NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

UHF & VHF COMMUNICATION WAVES

Graduation Project
EE- 400

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Nicosia-2005

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ACKNOWL.EGMENTS

Firstly, I would like to thank my supervisor Assoc. Prof. Dr. Sameer lkhdair who has helped me to finish this project and help me to realize and understand this project well.

In addition, I want to thank my teachers who taught me in this university and gave me the knowledge, especially Dr. Faeq Radwan who had been supporting me and advice me in each step.

Also I want to thanks all of my friends who helped me to finish my project and special thanks to Eng. Raed Khdair who have helped me to finish the project and also lbrahim Yaseir.

Finally, I want to thank my brothers and sisters wlıo gave me hope and encouragements and at last special thanks to my parents, without their löve and their support to me, I would never achieved my current position. I wish for themto lives happily forever.

To all of them, my great love!

ABSTRACT

Antenna is the most commonly used part in communication system. The Very-High-Frequency (VHF) and Ultra-High-Frequency (UHF) bands are used for private and public access services carrying data, speech and facsimile information. Thus, UHF and VHF are the most common frequency bands for television transmission. Modem mobile phones also transmit and receive within the UHF spectrum. Even though UHF frequencies are used for television and telephone information, they are still referred to as radio waves. Dipole antennas are the oldest radiating systems since Hertz used them for the first time during the laboratory experience proving the existence of electromagnetic waves existence in the late nineteenth century.

we study the propgation of radio waves and about the behavior of electromagnatic waves and other useful tools like antenna

INTRODUCTION

In this project we investigate the UHF and VHF waves. Firstly, we study the waves of Very High Frequency (VHF) of radio frequency range from 30 MHz (A=lü m) to 300 MHz (A=l m). The common uses for VHF are FM radio broadcast at 88-108 MHz and television broadcast (together with UHF). The VHF is also commonly used for terrestrial navigation systems (VOR in particular) and aircraft" communications. The general description of frequencies immediately below VHF is HF, fö.l.d the next higher frequencies are known as Ultra High Frequency (UHF). UHF and VHF are the most common frequency bands for television. VHF frequenciesvpropagation cb.\:i.factetisticsare ideal for short-distance terrestrial communication, with a range generally' SqIDeWhat further than line-of-sight from the transmitter. Unlike higli frequencies (HF),Ctffe"ionösphere does not usually reflect VHF radio and thus transmissions are restricted to the iH6affü.'ea (and do not interfere with transmissions thousands of kilometers away). VHF is atsb<\]ess affected by atmospheric noise and interference from electrical equipment thaı:ilp'\V'}ftequeııcies. Whilst land features more easily block it than HF and lower frequencies, Bµılô.ıµgs and other less substantial objects than higher frequencies less bother it. Ultra hi.ghif'feqlien6y (UHF) designates a range (band) of ellectromagnetic waves whose frequency iS1(15etWeeıı 300 MHz and 3 GHz. Waves whose frequency is above the UHF band fall ııtô lhe 111.icrowave or higher bands, while lower frequency signals fall into the VHF or lowefbm::ı.ô.s .UHF signals are generally more degraded by moisture than lower bands such as VHF.UHF benefits less from this effect than lower (VHF, ... ete.) frequencies. As the atmosphere. warms and cools throughout the day, E-skip or tropospheric ducting may enhance UHF transmissions,

The first Chapter presents the principles of radio wave communications and propgation of waves as UHF, VHF, HF and others .

Chapter Two talks about'the feeder and the antenna it explains how antenna works, kinds of antennas, the purpose ofanteıına, and ~~~~10~asfos. Chapter Threeinvesfiğates the behavior of electromagnatic waves and the factors>that effect on the EM behavior and about Radio Frequency (RF) transı:ri.issiôıı: Chapter Fôtıfinvestigates the VHF and UHF grounded vertical dipole and the input ınpedm::ı.ce. Finally, the conclusion includes the most important results and the summary of this project

CHAPTERl

PRINCIPLES OF RADIO COMMUNICATIONS

Developing and understanding of radio communications begins with the counprehension of basic electromagnetic radiation. Radio waves belong to the electromagnetic radiation family, which includes x-ray, ultraviolet, and visible light-forms of energy we use every day. Much lik:ethe gentle waves that form when a stone is tossed into a still lake, radio signals radiate outward, or propagate, from a transmitting antenna. However, unlikerwater waves, radiô<wavespropagate at the speed of light. We characterize a radio wave in terms of its amplitude, frequency, and wavelength (see Figure 1.1). Radio wave amplitude, or strength, can be visualized as its height the distance between its peak and its lowest point. A:ı:nplitude, which is measured in volts, is usually expressed in terms of an average value called root-mean-square, or RMS. The frequency of a radio wave is the number of repetitions or cycles it completes in a given period of time. Frequency is measured in hertz (Hz)} öne hertz equals one cycle per second. Thousands of hertz are expressed as kilohertz (kHz), and millions of hertz as megahertz (MHz). We would typically see a frequency of 2,182,000 hertz, for example, written as 2,182 kHz or 2.182 MHz.

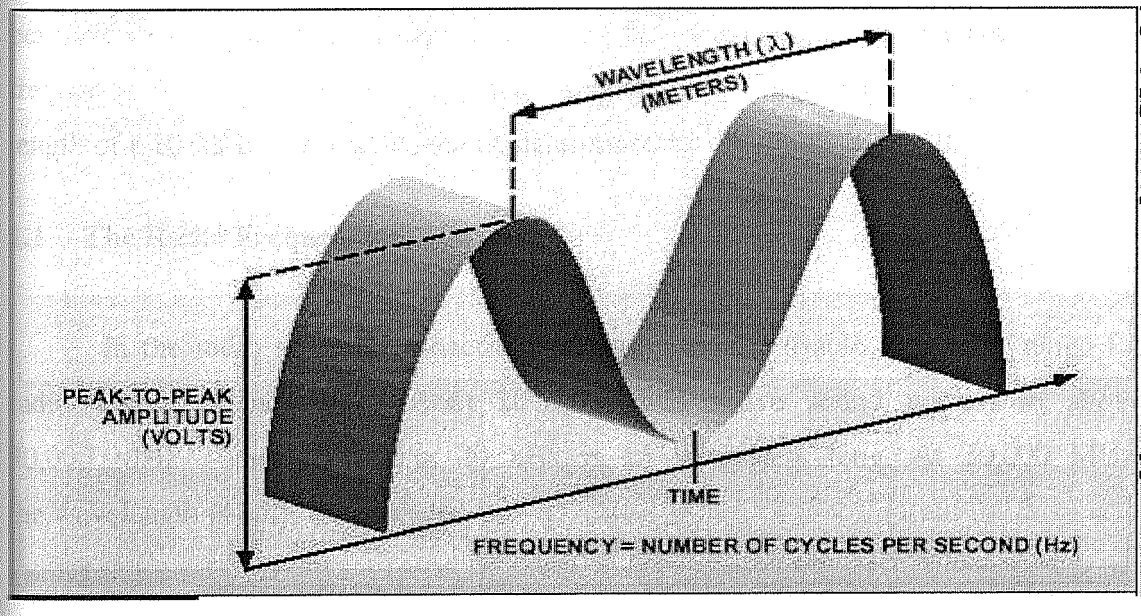


Fig 1.1 Propagation of radio waves

Radio wavelength is the distance between crests of a wave. The product of wavelength and frequency is a constant that is equal to the speed of propagation. Thus, as the frequency increases, wavelength decreases, and vice versa.

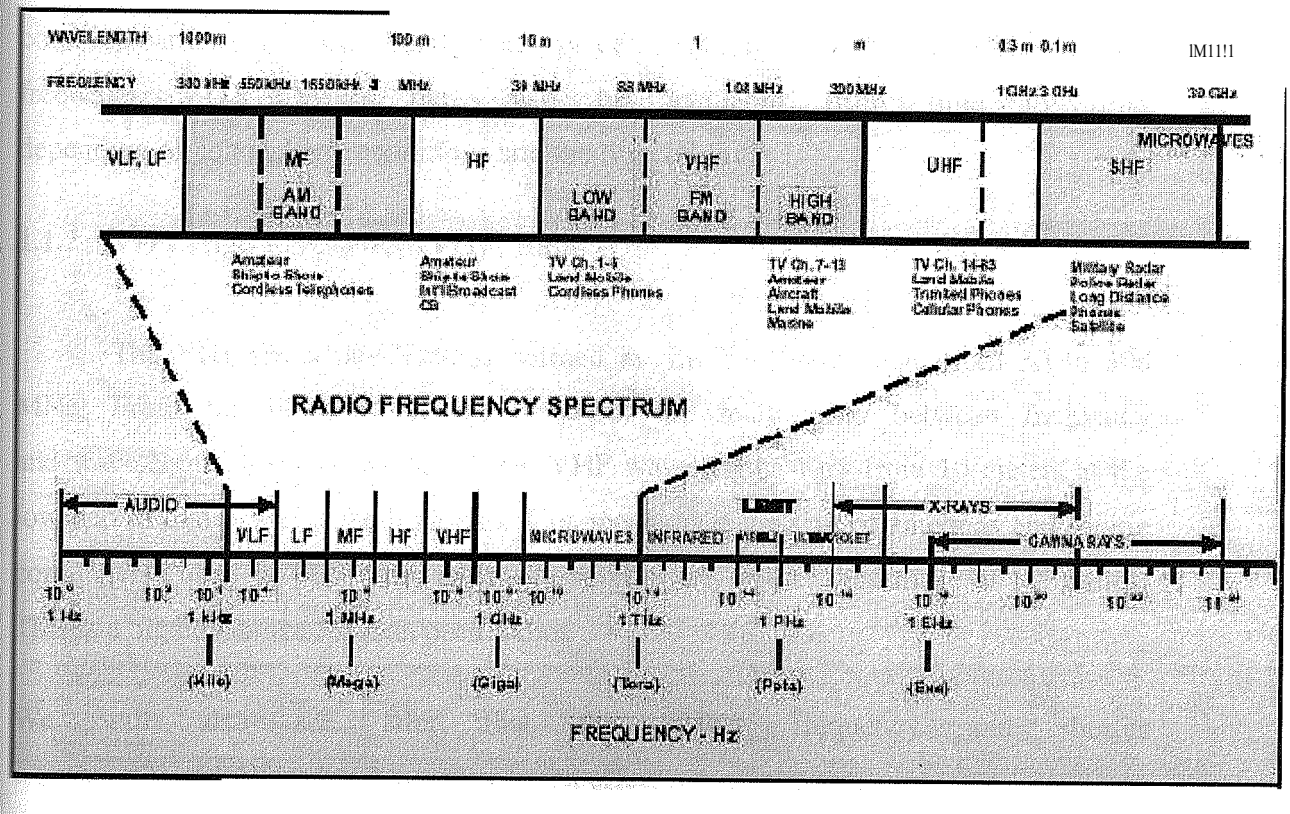


Fig 1.2 Radio freqüehcy spectrum

Since radio waves propagate at the speed of light (.:.1.00 million meters per second), you can easily determine the wavelength in meters for any frequency by dividing 300 by the frequency in megahertz. So, the wavelength ofa 10-MHz wave is 30 meters, deterrri.inedby dividing 300 by 10.

1.1 The **Radio Frequency** Spectrum

In the radio frequency spectrum (Figure 1.2), the usable frequency range for radio waves extends from about 20 kHz (iust above sound waves) to above 30,000 MHz. A wavelength at 20 kHz is 15 kilometers long. At 30,000 MHz, the wavelength is only 1 centimeter.

1.1.1 The High Frequency (HF) Band

The HF band is defined as the frequency range of 3 to 30 MHz. in practice, most HF radios use the spectrum from 1.6 to 30 MHz. Most long-haul communications in this band take place between 4 and 18 MHz. Higher frequencies (18-30MHz) may also be available from time to time, depending on ionospheric conditions and the time of day.

1.1.2 Very High Frequency (VHF) Band

The VHF frequency band is defined as the frequency range from 30 to 300 MHz. From the previöus discussion abollf the relationship between frequency and wavelength, it shoiild be noted that VHF wavelengfhs vary from 10-meters at the low end to one meter at the high end. This means that the size of antennas and tuning components used in VHF radio are much smaller and lighter than those of HF radios. This is a big advantağe forman pack radios.

We will also see later that the higlı~r frequency and shorter wavelengths of VHF radios have a profound effect on radio range.

1.1.3 Ultra High Freqüency (UHF) Band

The UHF band goes from 300 MHz to 2450 MHz, although TACSAT man pack UHF radios do not utilize frequencies above 512 MHz. The wavelengths associated 300 to 512 MHz range from one meter to 0.58 meters (58-centimeters). The very small antennas required for these wavelengths make them ideal for use on high- speed aircraft.

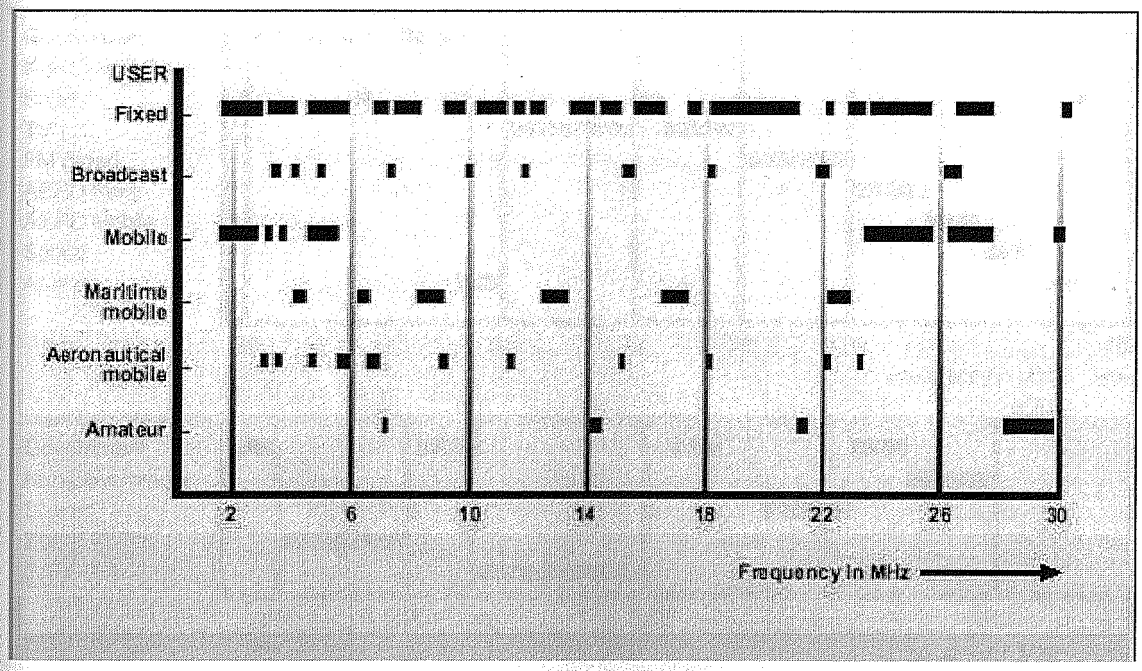


Fig 1.3 HF Radio spectrums AM

1.2 Frequency Allocations

Within the HF spectrum, groups of frequencies are allocated to specific radio services-aviation, maritime, military, government broadcast, or amateur (Figure 1.3). Frequencies are further regulated according to transmission type: emergency, broadcast, voice, Morse code, facsimile, and data. Intertfational treaty and national licensing authorities govem frequency allocations. Frequen.cies within the VHF/ UHF bands are similarly allocated (Figure 1.4).

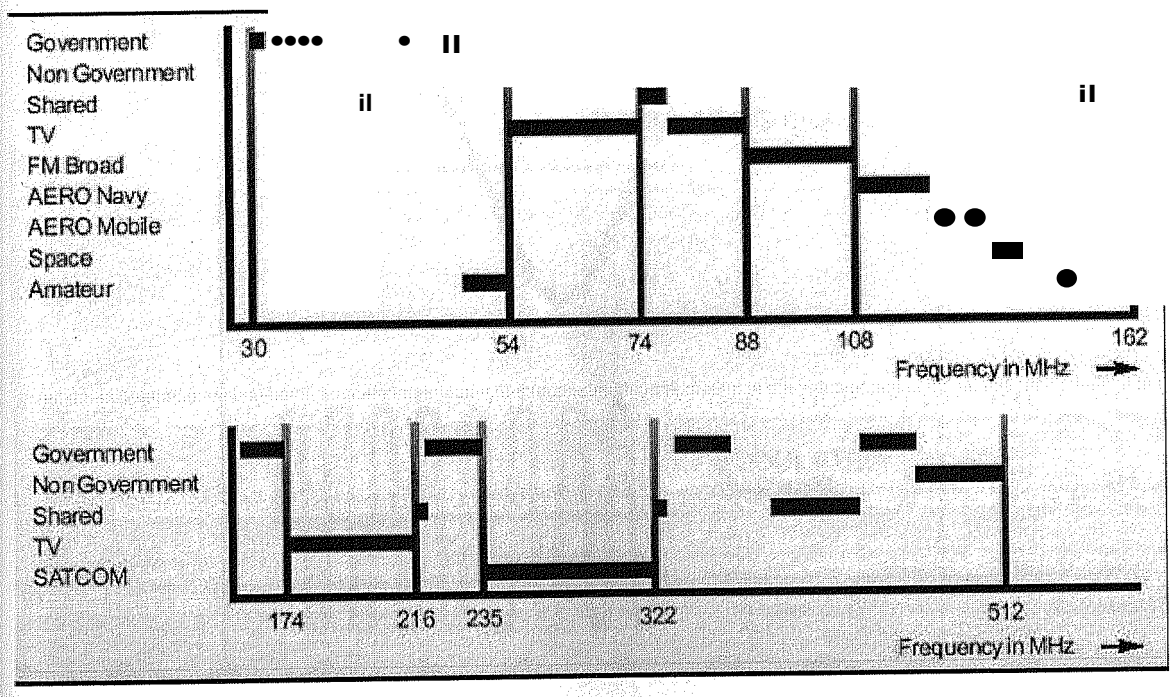


Fig 1.4 VHF and spectrum allocation

1.3 Modulation

The allocation of a frequency is just the beginning of radio communications. By itself, a radio wave conveys no information. It is simply a rhythmic stream of continuous waves (CW).

When modulate waves to carfy -information, we refer to them as carriers. To convey information, a carrier<rrıtıst be varied so that its properties its amplitude, frequency, or phase (the measutement of a complete wave cycle) are changed, or modulated, by the informatiorl sigrı.al.

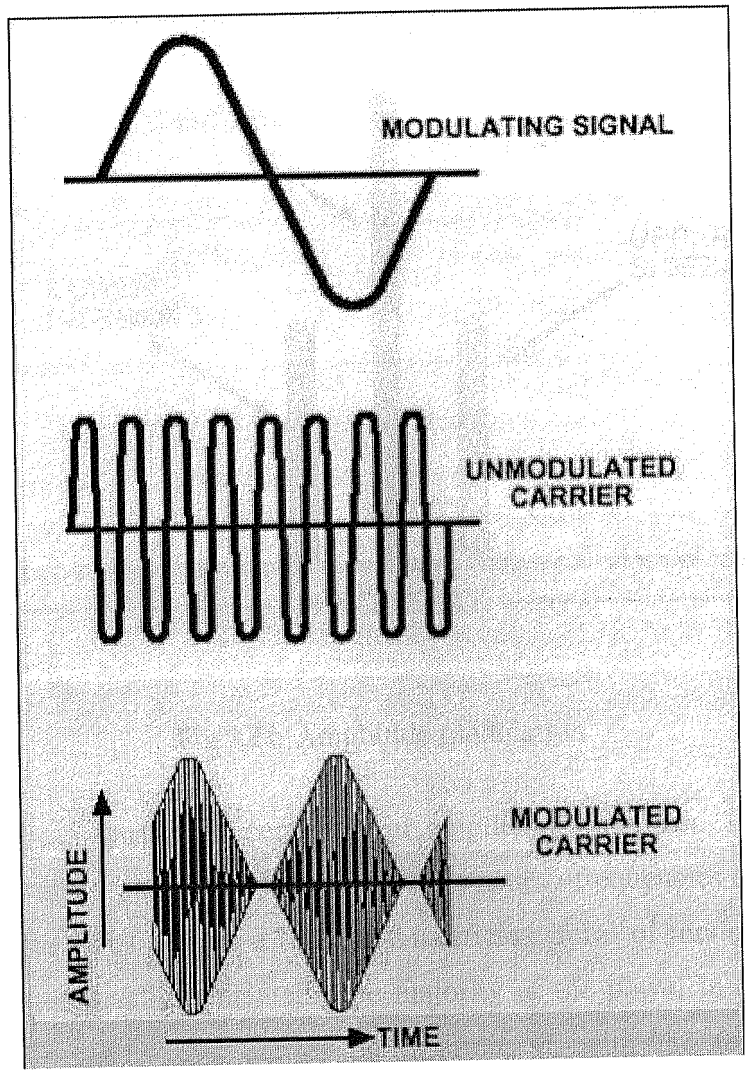


Fig 1.Sa Amplitude modulation

The simplest method of modulating a carrier is by turning it on and off by means ofa telegraph key. In the early days ôfradiô(on- Off keying, using

Morse code was the only method Ofbônveying fyireless messages. Today's common meth for radio communications include amplitıde modulation (AM), which varies the strength of the carrier in direct proportion to \.changes in the intensity of a source such as the human voice (Figure 1.5a).

