dipole". Suppose the electrical output of an oscillator is directed down two conductors, not connected at the ends. This will produce radiate electromagnetic energy from the open-circuit ends. it radiates energy much more effectively if the conductors are bent at the en.ds to form a right angle, with each bend being a quarter-wavelength long relative to the oscillator frequency. This is a "half-wave" dipole. it is not only effective in generating radio waves at a particular frequency, it is also effective in picking them up. This is true in general of ali antennas: they are "reciprocal", working much the same in transmission or reception, just in different directions. By itself, a dipole "broadcasts" in all radial directions evenly, but a directed focus can be obtained, through interference effects, by building an antenna with multiple dipoles, spaced at carefully designed intervals. Such "dipole arrays" were common with early longwave radars, and in a modi:fiedform persist today. Another way to create a "directional" antenna with a dipole is to mount it within a row of parallel conductive rods, with the rods of decreasing length to the "front" of the dipole (relative to the direction of focus) and of increasing length to the "back" ofthe dipole. This type of antenna is known asa "Yagi-Uda" or just "Yagi" antenna. it is recognizable as the modem broadcast TV antenna. A conceptually simpler directional antenna is the parabolic dish. This is con:figurationfamiliar with a modem satellite-TV receiver. It's really very much the same as using a parabolic mirror to focus light, only the wavelength of electromagnetic radiation is longer.

While parabolic dishes are usually circular, elliptical or cylindrical dishes with parabolic curvature can also be used if the radio beam needs to be focused along one axis but not along the other. An elliptical dish with the long axis vertical is used to create a narrow horizontal beam, useful for height-finding, while one with the long axis horizontal gives a narrow vertical beam, useful for surface targeting.

Incidentally, directional antennas don't always generate all their radio output in a nice neat directional beam. They may generate "sidelobes" that cause unwanted transmissions to the sides of the beam, or a "backlobe" in the reverse direction. The sidelobes and backlobe not only produce signals in undesired directions, they also rob the main lobe of energy.

In addition, as a general rule, the larger .the receiver dish, the greater the receiver sensitivity, since it creates a bigger "bucket" or "eye" to collect radio waves. However, the longer the wavelength, the bigger the dish has to be to focus the radio waves. Another little related fact is that the dish doesn't have to be solid. It can be a mesh, just as long as the mesh grid spacing is less than that of the radar operating wavelengths. This makes for a lighter antenna, and also one not so easily disturbed by the wind.

1.5 A simple Pulse Radar System

A discussion of voice radio is usefııl for'backğrôiliid ııfdisctıssing simple radar systems, but is also somewhat incidental, since a sıınple radar wôrks more like a wireless telegraphy set.

The best way to explain radar is to imagine that you are standing on one side ofa canyon, and shout in the direction of the distant wall of the canyon. After a few moments, you will hear an echo. The length of time it takes an echo to come back is directly related to how far away the distant canyon wall is. Double the distance, and the length of time doubles as well.

If you know that the speed of sound is about 1,200 KPH (745 MPH) at sea level, then if you have a stopwatch you can actually figure out how far away the distant canyon wall is.

lf it takes four seconds for the echo to come back, then since sound travels about 330 meters (1,080 feet) in a second, the distance is about 660 meters (2,160 feet).

Radar uses exactly the same principle, but it times echoes of radio or microwave pulses and not sound. Like a wireless telegraphy set, a simple radar has a transmitter and a receiver that can usually be tuned to a range of frequencies, with the transmitter sending out pulses, short bursts, of electromagnetic radiation and the receiver picking them up.

in the case of the radar, the receiver is picking up echoes from a distant target, which are then timed to determine the distance to the target, Early radars simply used an oscilloscope to perform the timing. An oscilloscope measures an electrical signal on a beam that moves or "sweeps" from one side ofa display to the other ata certain rate. The rate is determined by a "timebase" circuit in the oscilloscope.

For example, the sweep rate might push the sweep from one side of the display to the other in 100 microseconds (millionths ofa second). lf the display were marked into ten intervals, that would mean the sweep would pass through each interval in ten microseconds. While 100 microseconds would be shorter than the human eye could follow, the sweep is normally generated repeatedly, allowing the eye to see it.

Since electromagnetic radiation propagates at 300,000,000 meters per second, or 300 meters per microsecond, then each 10 micrôsecond i:rıtervalwould correspond to 3,000 meters, or 3 kilometers. lf the sweep on the scôpe is "triggered" tô start when the radar transmitter sends out the radio pulse, and the sweep displays an echo on the eighth interval on the display, then the pulse has traveled a total of 8 kilometers. Since this is the two-way distance, that means that the target is 4 kilometers away.

The display scheme described here is known as an "A scope", and allows the user to determine the range to a target. it would also be nice to know what the direction to the target is, in terms of its "altitude (vertical direction)" and "range (left to right direction)".

This is a bit trickier to describe, but no more complicated in the end. Some early radars, like the famous British "Chain Home" sets that helped win the Battle of Britain, simply transmitted radio waves out in a flood over their field of view, and used a directional receiver antenna to determine the direction of the echo. Chain Home actually used a scheme where the power of the echo was compared at separated receiver antennas to give the direction, which astoundingly actually worked reasonably well. Other such "floodlight" radars used directional receiver antennas that could be steered to identify the direction of the echo. Floodlight radars were quickly abandoned. They spread their radio energy over a wide area, meaning that any echo was faint and so range was limited. The next step was to make a radar with steerable antennas. For example, two directional antennas, one for the transmitter and the other for the receiver, could be placed on a steerable mount and pointed like a searchlight.

The transmitter antenna generated a narrow beam that could be steered like a searchlight, and if the beam hit a target, an echo would be picked up by the receiving antenna on the same mount. The direction of the antennas naturally gave the direction to the target, at least to an accuracy limited by the width in degrees of the beam, while the distance to the target was given by the trace on the A-scope. Of course, it would be more economical and easier to use one antenna for both transmit and receive instead of separate antennas, and it was possible because a radar transmits a pulse and then waits for an echo, meaning it doesn't transmit and receive at the same time.

The problem is that the receiver is designed to listen for a faint echo, while the transmitter is designed to send out a powerfül pulse. If the receiver were directly linked to the transmitter when a pulse is sent out, the receiver would be: fried.

The solution to this problem was the "duplexer", a circuit element that protects the receiver, effectively becoming an open connection while the transmit pulse was being sent, and then closing again immediately afterward so that the receiver could pick up the echo.

The receiver is also generally fitted with a "limiter" circuit that blocked out any signals above a certain power level. This prevents, say, transmissions from another nearby radar from destroying the receiver.

After this evolution of steps, we have a simple, workable radar. it has a single, steerable antenna that can be pointed like a searchlight. The antenna repeatedly sends out a radio pulse and picks up any echoes reflected from a target. An A-scope display gives the interval from the time the pulse is sent out and the time the echo is received, allowing the operator to determine the distance to the target.

The transmitter emits pulses on a regular interval, typically a few dozen or a few hundred times a second, with the A scope trace triggered each time the transmitter sends out a pulse. The number of pulses sent out each second is known as the "pulse repetition rate" or more generally as the "pulse repetition frequency (PRF)", measured in hertz.

The width of a pulse is an important but tricky consideration. The longer the pulse, the more energy sent out, improving sensitivity and range. Unfortunately, the longer the pulse, the harder it is to precisely estimate range. For example, a pulse that last 2 microseconds is 600 meters long, and in that case there is no real way to determine the range to an accuracy of betler than 600 meters, and there is also no way to track a target that is closer than 600 meters. in addition, a long pulse makes it hard to pick out two targets that are close together, since they show up as a single echo.

PRF is another tricky consideration. The higher the PRF, the more energy is pumped out, again improving sensitivity and range. The problem is that it makes no sense to send out pulses at a rate faster than echoes come back, since if the radar sends a pulse and then gets back an echo from an earlier pulse, the operator is likely to be confused by the "ghost echo". This is actually not too much ofa problem, since a little quick calculation shows that even a PRF of 1,000 gives enough time to get an echo back from 150 kilometers (185 miles) away before the next pulse goes out. However, propagation of radar waves can be freakishly affected by atmospheric conditions, and sometimes radars can get back echoes from well beyond their design range. This is why radars were developed that could be switched between two different PRFs. Switching from one PRF to another would not affect an echo from the current pulse, since the timing would remain the same, but such a switching would cause a ghost return from a current pulse to jump on the display.

Incidentally, the power of the pulse is given as "peak power", usually in kilowatts or megawatts. This may be an impressive value, but it's only the power that goes into the pulse itself. Suppose we have a pulse width of 2 microseconds with a peak power of 150 kilowatts. If we have a PRF of 500, then the time from pulse to pulse, or "pulse period", is 1/500 = 2 milliseconds, or two thousandths ofa second. This means that the average power transmitted by our radar is only:

$$\frac{150Kw(2\ microseconds)}{2\ milli\sec ondes} = 0.15kw = 150\,watts \qquad (1.6)$$

which is about as much as the power draw ofa bright household light bulb.
Doppler radar can be divided into several different categories according to the wavelength of the radar. The different bands are L,S,C,X,K. The names of the radars originate from the days of WWII.

1.6 Band Radar

1.6.1 L Band Radar

Operate on a wavelength of 15-!30 cıtı and a frequency of 1...2 GHz. L band radars are mostly used for clear airturbülence studies.

1.6.2 S Band Radars

Operate on a wavelength of 8-15 cm and a :frequency of 2-4 GHz. Because of the wavelength and frequency, S band radars are not easily attenuated. This makes them useful for near and far range weather observation. The National Weather Service (NWS) uses S band radars on a wavelength of just over 10 cm. The drawback to this band of radar is that it requires a large antenna dish and a large motor to power it. It is not uncommon for a S band dish to exceed 25 feet in size.

1.6.3 C Band Radars

Operate on a wavelength of 4-8 cm and a frequency of 4-8 GHz. Because of the wavelength and frequency, the dish size does not need to be very large. This makes C band radars affordable for TV stations. The signal is more easily attenuated, so this type of radar is best used for short range weather observation. The frequency allows C band radars to create a smaller eam width using a smaller dish. C band radars also do not require as much power as an S band radar.TheNWS transmits at 750,000 watts ofpower for their S band, where as a private TV station such as in Des Moines only broadcasts at 270,000 watts of power with their C band radar.