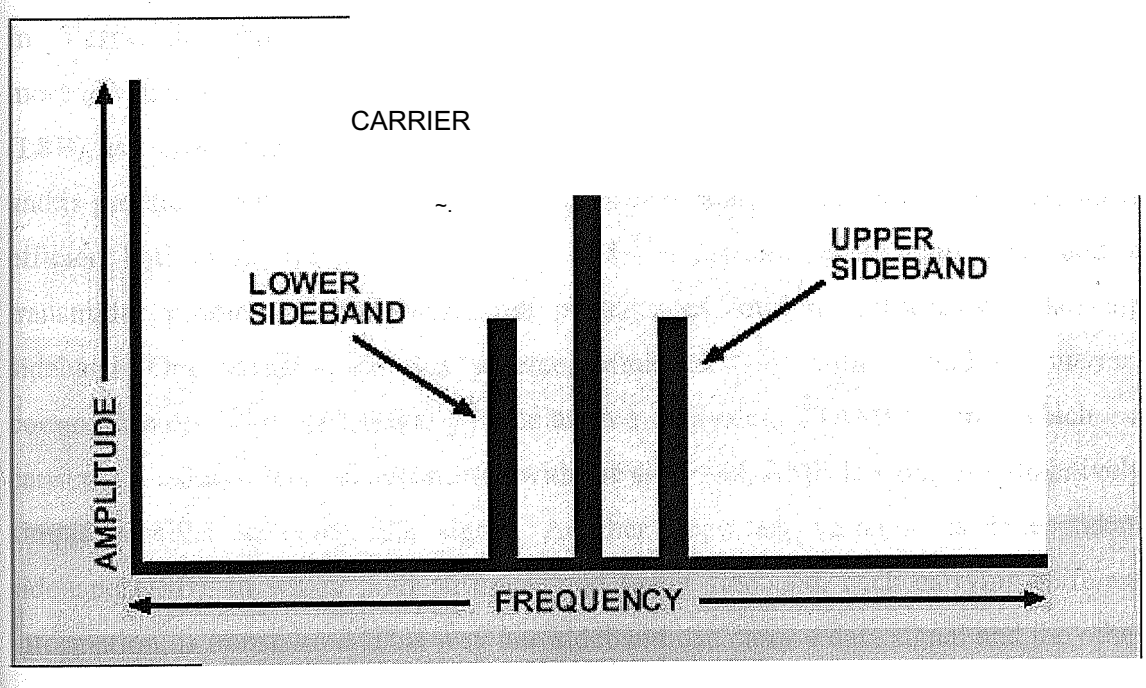


Fig 1.5b Amplitud.eföod.ulation

In other words, information is contained in amplitude variations. The AM process creates a Carrier and a pair of duplicate sidebands nearby frequencies above and below the carrier (Figure 1.5b). AM is a relatively inefficient form of modulation, since the carrier must be continually generated. The majority of the power in an AM signal is consumed by the carrier that carries no information, with the rest going to the information- carrying sidebands.

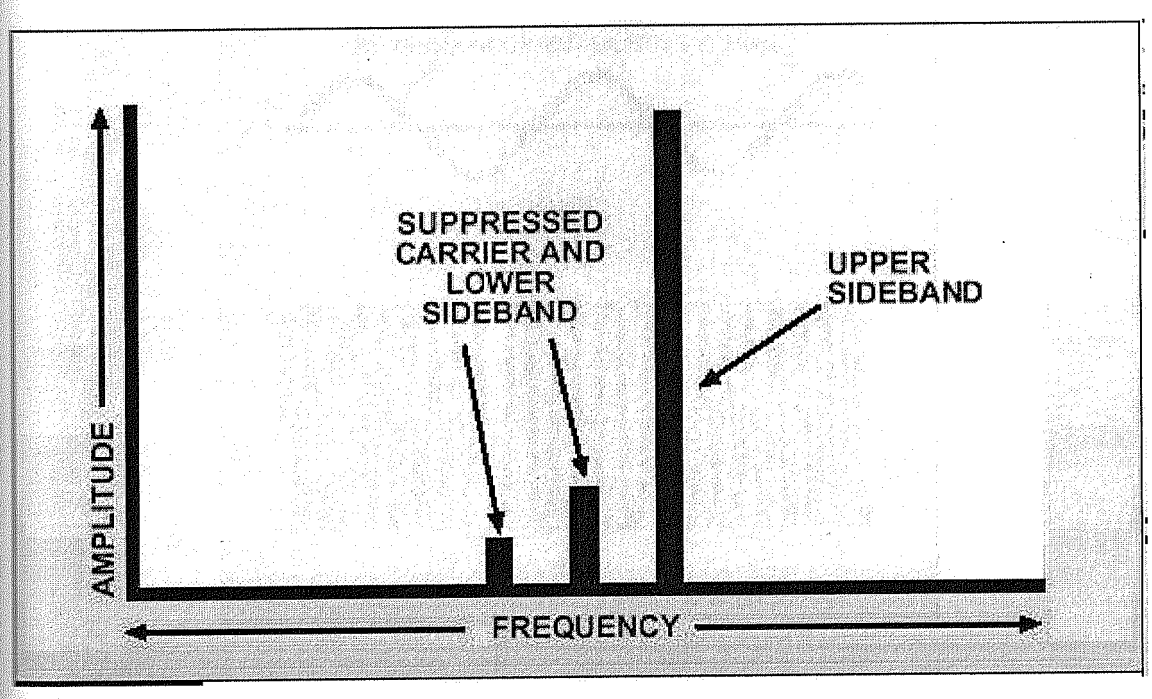


Fig 1.5c SSB in the F-D

In an efficient technique, single sideband (SSB), the carrier and one of the side bands more are suppressed (Figure 1.5c). Only the remaining sideband, upper (USB) or lower (LSB), is transmitted. An SSB signal needs only half the bandwidth of an AM signal and is produced only when a modulating signal is present. Thus, SSB systems are more efficient both in the use of the spectrum, which must. accommodate many users, and of transmitter power. All the transmitted power goes into the information- carrying sideband. üne variation on this scheme, eften used by military and commercial communicators, is amplitude modulation equivalent (AME), in which a carrier at a reduced level is transmitted with the sideband. AME lets one use a relatively simple rece iver to detect the signal. Another important variation is independent sideband (ISB), in which both an upper and lower sideband, each carrying different information, is transmitted. This way one sidebaııd can carry adata signal and the other can carry a voice signal.

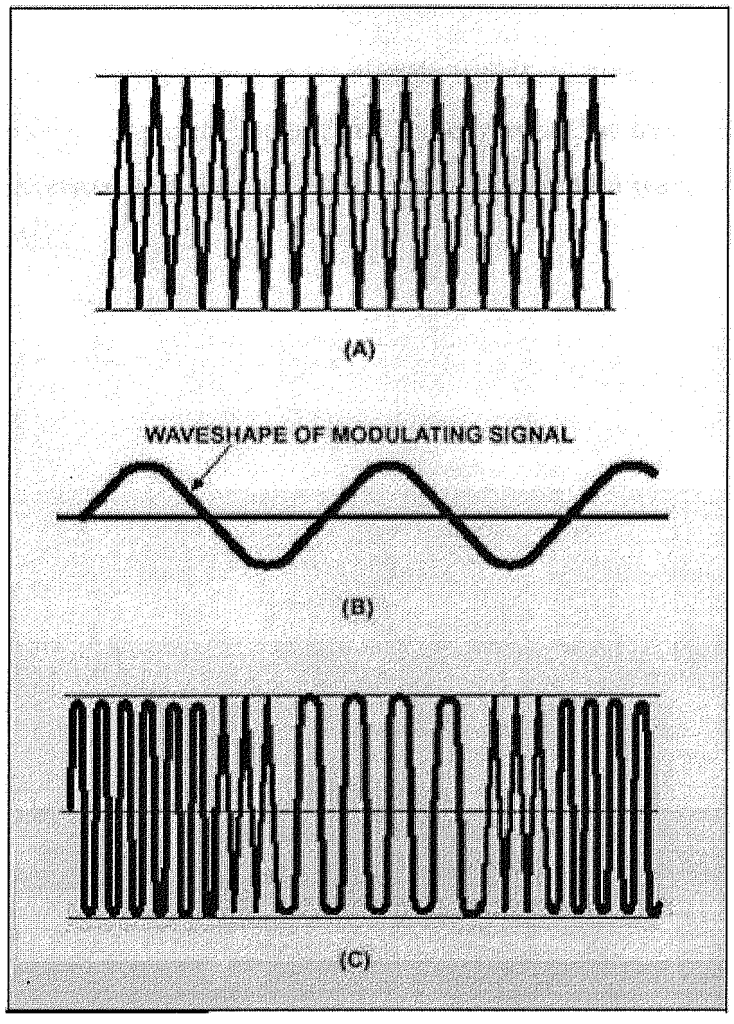


Fig 1.Sd Frequency modulation

Frequency modulation (FM) is a technique in which the carrier' s frequency varies in response to changes in the modulating signal (Figure 1.5d). For a variety of technical reasons, conventional FM generally produces a cleaner signal than AM, but uıses much more bandwidth, narrowband FM, which is sometimes used in HF radio, provides an improvement in bandwidth utilization, but only at the cost of signal quality. It is in the UHF and VHF bands that FM comes into its own, Remember that the HF band is generally defined as occupying the spectnımfrom 1.6 MHz to 30 MHz. This is a span of only 28.4 MHz. The VHF band covers the span of from 30 MHz to 300 MHz, which is a span of 270 MHz; nearly 10 times the span of HF. This extra room means that a channel bandwidth of 25 kHz is used to achieve high signal quality. Other schemes support the transmission ôf data over radio channels, including shifting the frequency or phase ôfthe sifgnal.

1.4 Radio Wave Pröpagation

Propagation describes how radio signals radiate outward from a transmitting source. The action is simple to imagine for fı:ı.dio waves that travel in a straight line (picture that stone tossed into the still lake). The tnıe patlı radio waves take, however, is often more complex.

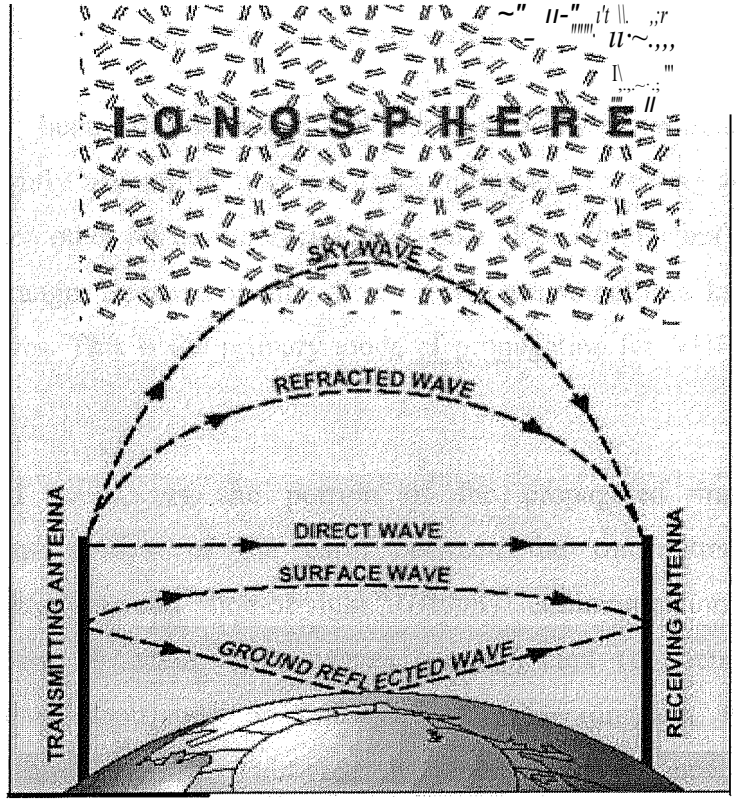


Fig 1.6 Propagationwaves

There modes of propagation: ground waves and sky waves. As their names imply, ground waves .travel along the surface of the eartlı, while sky waves "bounce" back to earth. (Figure 1.6) slıows the different propagation paths for radio waves.

Ground consist of tlıree compônents: surface waves, direct waves, and ground-reflected waves. Surface waves travel along the surface of the earth, reaching beyond the horizon. Eveıitually, the eartlı absorbs surface wave energy. Tlıe frequency and conductivity of the surface over which tlıe waves travel largely determine the effective range of surface waves. Absorption increases with frequency.

Transmitted radio signals, which use a carrier traveling asa surface wave, are dependent on transmitter power, receiver sensitivity, antenna characteristics, and the type of patlı traveled. For a given complement of equipment, the range may extend from 200 to 250 miles over a conductive, all- sea- water patlı. Over arid, rocky, non- conductive terrain,

however, the range may drop to less than 20 miles, even with the same equipment. Direct waves travel in a straight line, becoming weaker as distance increases.

They may be bent, or refracted, by the atmosphere, which extends their useful range slightly beyond the horizon. Transmitting and receiving antennas must be able to "see" each other for communications to take place, so antenna height is critical in determining range. Because of this, direct waves are sometimes known as line-of-sight (LOS) waves. This is the primary mode of propagation for VHF and UHF radio waves.

Ground-reflected waves are the portion of the propagated wave that is reflected from the surface of the earth between the transmitter and receiver. Sky waves make beyond line-of-sight (BLOS) communications possible. At frequencies below 30 MHz, radio waves are refracted (or bent), returning to earth hundreds or thousands of miles away. Depending on frequency, time of day, and atmospheric conditions, a signal can bounce several times before reaching a receiver.

1.5 VHF/ UHF radio propagation

While many HF propagation charactetistics are associated with the ionosphere and wave reflections from it, the effects of local area topography and conditions in the .lower.. atmosphere mostly govem VHF and UHF propagation. Similarly, ground wave prCJpıgıtion .is a very important mode of HF wave propagation, but at frequeı:çieş... ahCJye 30 MHz, ground waves are absorbed almost immediately and hav~ a/11~gligible beneficial impact. Frequencies in the VHF and UHF bands usually pe11~trate1lıe ionosphere and speed out into space. That means that reflection off the iönosphere cannot be used to reliably extend communications range of these frequencies. For the most part, the transmitting and receiving antennas must have a fairly unobstructed patlı between them for communication to take place, hence the'term.Titie-öf~sight(LOS).

1.6 Height Matters for LOS Range

The visible horizon observed at approximately five feet above a flat surface of earth is less than 2.7 miles away (Figure 1.7). This is approximately the maximum LOS radio range from a manpack radio on the back of a standing man to another manpack radio that is lying on the ground.

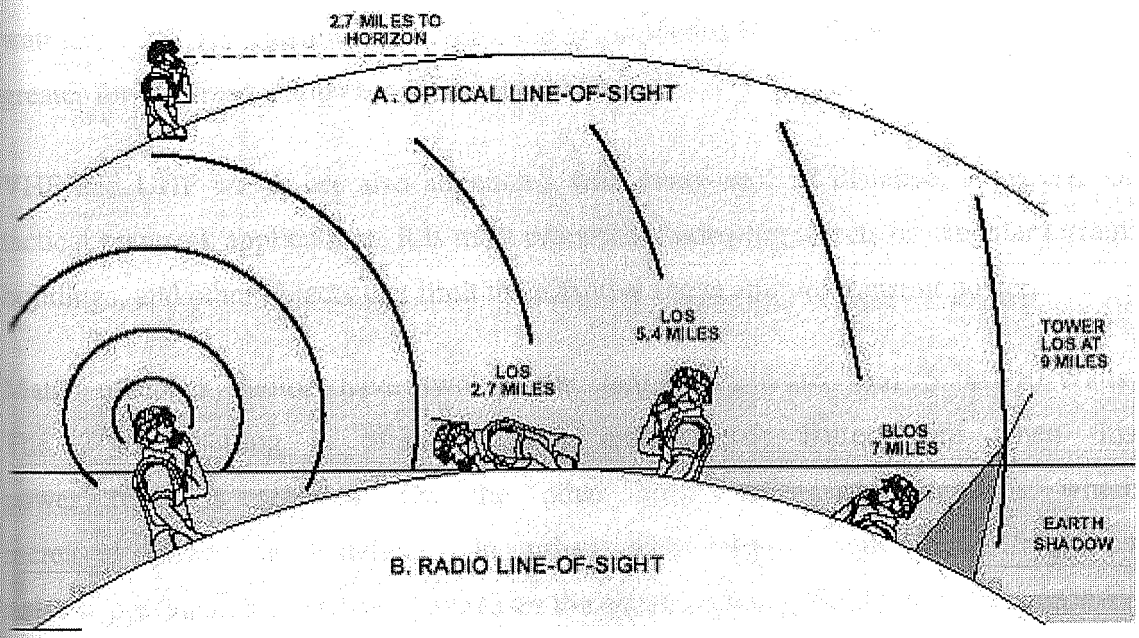


Fig 1.7 Radio LOS range

(Figure 1.7) shows that if the receiving raclig:\,Vere elevated to the back ofa standing man, this maximum distance would be clqµbl~cl..In this case, the LOS distance would be 5.4 miles. However, if the second map. yY.~fe.standing beyond this distance, say at 7 miles from the transmitting radio, the s];ı,~cl9.}Yip.g effects of the earth's curvature would prevent the second man from receiving the ra.dio wave. In this case, 7 miles is BLOS and is not within reach of VHF or UHF radios in these positions.

It is clear that the elevation of both the transmitting and receiving antennas is crucially important. For example if the receiving antenna were mounted ona 26-foot tower, the total LOS distance would be increased to 9 miles. Of course, if the radiomen were both located on the tops of mountains, the LOS range might be as much as from 50 to hundred miles. For ground-to-air UHF communications, the aircraft can be 100 miles away or more and still maintain contact.

1.7 Transmitting Power and Radio Range

For HF radio communications, transmit power is an important item. For very long distances, particularly for both sky wave and ground wave propagation, every distance attenuates (decreases) the signal. For most systems, when doubling the distance, the radiated signal is divided by four!

Therefore, transmit power is often the limiting range factor. It is common to see 500-watt and 1-kW HF transmitters in vehicular or shipboard HF applications, and 10-kW or greater for HF fixed station broadcast sites.

VHF and UHF waves are also attenuated with every mile of distance. However, for tactical manpack applications, it is most ofteırthe shadowing effects of irregular terrain, buildings, and other objects that limit the effective range and not transmit power.

Many manpack radios have two power settings: 2-Watts and 5 to 10-Watts. The 2-Watt setting is often adequate and extends battery life when this power level is selected. On the other hand, there are situations where increased power is beneficial. in urban areas where high radio frequency noise is prevalent, higher power increases the siğnal-to-noise (SNR) ratio and improves reception; modem high data rate modulationwaveforms require a high SNR to be effective.

UHF ground-to-air communications benefit from higher power because the typical range is 100-miles or more. Lastly, although tactical manpack UHF SATCOM radios with only 18-Watts located in Europercan contact a satellite in an orbit 22,000 miles above the earth's equator, communication is more reliable when higher power is used.

These higher power VHF and UHF radio sets are typically mounted in vehicles or fixed stations with 50-watt power amplifiers to boost the power of the manpack transceiver.

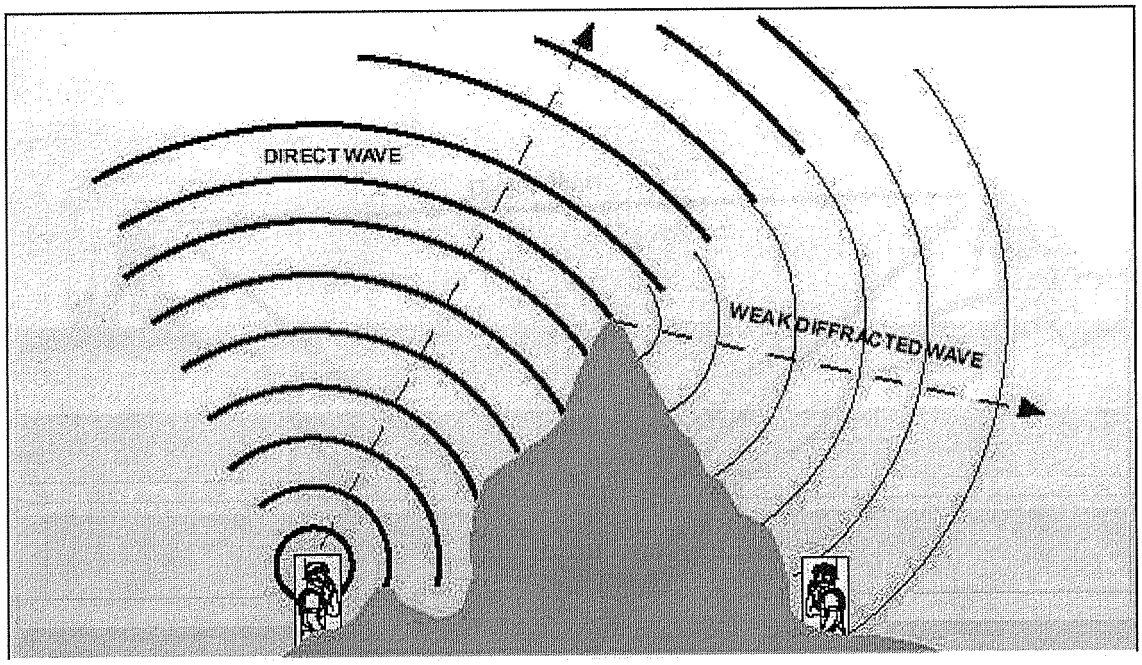


Fig 1.9 VHF & lJHFdiffraction

1.8 VHF and UHF.Radio Reception BehindRldges

For the most part, ridges and hills form shadows of VHF and UHF radio waves. However, there is an important exception wheniit comes to very sharp ridges or other kinds of abrupt barriers. This is caused by a ph~11omenonknown as Diffraction (Figure 1.9). When a VHF or UHF wave comes to .a $harp edge, a portion of the wave bends around the edge and continues propagation as .if.a very low power radio was placed at the top of the ridge. it is important that the ridğ~be relatively sharp. A well- rounded hill or the curvature of the earth is not sufficient to cause this effect. This effect is important in a battlefield situation where asQldier must seek shelter behind a ridge.

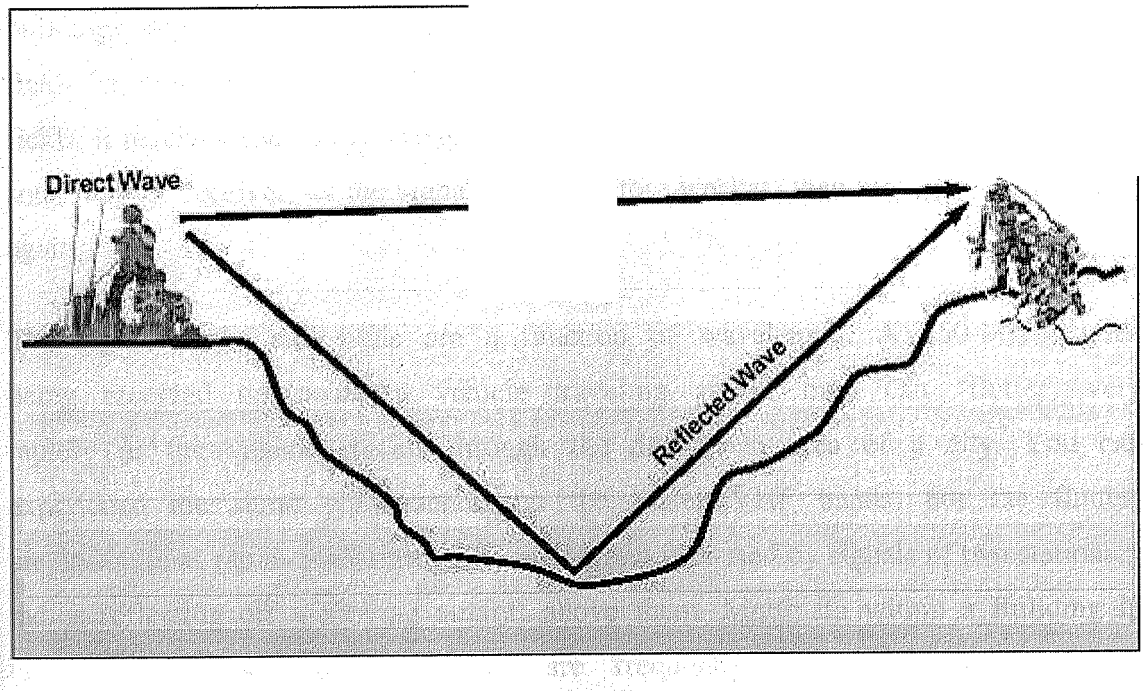


Fig 1.10 Wave reflection cause multipath distortion

1.9 Reflections and Multipath Distortion

VHF and UHF waves can be reflected off dense surfaces like rocks or conductive earth, just like a beam of light can be reflected off a wall or a ceiling. Sometimes several paths exist between a transmitting and receiving antenna (Figure 1.10). In this figure, there is a direct LOS path between two radios, but there is also a reflected path from the bottom of a valley between them. It is clear that these two paths are of different length, and that the direct path is the shorter of the two. Since radio waves travel at a constant velocity, the direct path wave arrives at the receiver before the reflected path. This means that the same broadcast information reaches the receiver at two different times. The effect of this is much like echoes that one hears in an acoustically .poor room. If the echoes are close enough to each other, it is hard to understand what is being said. In radio terminology, this is called rnultipath distortion. Although it is annoying with voice communications it is devastating to high data rate digital communication. A subsequent chapter will discuss some of the ingenious ways that have been devised to minimize the effects of this type of distortion. "Picket fencing" is a form of multipathing common to vehicular mounted radios. It is prevalent with VHF and UHF. The higher the frequency, the more pronounced the effect is. It is usually caused by interference or reflections of signals from man-made objects such as

buildings, houses, and other structures. These objects cause constructive and destructive fields (or strengthened and weakened signals) so that when a vehicle travels through the fields, it receives altemately stronger and weaker signals. There is usually a "swishing" sound in the receiver, as the signals rapidly grow weaker, then stronger, then weaker again.

The signal peaks and nulls are a function of wavelength. A 450-MHz signal being received on board a vehicle traveling at 60 mph can "flutter" very rapidly as the vehicle travels through the downtown area of a city. You can experience the same .phenomenon VHF bands, but the flutters are not quite as rapid. Sometimes this caused by signals of two stationary radios reflecting off a moving aircraft Multipath within a Building In tactical situations, manpack radios are frequently operated under cover in buildings: VHF and UHF waves have trouble penetrating reinforced concrete exterior walls, but they pass through windows and light interior wall partitions with comparative ease.

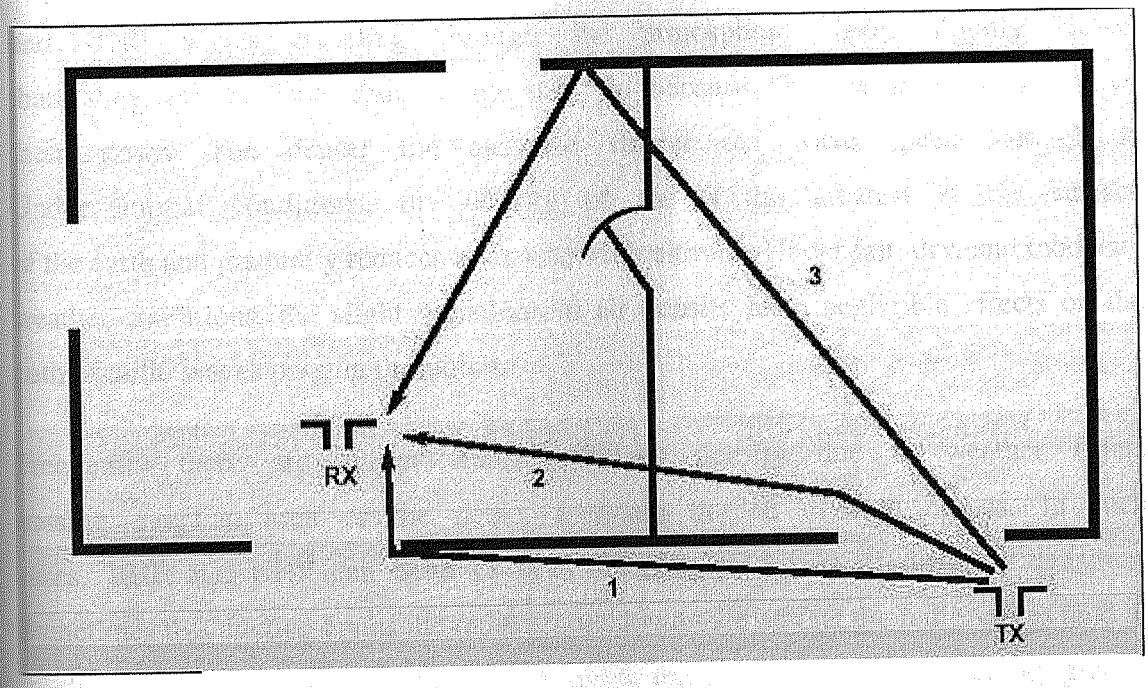


Fig 1.11 UHFNHF diffraction andmultipath within a building

Figure 1.11) shows a receiver in a room of a building with a transmitter located outside. In this case, there are three paths from the transmitter to the receiver, and none of them is direct.

Path passes through the window nearest the receiver location, and is diffracted around the sharp edge of the window frame to the receiver. Likewise, patlı 2 just misses having a direct patlı to the receiver. It is diffracted slightly by the window frame nearest the transmitter and then passes through an interior wall on the way to the receiver. Patlı 3 goes through a window and an interior wall before striking an outside wall of the building and then reflecting back to the receiver.

Each of these paths has a different distance and, therefore, can cause multipath distortion. Frequently just movingithe receiver a few feet in some direction will avoid one or more of the available paths\ahd the reception of the signal may be greatly improved.

1.10 VHF and UHF Wave Ducting

The suggested limits on LOS range are sometir exceeded in practice. One of the principal reasons for this is an effect called "ducting." VHF and UHF waves traveling through the atmosphere travel slightly slower than they do in free space, and that is because the density of air slows them down. The denser the air, the slower the wave speed through it. Under normal conditions, the density of air is the greatest at the surface of the earth and gradually reduces in density with altitude. Under fair, dry, and moderate weather conditions, the slight variations in air density have negligible effects on the path of radio waves passing through it.

Frequently are abrupt changes in air density due to weather fronts passing over an area or the heavy moisture burden of rain clouds. in such cases, VHF and UHF can bend or duct between air layers of different densities. Sometimes this ducting bends the radio waves downward so that the radio waves tend to follow the curvature of the earth. In such cases, the LOS range is considerably greater than the optical LOS range. This type of wave propagation is impossible to predict; it is not practical to plan on it for range improvement. However, when ducting conditions exit, they generally do so for hours ata time.

CHAPTER2

FEEDER AND ANTENNAS

Is it an Antenna oran Aerial? The words antenna and aerial means the same and the two words can be used completely interchangeably!

2.1 Feeder requirements

Recall the correct cable to use for RF signals and that coaxial cable is most widely used because ofits screening qualities. In order to the 'RF' Signal to reach the Aerial from the Radio; we use what is known as a 'FEEDER'. The goal is to carry the signal from the transmiiter to the aerial with as little loss as possible and with none or very little radiated sigıal>The transmitter you lise creates a signal at the RF connector, which has to be transport~d./to your aerial. Any reduction (loss) in the amount of that signal delivered to the aert:ıJdue to it passing along the feeder must be kept as low as possible - else you could ~1id up with nothing at the aerial!! The feeder must also not radiate any of the signal(gf~s little as possible) else, that radiated amount too would not reach the aerial and çqtıld. cause problems, which will be outlined, to you in the section on EMC by being t~~iafed in the wrong place. So The feeder, comes in several forms, the most popular cablefpfthis purpose, amongst Foundation Licence holders, is COAXIAL CABLE. It is easy tojI1.~ta.llf111d it construction is simple to understand.

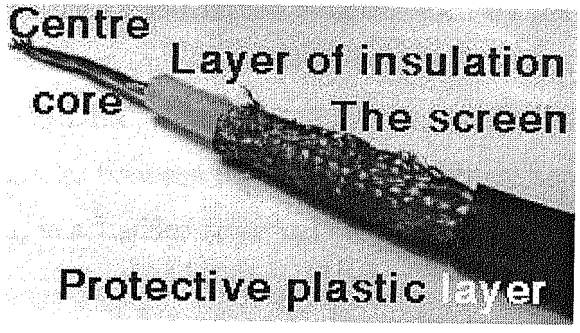
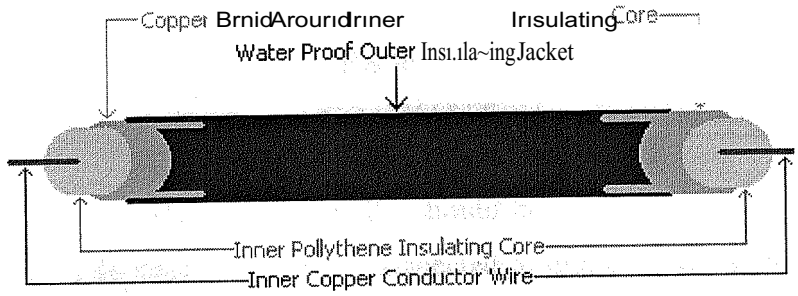


Fig 2.1 Coaxial wire

Coaxial feeders are an unbalenced feeder and come in a variety of diameters. It consists of a single or multi-stranded insulated centre wire, with a braided wire sheath wrapped around it. This wire braid is .then covered with aninslilation layer: of a flexible plastic. The inner insulation can be of flexible plastic or polythene insulation. The outer braid (screen) is used to retain the signal within the cable. The braid must be continuous through the plugs and sockets; it is often soldered to ensure good connection.



Coaxial Cable

Fig 2.2 Coaxial cable

The Impedance of the cöax.ial cable is. determine.d as the relationship of the distance between the inner outer brafded screerL *Th.e* i:ınpedance of the coaxial cable is also determined by the diameter of the inner wire, and by the type of the dielectric insulator material between the inner wire conductor, and the outer screen braided wire conductor. Though coaxial cable conıes in many different diameters, two common diameters of approx 3/16" and 5/16" are more often used in amateur radio, with the larger of the two heing preferred due tô its 'LOWER LOSS' characteristics for VHF use. Other feeders are Ribbon feeders is a 'balanced feeder' consist of two insulated wires attached to each other, andrllnn.ing parallel to each other.

The "IMPEDANCE" of the ribbon feedefis determined by the diameter of the wire used, and the distance between the two wires'irrthe ribbon feeder. This type of feeder is called 'BALANCED FEEDER', Normal 300 OHM ribbon feeder has a distance of approximately 1 Centimeter between to the wires, 'which are separated with a flexible plastic type of insulator, in a 'Ladder' style pattem.

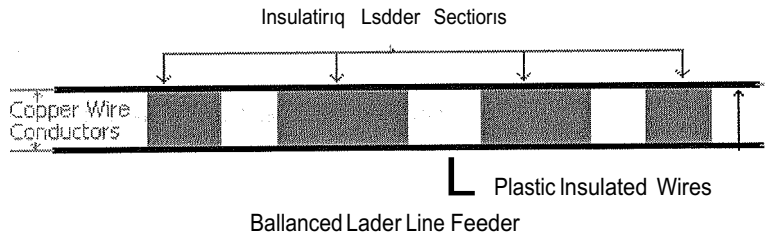


Fig 2.3 line feeder

The Cables which are mainly used by Radio Amateurs ate 'OPEN WIRE' Feeder, (450 OHM, 300 OHM and 75 OHM), and 'COAXIAL' Feeder (75 OHM and 50 OHM).

suppose that the plugs and sockets for RF should be of the correct type and that the braid of coaxial cab1eıı1ust be correctly connected to minimize RF signals getting into or out of the cable.

Identify BNC and PL259 plugs.

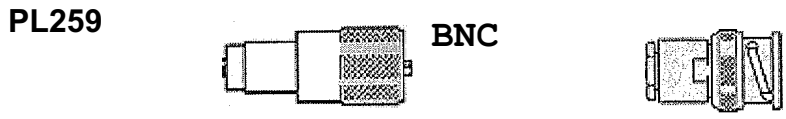


Fig 2.4 Plugs

The two connectors shown above at figure (2.4) are those, which you must be able to recognize. The PL259 is the connector most ofterı associated with HF and VHF coaxial feeder and the BNC with UHF coaxial feeder (but it is also used at VHF).

What is to be understood by HF VHF !f~.~~r? For Amateur Radio purposes HF is any frequency from 1MHz to 30 MHZ, VHF is 144MHZ to 146MHz UHF is above 430MHz. The point to understand here is that the connectors are of different quality and whilst this might not matter at allat HF it does atUHF and to a lesser extent at VHF. At lUHF, the PL259 would be said to be a "lossy" connector, as it absorbs some of the power trying to reach the aerial. The better constructed, and usually constant impedance of the, BNC is therefore to be preferred at the, higher frequencies.

In each of these connectors the centre and the screen must be properly connected at both ends of the cable and there must NOT be a short circuit between the centre and the braid (screen) else the cable will not function properly.

we will want to carry out a resistance check on any cables that you make up the there is not a dead short between outer to inner (This is assuming no connection to the antenna as you could have an inductive connection which given you a false reading- in this cast you need to know that the otter is connected and you may have no other way than by piercing the outer so that the meter probe can be put in contact with the braid and the other probe placed on the outer of the connector, make the continuity reading and when satisfied all is well tape up the small hole in the cable outer).

2.2 Purpose of the ~ntenna

The electricaksfüğnalor electrical energy that comes from the 'radio transmitter' to the aerial via the CC>~:,tial>feeder is actually a tuned radio frequency Signal. In order for this signal to leave thecoaxial feeder and radiate into the air, we need what is called an AERIAL.

These Aerial needs to be ınade for the band of operation, and preferably tuned to the frequency that the transmitt~r.ıs operating on. With a properly tuned aerial on the end of the coax, the electrical enerğyi or to use the correct term, the Radio Frequency Signal (RF signal), will now radiateirıtothe atmosphere.Iand at HF into the ionosphere and be reflected back but more about füa.tii11thesection on Propagation) so the person that you wanting to talking to can hear you.

The same rule applies with the receivedsfğ11a.l,inthat the correctly tuned aerial must be nsed to receive a signal properly. Norrıially iılAmateur Radio use, we use the same aerial for receiving as we do for transm.ittingiöı:ı.fothat same given frequency.

2.2.1 Polarization

The polarization of the antenna is dependent upon how the radiating elements are orientated. Vertically gives vertical polarization horizontally gives horizontal polarization.

2.2.2 FM transmissions

It is usual for FM transmissions to be from a vertically polarized antenna such as the 1/4 wave 5/8 wave.

2.2.3 **SSB Transmissions**

SSB transmissions are usually from horizontally polarized antennas. This is particularly important at VHF and UHF as cross polarization will mean that we will not hear signals very well if at all now will your signals be heard very well if at all.