1.6.4 X Band Radars

Operate on a wavelength of 2.5-4 cm and a frequency of 8-12 GHz. Because of the smaller wavelength, the X band radar is more sensitive and can detect smaller particles. These radars are used for studies on cloud development because they can detect the tiny water particles and also used to detect light precipitation such as snow. X band radars also attenuate very easily, so they are used for only very short range weather observation. Also, due to the small size of the radar, it can therefore be portable like the Doppler on Wheels. (DOW) Most major airplanes are equipped with an X band radar to pick up turbulence and other weather phenom enon. This band is also shared with some police speed radars and some space radars.

1.6.5 K Band Radars

Operate ona wavelength of .75-1.2 cm or 1.7-2.5 cm anda corresponding frequency of 27-40 GHz and 12-18 GHz. This band is split down the middle due to a strong absorption line in water vapor. This band is similar to the X band but is just more sensitive. This band also shares space with police radars: Bands **Section.** Especially with S band radars, see the bands section, a large dome is needed. Since this dome can easily be over 30 feet in height and on top of a tower over 100 feet in height, it can be visible from long distances. The dome essentially just houses and protects the radar dish. it is made of a material that allows the signal to leave through it and also return through it. inside that dome is the dish itself.

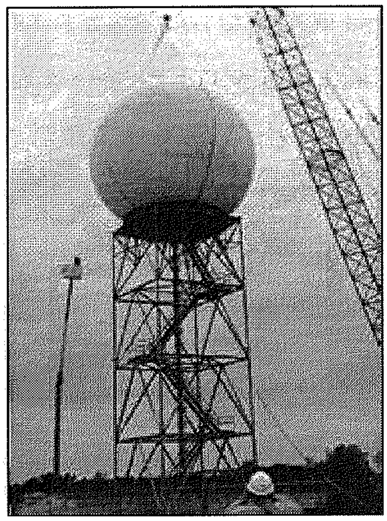


Figure 1.6: Band Radar

The main purpose of the dish is to focus the transmitted power into a small beam and also to listen and collect the returned signal. More information about dish sizes can also be found in the bands section. In a nutshell, that is essentially what a radar's dish does. That visible part is really just a small part of what actually mak:es the radar work. There are three components in a WSR-88D radar besides the dish and tower. These are the Radar Data Acquisition (RDA), the Radar Product Generator (RPG), and finally the Principal User Processor. (PUP)

- RDA - The radar <lata acquisition unit is what houses the actual transmitter and the receiver.

  The transmitter sends out multiple pulses every second. Between those pulses, the receiver receives the reflected energy from the pulse. Since precipitation is moving and every return signal is different, it reads over 20 pulses per second and sends that <lata on to the RPG.

- RPG - The radar product generator receives the information from the receiver. It ta.kes the 20 or more pulses that the receiver received in one second and averages them together. After the RPG gets the information from one volume scan, or one rotation of the radar, it creates the products that we see on TV or the Intemet. Some of these products are the reflectivity of the precipitation and also the velocities of the precipitation calculated using the Doppler Effect.

- **PUP -** The principal user processor is the unit that allows for the interface with the radar. This has been in the past the only workstation that allowed a user to access the radar data and control the radar. Now, the NWS is installing AWIPS in ali of their offices. This allows anyone in the building to access the radar data. This will aid in monitoring multiple storms and help get warnings issued more quickly.

CHAPTERTWO

TYPES OF RADAR

2.1. Introduction

Radar systems can be classified by their operational characteristics or by their functions. We will begin by briefly describing the types of radar based on the individual techniques they employ, and then we will describe some of the applications of modem radar systems. At the end of this section, we will briefly discuss radar applications by the radio frequency bands used.

2.2. Airport Surveillance Radar

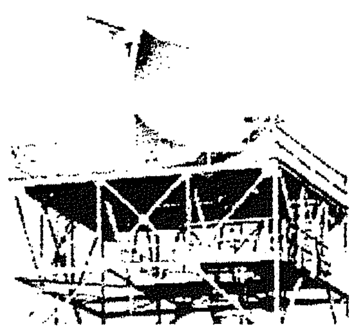


Figure 2.1 Airports Surveillance Radar.

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

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

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

The reflector antenna shown in the photograph is a section of a paraboloid. it is 16.5 feet wide and 9 feet high. Atop the radar (riding piggyback) is a lightweight planar array antenna for the air-traffic-control radar-beacon system. lts dimensions are 26 feet by 5.2 feet. ATCRBS is the primary means for detecting and identifying aircraft equipped with a transponder that can reply to the ATCRBS interrogation. The ATCRBS transmitter, which is independent ofthe radar system and operates ata different frequency, radiates a coded interrogation signal. Aircraft equipped with a suitable transponder can recognize the interrogation and send a coded replyat 'a frequen.cy·differenffroın the interrogation frequency. The interrögator miğhtthen askthe aircraf], by means of other coded signals, to automatically identify it self and to report its altitude. ATCRBS only works with cooperative targets (i.e., those with an operational transponder).

2.3. CW **Radar**

The CW radar gun, which operates on the homodyne principle, is low powered 1OmW X-band radar used to acquire target Doppler signatures. With a weight of about 10 kg including its own batteries it is portable and can be set up ona photographic tripod in less than two minutes. This makes it ideal for observing cooperating or non-cooperating battlefield radar targets at ranges of 1 km or less.

Figure 2.2 CW Radar.

The radar has been employed in the collection of radar Doppler signatures :from civilian and military targets such as men, wheeled and tracked vehicles and helicopters.

New radar has recently been constructed for JEM studies. This is shown below. The microwave head transmits about 35 mW of power at X-band which is focused by a 45 in parabolic dish. The operator views the target visually using a gun-sight (there is a small hole in the dish) and simultaneously listens to the signature of the aircraft through headphones. The radar is mounted on a post on which there are roller and journal bearings for azimuth and elevation. The operator steers the antenna assembly manually. The whole system is attached to the bed of a small truck.

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

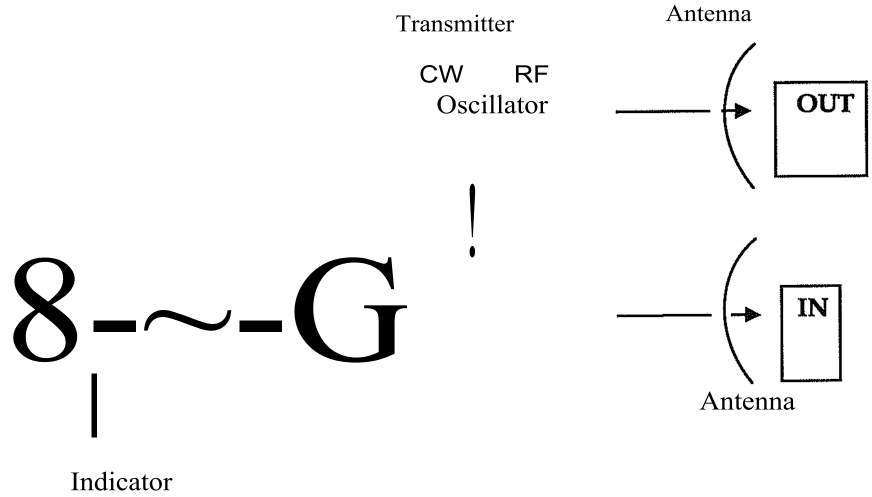


Figure 2.3 Continuous wave radar components.

The following applet allows you to calculate the signal to noise ratio ofa received radar signal according to the radar equation. CW radar transmits and receives simultaneously, so it uses the Doppler frequency shift produced by a moving target to separate the weak echo from the strong transmitted signal. A simple CW radar can detect targets, measure their radial velocity (from the Doppler frequency shift), and determine azimuth angle from the direction of arrival of the received signal. To determine range, however, a more complicated waveform must be used.

2.4 Pulsed Radar System

2.4.1 Operation ofa Pulsed Radar Systeı:rı

The frequency generation and timing system, discussed iri'Parts of a Radar System, periodically cause the transmitter to generate a pulse or burst of illumination electromagnetic energy.

The power levels of this burst vary depending on the environment and the required performance of the system.

The width ofthe pulse can vary between nanoseconds and milliseconds. The transmitted pulse is nota true "pulse", i.e. it is not one single peak of electromagnetic energy. A carrier waveform is in fact transmitted for the pulse duration.

The transmitter unit, which transmitted the RF pulse, then waits for the echo.

If the echo is received D t seconds later then the range can be easily worked out as:

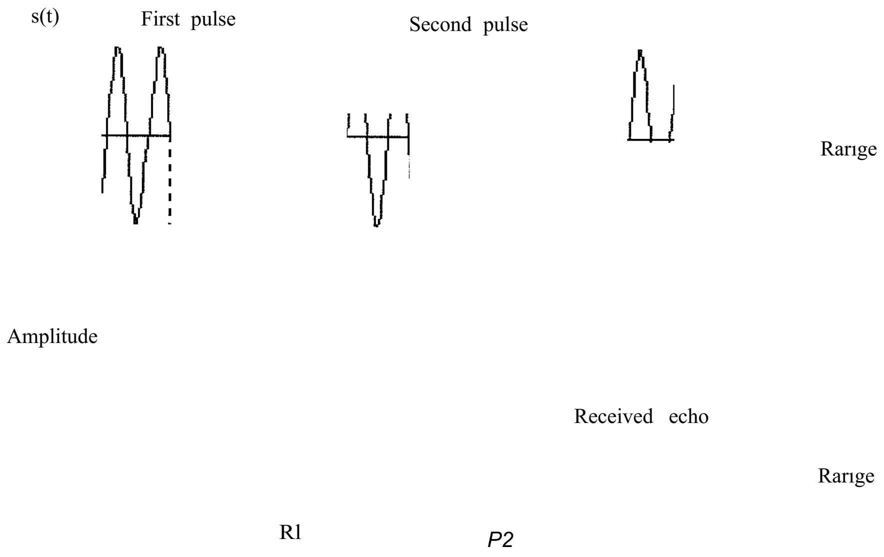
$$R = \frac{C.\ Dt}{2} \qquad (2.1)$$

The transmitter does not wait indefinitely for the echo as there is a maximum range from which a targets echo is so weak it can not be detected.
Therefore the transmitter waits for inter pulse period (IPP) which dictates the maximum range, Rmax, which the pulsed radar system can detect a target.
The inverse of the IPP is the pulse repetition frequency (PRF).
Another factor, apart from Rmax, that in:fluences the PRF is the antenna rotational frequency. The antenna rotates so as to try to detect targets all around it.

To measure the time delay it takes for the echo to reach the receiver we need a reference point in the transmitted signal. The echo that will be picked up by the receiver from the target will be an attenuated version of the transmitted signal and so its shape will be very similar to that of the transmitted pulse.
The pulse shape to be transmitted therefore needs to have, one and only one, sharp reference point.

2.4.2 Range Ambiguity

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



Example of range ambiguity. The range to the target could be P2 or R1 + P2.

Figure 2.4 Range Ambiguity.

If for instance the target echo was detected 0.000005 seconds after a pulse, and the IPP is 0.0006. Rmax for this system is therefore 90km. The echo could therefore have come from a range of 750m or 90.75km.

It is therefore the IPP or the PRF that determines the amount of range ambiguity.

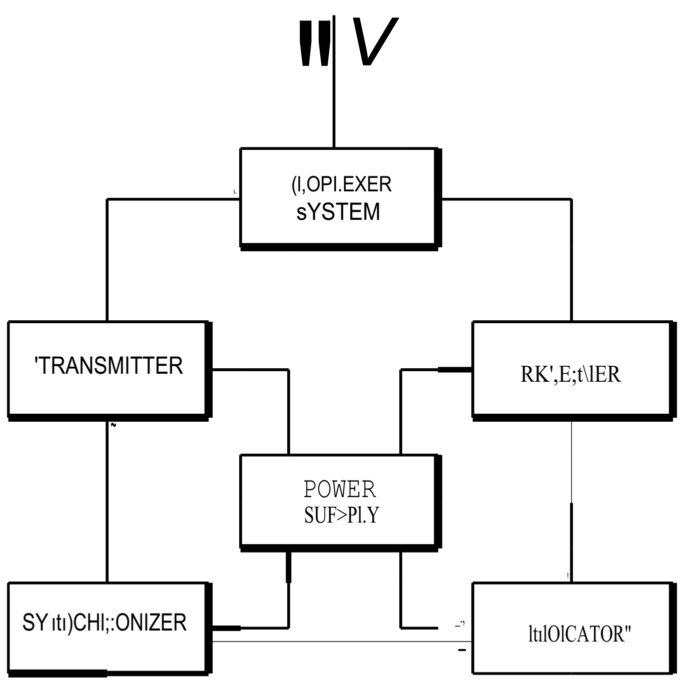


Figure 2.5 Pulse radar.

- What can be done about range ambiguity?

If we set the PRF to a large enough value we can be certain we will not get any echoes from greater then Rmax.

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

2.4.3 Range Resolution

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

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

2.5 Over the Horizon Radar (0TH)

The main problem of modem radar is involved in increasing the operating range. This is usually limited by line of sight, i.e. the horizon, in conventional radar systems.

To over come the line of sight problem there is great interest in using high frequency radars (3-30 MHz), where the radar signal is reflected by the ionosphere. This technique can be used to detect targets that are completely obscured by the horizon. The other is to use ground wave radar. We will look here at high :frequency0TH radar as it is the most common.

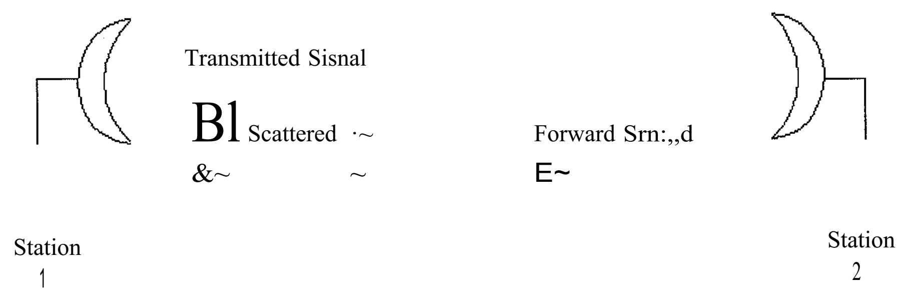


Figure 2.6 0TH Radar.

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

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

Most 0TH radar systems use a single hop technique as illustrated below. This technique gives a range of about 3000Kms.

To transmit signals over such a long range and still be able to detect the back scattered echo means that very high powered transmitters are required. If the receiver and the transmitter are close together then a large amount of noise can be induced into the receiver by the transmitter. For the above reason some 0TH systems separate the receiver and the transmitter and are therefore biostatic systems.

An example of a separation of receiver and transmitter is found in a US 0TH radar installation in Maine where the receiver and transmitter are separated by 162km. This radar has a minimum range of 800km and a maximum range of 3000km. the range resolution of such a system is about 2km and velocity resolution of about 27km/h.

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

2.5.1 Case Study - W ARF 0TH Radar

WARF stands for Wide Aperture Research Facility.
Uses ofthe W ARF facility include:

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

A giant receıvıng array which is 2.5km long. it is formed by two rows of 256 asymmetric vertical monopoles, each about 5.5m long. The antenna array may be electronically steered +/- 32 degrees in both the east and west directions. The gain ofthe receiving antenna is about 30dB.The system has a fine azimuth resolution of 0.5 degrees. The range resolution is about 1.5km.
Target signals are extracted from interference and clutter using correlation and filter processing techniques, along with Doppler processing

2.6 Simple Pulse Radar

Pulse radar is by far the most widely used technique and represents what might be called "conventional" radar. Even in more complex radar systems, a pulse-modulated waveform is generally used. These more advanced radars are distinguished from simple pulse radar by the fact that they have additional features that provide enhanced performance.

The figure above is a simplified representation ofa pulse that might be generated by the transmitter of medium-range radar used for aircra:ft detection. The waveform in the figure is a visual representation of the changes in output voltage of the transmitter over time. The numbers in the figure are hypothetical, but they are similar to what might be expected for a ground-based radar with a range of 50 to 60 nautical miles (or 90 to 110 kilometers) such as those used for air traffic control at airports.

The pulse width in this example is given as one millionth of a second {1 microsecond), and the time between pulses is given as one thousandth of a second (1 millisecond), which corresponds to a pulse repetition frequency of 1,000 hertz (Hz) or cycles per second. Note that the figure shows only a few cycles of the waveform during the pulse; in reality, a system like this could have 1,000 cycles of the wave within each pulse. The pulse power, called the peak power, is shown here as 1,000,000 watts (1 megawatt). Since this system does not radiate continually, however, the average power, which is used to measure the capability ofa radar system, is much lower than the peak power. In this example, for instance, the average power would be 1,000 watts (1 kilowatt).

An echo signal from a target might be as weak as one trillionth of a watt. What this means is that the power levels in a radar system may be very large on the transmitter side and very small on the receiver side. Another example of extremes encountered in radar systems is timing. Air surveillance radar might have pulse duration of one microsecond, while other types of radar can have equivalent pulse widths a thousand times smaller, in the nanosecond range.

2.7 Moving Target Indication (MTI) Radar

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

2.8 Pulse Doppler Radar (Witb Higb Pulse Repetition Frequency)

Pulse Doppler radar is another form of pulse radar that uses the Doppler frequency shift of the reflected signal to eliminate "clutter" and detect moving objects. The difference between pulse Doppler radar and MTI lies in their respective pulse repetition frequencies (prf). For example, a high-prf pulse Doppler system might have a prf of 100 kilohertz (kHz), while a typical MTI system hasa prf of about 300 Hz. The MTI uses a lower PRF so as to obtain an unambiguous measurement of range. The tradeoff is that such a system yields highly ambiguous readings of radial velocity and can even miss some detections. Conversely, pulse Doppler, with its high PRF, yields unambiguous radial velocity measurements but highly ambiguous range readings. Range in pulse Doppler is sometimes resolved by the transmission of multiple waveforms with different prfs.

2.9 Pulse Doppler Radar(Witb Medium Pulse Repetition Frequency)

This type of pulse Doppler radar operates ata lower J?RF (1 0 .kHz, fo.r example),than the high-prf systems, and it yields.>ambiguities. in. both.<range. and .Doppler shift measurements. it is, however, berter for detecting aircraft with low closing speeds than is high-prf pulse Doppler. An aircraft-mounted medium-prf pulse Doppler radar might have to use as many as seven or eight different prfs to obtain accurate target information.

2.10 High-Range-Resolution Radar

This is a type of radar that uses a very short pulse width to provide extremely accurate range measurements. Such radars provide range resolution from several meters to a fraction ofa meter, and they can profile a target and measure its length in the range dimension.

2.11 Pulse-Compression Radar

For accurate range measurements at long distances it would be desirable to transmit very short pulses with high peak power and high-energy waves. Unfortunately, this ability is limited in practice by voltage breakdown, or arcing in the transmitter or antenna. Thus, high-range-resolution radars with short pulses are limited in peak power and, therefore, also in operating range. Pulse compression solves this problem by transmitting a long, high-energy pulse that is modulated in either frequency or phase. The modulation allows the pulse to be compressed in the receiver, thus achieving the range resolution of short-pulse transmission with longer pulses.

2.12 Synthetic Aperture Radar (SAR)

With conventional pulse radars, the resolution in range is much berter than what can be achieved in angle. Recall that angle (also called cross-range) accuracy is greatest with narrow beam-width transmission. Unfortunately, this is hard to achieve except with the very largest antennas. There is, however, a way to obtain good cross-range accuracy by resolving the angle in terms of Doppler frequency shift. Remember that when an object is moving toward the radar it compresses the re:flected energy, thus raising the frequency, and that when the object is moving away it does just the reverse, lowering the frequency. Not surprisingly, this effect also happens when the radar is moving and the target is stationary. This can be accomplished by mounting radar on an aircraft or spacecraft and viewing the ground.