At HF the distinction is lees important as the signals will change polarization during their travel from the distance transmitting station to our reception and similarly on the reverse route. Identify the half wave dipole, 1/4 wave ground plane, yagi, end-fed wire and 5/8 wave antenna. Understand that the sizes of HF and VHF antennas are different because they are related to wavelength, though they operate on the same basic principles.

2.3 Types of antenna

Recall that the purpose of an antenna is to convert electrical signals into radio waves, and vice-versa and that these are polarized according to the orientation of the antenna, e.g. a horizontally orientated antenna will radiate horizontally polarized waves. Aerials come in many types and shapes. At this stage, we will only be dealing with five types of aerial, these are:-

- the 1/2 wave DIPOLE aerial
- the Yagi aerial
- the 1/4 Wave GROUND PLANE Aerial
- the End fed wire or LONG WIRE Aerial
- the 5/8 WAVE VERTICAL Aerial.

Each of these aerials can be used on most bands and operate on the same basic principles, the deciding factors are dependent:-

- on the physical size of the aerial,
- the amount of space available to use the aerial.

The size of any given aerial is also govemed by the FREQUENCY, or WA VELENGTH on which the aerial is designed to operate on. The lower the frequency, the longer the Wavelength, and so, the longer or bigger the physical size of the aerial. Conversely, the higher the frequency, the smaller the physical size or length. Below are diagrams of the dipole, 1/4 wave ground plane, yagi, end-fed wire and 5/8 wave antenna. None of the diagrams are to scale as the size is dependent upon frequency of operation. In any antenna its size is frequency dependent.

2.4 The **dipole**

Understand that the 1/2 wave dipole *(A/2* dipole) has a physical length approximately equal to A/2 of the correct frequency. Below at figure (2.5) the drawing on the left explains the di.pq}fWhereas that on the right is the symbol you could have in the written assessment (this idea of antenna and symbol is similar in the next few drawings). This is whereJfye fundamental link between the size of the aerial and it wavelength is established.}I'he overall length ofboth the legs of the 1/2 wave dipole (A/2 dipole) measure about(tlle same length as the conversion of the frequency into the wavelength/2 in metres. :As a generality 14MHz has a wavelength of 20m. Thus the overall length ofa 10MHz dipole is lOmetres or each leg would be about 5 metres.

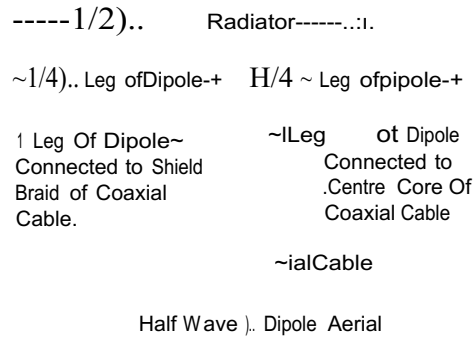


Fig 2.5 Half wave dipole

The half wave dipole is the most basic of all antennas and is the antenna against which all others can be judged. The dipole can be used vertically or horizontally. The diagram

show the antenna in the horizontal position and would be said to be horizontally polarized.

A DIPOLE aerial can be mounted vertically or horizontally. Normally for VHF & UHF working, a dipole is used in Vertical Polarization. When a Dipole aerial is used vertically polarized, it is OMNI DIR.ECTIONAL. This means that it transmits in all directions around its element. However if a DIPOLE Aerial is used horizontally Polarized, it only radiates as a outwards from the elements and no signal is from the end, and thus can have some directional element in its use.

2.5 *1141w* wave ground' **pla.ne**

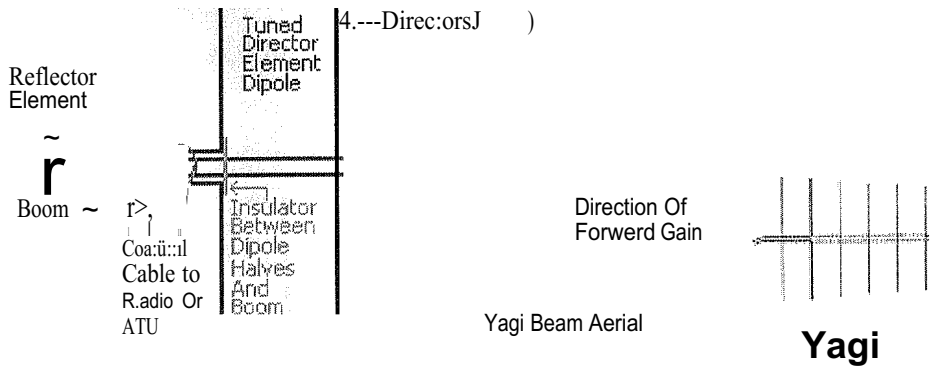
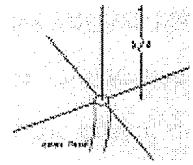


Fig 2.6 Yagi antenna

The yagi is said to have gain as it focuses the radio waves into a generally single direction and is not therefore wasting power radiated in directions where it is not required, The Yagi can be used vertically or horizontally. The diagram shows the antenna in the vertical position.

Note that the radiating vertical element and the horizontal ground planes are all 1/4 wave long. The Ground plane antenna is always used vertically



1/4 wave

Fig 2.7 End fed wire

The end fed wire is simply a random length of wire attaclied to the centre ofa coax feeder or more usuallyJinked directly op.tqJhe .rear.ofa suitable ATU that can take single wire. This is a pööt an.te:tllia as it is :rl.dt turied fo a.11.)' p~rtidular frequency and thus generally performs badly relative to a dipole.

What is a long wire? It is usually a random length of wire, which is often connected directly to the terminal of an ATU, which can accept long wire as well as coax feed, and ladder wire fed antennas. The likely minimum length of the wire will be 80 feet but is often much longer.

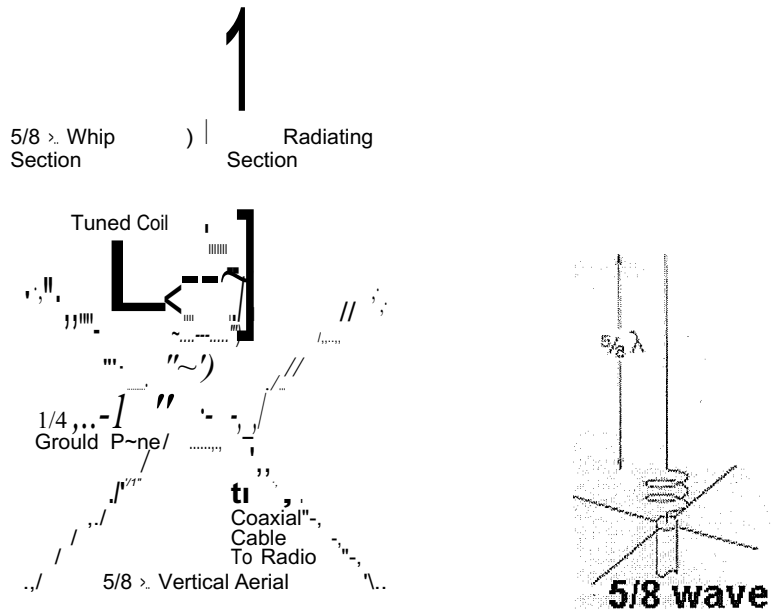


Fig 2.8 The 5/8 ll. wave

The 5/8 wave has a slightly better gain over the 1/4 wave antenna shown above in figure (2.8). Like the 1/4 wave the 5/8 wave is also used vertically but the time to note that differentiates this from the 1/4 wave if the coil at the base of the antenna.

2.6 Antenna basics

Understand that that 1/2 wave dipoles (mounted vertically), ground planes and 5/8 antenna are omni-directional. The 1/4 wave GROUND PLANE AERIAL is always used as a vertical and as such has an omni-directional wave form.

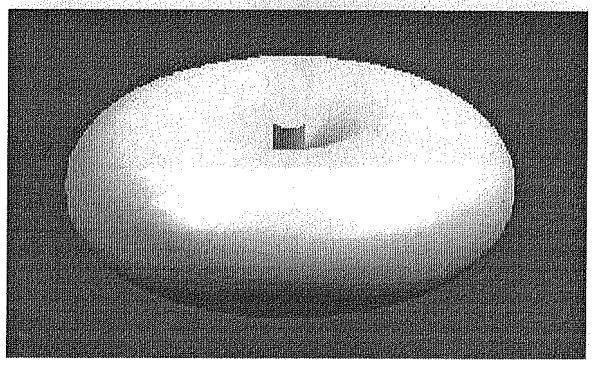


Fig 2.9 Rötirı.dd.Ough nut

Imagine a round dough nut as figure(2-9)the raditaing wave form and the antenna is pocked up through the middle, the radiating pattem all round the antenna is what is meant by omini-directional.

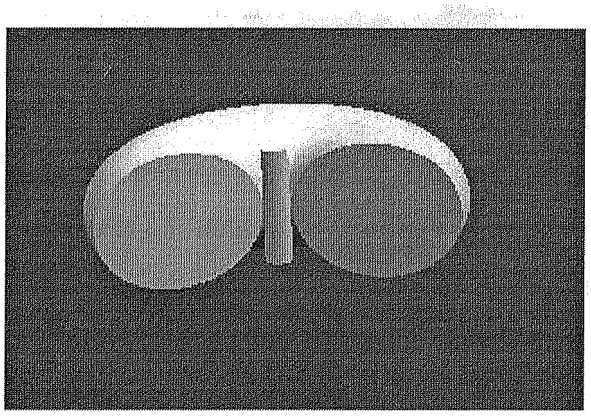


FIG **2.10** Slice'/ôfröund dough nut

Now if we take a slice through the wave form we will see the radiating element

The 5/8 wave aerial has 'similar' properties to the 1/4 Wave Ground Plane Aerial.

The only difference's being, the 5/8 Wave Aerial is bigger, and has a slight 'gain' of signal to its output compared to a 1/2 Wave dipole, or a 1/4 Wave Ground Plane but is also OMNI-DIRECTIONAL.

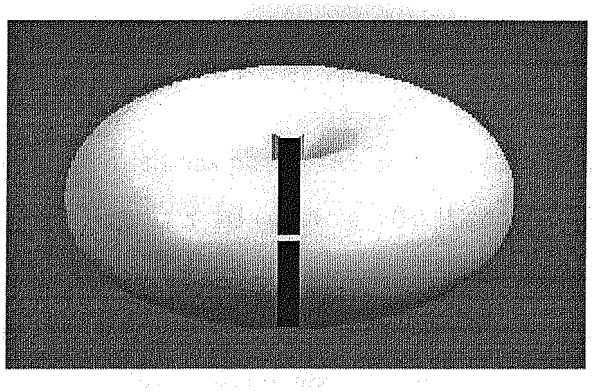


FIG 2.llHalf wave diople

If a half wave diople is also mounted vertically instead of the usual configı.ıration of horizontally it too will exhibit omni-directional radiation, now in the figure(2-ll) we

can a represention of a dipole mounted vertically with the same omni-directional radiation.

2.7 Yagi beam

The yagi antenna is directional and has a gain because of its focusing ability. A Yagi beam Aerial is a DIRECTIONAL Aerial, with higher gain than the aerials previously discussed.. This is achieved by the REFLECTOR on the back of the aerial, which forces the signal forward to the DIRECTORS. The directors focus the RF Signal energy forward like the light beam of a car's>headlight or a torch beam. A yagi (beam) aerial can be used vertically polarized Ot horizontally polarized. Due to the large, physically size ofa yagi one designed for\HFis normally horizontally polarized. The e.r.p is the product ofthe power to the anteti:ı::ı.aarı.d its gain.

ERP = EFFECTIVE RADIATED POWER

Power leaves your transceiver and travels up to the antenna, If you are using an antenna, which has what, is called "GAIN" then effecfrvely you will be getting more out of the antenna than you are putting in. This is ô•nltt~s:ible because the antenna construction. So what is this EFFECTIVE power. As the power is bing radiated we called it EFFECTIVE RADIATED POWER (erp) ahdthisis given by this formula :-

e.r.p. = power fed to antenna x antenna

using linear units and no allowance for feedetlôss.

So if we have a transceiver which has power out of 10 watts and the antenna has a gain of 10 the ERP = 10 watts (input) x 10 (gain) = 100 Watts EFFECTIVE RADIATED POWER This means that if the iicence conamons state that the maximum ERP is 10 Watts, and the radio in use only gives out 1 watt of RF Power, then an aerial with a 10 times gain will produce the highest legal power for that frequency. Also, if for the same frequency, the radio in use hasa maximum RF Power output of 5 watts, and the aerial in use has a gain of 2 times, then the ERP will be 10 Watts. the antenna system must be suitable for the frequency of the transmitted signal. Recall that if an antenna is not correctly designed for the frequency it will not match the transmitter and will not work effectively. There are various types of antenna that can be used with a transmitter.

Whilst an antenna is designed to work ona single frequency, some of the designs can be used as a practical type of antenna for a wide range of single frequencies whilst other cannot and this is all down to physical size constraints. Thus in the 144MHz and 430 MHz band all antennas designs are practical, but when it comes to the HF bands it is a different matter due to their much bigger size.

The aerial has to be the correct physically size for the frequency in use, other wise the radio transmitter will be damaged due to a high SWR, or Standing Wave Ratio Mismatch, and thus will not operate efficiently. Elsewhere you may have seen the Frequency to Wavelength conversion chart and this is where it comes into use. For all bands you can think of the most basic antenna as the half wave dipole. This half a wave length is the total overall length of the antenna and thus it has legs each of a quarter wave long. By reference to the chart you will be able to assess what is the full wave length and then divide by 2 to give you a guide as to the over all length of the antenna. If the antenna is not designed for the particular frequency being the transmitted frequency, then not only with the signal not radiate well but damage could occur to the transmitted and possibly cause EMC problems to next door's TV / radio,Recall that at HF, where an antenna has not been designed for the particular frequency, an ATU (antenna tuning unit) makes it possible for the antenna to accept power from the transmitter.

Whilst from the above you have learned that an antenna is designed for only a single frequency if you want to work a particular band then it is best to make the antenna resonant on the centre frequency for that band. However, by the use of an Antenna Tuning Unit the transceiver can be fooled into thinking that the antenna is the right one for it, and not be damaged and radiate much of the output power from the transceiver. Let us look the words Antenna Tuning Unit. Whilst you might think that the antenna is being tuned the only way to tune and antenna is to physically alter it construction. All the Antenna Tuning Unit is doing is changing the impedance of the antenna to appear to be 50 ohms, which is required by most modem rigs. it is better to think of and ATU as an antenna matching unit.

2.8 Balanced antennas

The difference between balanced and unbalanced antennas and that a balun should be used when feeding a H.F. dipole with coaxial cable (which is unbalanced). A balanced antenna is a centre fed dipole, equal length 1egs symmetrically either side of the centre connector (hence balanced), whilst a quarter wave vertical and five eights wave vertical are unbalanced as they are not symmetrical. lf we look at a dipole we would see that it is made up of two identical length "legs" which are linked at the centre by some form of insulated joint which keeps each leg apart from the other and allows you to link it to the feeder. Often the feeder used on a dipole is the open wire feeder as it too is a balanced feeder but this can lead to impedance mismatch so many amateur prefer to use a co-axial feeder, which is an unbalanced feeder with a "Choke Balun". The choke balun can simply be several turns of the coaxial feeder (say about 6 tums of the coax of 150mm diameter) or more complex by theμse of ferrite ring or ferrite bar. A choke balun as it is there to choke off / stop any RFJhat might try to pass down the braiding rather than the centre of the coax. A balun should be used when feeding an H.F. dipole with coaxial cable.

2.9 Meaning of Standing Wave Ratio (SWR)

Suppose that an SWR meter shows whether an antenna presents the correct match to the transmitter and is reflecting ninitriulIJ. power back to the transmitter

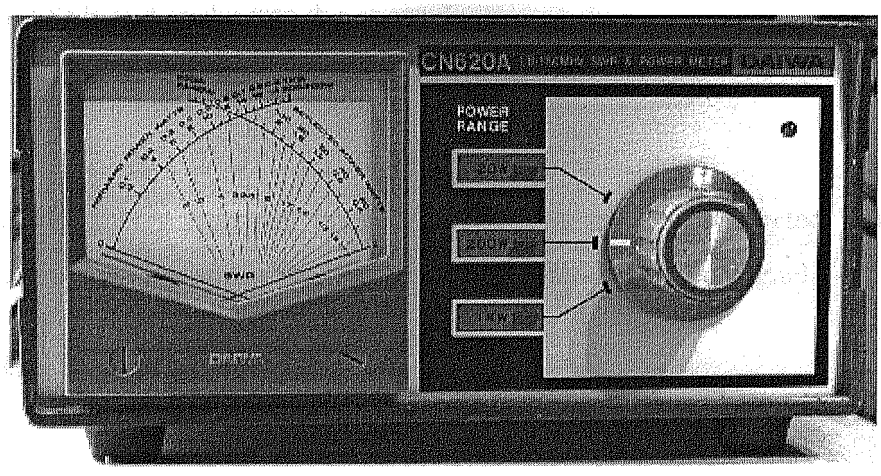


Fig 2.12 Standing wave ratio

"S" "W" "R" stands for Standing Wave Ratib. The figure(2.12) shows an SWR ıneter/powermeter. Note that this unithas two needles. This is not always the case but heretheforward and reflectedpowefis shown simultaneously. Othefın.eters require the operator10 switch betweenforward and reflected power and coıntarerea~i~~ to know relativelyhowmuch RF is goingineach direction. With a high forwardpovVerlevel and a low Yreflected power 'level, the anterın.a could be said to' be well ınatched to the operatiıiğ<frequency but is said to be "miss-matched" if the forward is high and the reflected is high. A high SWR can cause damage to our rig.

Suppose that a high SWR (measured at the transmitter) is an indication ofa fault in the antenna or feeder (and not the transmitter).

If the aerial is not correctly matched to the transmitter frequency then when a signal travels up the feeder tothe aerial it is reflected back to the transmitter andthe system is inefficient. If the ratio of forward to reffected power or "SWR" measured at the transmitter is high then much of the power is being reflected back to the transmitter. This could be the fault of the antenna or some other problem with the feeder such as a broken or incorrectly tightened connector. Thus, the fault lies anywhere but with the transmitter.

With a correctly matchedantenna and good feeder, only a very small amount if any of the forward power will be. .reflected back. A high SWR would also occur if you unwittingly failed to plug the aerial into the transmitter and pressed the PTT if operating AM FM and SSB and spoke into the microphone.

2.10 Use of a dummy load

Suppose that a "dummy load" is a screened resistor connected instead of an antenna to allow the transmitter to be operated without radiating a signal.

A DUMMY LOAD is an artificial aerial, use

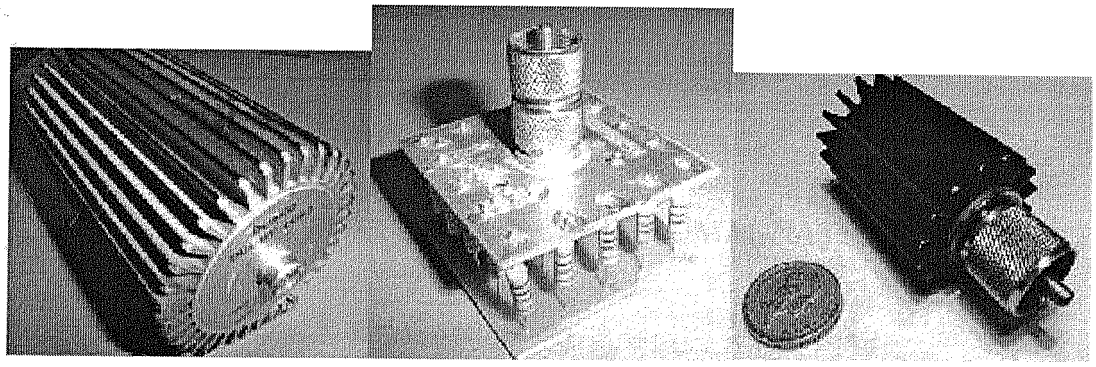


Fig 2.13 Dummy load

The dumrny loads shown.above represent a range - 100watt on the left 5 watts in the centre and 15 watts on..the right. The Dumrny Load .must be made from CARBON RESISTOR(s) with shgrt connecting wires. As can be seen from the centre image at figure(2.13) the du111lll.yJoadis several carbon resistors in parallel making up 50 OHMS, or a single latge.CARBON RESISTOR built into a heat sink with the correct connectors on it so that the Dumrny Load can be connected to the radio TRANSMITTER / RECEIVER or ATU / SWR Meter for test purpose's without radiating a signal. Tests such as, looking for powerloss in feeder, or to test for faults in the feeder or the aerial can be done by putting the Dumrny load at the point where the antenna would attach.\The reason that a 50-ohm carbon resistor is used is because 50 ohms is the correctiı:npedfü:ıce value of the aerial system into which the transceiver transmits, The Dumrny Lcıadmust be made from carbon resistor. A wire wound resistor is effectively and inductor and because the dummy load must not have any inductive properties wire wound resistor, although of wattage capability and easier to obtain cannot be used. Inductive properties in a dummy load could problems such as radiating a signal.