Imagine wide-beam radar with good range resolution mounted on an airplane. As the airplane :flies past a target on the ground, the radar emits multiple pulses that are partially re:flected by the target back to the antenna. As the airplane approaches the target, the Doppler Effect causes the echo frequency to rise. But ata certain point (when the plane passes closest to the target) the echo frequency begins to fall again. The point of peak frequency rise represents the cross-range position of the target. Another way to describe this process is to say that ali of the observations made during a certain travel distance of the airplane (and radar) are recorded or stored in computer memory and processed together later. The effect is that of having a very large antenna, the diameter of which is the distance traveled by the airplane. This distance is called a synthetic aperture, and the process is called synthetic aperture radar, or SAR. With SAR, cross-range measurements comparable to the best range measurements can be achieved. SAR processing has been used extensively on aircraft and spacecraft to observe the Earth and on deep-space probes to study the planets in our solar system. See previous comments on SAR.

2.13 Inverse Synthetic Aperture Radar (ISAR)

ISAR systems employ the same principle as SAR, except that in this case the radar is stationary (i.e., ground-based). ISAR depends on the target's movement to provide the Doppler frequency shift between various parts of the target and the radar unit in order to obtain high-resolution cross-range measurements. If ISAR is used for cross-range determination in conjunction with short-pulse or pulse-compression radar for ranging, a two-dimensional, high-resolution image ofthe target can be obtained.

2.14 Side-Looking Airborne Radar (SLAR)

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

2.15 Bistatic Radar

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

2.16 Tracking Radar

This type of radar employs a large "dish"-type antenna that emits a narrow, symmetrical "pencil" beam. The purpose of tracking radars is to track a single target in both range and angle to determine its patlı, or trajectory, and to predict its future position. Single-target tracking radar provides target Iocation almost continuously, with a typical tracking radar measuring target location at a rate often times per second.

2.17 Scatterometer Radar

This type of radar measures backscatter accurately to obtain information such as wind speed over oceans. Radar images are composed of many dots, or picture elements. Each pixel (picture element) in the radar image represents the radar backscatter for that area on the ground darker areas in the image represent low backscatter, brighter areas represent high backscatter. A useful rule-of-thumb in analyzing radar images is that the higher or brighter the backscatter on the image, the rougher the surface being imaged.

2.18 Track-While-Scan Radar

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

2.19 3-D Radar

Conventional air-surveillance radars measure target location in terms of range and azimuth angle, but elevation angle, :from which target height can be calculated can also be determined. in fact, trackiııg radars measure elevation angle, as well as range and azimuth. So-called 3-D air surveillance radar measures range in the conventional manner but uses an antenna that is rotated about a vertical axis to determine azimuth angle and has either fixed multiple beams in elevation or a pencil beam that is scanned up and down to measure the elevation angle.

2.20 Electronically Scanned Phased-Array Radar

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

2.21 Frequeney-Modulated Continuous-Wave (FM-CW) Radar

In this type of CW radar, the frequency of the transmitted signal is continually changed, generally in a linear manner, so that there is an up-and-down altemation in frequency. This means that the frequency of the returning echo signal will differ from the signal then being transmitted. The difference between the two frequencies is proportional to the range of the target, so the measurement of the frequency difference allows range to be determined. Phase modulation of CW signals has also been used to obtain range measurements. The most common form of FM-CW radar is the radar altimeter used in aircraft to determine height above the ground.

2.22 Weather radar

2.22.1 Introduction

Weather radar's inauguration held on 20th of September in2000.The :radar is 515 m above sea level and it is 24 m high. Compared to other weather radars in Finland Luosto radar has a digital receiver and larger antenna giving berter resolution of observations, which is especially important in the winter conditions of Lapland. The radar is also used in development of radar technology and signal processing algorithms. Doppler-radar Covers almost the whole Lappland without the most northest part .

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

2.22.2 Weather Radar Working

As it turns, the radar antenna sends out short high-powered bursts of microwave energy in different directions. When such a pulse meets an obstacle, e.g. raindrops, the energy is scattered; a very small part of this arrives back at the antenna. The radar measures the strength of the received signal and its delay time, which is proportional to the range of the obstacle. Thus the intensity of the rain, as well as its position and height, can be determined. With a Doppler radar the speed of the raindrops can also be measured. Although the transmitted pulse is very powerful, the signal received at the antenna from the scattering raindrops is extremely weak. This places great demands on the stability and sensitivity of the radar receiver. The received signal is composed of the combined effects of the scattering from a great number of raindrops; the tadar can measure conditions within a rainshaft, and can also penetrate to measure other rain areas beyond .

2.22.3 Technical Aspects

The main units in weather radar are the antenna with its pedestal, the transmitter, the receiver and the associated computer systems. The main computer controls all aspects of the radar's operations and passes on the measurement results to the FMI main office in Helsinki.

Technical data	Measureme:iit
Antennadiameter	Luosto 6.1 m, other ra.dars4.2 m
Radome diameter	Luôstô 9.Tn:i, ôther fadars 6.2 m
Beamwidth	Liiosto 0.7 degrees, other radars 1 degree
Transmitter	Radial magnetron
Frequency	5600-5650 MHz
Wavelength	approx. 5.3 cm
Transmitted pulse power	250KW
Average transmitter power	300W

CHAPTER THREE

AIRPORT SURVEILLANCE RADAR

3.1 Introduction

Surveillance radar a device which, by measuring the time interval between transmission and reception of radio pulses and correlating the angular orientation of the radiated antenna beam or beams in azimuth and/or elevation, provides information on range, azimuth, and/or elevation of objects in the patlı ofthe 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 a.s an instrument approach aid. The DFW terminal radar approach control (TRA.CON) facility provides radar coverage with four ASR-9 installations.
2. ARSR is a Iong-range radar system designed primarily to provide a display of aircraft locations oveflarge areas. The Fort Worth air route traffic control center (ZFW ARTCC) prôviô.es radar coverage with a total of 9 long range radar installations, 2 radar bea.côll.ônlysites and one ASR-9 installation.

3.2 Airport Surveillance Rad.ar (ASR)

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

Reliable maintenance and improved equipment have reduced radar system failures to a negligible factor. Ali of the DFW RADAR facilities have components duplicated-one operating and another, which immediately ta.kes over when a malfunction occurs to the primary component.

The characteristics of radio waves are suchthattheynôfnıallytravel·.in a continuous straight line unless they are:

1. "Bent" abnormal atmospheric phenô111ena such as teın.peratjı:re inversions; the bending of radar pulses, often called anormalou.s propağation.()f.dticting, may cause many extraneous blips to appear on the radar operatôt's displayif the beam has been bent toward the ground or may decrease the detectiotıı-aı:iğe if the wave is bent upward. it is difficult to solve the effects of aı:ion:ıalou.s propagation, but using beacon radar and electronically eliminating stationary and slow moving targets by a method called moving target indicator (MTI) usually negate the problem.
2. Reflected or attenuated by dense objects such as heavy clouds, precipitation, ground obstacles, mountains, ete.; radar energy that strikes dense objects will be reflected and displayed on the operators scope thereby blocking out aircraft at the same rage and greatly weak:ening 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 MTl is that an aircraff flyinğ a speed thaf côincides with the canceling sigıial öf the MTI (taı:iğeı:itia.Fôf "blind" speed) tıfaf nôfbe displayed to the radar côtıtfoller.
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 ora sleekjet fighter will be more difficult to see on radar that a large commercial jet or military bomber. Here a gain, the use of radar beacon in invaluable if the aircraft is equipped with an airbome transponder. All radars in the lone star SMO have the capability to interrogate

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

3.3. Air Traffic Control Radar Beacon System (ATCRBS)

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

- Interrogator. Primary radar relies ona signal being transmitted from the radar antenna site and for this signal to be reflected or "bounced back" from an object (such as an aircraft). This reflected signal is then displayed as a "target" on the controller's radarscope. in the ATCRBS, the interrogator, a ground based radar beacon transmitter-receiver, seans in synchronism 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 airbome radar beacon transmitter-receiver automatically receives the signals from the interrogations being received on the mode to which it is set. These replies are independent of, and much stronger than a primary radar 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 refersto in the control and separation oftraffic.
- 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 ofradar targets
    * Rapid target identification.
    * Unique display of selected codes.

A part of the ATCRBS ground equipment is the decoder. This equipment enables the controller to assign discrete transponder codes to each aircraft under his control .
Normally only one code will be assigned for the entire flight. The ARTCC computer on the hasis of the National Beacon Code Allocation Plan makes assignments. The equipment is also designed to receive MODE C altitude information from the aircraft.
It should be emphasized that aircraft transponders greatly improve the effectiveness of radar system.
Center Radar Automated Radar Terminal System (ARTS) Processing (CENRAP) was developed to provide an altemative to a non-radar environment at terminal facilities should an Airport Surveillance Radar (ASR) fail or malfunction. CENRAP send aircraft radar beacon target information to the ASR terminal facility equipped with ARTS procedures used for the separation of aircraft may increase under certain conditions when a facility is utilizing CENRAP because radar target information updates at a slower rate than the normal ASR radar. Radar services for VFR aircraft are also limited during CENRAP operations because of the additional workload required to provide services to IFR aircraft.

3.4. Primary Surveillance Radar (PSR)

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

3.5 Secondary Surveillance Radar (SSR)

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

3.6 Problems with Primary Radar

As you can see from the previous slides:

1. Rain makes targets difficult to see.
2. Birds can show areturn that looksIikean aircraft.
3. Some aircraft do not show UP at all.
4. Clutter fronr öther il:ıforrna.tiô:rirnakes aircraft difficult to see.

Secondary Surveillance Rada:thelps .to solve these problems.

3.7. SSR helps us Sort it out

All the transponder equipped aircraft have numbers. Even the ones without primary retums ! Birds and ali en 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 aırspace.

in this example,

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

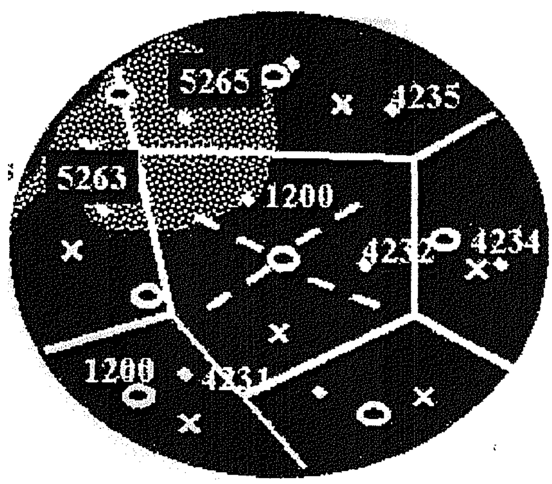


Figure 3.1 Monitor of SSR shows the targets.