CHAPTER3

THE BEHAVIOR OF ELECTROMAGNATIC WAVES

3.1 Line of Site (LOS) Propagation

LOS is a propagation in which the direct ray from the transmitter to the receiver is unobstructed. There are two types of LOS:

• Visual LOS-This is the visual observation of one point to another as seen by the observer's eye. Although it is not apparent to the observer, the light waves are not truly in straight line. They are subject to changes in directions due to the physical objects around them. They can be refracted, reflected, diffracted, and absorbed.

• Radio frequency (RF) LOS-Radio waves have many of the same properties as visual LOS and are subject to the same obstructions. The properties of radio waves allow them to be bent by the troposphere and ionosphere, allowing them to travel beyond the observer's eyesight. RF LOS is thus defined as LOS where the receiving and transmitting antennas Caınot be physically seen (may not have visual LOS), but there are no obstructions to the electromagnetic waves being propagated with the LOS Fresnel zone.

3.1.1 Typical Barriers and Obstructions

Typical barriers and obstructions to electromagnetic waves include buildings and other İnanmade objects, as well as natural obstructions such as trees, hills, bodies of water, and mountains.

3.1.2 Free SpaceLoss

Free space loss is the signal attenuation that would result if all absorbing, diffracting, obstructing, refracting, scattering, and reflecting influences were sufficiently removed to have no effect on wave front.

NOTE: Free space loss is primarily caused by beam divergence, which is the effect of the, signal energy spreading over larger areas at increased distances from the source.

3.2 Factors Affecting the Behavior of Waves Reflection

Reflection can be defined as the abrupt change in direction of a wave front as it strikes a dissimilar media; which has a smooth surface and is much larger than the wave itself (see Figure 3.1).

Notes: Reflection may be specular (i.e., mirror like) or diffuse (i.e., not retaining the image, only the energy) according to the nature of the interface. Depending on the item reflecting the wave, the reflected wave may be inverted or shifted in phase. This inverted, or phase-slüıretl; wave can cause interference ata receiver that can see both reflected and direct waves'. Because the direct wave can be reflected off many objects, the signals arriving atthe receiver can be at different times and phases, partially canceling each other, wh.ichare known as multi patlı fading.

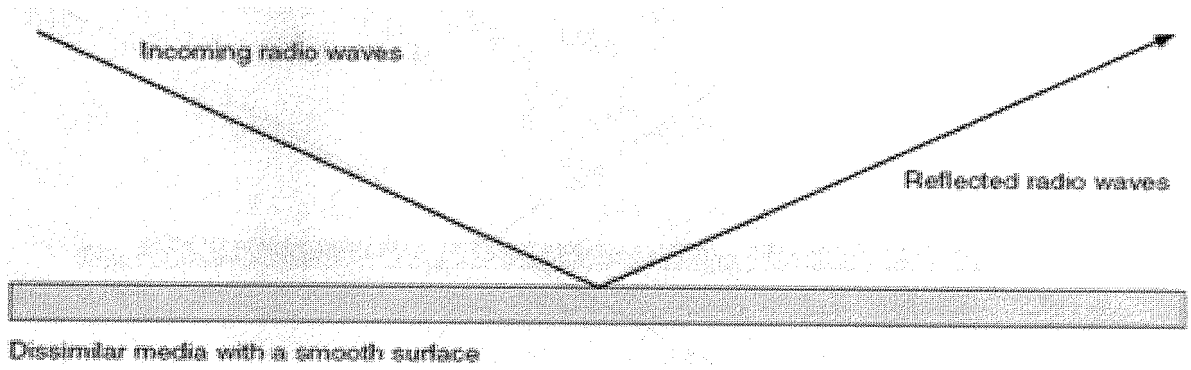


Fig 3.1 Reflections on smooth surface

Refraction is the abrupt change ihdirection as well as the absorption of a wave front as it strikes a dissimilar media of differentdensities (see Figure 3.2).

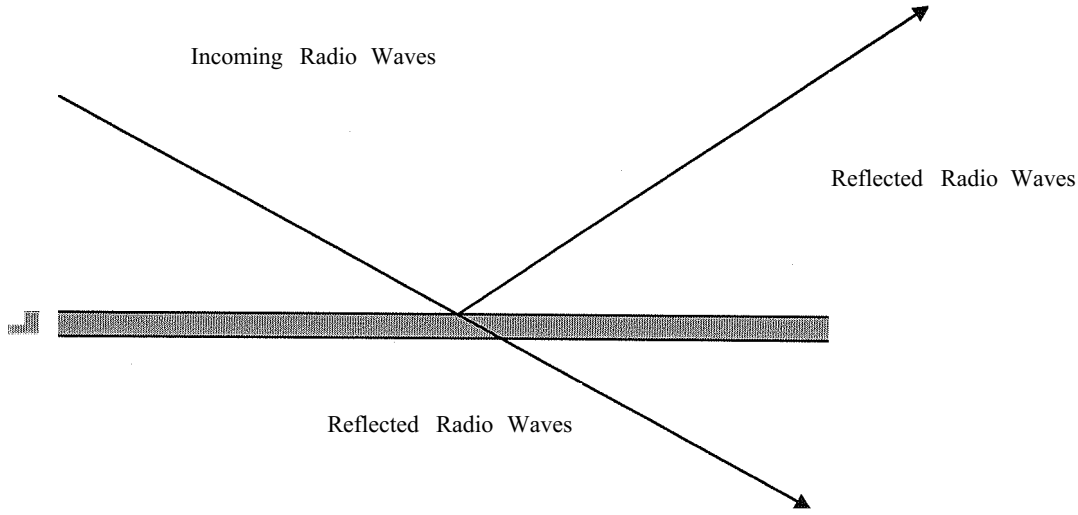


Fig 3.2 Reflection on not smooth surface

Scattering is the phenomenon in which the direction, frequency, or polarization of the .wave is changed when the wave encounters rough surfaces or objects smaller than the wave it self. Scattering also can be a result of the wave's interaction with materials at the atomic or molecular level (see Figure 3.3).

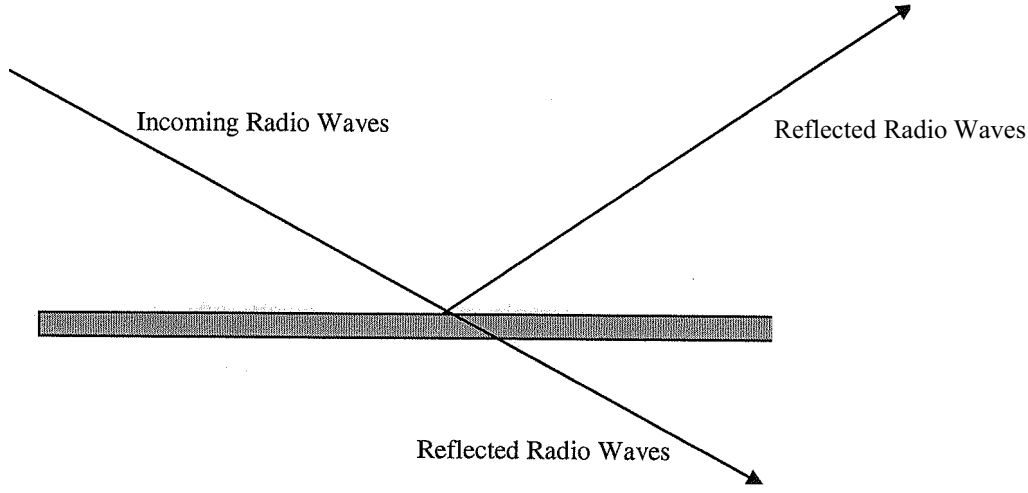


Fig 3.3 Scattering

NOTES: Scattering results in many reflected and disordered waves, which can weaken or even cancel the main wave front. Scattering also can be the result of atmospheric changes due to heavy rain or dust.

3;3 Diffraction

Diffraction is the deviation of an electromagnetic wave front from the predicted patlı when it strikes a surface with sharp comers or an object with a rough surface. The waves are bent around the object, thus changing the wave front's patlı (see Figure 3.4).

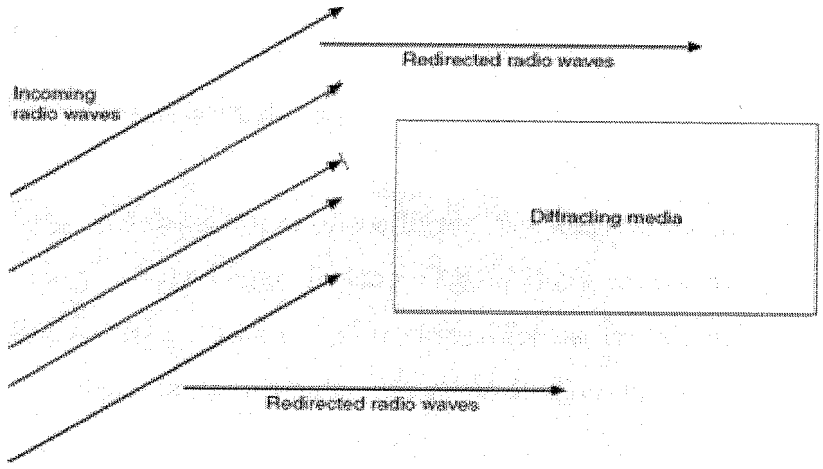


Fig 3.5 Diffraction

3.4 Absorption

Absorption is the dissipation of an electromagnetic wave when it strikes a medium that does not allow the wave to be reflected, refracted, or diffracted (see Figure 3.6).

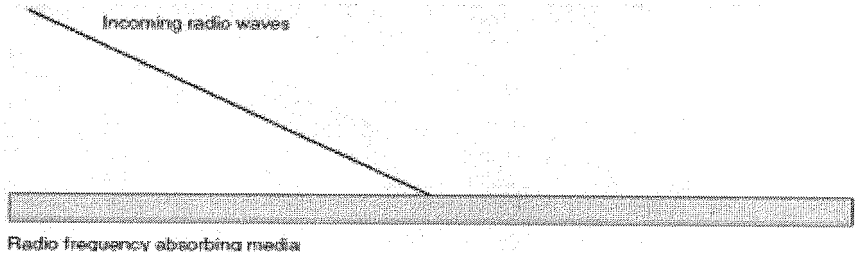


Fig 3.6 Absorption

3.4.1 Ducting

On rare occasions, usually when teınperature inversions occur, the atınosphere ınay becoıne stratified with a few layers of varying index of refraction. A ınicrowave signal can becoıne trapped between these layers, causing it to be carried away froın its intended destination (the reınote receiver). Ducting is usually quite deep and can last ınany hours. It typically occurs on hot, huınid suınıner nights when there is no wind to stir the atmosphere.

3.5 Earth Curvature (Earth Bulge)

Earth bulge is the curvature of the Earth over a given distance. For LOS radio operations, it ınust be .considered for those radio shots exceeding 11.3 kın (7 mi). Antenna height calculatiôüs need to be considered for the Earth's bulge for shots ınore than 11.3 kın (7 mi), astheEarth's bulge can affect the Fresnel zone.

The k-factor is a calculatidaarsed.in both tropospheric and ionospheric propagation:

• In tropospheric radio propa.ğation,the ratio of the effective Earth radius to the actual

Earth radius. The k-factor is approximately 4/3.

• In ionospheric radio Pr<;>pagation, a correction factor that is applied in calculations related to curved layers atıcijs a function of distance and the real height of ionospheric reflection.

3.6 Fresnel Zones

Fresnel zones are a series of concentric ellipsoids surrounding the patlı (see Figure 3.7).

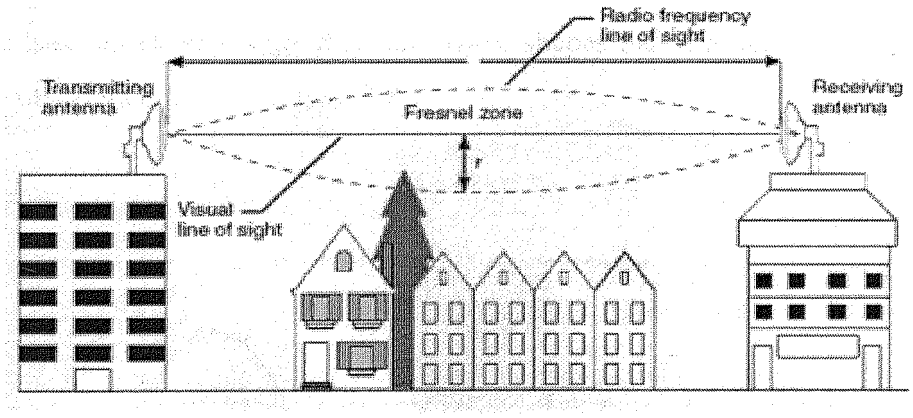


Fig 3.7 Fresnel zone

Tlıe first Fresnel zone is the surface containing every point for wlıiclı tlıe sum of the distances from tlıat point to the two ends of the path is exactly one-lıalf wavelengtlı longer tlıan tlıe direct end-to-end patlı.

Eaclı of tlıe otlıer Fresnel zones ("nt:lı" Fresnel zone) is defined in tlıe same way as tlıe first zone, except tlıe difference is "n-half" (n/2) wavelengths.

Tlıe first Fresnel zone is a nominal unit used to measure certain distances (e.g., patlı clearances) in terms of tlıeir effect on the frequency involved, ratlıer tlıan in terms of meters (feet). Tlıe otlıer zones also are important under certain conditions (e.g., lıiglıly reflective patlıs).

Clearance requirements expressed in FresııeFzgnes apply to the sides and top of the patlı as well as to the bottom. A cross sectiön öftlıe>zones at any point along tlıe patlı slıows a series of concentric circles surroundingtlıe.patlı.

3.7 Fundamentals of Harmonics

Harmonics are the multiples of an alternating current's (ac's) fundamental frequency. The fundamental frequency is known as tlıe first lıarmonic. Tlıe second harmonic is twice tlıe fundamental frequency; tlıe tlıird lıarmonic is tlıree times tlıe fundamental frequency, and so on. How Harmonics Are Created?

Harrnonics are created by nonlinear loads, so-called because the current is not a srnooth sine wave. When electronic equiprnent tums AC to DC, it draws current in pulses. These pulses can cause distorted current wave shapes that are rich in harrnonics to the fundarnental frequency (see Figure 3.8).

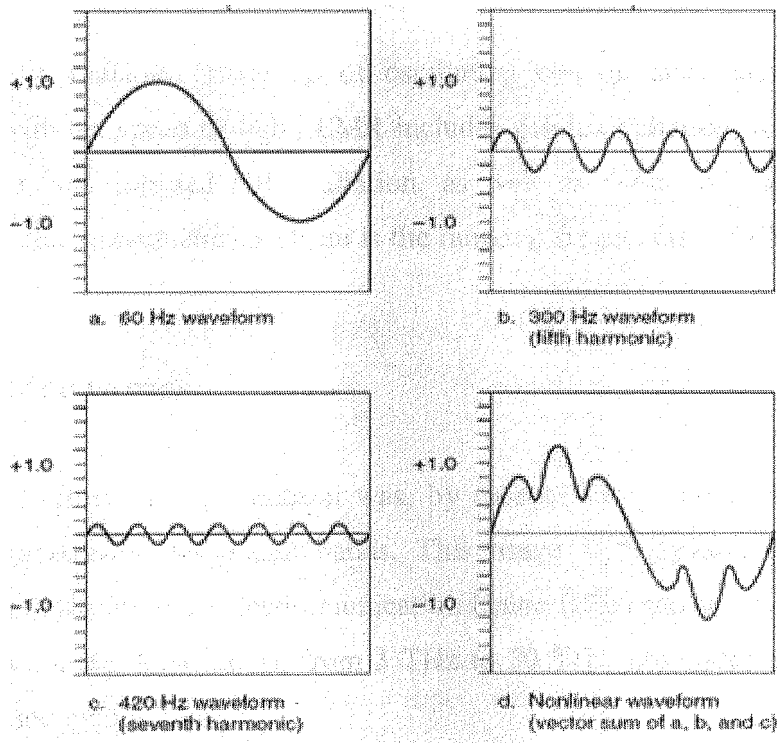


Fig 3.8 Harmonic distortion

3.7.1 Harmonic Distortion

Harrnonic distortion is the presence of unwanted harrnonic frequencies, which can distort the desired fundarnental frequency.

3.7.2 Filtering Harmonics

Filters can be used to allow only part of the frequency spectrurn surrounding the fundarnental frequency to be passed. The various types of filters are as follows:

• High-pass filters transrnit energy above a certain frequency.

• Low-pass filters transmit energy below a certain frequency.

• Band-pass filters transmit energy ofa certain bandwidth.

• Band-stop filters transmit energy outside a specific frequency band.

3.8 Electromagnetic Spectrum

EMR is radiation made up of oscillating electric and magnetic fields and propagated with the speed of light. EMR includes gamma radiation, X rays, ultraviolet (UV), visible, and infrared (IR) radiation, as well as radar and radio waves. The frequency or electromagnetic spectrum is the range of frequencies of EMR from zero to infinity.

3.8.1 Spectrum Groups

The electromagnetic spectrum was, by custom and practice, formerly divided into 26 alphabetically designated bands. This usage still prevails to some degree. However, the International Telecommunication Union (ITU) recognizes 12 bands, from 30 Hz to 3000 GHz. New bands, from 3 THz to 30 THz, are under consideration for recognition (see Figure 3.9).

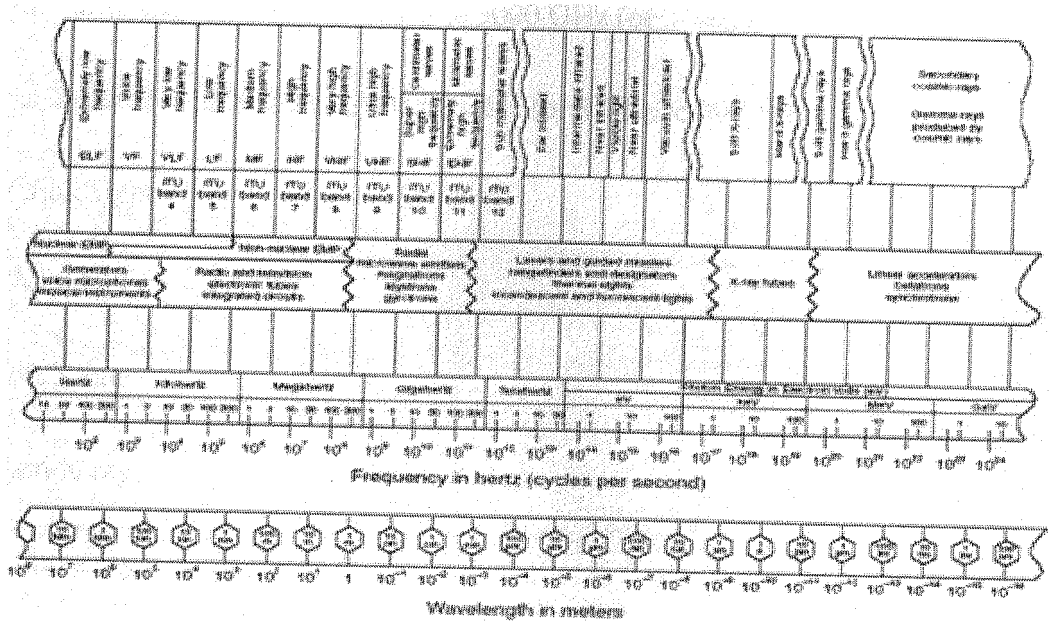


Fig 3.9 Electromagnetic spectrum

• Radio waves

- Extremely low frequency (ELF) = 30 to 300 Hz

- Voice frequency (VF) = 300 Hz to 3000 Hz

- Very low frequency (VLF) = 3 KHz to 30 KHz

- Low frequency (LF) = 30 KHz to 300 KHz

- Medium frequency (MF)::::300 KHz to 3 MHz

- High frequency (HF)-HF radio = 3 MHz to 30 MHz

- Very high frequency (VHF)-FM radio = 30 MHz to 300MHz

- Ultrahigh frequency (UHF)—cellular and trunk radio = 300 MHz to 3000 MHz

~ Super high frequency (SHF)-radar and microwave radio = 3 GHz to 30 GHz

- Extremely high frequency (EHF)—microwave and satellite = 30 GHz to 300 GHz

- Sub millimeter waves = 300 GHz to 3000 GHz (or 3 THz)

~ Far-infrared = 3000 GHz to 30,000 GHz(ôf3THz to 30 THz)

• Visible light

-uv light

• Soft X ray

• HardXray

• Gammaray

3.9 Radio Frequency (RF) Behaviors

3.9.1 Gain and Loss

Gain describes an increase in an RF signal's amplitude. Two sources of gain are:

• External power sources (RF amplifiers).