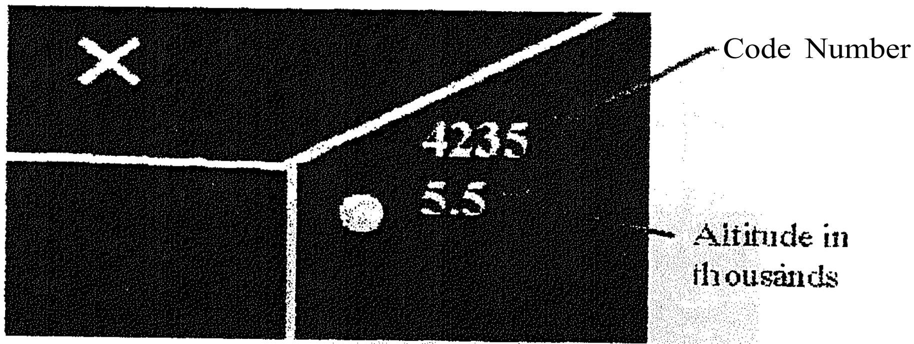


Figure 3.2: Monitor of SSR show the altitude of the plane.

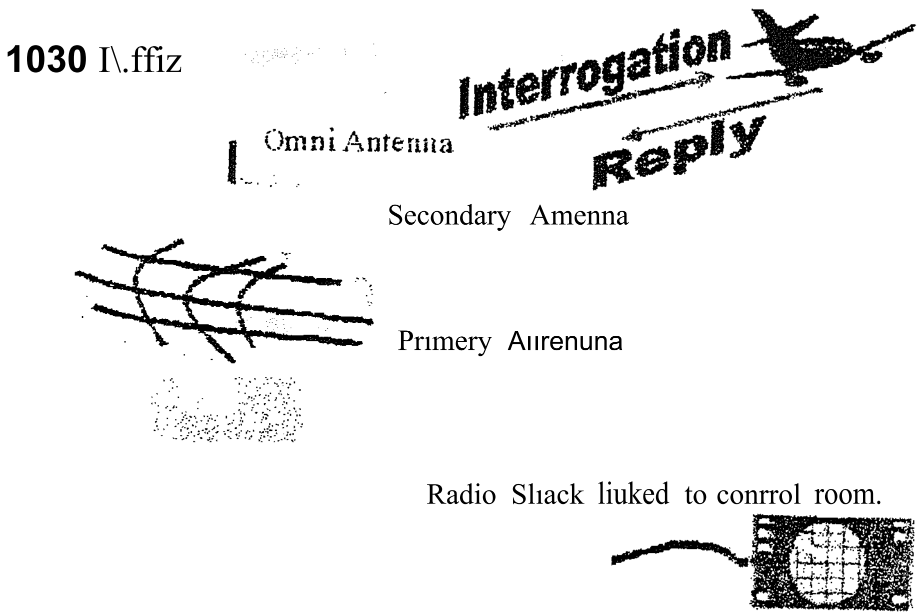


Figure 3.3: The ground system.

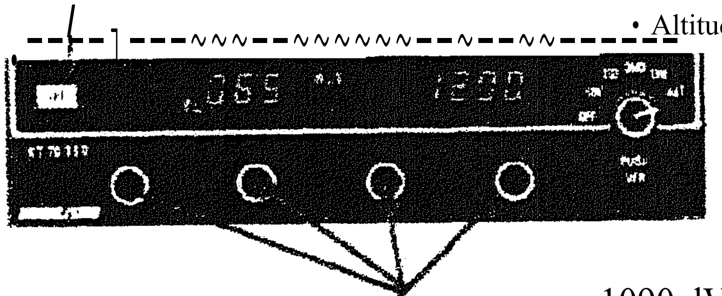


Figure 3.4: The airbome system.

3.8 Why it's 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 tö screeııi:rıg by mountains or even - if the aircraft is flying low enough- by the earth's cilivature.

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

3.9 The Radar's Role in the.A.TC

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 con:flictwith any ofthe other targets on the screen.

lf in doubt about a particular target's identity, the controller can request that aircra:ftto undertake a specific man oeuvre, such as a turn 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 ancls9me from ofpositive 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 sign.alto the aircraft to which the aircraft replies with coded transmission. The aircraftın.1.1st therefore be equipped with response equipment, known asa transponder.

in order to identify a target, the ground controller will ask that aircraft to transponder or 'squawk' an assigned code numbe.r vvhichjrrımediately highlights a target on the controller's screen, identifying it as that partictılat airct~ft.Jf1:he,:ıircnıft is equipped with what is known as a Mode C transponder, the altitude oftlıa.f~i.ı-praftvvillappear as an unidentified target.

These days, most radar <lata 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 ali transponder equipped aircraft in their sector, but also any traffic operating without transponders, for upper level en route surveillance, longer range secondary surveillarrce radar is generally used alone because there is less traffic control densityand few, if any, aircraft operate in those sectors without transponders. Like its prinıaty counterpart, secondary radar is a line of sight tool and range restricted. Where full secondary radar coverage is available, it is possible to reduce the separations required between aircraft and, therefore make more efficient use of the available airspace, thereby increasing the capacity of that controlled airspace. However radar is limited to a range of about 200nm. On land, it is usually possible to install a sufficient 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.

3.10 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 retum, and using ali this information, define the aircraft's precise position.

3.11 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.

3.12 Mode S

'Mode select', or 'Mode S' as itis rnorecornınoıılyknow:n,isasystemwhicherıharıces existing radar-based surveillance and provides an additional dafalirik fü:n.ctio11.Ifhas been developed in order to over come sensitivity of existing systems 'to sy:nchrönôus 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 ali 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 froınr.the cockpit. Mode S codes are derived from the aircraft's registratio:rı.:xm.:trı:ı.ber10:t öther numbering scheme.

Another key feattıre ofiMôde S<is thatitcatı+selectivelyinte:rtôğate\i:rı.dividtıal:aircraft even if several transpôncle:riequippedaircraft>afe sirnu.lfaneôu.sly/iwithi:rı. view of the ground sensor. A Mede Straıısp011der.However, in order'to pick up unknown aircraft, a sensor periodically broadcasts a Mode S 'all...call' interrogation. Any Mode S transponder which has not been specifically commanded to ignore all-call interrogation will reply. ünce a transponder has responded to all-call interrogation will reply. ünce a transponder has responded to all-call interrogation and been identified, the sensor will then instruct it to ignore all further all-call interrogations. Mode Sis claimed to improve overall surveillance accuracy by a factor ofup to four.

As it is datalink tool, mode S used the basic surveillance interrogation and replies to pass datalink message, taking advantage of the selective address to exchange more

comprehensive <lata. 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.

3.13 Displays

Display technology has :n:1.ade great strides over the last few years, giving controllers a much clearer picture of the airspace they are controlling.
From the early days of round horizontal monochrome displays, air traffic control authorities are increasingly switching to vertical square color screens.
Until the advent of SSR, all radar surveillance involved the use of primary sensors. The <lata generated by these sensors was displayed on round PPI (Plan Position Indicator) screens with a beam making a circular scan of the screen represent each revolution of the radar antenna, updating the echoes with every revolution. But, as well as picking up aircraft, the screen also displayed all ôthef 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' ifwas at least possible positively to identify and label targets and, as display technology improved, to select the amount of additional iiformation that was'displayed on the screen. it was possible, for example, to screen öti.ttettain and weather echoes, leaving just the active targets and giving controllers a mti.chdeafer picture.

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

The radar set AN/SPS-49 is an L-band, long-range, two-dimensional, air-search radar system that provides automatic detection and reporting of targets within its surveillance volume. The AN/SPS-49 performs accurate centroiding of target range, azimuth, amplitude, ECM level backgröund, and radial velocity with an associated confidence factor to produce contact' data for command and control systems. in addition, contact range and bearing inforınation 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 löW-altitude targets in all sea states, and also utilizes an upspot feature to provide coverage for high diving threats in the high diver mode. Extemal control of AN/SPS-49 mödes 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 autornatic'target detection capability with pulse Doppler processing and clutter maps, ensuring reliable detection in normal and severe types of clutter, an electronic counter-countenneasures 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 electrönic 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 successfultarget identification, designation, and engagement with either long range (SM-1 or SM-2) missiles and/or short range local defense missiles. A key feature ofthe most recent version öf the radar, the SPS-49A (V) 1 is single-scan radial velocity estimation of all targets allowing faster promotion to fırın track and improved maneuver detection. This is done using unique signal processing techniques originated and tested by the Radar Division ôfNRL using 6.1 and 6.2 office ofNaval Research (ONR) funds. The AN/SPS-49(V) radar is a narrow beam, very long range, 2D air search radar that primarily supports the AAW rnission 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 Iong-range mode, 'the AN/SPS-49 can detect small fighter aircraft at ranges in excess of 225 nautical iıiiles:>Its>narföwbeam width substantially improves resistance to jarnming. The additioıiôfcôherent side lobe canceller (CSLC) capability in some AN/SPS-A9(V) radars alsô j:)tôvides additional resistance to jamming/interference by canceling the jaınming/iritetference signals. The moving target indicator (MTI) capability incotpôrated iıi the AN/SPS-49 (V) radar enhances target detection of low-flying high speedtafğetsthtough the cancellation of ground/sea return (clutter), weather and similar statioıiaıytargets. in 12-RPM mode operation, this radar is effective for the detection of hostile lôwflyiıig and POPUP!c targets. Features ofthis set include:

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

• Digifaf ptбcessing techniques used extensively in the automatic target detection modificatiôıi

• Perfoımarice monitors, automatic fault detectors, and built-in-test equipment, and automa.ticбı:ılirie self test features

Band	L
Frequency Band	850 to 942 MHz,three selectable 30MHz bands, 48 discrete frequencies
Transmitting Power	360 kW peak, 280 kW specified peak power,12-13 kW average power
Antenna Parameters	Parabolic Reflector stabilized for roll and pitch, 7.3m/24 ft wide, 4.3ırı114.2 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 iıicroseconds

3.15 Upgrading the Nation's Largest Space Surveillance Radar

Some of the custom electronics assemblies designed at SwRI for the AN/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 introdüced 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 concem for the Electro explosive devices, such as ejection seats and munitions.