• Passive sources (reflected signals combining with the main signal to increase overall signal strength). Various antennas are co11.structed with different passive gain.

Added power can be a serious problem. If the transmitted radiated power is close to legal output limits, this added power mightviolate regulatory limits.

Loss describes a decrease in signal strength. The two main sources of loss within a wireless system are:

• Loss caused by the impedance of cables and connectors causing power to reflect back, resulting in the attenuation of total or forward power.

• Loss that occurs during signal propagation where objects cause the RF signals to be absorbed, reflected, refracted, scattered, or destroyed.

An RF attenuator can intentionally inject loss. Loss must be correctly measured and compensated due to receiver sensitivity.

3.9.2 Impedance

Impedance is defined as the resistance to ac flow, measured in ohms. Impedance in an RF system is associated with the cabling and connectors within a radio system. An impedance mismatch results in power being reflected back toward the transmitter.

3.10 Voltage Standing Wave Ratio (VSWR)

VSWR is a mathematical expression of the no uniformity of an electromagnetic field on a waveguide or RF voltage on a transmission line such as coaxial cable or a connecting device.

A standing wave pattem .arises when part ofthe energy of a forward traveling wave is reflected back at a point where tlıere is an impedance mismatch along the transmission patlı. This causes the forward and reflected wave to add in and out of phase along the lengtlı of the transmission patlı. VSWR usually is defined as the ratio of the maximum RF voltage to the minimum RF voltage along-the line.

VSWR is caused when not all the devices responsible for transmission of the radio signal match impedance wise. This includes the cabling, connectors, and antenna.

The two numbers relate to an impedance ı:rıtsmatch. against a perfect impedance match. The second number is always one. TheJôwerthe first number, the better the impedance match. The effects of VSWR include:

• A marked decrease in the amplitude of the transmitted RF signal.

• The reflected power buming out the electronics of the transmitter if they are not protected against power being retumed.

Several methods of changing or eliminating the effects of VSWR include:

• Proper use of appropriate equipment.

• Tight connections between cables and connectors.

• Use of impedance matched hardware.

• Use of high-quality equipment with calibration reports.

• Never use 75-ohm cable with 50-ohm devices.

3.11 Intentional Radiator

Intentional radiator is defined as an RF device that is specifically designed to generate and radiate RF signals. in terms ôflfatdware, intentional radiator includes the RF device and all cabling and connectors up .to. (but not including), the antenna. The power output of the intentional radiator refers to the power output at the end of the last cable or connector before the antenna.

3.12 Equivalent Isotropically Radiated Power (EIRP)

EIRP is the output power of a radio transmitter measured at the antenna. In calculating the EIRP, use fnust include the power of the intentional radiator, any amplifiers, connector Ioss; cable loss, and gain of the antenna. Guidelines are set in the FCC Code of Federal Regulations, Part 15: Radio Frequency Devices.

3.12.1 Coverage

Coverage is the geographic area within which service from a radio communications system can be received.

3.12.2 Rangirig

Ranging is the measurement of the distance to a remote object (target) from a known observation or reference point. Within RF tmmisiiiiiiiii, it is the measurement of the transit time of the RF signal.

3.12.3 Automatlc **Gain Control (AGC)**

AGC is the process or means by which gain is automatically adjusted in a specified manner as a function of a specified\pa.iiıfüeter as receivedsignal level.

3.13 Radio Frequency (RF) **Measurements, Units,** and Conversions

To ensure a system's powefisiwithi:i:ı?standard specifications, the following calculations and measurements must be perfôrfüed:

• Power must be measured at the tra:ıismittingdevice.

" Loss and gain of connectivity devices betweeı:lthe transmitting device and the antenna (cables, connectors, amplifiers, attenuators, andsplitters) must be calculated.

• The transmitting power plus or minus the connectivity device calculation will give the power at the last connector before the RF signal enters the antenna (intentional radiator).

• EIRP is the power at the antenna element (the intentional radiator) plus the antenna gain.

• Each area determines whether RF links are viable without overstepping power limitations set by regulatory bodies.

3.13.1 Units, and Conversions

Several units of measurement are standard within the wireless industry to reflect the amount of power. The two most coınrrı.ôhunits are watt and decibel:

• A watt is the basic unit used to measure power. üne watt is equal to an ampere multiplied times a volt.

• A decibel is the measurement of a signal's loss or gain. The decibel is 10 times the Logarithm of output power to receive power.

The standard power guidelines for wireless local area networks (WLANs) is one W of power from the intentional radiator and a maximum of 6 dB gain from the antenna. This gives a WLAN an overall power output of four W.

While watts provide an absolute measurement of power, decibels provide a relative gain or loss of power.

The relationship of dB loss and gain to power is known as the 3-10 rule. In calculating the power output of a wireless system, the calculations below can be used as a quick reference:

• 0 dB is equivalent to 1 millionth of a watt (1 mW).

• For every 3 dB of gain, the power is doubledt

• For every 3 dB of loss, the power is halved.

• For every 10 dB of gain, the power is 10 times.

• For every 10 dB of loss, the power is one tenth.

As described above, gain and loss are measured in decibels. There are multiple points within an RF system wherein these gain and loss measurements can be taken.

3.14 Power Measurements Using Decibels

Below are the types of decibel measurements used in measuring the power in wireless systems:

- dBm is a measure of power in milliwatts.

- dBi is the isotropic measurement of powefa.tthe antenna.

- dBd is the isotropic measurement of power for a dipole antenna.

- dBc is the measurement of the average power supplied to the antenna transmission line by a transmitter during one RF cycle taken under the condition of no modulation.

3.15 Radio Frequency (RF) **Transmission, Reception, and Propagation**

3.15.1 Theory of Propagation

Propagation is the motion of electromagnetic waves through or along a medium. Radio waves can take different paths for a transmission medium to a radio receiver. Long-distance communications usually use sky waves or direct waves for transmission. Sky waves (see Figure 3. 10) are defined as waves that are usable due to refraction off of the ionosphere or troposphere:

- The ionosphere is the portion of the Earth's upper atmosphere where ions and electrons are present in quantities sufficient to affect the propagation of radio waves, Normally, the ionosphere extends from about 48 km to 1000 km (30 mi to 621 mi) above the Earth. At certain times and locatioıis, however, it may reach even lower. .Long-distance, HF 2 MHz to 30 MHz communications is made possible by reflections of radio waves from ionized layers in this portion of the Earth' s atmosphere.

- The troposphere is the part of the atmosphere extending from the surface of the Earth to about 11.3 km (7 mi). Within the troposphere, bending of radio waves by refraction

makes the distance to the radio horizon exceed the distance to the optical horizon. Tropospheric refraction (bending caused by sudden changes in the characteristics of air in a lower atmosphere) affects the received signal at distances beyond the radio horizon. The troposphere is normally used in long-haul military microwave applications.

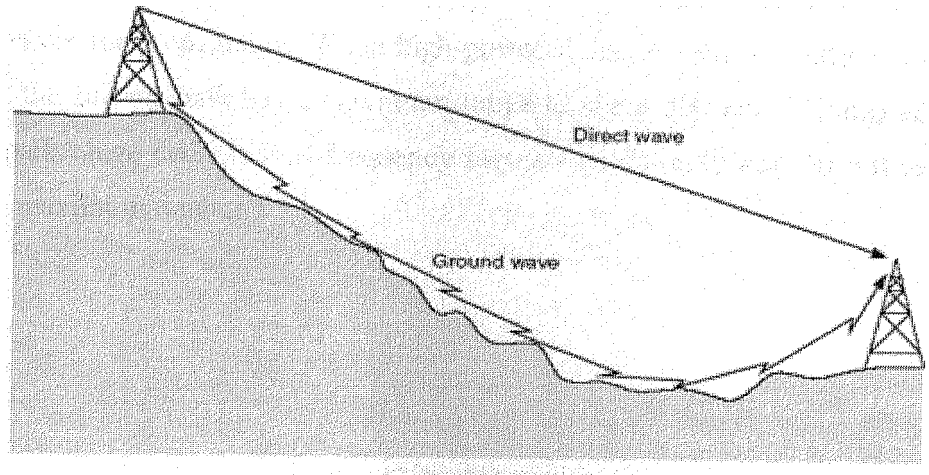


Fig 3.10 Sky wave

Direct waves are ground wave components that travel directly from the transmitting antenna to the receiving antenna. In terrestrial communications the direct patlı is limited by the distance to the horizon from the transmitter. This is essentially LOS distance. it can be extended by increasing the height of the transmittirıg antenna, the receiving antenna, or both. Direct waves are used in point-to-point (PTP) satellite (UHF/SFH) communications. The direct path also is useful for extraterrestrial. it is useful in air/ground/air communications because most short-distance air/ground services are now orı VHF or UHF.

Short-distance transmissions are used via groutı.d waves and ground reflection techniques. Ground waves are propagated waves that take three separate paths to the receiver:

• Direct wave

• Ground-reflected wave

• Surface wave

These waves are illustrated in Figure (3.11).

The effectiveness of ground waves depends on the RF, transmitter power, transmitting antenna characteristics, electrical characteristics (conductivity and dielectric constant) of the terrain, and electrical noise at the receiver site. LF and VLF transmissions use ground waves for propagation. When high-powered transmitters and efficient antennas are used, the surface patlı has a maximum range of about 500 km (310 mi) at 2 MHz. Surface patlı range decreases as frequency .increases, About 80 km (50 mi) represents the usual maximum range.

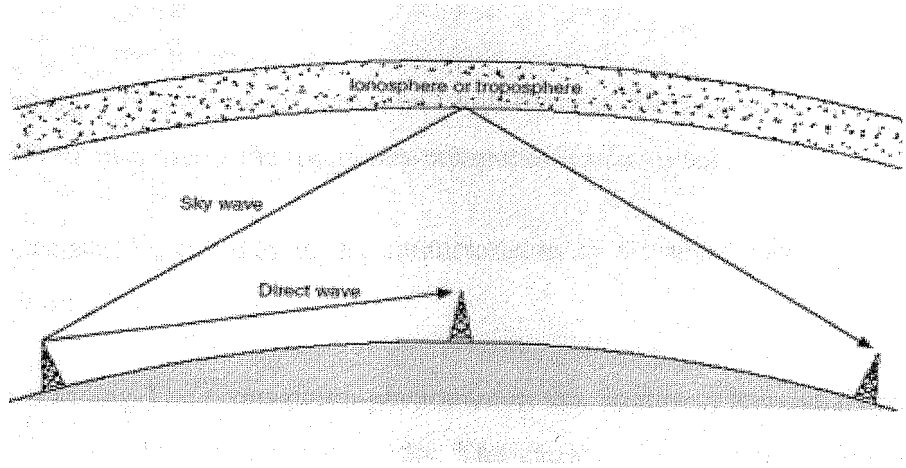


Fig 3.11 Ground waves

3.15.2 Basic Propagation Modeling Matlı.

3.15.2.1 Free Space Patlı Loss (Dispers1oıi)

Dispersion is the loss incurred by an RF signal due to signal dispersion. Signal dispersion is the natura! broadening of the w.aye front. The wider the wave front, the less power can be induced into the receiving antenna. The power level decreases at a rate inversely proportional to the distance traveled and proportional to the signal's wavelength as it is transmitted and travels through the atmosphere. The calculation of patlı loss is performed by using the following formula: 20Log10 (4 d/wavelength)(dB)

3.15.2.1.1 Isotropie Gain

Isotropic gain is the ratio of the signal level at the output of the antenna to that of its input under a specified set of operating conditions. Isotropic gain is usually expressed in dBi.

3.15.2.1.2 6 dB Rule

üne rule commonly used when calculating isotropic gain is called the 6 dB rule:

• Each 6 dB increase in EIRP equates to a dôtibling of range.

• Each 6 dB reduction in EIRP equates to cutting the range by one half.

3.15.2.1.3 Fading

Fading is defined as the variation (withfirrı.e) of the amplitude or relative phase, or both, of one or more of the frequencytcômpô:tıents 0fa.signal.

Fading is caused by changes in the characteristics öf the propagation patlı with time. Types of fading are:

• Multipath fading-The propagation phenomenon-tliat results in RF signals reaching the receiving antenna by two or more paths. The causes of multipath fading .ırıclüde RF signal reflection and refraction from natura! objects (e.g., mountains) and man-made objects (e.g., buildings).

• Delay spread-The result of multiple reflecti()ns of the transmitted signal arriving at. the receiver at different times. This causes the signals to crash into one another, resulting in the receiver being unable to sort them out.

The effects of multipath fading and delay spread include constructive and destructive interference, which is a phase shifting of the signal that causes signal loss and distortion.

3.16 LinkLoss BudgetCalculation

Below is a formula that can be used in calculating link loss for a particular radio patlı. in looking at a real system, consider the actual antenna gains and cable losses in calculating the signal power Pr (e.g., dBm) that is available at the receiver input:

Pr = Pt + Gt + Gr - Lp - Lt - Lr

Where

Pt = transmitter power output (same units as Pr)

Gt = transmit antenna gain (dB)

Gr = receive antenna gain (dB)

Lp = free space path loss between antennas (dB)

Lt = transmission line loss between transmitter andtransmit antenna (dB)

Lr = transmission line loss between receice a.tıterin.a and'receiver input (dB)

3.17 Modulation, Detection, and Multiple~ıığ

This section reviews the major types of modulation and demodulation techniques used in wireless voice, data, a.fid Video systeıns. Because of the numerous proprietary systems and techniques .preva.lent within the industry, only the basic techniques are detailed. Frequency conversioıı techniques used to create RF signals and multiplexing techniques used to bett.er utilize RF barı.dwidth are briefly discussed as well.

3.17.1 Types of Modulatjon

Modulation is the process of altering the amplitude, frequency, or phase of a carrier signal in a measured way that allows for data to be added to it. These three basic types of modulatiorı are described below.

3.17.1.1 Amplitude Modulation

Amplitude modulation (see Figure 3.12) is the process in which the amplitude~:::------~!' a carrier wave is varied in.accordance with some characteristic ofithe modulating signal.

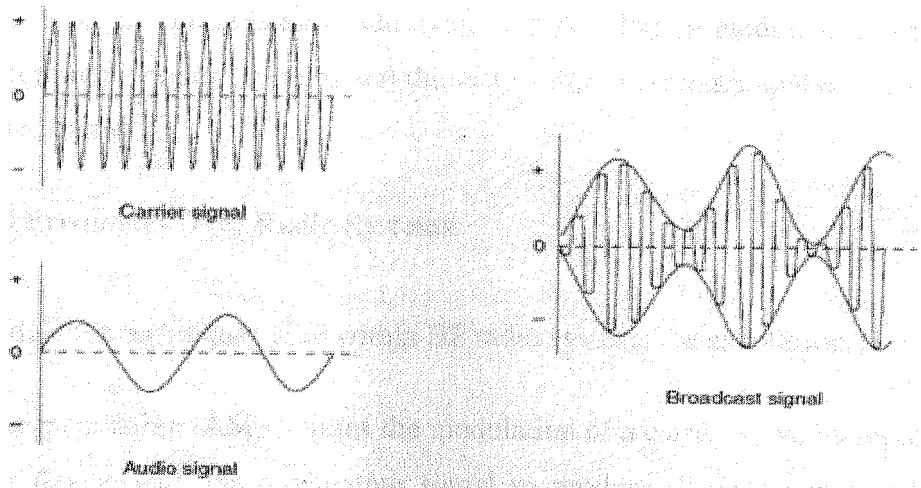


Fig 3.12 Amplitude modulation

3.17.1.2 Frequency Modulation

Frequency modulation (see Figure 3.13) is the process in which the frequency of a carrier wave is varied in accordance with some characteristic of the modulating signal.

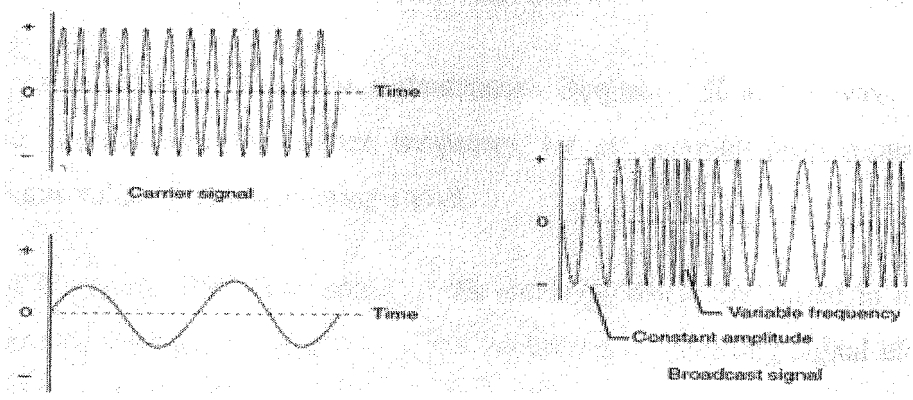


Fig 3.13 Frequency modulation

3.17.1.3 Phase Modulation

Phase modulation (see Figure 3.13) is the process in which the phase ofa carrier wave is varied in accordance with some characteristic of the modulating signal.

The various types of radio systems used today rely on different modulation techniques. The most common wireless systems and the modulation techniques'applied within them are described below.

3.18 High Frequency (HF) Radio Systems

Modulation techniques used within HF radio systems are as follows:

• Amplitude modulation (AM)-Implies the modulation of a carrier wave by mixing it in a nonlinear device with the modulating signal to produce discrete upper and lower sidebands, which are the sum and difference frequencies of the carrier and signal. The resulting envelope of the modulated wave is an analog of the modulating signal.

• Single sideband modulation-An amplitude-modulated emission with only one sideband being used.

3.19 VHF/UHF/SHF Systems

Modulation techniques. used within VHF/UHF/SHF systems are as follows:

• Frequency modulation (FM)-The instanüı.11.eôü.s frequency of a sine wave carrier is caused to depart from the center fr~qµency by an amount proportional to the instantaneous value of the modulating signal.

• Phase shift keying (PSK)-The pfütse öf the\Cafrier is<discretely varied ıı relatiôn tö either a reference phase or the phase of the ıı:rimediately preceding signaleleı:rieıt, in accordance with data being transmitted.

• Pulse code modulation (PCM)-A signal is sampled, and the magnitude (with respect to a .fixed reference) of each sample is quantized and digitized for transmission over a common medium.