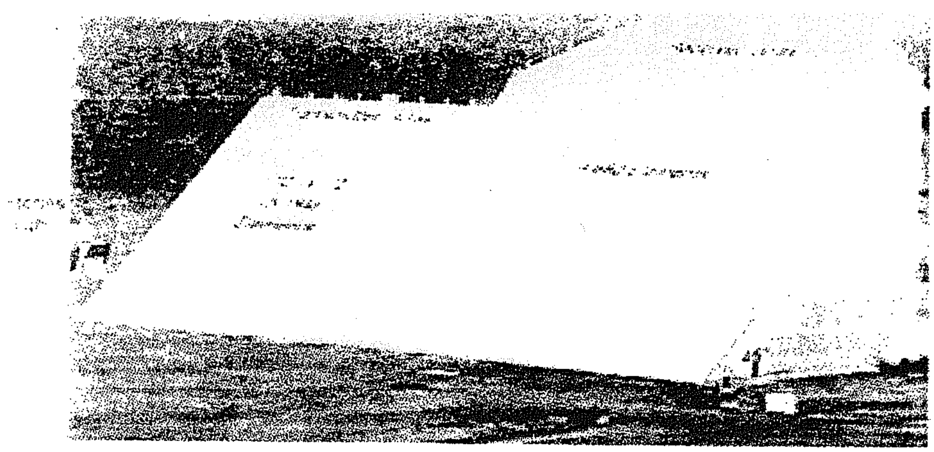


Figure 3.7 The AN/FPS-85 Phased Array Radar Facility in Florida,USA.

SwRI engineers determined that reliability, supportability, and reliability gains in the transmitter array system could be realized through modem design approaches that would replace high-power vacuum tubes with, RI; power. transistor and integrated electronic technology. As the project progressed, new transmitter designs were developed, prototyped, and tested by modifying governmerıt-furnished radar transmitter units. The basic concept has been successfully demorıstrated, .atıd a -large four-year production effort to modifylh.e rulltratısnrıttefarra.y syste:rrı is plaıırіed. The Air Force has endorsed the upgrade pları and is prepared to carry out the modification program with SwRI as the principk-erıgiıieering consultant,

CHAPTER FOUR

APPLICATION iN ERCAN AIRPORT

4.1 Civil Aviation Department in Ercan Airport

Name of the Governınental Organization: civil Aviation Department, Ministry of Coınmunication and works, Turkish Republic ofNorthem Cyprus (TRNC).

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

4.2 Radar Systems in Ercan Ail".port

Radar systems in Ercan Airpopt (The Ma.inAirport fü Nôrthetri Cyprus) is consisting of Primay Survellance Radar (PSR), Secondary Surveillance Radar (SSR), Multi Radar Tracking (MRT), JJ8ıftılti .Channel Tracking (MCT), Associated modem, Coınmon Display System (C:IJŞ)lll'l.q]:)igital System (DDS) the last two for monitoring.

4.2.1 PSR

Primary Surveillance Radar (PSR) it has 60 nıni. 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 ôflighfl 62 000 nıni/s, when it hits the targets i.e. the plane it reflects back and the receivei' of oiir system detect the echo and true the formula of

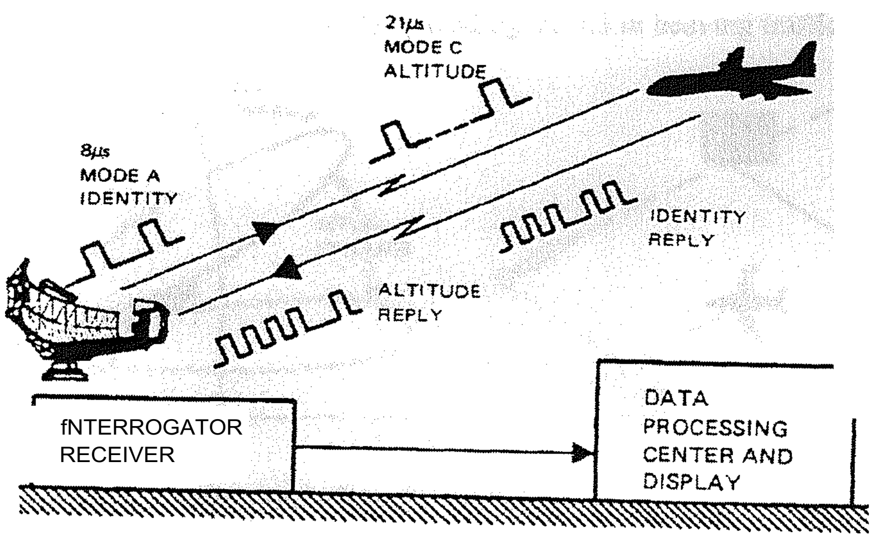
$$R= Ct/2 \tag{4.1}$$

Where R is the range, C is jhe 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 cmly.

4.2.2 SSR

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

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



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

4.2.2.1 SSR Performanee and Limitations

The attached document contains .part of annex 10 of the convel1.tion of(IN C A) and it gives specifications and recommend~tjgps of for S.Ş~.tô whichthe·SSR must add here

- Detection the aircraft position 'VVitİıötit..'to use n~~~~s~ly- t~e)deCod4ı-g equipment;
- Identification of the a~jf~~!ight code; I
- To identify, when it.is req1.1eşted, a signal.aircraft from the.reply.ôfSpeciaLpulseSPI (Special Pulse Identification);
- To indicate, immediatlyian aircraft in an emergency condition or with the\tadio communication system in trouble such performance must be available, typically with in following limits for all the conditions
- Up to 200 nautical miles ranges
- Up to an altitude of 30.480 meter (100.000) for elevation angles between .5 /45
- Foran azimuth angle of 360
- The advantages gamed from an SSR system are off set by the following problems
- Interrogation by antenna side lobes
- Interrogation by means multiple patlı figure 4.2
- Interrogation by coming from other SSR system figure 4.2
- Replies coming from aircrafts closely spaced figure 5.3 in heaving traffic areas.

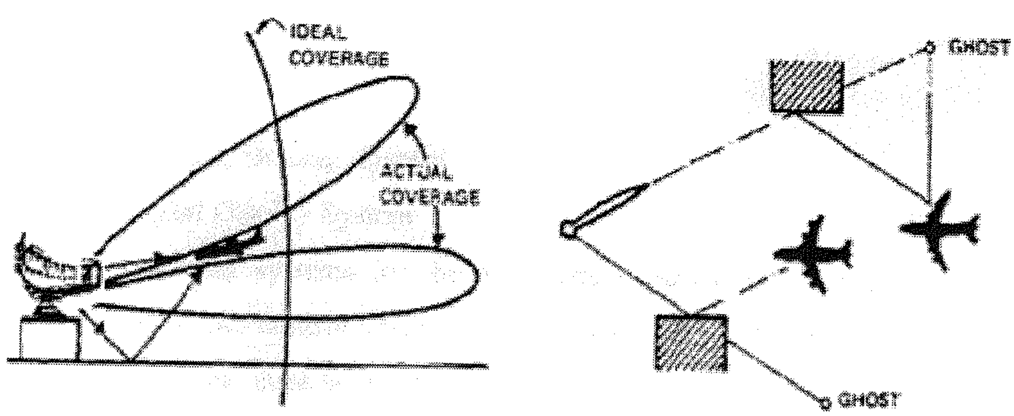


Figure 4.2 Reflection influence on SSR coverage in Ercan Airport

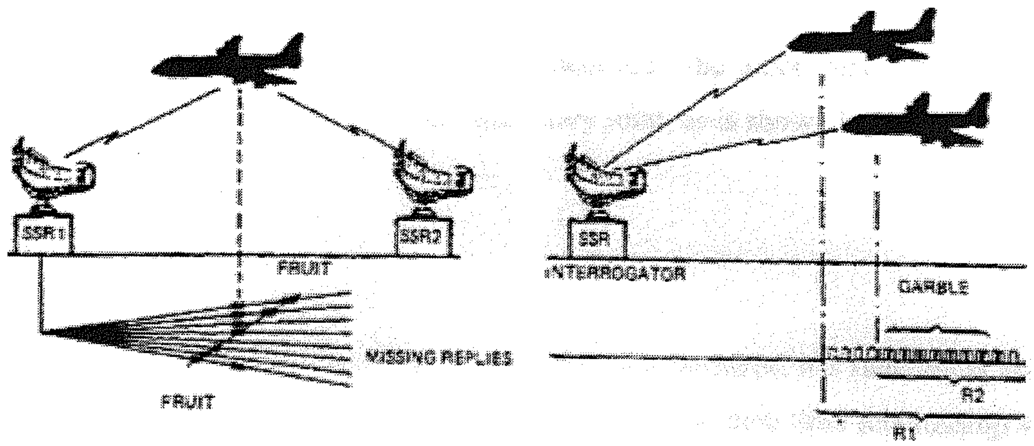


Figure 4.3 SSR Interferences Ercan Airport

4.3.3 MRT and MCT

MRT means Multi Radar Tracking,

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

4.3.4 CDS and DDS

CDS means Common DisplaySysterii

DDS means Digital Display System

These are monitoring systems for the air traffic controls role 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 ofthe plane is, very easily, and in a very clearway.

4.4 Basic Elements of Pulse Radar Systems in Ercan Airport

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

4.4.1 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 ofthe proper length .The timer may be a separate unit by it self or it m.aybeincluded is the transmitter or receiver.