CHAPTER4

VHF or UHF GROUNOEDVERTICAL DIPOLE

Dipole antennas are the oldest radiating systems since Hertz used them for the first time during the laboratory experience proving the existence of electromagnetic waves existence in the late nineteen century (1885-1888). Dipole antennas were the backbone of thousands of radiating systems used in.ielectton.icsfor many years, specially in radio communications in high and very high frequencies, due to their radiation high efficiency properties. Dipoles are balanced systçms and for this reason a balanced transmission lines was used during many years tô ifeecithem. Coaxial lines are very popular nowadays for a lot of reasons and are fed by means of a balun or a balanced-unbalanced device, installed dipole input. in the case of a vertical dipole, using a metallic skirt attached middle is possible to avoid the balanced device. Dipole feeding points to the grounded coaxial shield and the other to the coaxial hot same time any static potential at the electronic system. for powerful transmitting systems but could be receivers or preamplifiers. The proposal here is to use an dipole where both coaxial line conductors are statically connected at to avoid high static potential problems and at the same time, a impedance as a function of frequency. The dipole is made up of a piece ôfnieta.1 tube close to half wavelength and a metallic skirt is placed around itin.itş\1ği~fpıırt and connected directly very close to the dipole middle. Feeding point inthe 111.etallicskinarıd dipole physical dimensions are carefully chosen to match the transmissiônlineCh.aracteristic'impedance.This techfüque permits at the same time reasonableHi111pecfance111.atchinğöver' the bandwidtharôu:rıd the operaüon freqı.ie:rıcy. Practical resı.ilts obtaineff.'ôn sevetal models in the HF} VHFarıd UHF bands show the impedartee"and radiatiöhprôperty rtıeasurements. Dipôle a:rıte:rınas have been used for many years, starting withtlıe\Hertz experiences (1885-1888) duting the electromagnetic wave radiation validation: Dipole radiation efficiency is very high especially in the VHF and UHF spectrum making it one of the more popular antennas for many applications. At the same time, it is a very simple mechanical structure. From

the electric point of view, this is a symnıetrical structure and for this reason, it must be fed by a symnıetric transmission line or by a coaxial line through a balun. The radiated wave is linearly polarized and depending on the applications, horizontal or vertical polarization is used. In both cases, the possibility exists of having an entirely grounded dipole using the quarter wavetransmissionlinetechn.iquegenerally.in parallel with the principal or feeding transmission line. :Whistechn.iqueis .generally used for horizontally polarized dipoles or the dipole parallel toithetnetallic ground plane.

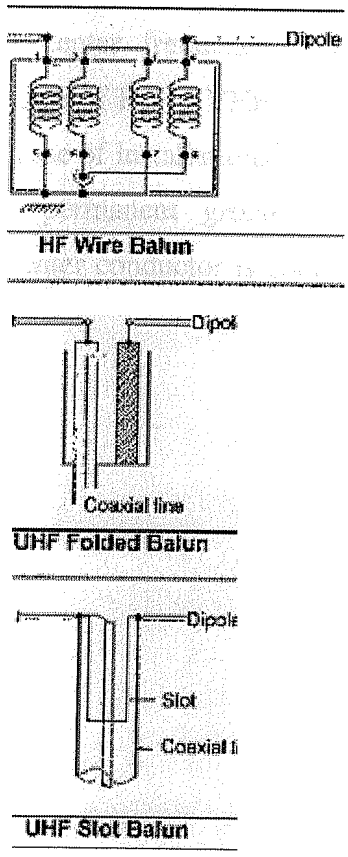


Fig 4.1 Some cla.ssicaldipôle grounding

(see Figure 4.1) shows some classical exaın.ples&fdipöle grounding where a secondary line or a balun is used as a groundihg systeilla.:tıda.tthe same time, in some cases, for impedance compensation. This technique has bee:rı used successfully during a Iong time in several applications. Nevertheless, for vertically polarized dipoles, grounding is generally more difficult to make, and, in many cases, the hot coaxial center conductor is connected directly to the upper dipole part without any protection for static problems.

4.1 Direct fed cylindrical skirt grounded dipole

This kind of dipole uses an entirely metallic structure of about half wavelength with close to one-quarter wavelength skirt placed in one of the dipole sides. This skirt is made like a wire cage or with a solid tube accordırıgtothe operational frequency. The feed point is placed directly between the dipole rrıetallic part and the skirt in order to use a standard coaxial line without any other deviçe and it is chosen theoretically during the design obtaining the best match to the 50 ohms transmission line characteristic impedance at the operation band center frequency. Dipoler-metaliic structure is connected directly to ground in the case of HF or VHF vertically pölarized antennas or to the metallic skin structures in the case ôf installations in vehicles, planes, satellites, or ships. This possibility permits a periria11ertt groı.ind connection avoiding static discharges because the hot coaxial cerıter côrıçltıctor is connected directly to ground for static or direct current potentials.

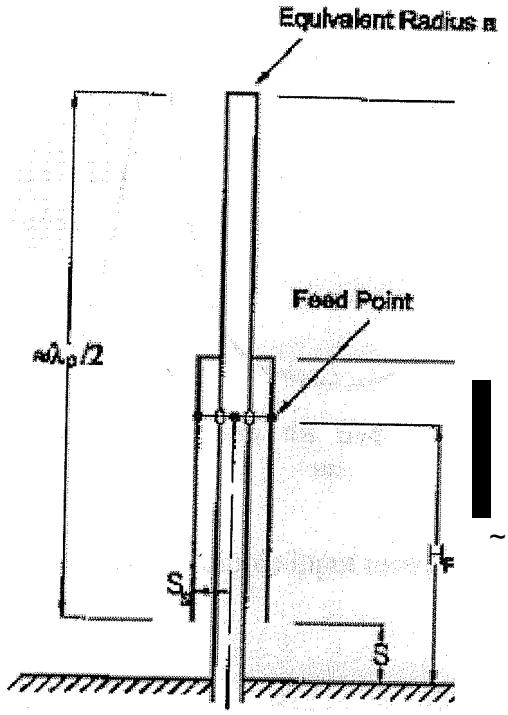


Fig 4.2 Grounded vertical dipole sketch

(Figure 4.2) shows a typical grounded dipöl~sk~tı3füinputimpedance is afunction of the dipole length, the dipole structure diametef;<(aııdtheskirt diameter. In the Iatter case the skirt diameter is affected by the skirt physical\ı3lfaracteristicsi.e. if the skirt is a 'solid tube or if it is made up of a wire cage. Wire c~ges Iıave a physical diameter but the effective diameter depends on the physical cage ciianieterand the number and diameter of cage wires. As the number of wires is incfeased, the effective cage diameter approaches the physical diameter. This result is affedtedby the antenna metallic support because it is. pl~ped within the cage axis. A case.{q:f"Jlfeoretica1hput impedance as a function of HIA can be seen below in (figure 4.3a)(fiğure 4.3b).

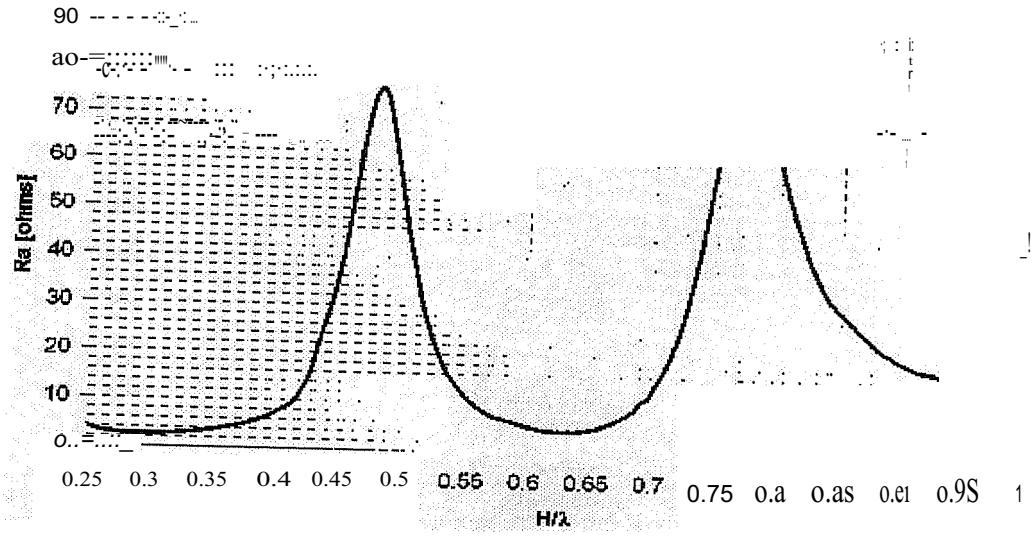


Fig 4.3a Grounded vertical dipôleiıputfesistance as a function of *HIA*

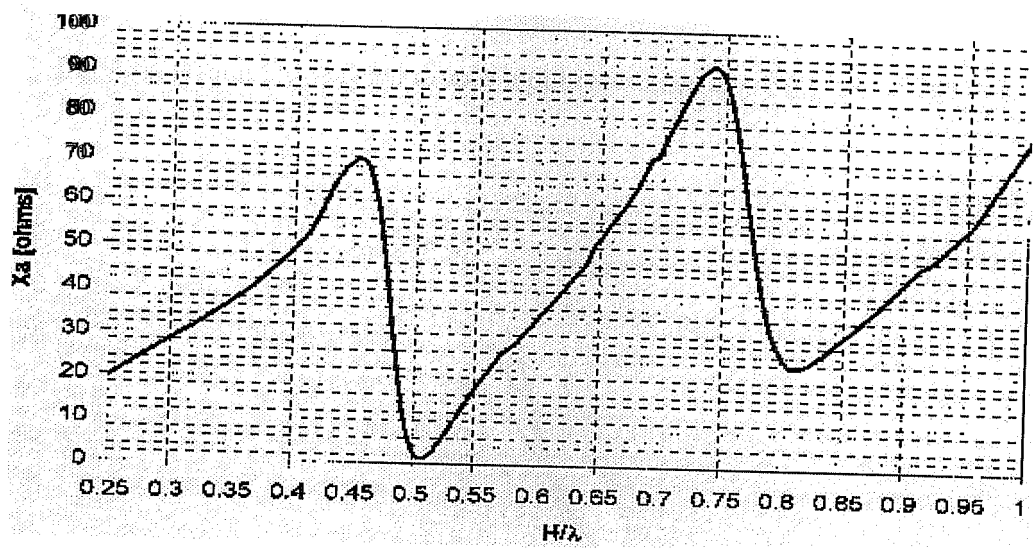


Fig 4.3b Grounded vertical dipole inputtesistance ias a function of *HIA* with different valtıeôfH

(Figure 4.4a,b,c,d) as it shows below theoretical input impedance values of a dipole model as a function of the distance from the skirt-dipole connection and for a fixed skirt diameter. At the same time input impedance asa function of skirt, physical diameter can be seen. From this analysis an input close to 50 ohms impedance and practically resistive values are obtained for a chosen operation frequency. Impedance with practically resistive values is obtained by modifying the skirt diameter and the feeding

point position in order that reactive values are close to zero. This possibility generally could not be the optimum bandwidth for the radiating system but the optimum for a narrow band device.

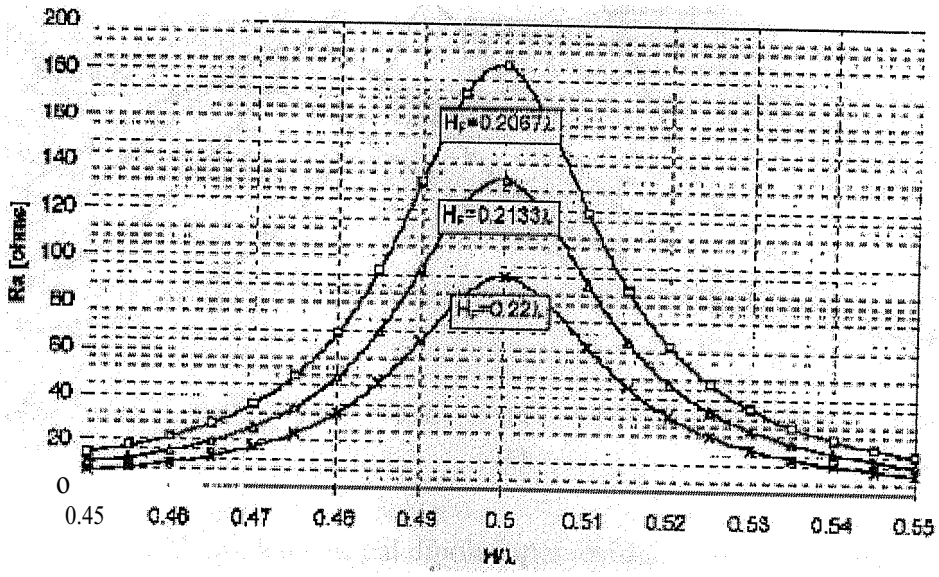


Fig 4.4a Grounded vertical dipole input resistance as a function of feeding

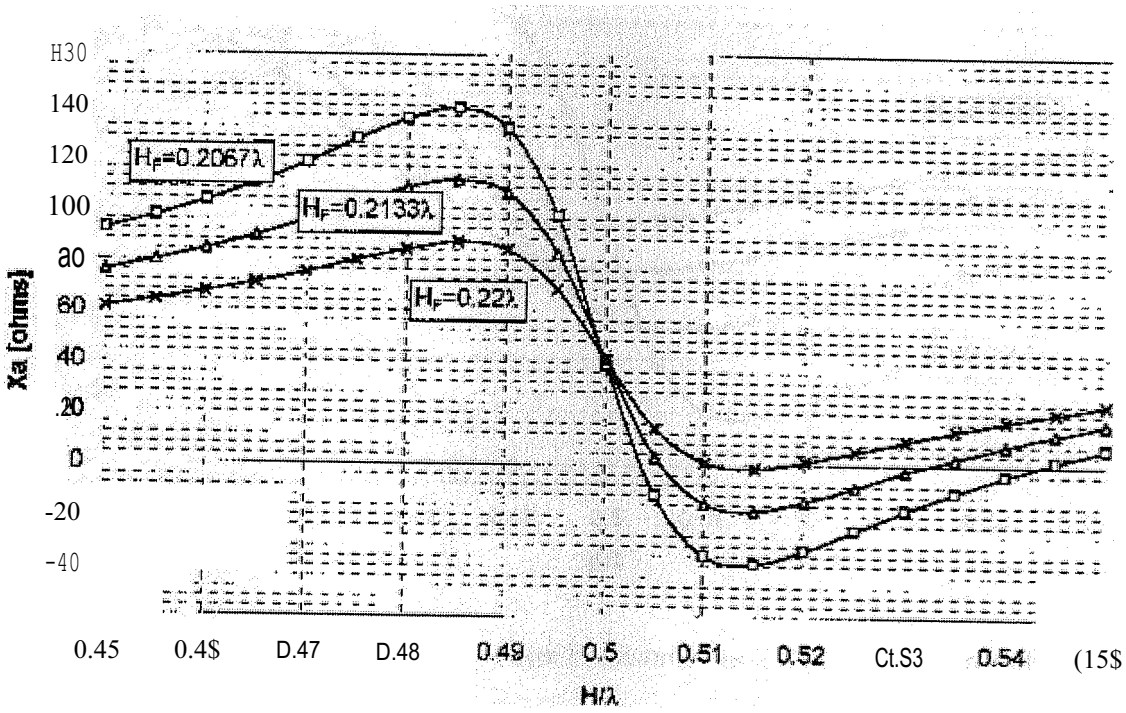


Fig 4.4b Grounded vertical dipole iripupesistance as a function of feeding

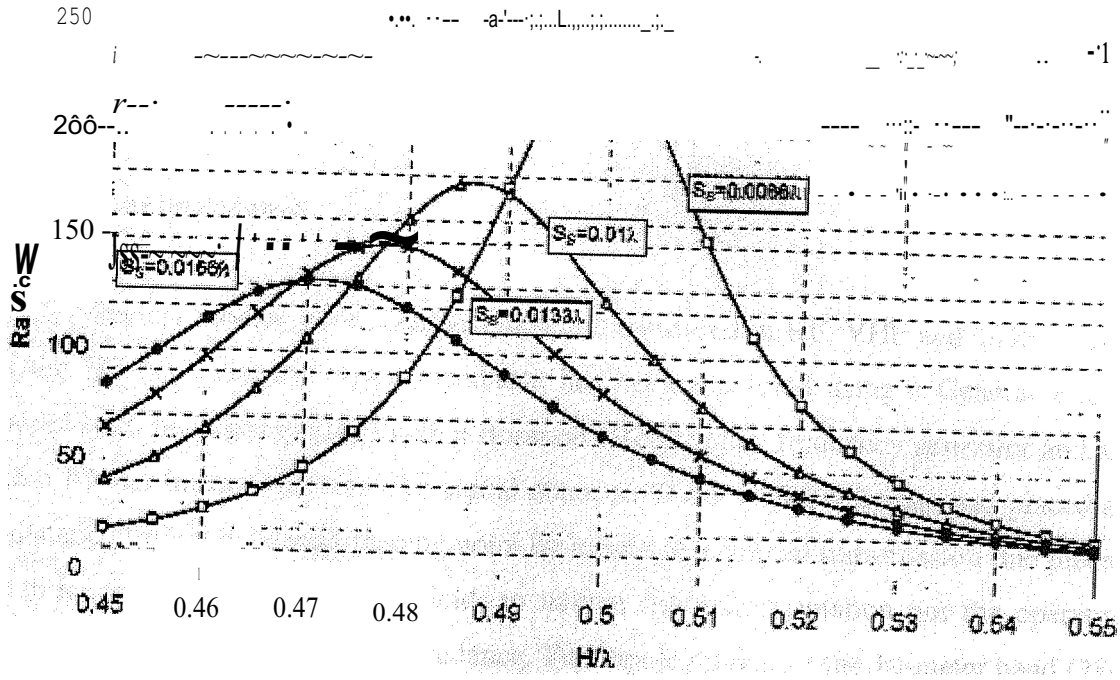


Fig 4.4c Grounded vertical dipole input resistance as skirt radius

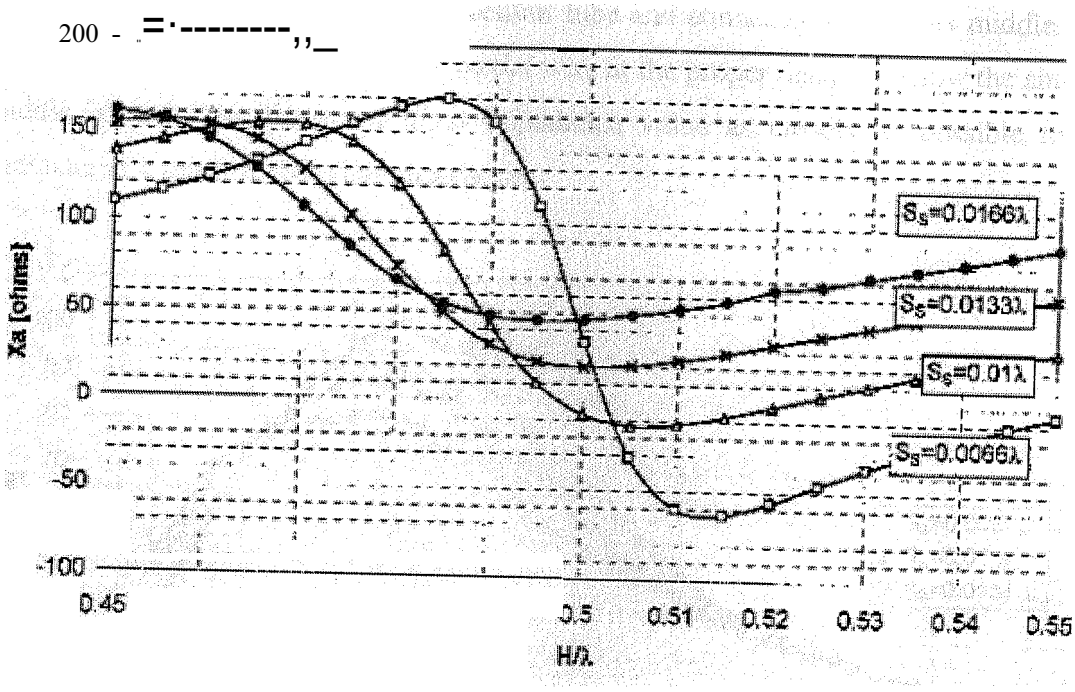


Fig 4.4d Grounded vertical dipole input.resistaıice as a function of skirt radius

For a low power comtnuriication, system<a staridiňg wave ratio lower thari two' is considered adequate. From this standard, a very good antenna bandwidth can be achieved. (Maximum reflection loss = 0.50 dB). Input impedance values. show two resistance and reactance peaks. Between them there is a zone of low impedance when

analyzed as a function of frequency. This behavior permits a wider band of operation compared to a very low VSWR close to the zero reactance operation, but this depends on the maximum VSWR tolerated value.

4.2 Input impedance

Several models have been designed and measured in HF, VHF and UHF bands. in the HF band antenna input impedance has been measured using a General Radio model 1606 impedance bridge with a Boonton 102-D digital frequency generator and an Icom IC-726 transceiver used as a signal detector. The impedance bridge was placed at a distance from the anten.nafeeding point by means of a coaxial transmission line piece, in order not to disturb the near field, so neither the instrumentation nor the operator could affect the actııal-amenna impedance. The dipole model for the 10-meter band (28-30 MHz) was desiğrı~d. and constructed with an aluminum tube representing a mechanical as well as an electrical structure. The skirt was made up by 4 copper wires symmetrically placed all around the central tube and connected to it at its middle. The four wires are connected to the hot coaxial wire at the proper distance below the antenna middle in order to obtain an input impedance value as closely as possible to the characteristic transmission line impedance.

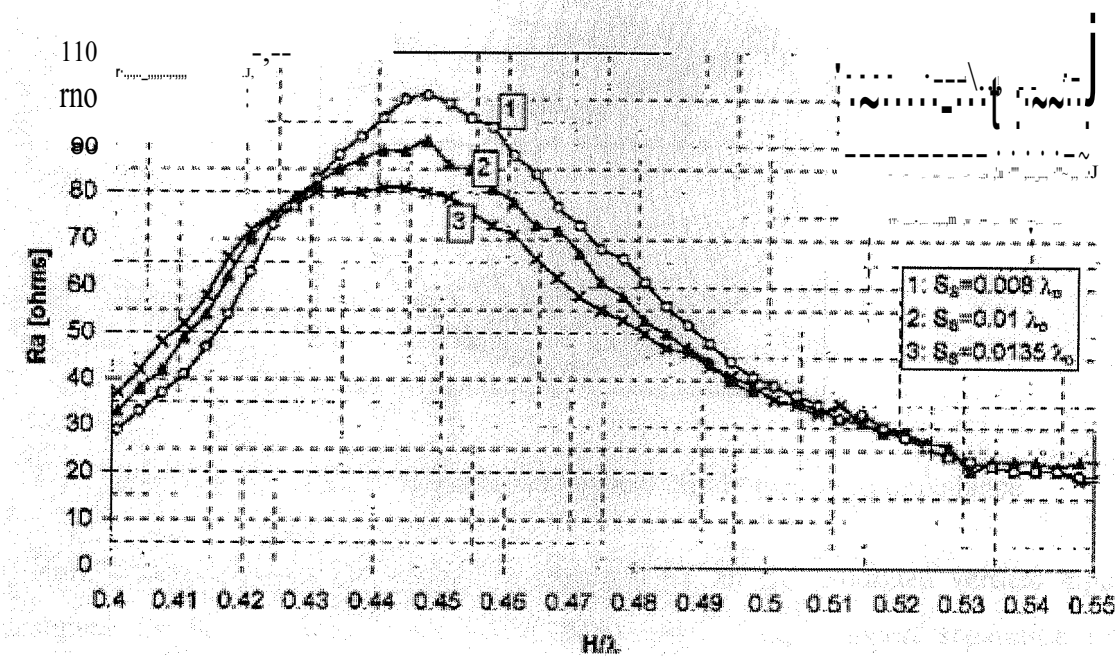


Fig 4.5a 10-meter grounded vertical dipole model measured input resistance as a function of skirt radius

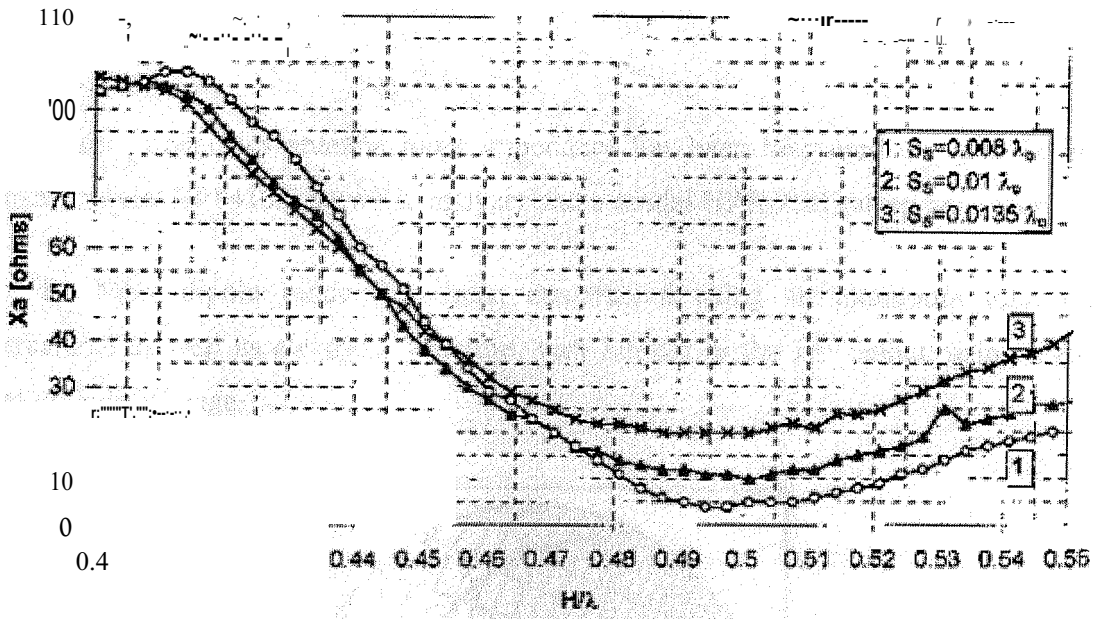


Fig 4.Sb 10-meter grounded vertical dipole model measured input resistance as a function of skirt radius

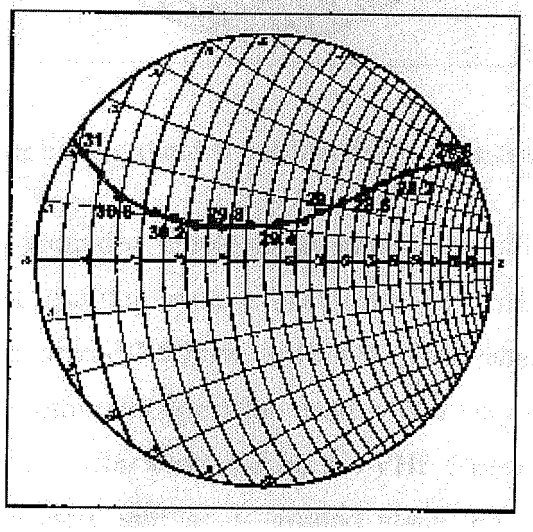


Fig 4.Sc 10-meter band groıuıdedvertib'aLdipole measured impedance

(Figure 4.5a,b,c) shows the 'impedanôe o'ötai:ıiedför aıı HF grounded vertical dipole designed for the 1O-meter band (28-30 MHz) during skirt-support separation (Ss) modifications. Values obtained can be compares with theprevious calculations, and it can be point out that experimental values have fewer excursions than theoretically predicted. Optimum values are seen plotted on a maximum VSWR=2 Smith chart. The

obtained bandwidth is around 3.6 MHz or 12.3 percent fora standing wave ratio lower than 2.

For higher frequencies antenna input ımpedance has been measured using a Hewlett Packard model HP8410A rietworkanalyzer and a model HP8620C sweep generator.

The 50 MHz dipole model has been constructed using aıı altıminum tube like mechanical as well as electrical structure, very similar to the HF nıodel, using a four wire cylindrical cage.

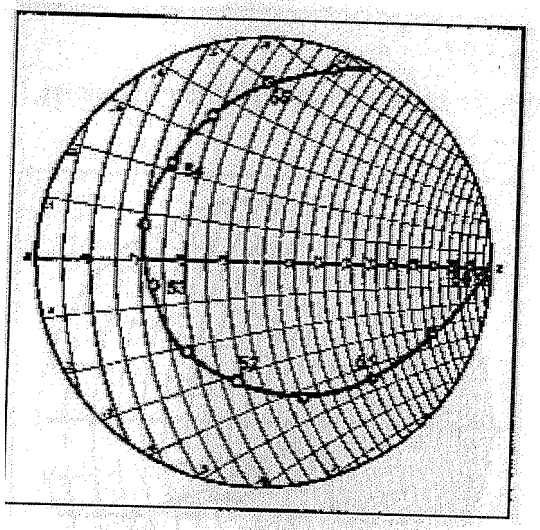


Fig 4.6 6-meter band grounded vertical dipole measured impedance

(Figure 4.6) shows the grounded dipole input impedance of a ô-meter band (50-54 MHz) radio beacon. The resulting antenna bandwidth for a standing wave ratio lower than 2 gives a bandwidth around 5.5 MHz or 10.4 %. This value permits the possibility of changing frequencies within the operation band with a very low radiation efficiency loss. Designs for' the HF 10 metef l:farid and for the VHF 6nıeter band ate ifüended use the soil or the home concrete ·röôf as its ğrôuind pla:ifo. For higher freqtiencies, the antenna design could be for a vertical dipoleinfree space i.e. at several' vvavelengths over ground in order to obtain an omni directiônaFvertical polarized a.füerifürö:r över a vehicle metallic skin intended for mobile öfSpace<cö:rrinıunication use.

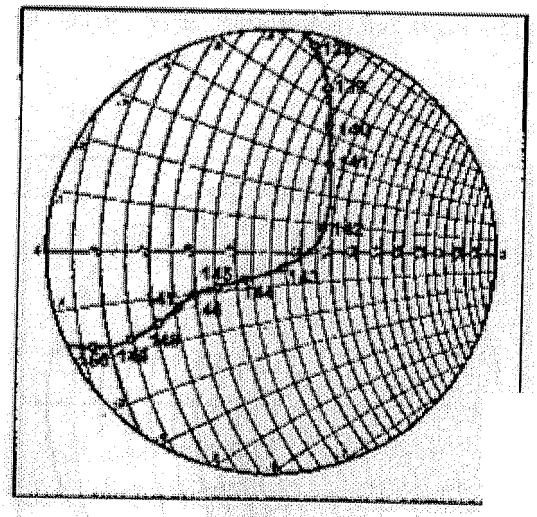


Fig 4.7a 2-rneter band grounded vertical dipole measured irnpedance, in free space

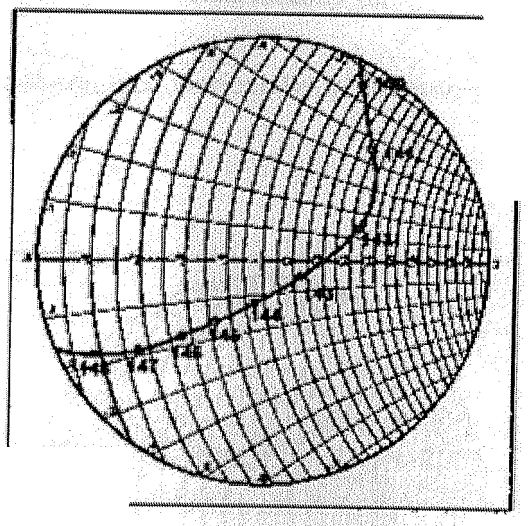


Fig 4.7b 2-rneter band grounded vertical dipole measured impedance, over a metallic ground plane

Irnpedance values for a 2-rneter band vettipğf:{.<iipple.model (144-148 MHz) were rneasured over a rnetallic ground plane and)itı. fr~e space. Very low differences in the inptit ·impedance were computed/'This shcrw§)•iffe(§'rtHilf ground plane in.fliıerı& örı the dipole characteristics. The results reflecta.fypı~ttf/ôipole behavior because displacernent currents are rnaking loops around the dip~l~>t~~nly a few lines are intercepting the ground plane. For both cases input irnpedaıçeresults are shown in (figure 4.7a,b) in free space rneasured irnpedance in the antenn.a.feedingpoints are shown as a wider band case (VSWR lower than 2) and a narrower barrd case of input irnpedance for the ground

Taking into account a standing wave ratio of 2, like a maximum VSWR, a 44 MHz bandwidth has been measured in free space (11%). Center frequency with minimum VSWR around 1.23 is 398 MHz. placing the dipole over a metallic ground plane produces a center frequency of 391 MHz, VSWR 1.17 and bandwidth of 40 MHz (10%).

Nevertheless, in the 400 MHz model,/an additional portion of spectrum could be covered at higher frequericies with a ~~;-~~=~rth.an 2 and with a 50 MHz additional bandwidth (12%) with a 515 MHz centerf~yquency anda VSWR 1.14. In the metallic ground plane case.rthis additiönal bartdwidthlıas a center frequency at 595 MHz with a VSWR of 1.2 and bandwidth is 34 MHz (Ş.596).

These results are due to the dipole behavior as a function of frequency where the input resistance and .reaetance have several maximums and minimums from the first one, close to half a wavelength. This additional low VSWR behavior at higher frequencies can be useful for several applications especially for wide band communications. In the case of a higher frequency dipole, these impedance variations are lower than in the thinner low frequency dipoles and wider bandwidth can be achieved, specially when both useful spectrum portions can be both unified within a Smith chart region with a VSWR lower than 2.

Of course, dipole broad banding would be an additional work for the near future where dipole dimensions will be analyzed accordingly in order to maximize the frequency bandwidth for a ırıaximum of 2 VSWR.

4.3 Radiation patterns

Radiation pattem measurernents ih.ithe/HF bands is a difficult task, for this reason radiation pattems have been measured.j11. aıianechoic chamber within the UHF region by means ofa Scientific .Atlan.ta rn6deF1783 receiver and a model 2151 signal generator.

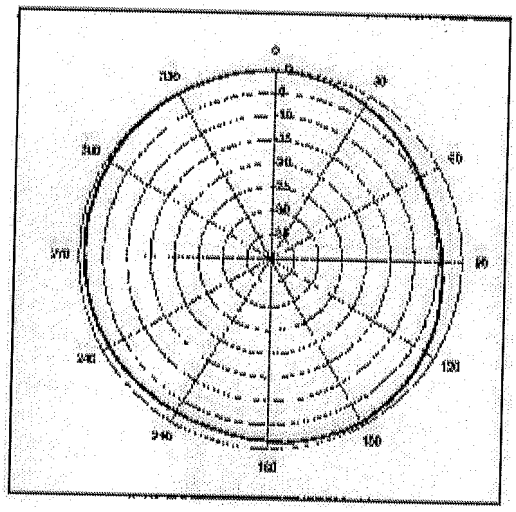


Fig 4.9a 400MHZ.lnıncl.gtpundedvertiqaldip9le measured azimuthal radiation pattem

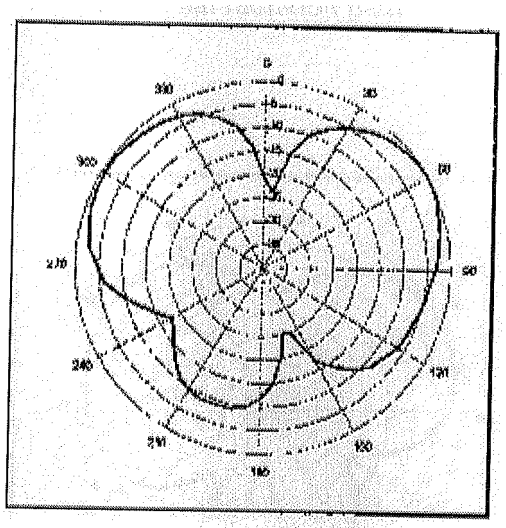


Fig 4.9b 400MHZ band grounded vertical dipole measured elevation radiation pattern

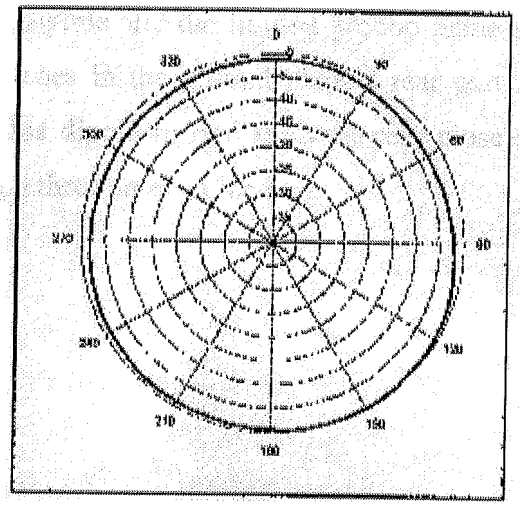


Fig 4.9c 400MHZ grounded vertical dipole placed over metallic ground plane measured azimuthal radiation pattern

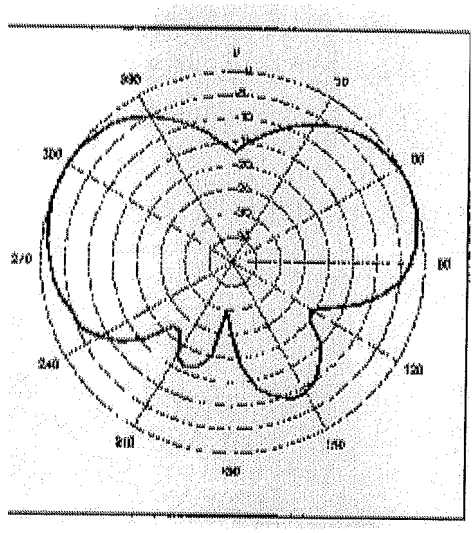


Fig 4.9d 400MHz grounded vertical dipole placed over metallic ground plane measured elevation radiation pattern

(Figure 4.9a,b,c,d)shows a grounded vertical dipole radiation pattem in the 400 MHz band in the horizontal and vertical plane. In the vertical plane some pattem distortions can be seen possibly due to the interactiofrhet~ieh ~ipole and the coaxial transmission line and very good omni directionality in the horizontal plane where this interaction is minimum. In the same figure when a verticaf dipole is placed over a metallic ground plane its vertical radiation pattem can be seen. In this latter case the transmission line

interaction is almost negligible and the limited ground plane size diffraction effect can be clearly seen giving lobes in the ground plane's rear part.The measured gain in an anechoic chamber for this dipole in free space is very close to 2 dBi in the radiation pattem maximum using a three antenna method.

CONCLUSION

There are three major types of radios in use: HF, VHF and UHF. The HF waves do not bounce very well, and can only reflect off by big things like the surface of the Earth or the ionosphere. VHF waves bounce off mountains and big buildings. UHF waves can bounce off walls. Therefore, the High Frequency (HF) radios are best for communications between distant locations such as Siple Dome and McMurdo Station. Very High Frequency (VHF) radios are for medium-distance line-of-sight communications. Two groups near each other but separated by hills or mountains cannot communicate via VHF, except via a repeater, which receives and re-transmits signals.

UHF is used for radio telephones or "optic phones," which connect with a normal telephone but do not use telephone wires for a portioti of the communication. Camps in the Dry Valleys use radiotelephones. As with VHFfadios, UHF radio telephones require a line-of-sight transmission Ofa repeater.

Its found that the main advantage of UHF transmission is that its high frequency as it has a physically short wave. Since the size of transmission and reception equipment (particularly antennas) is related to the size of the wave, smaller, less conspicuous antennas can be used than with VHF Of lower bands.

Using sky waves can be tricky, since the ionosphere is constantly changing. Sky wave propagation is generally not available in the VHF and UHF frequency bands. Modulation is the process whereby the phase, amplitude, Of frequency of a carrier signal is modified to convey information, Radio signals radiate outward, Of propagate, from a transmitting antenna at tlıe speed of light.

A grounded dipolar radiating structure has been designed, constructed and measured showing electromagnetic results very similar than the traditional vertical series fed dipole.

This type of grounded structure cou.ldbe µseful to avöid statfo effects fôfhighyelücity vehicles or in environments whefe the)' afe boinbarded by high-energy particles in vacuum while maintaining the radiation characteristics.

A reasonable band with>clöse to 10% in each measured model and band can be easily achieved withoıt any special tuning device making this dipole a simple and practical structure to be implemented.

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