4.4.2 Modulator

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

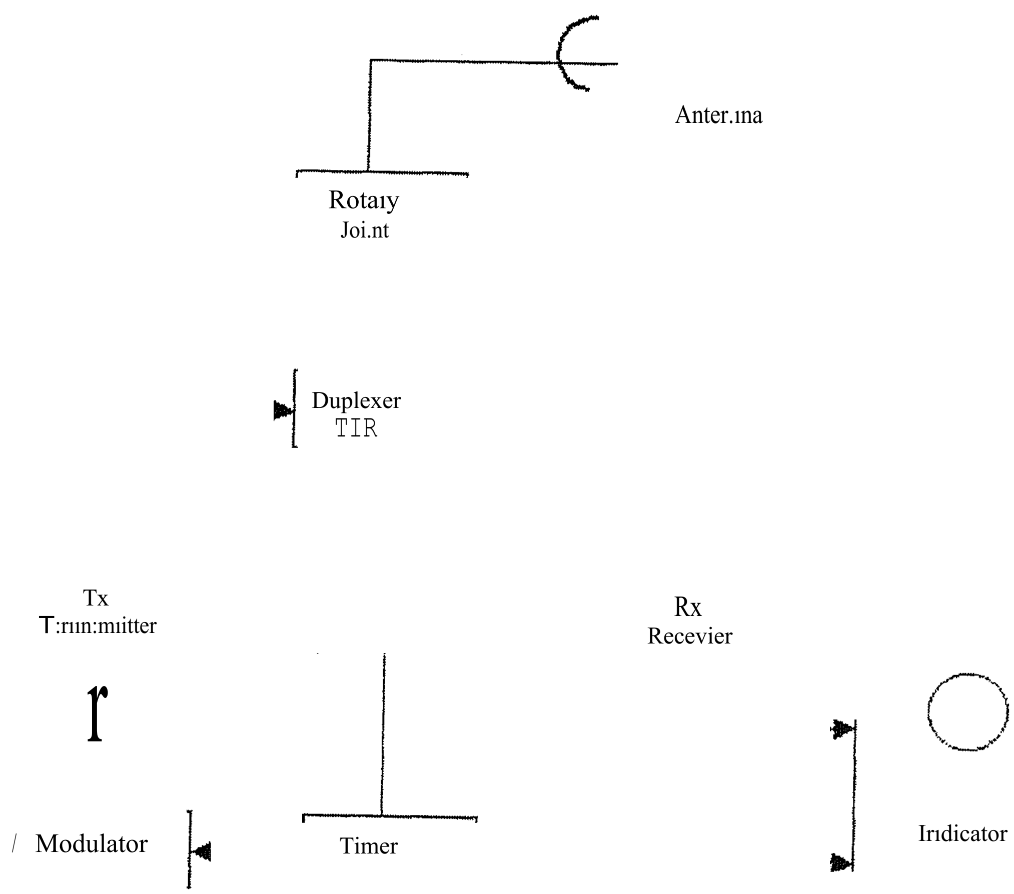


Figure 4.4 Basic elements of pulse systems radar in Ercan Airport

4.4.3 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.

4.4.4 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 seatching(iillfie presence of targets in the area is established by this searching.

4.4.5 Duplexer

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

4.4.6 Rotary joint

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

4.4.7 Receiver

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

4.4.8 Indicator

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

4.5 Important Aviation System has Related with Airport Surveillance Radar in Ercan .t\ir.port

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.

4.5.1 The Navigational Aids Systems in Ercan Airport

The purpose of navigatiori 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 ofVOR, NDB and DME.

4.5.1.1 VOR

VOR is (Very High Frequency (VHF) Qmni..directioııa.1Radio Range), each VOR equipment has a name of three characters aııd 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 transınission; there are 360 radials 0 degree is adjusted to magnetic north. The frequency of VOR equipment is between 108 MHz- 117.95 MHz, VOR equipment consists of solid state plug in modules, 220 VAC is converted to 40 vdc, 12 vdc and 24 vdc by transformer. There are mainly six parts in VOR equipment

1. Power supply
2. Transmitter

3. Modulator
4. Electronic goniometric
5. Entenna
6. Monitor

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

4.5.1.2NDB

NDB is Non Directid1 1al Beaeon; 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 côde signal that it emits at :frequentintervals, it offers no tracking guidance and most aircrafts are fitted with an Automatic Direction Finder (ADF) to identil' the direction of the beacon :fromthe aircraft. NDB's are usually used in the vicinity ofairports as an aid to locating the airport itself

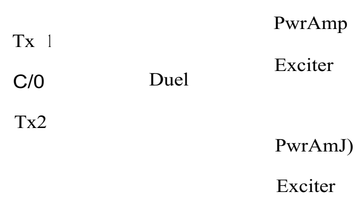


Figure 4.5 The NDB system

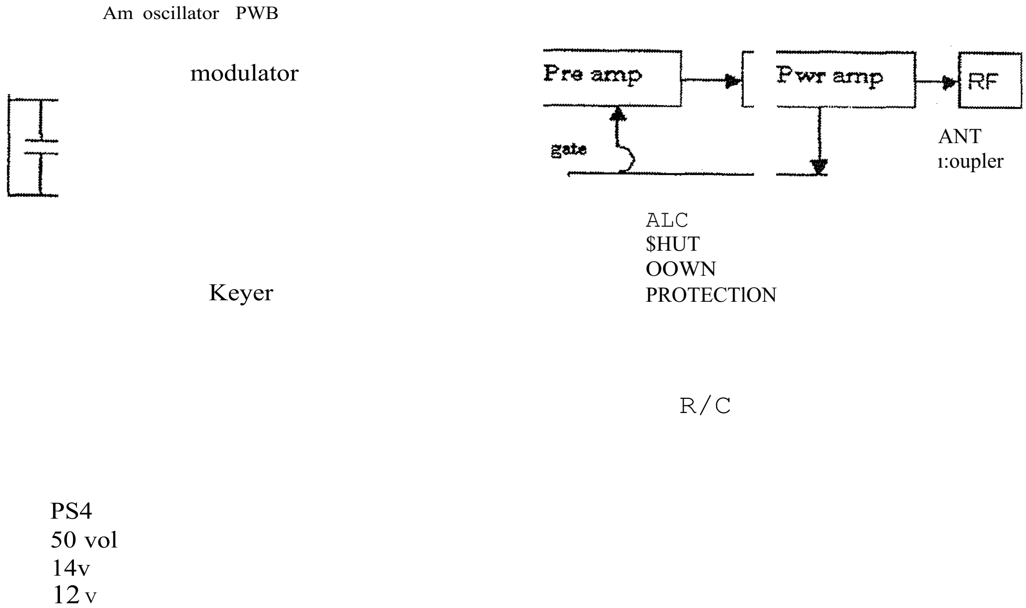


Figure 4.6 Blockdiağtam of NDB in Ercaı:ı. l\;irport

4.5.1.3 DME

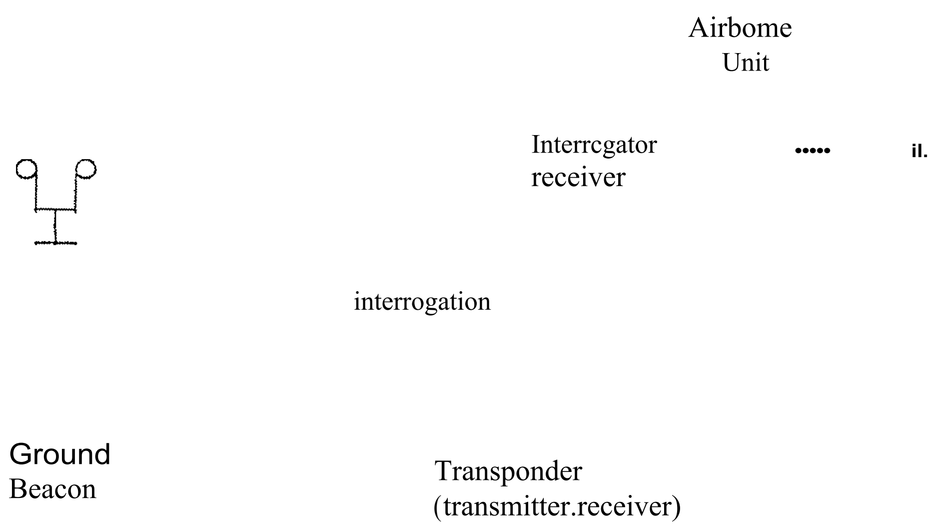
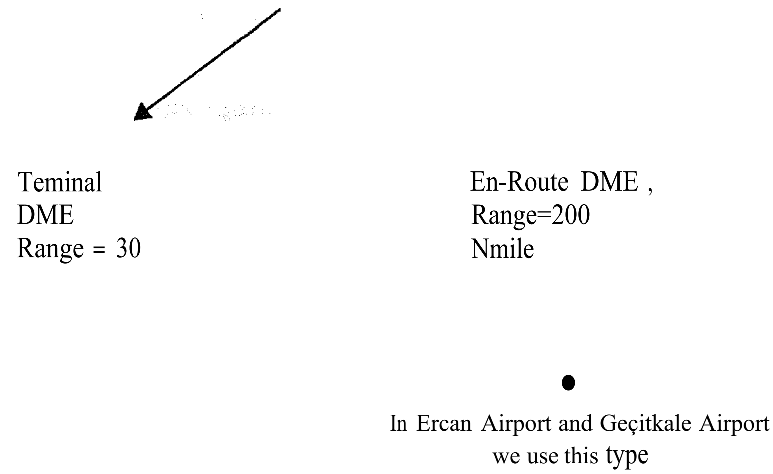


Figure 4.7 The DME system in Ercan Airport

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



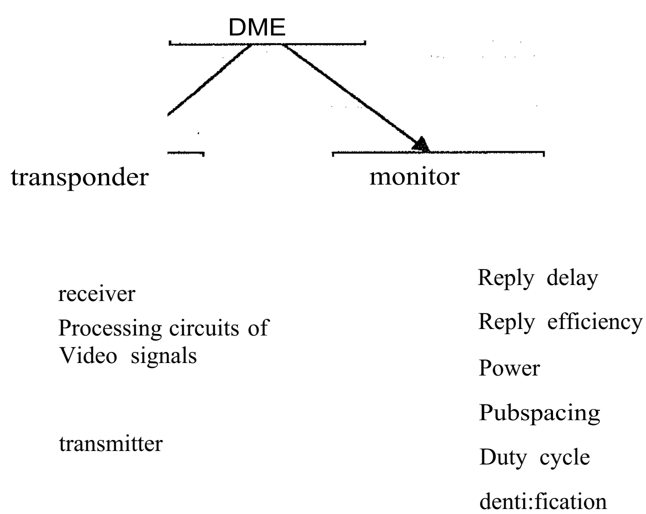
Fiğııre 4.8 Types ofDME

Face standard FSD-15 is used in Ercan Airport and .the'Nrsys Naviga.tion FSD-45 is used in Getcitkale Airport, TheworkingprincipleofDME:

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

M=t. C (4.2)

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



Fignre **4.9** 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,

Airport	Channel	Interroga1:ioıı frequençy	Reply Frequency	Pulse Fr~quency	VHF Channel
GKE	90x	1114 MHz	1177 MHz	12 us	114.3 MHz
GKE	90y	11 14 MHz	1051 MHz	30us	114.3 MHz
ECN	117x	1 141 MHz	1024MHz	12 us	117.0MHz
ECN	117y	1141 MHz	1078MHz	30us	117.0MHz

See figure 4.10 the gerieraldfağrarri ôfDME

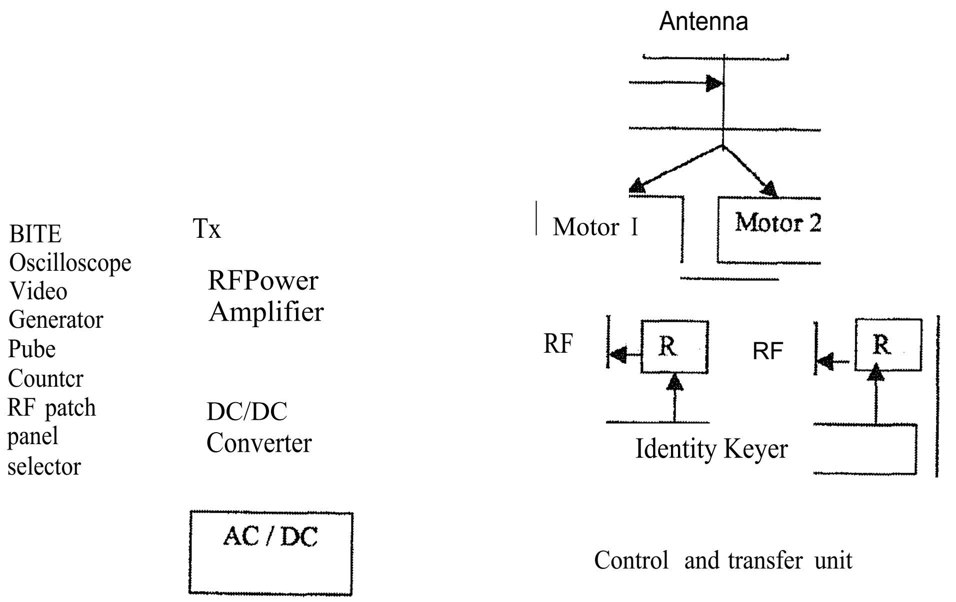


Figure 4.10 General Diagram ofDMEin Ercan Airport

4.5.2 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. 7MHz	Air traffic control frequency
126.9MHz	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 freqtıency)

Local system situated in Ercan Airport for local frequency as,

120.2 MHz	2 transmitters,2receivers
126.7 MHz	1 transrnitter?Ireceiver
126.9 MHz	I transmitter, I'receiver
121.5 MHz	1 transmitter,I receiver
118.1 MHz	1 transmitter, 1 receiver

Yayla station system situatedinyayla over mountains,

126.7MHz	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 becaııse they are situated over the mountains.

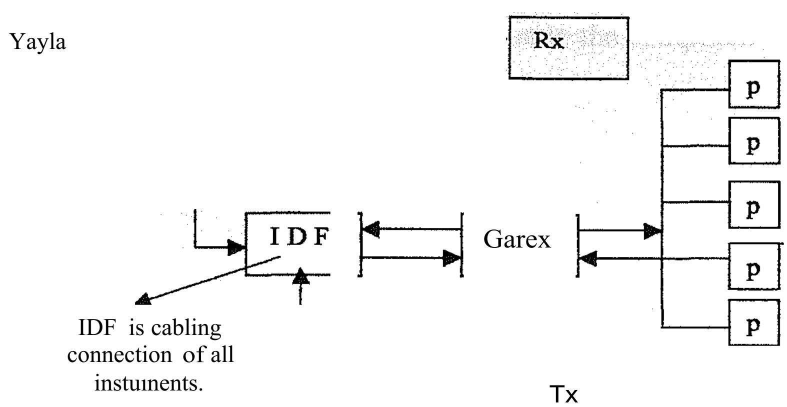


Figure 4.11 Voice communication in Ercan Airport

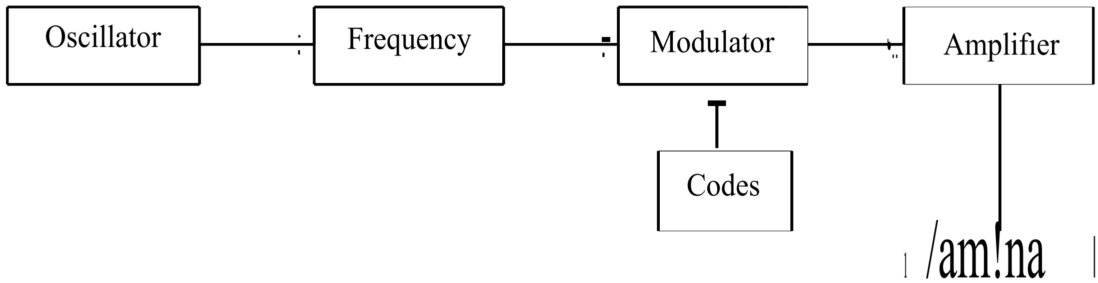


Figure 4.12 Simple bl()ck diagram oftransmitter in voice cotrirı:ırinicatiôn

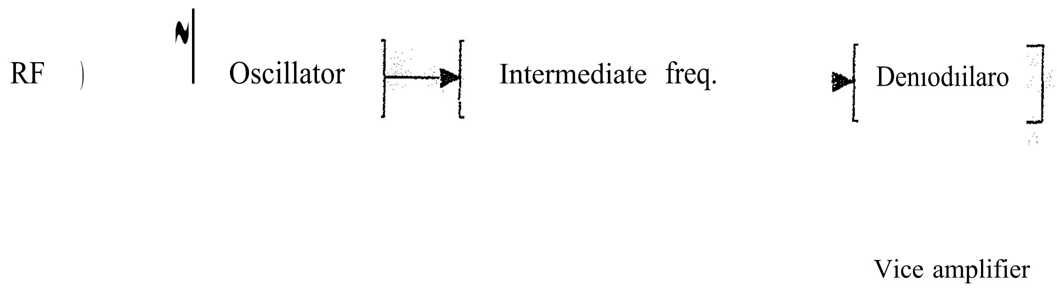


Figure 4.13 Simple bfockdiagram offeceiver in voice communication

4.5.2.1 Garex 210

The main controlling and switchingin.struınent for voice comimınication system. All the receivers, transmitter, position intercom telephone lines are all connected and contrölled 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 ali the system and gives their information to the computer.

4.6 Summary

We can now understand the important of radar systems which include the SSR which inform the ATC room in Ercan about all the civil plans around Cyprus, as we mention that there are transponder in the plan resend the signal an.el irtfôrrtl Ertan the altitude arıd the identity of the plan, look at the figure 4.1 then we kııow the navigation systems which consist of three main parts D1VIE, V OR.. and NDB iliese systeiııs make insurance for the plan ,so the pilot can know the alt:itude Ôf the planiarıd ıts ıôcation . here come the VHF voice communication systems , which is Very impôttaııt also , the pilot can contact with the ATC room by fliis system by the frequen.cies 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 mcmitorin the A'I'Ç ropı:ıı , the vııotof/cours~ .will look at the transponder of DM.EJo make insurance, the plan .can know whatis going on the space by contact Ercan and.:whatis the speed ofthe other plans so the employee of ATC room here has big responsible .to what happening in the air.

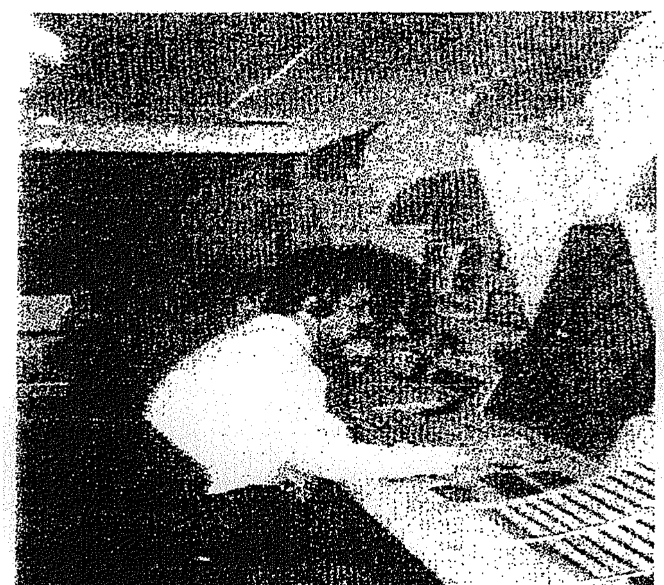


Figure 4.14 The new ATC room in Istanbul, and its similar to ATC room in Ercan

CONCLUSION

Most of the airports are using the secondary
and for the air traffic control (ATC), secondary
processing f data transmitted by the aircraft, the range,
(call sign) of an aircraft. The coverage can reach 250 nautical
more useful information than Primary Surveillance Radar (PSR) but
proper functioning ofthe aircraft's transponder. To provide the best with a
continuous display of aircraft targets, the SSR is usually paired with a traffic
control operation.

The future of radar does notlie.in.larger and more powerful systems, but rather in slightly smaller systems that are niore ağile, intelligent and difficult to detecfb ecause of the larger bandwidths tfüı.fwillibe used. The resolution of radars, and the}Jı umber of targets that can be tracked, can be expected to increase as large amountsiôf low-cost computer power become avaifable.

We hope that this project has conveyed the mainideas and helped you to uıı derstand 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 ar~~; and sensed some of the excitement of working in this field.

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