NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

AN EXPERIMENTAL STUDY ON UHF AND LOG-PERIODIC ANTENNAS

GRADUATION PROJECT
EE-400

Student : Ziauddin Ahmad Siddiqui (971389)

Supervisor : Assist. Prof. Dr. Kamil Dimililer

Lefkosa – 2000

ACKNOWLEDGEMENTS

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The antenna and all instruments used in this project were conducted in B.R.T, which is a local radio and television channel here in Northern Cyprus.

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Later on when computers were introduced, the theory of antennas was again revived. With this new power tool, new numerical techniques were used through computers that solved mathematical problems which were previously unsolved.

Since Hertz and Marconi, antennas have become increasingly important to our society until now they are indispensable. They are everywhere, our homes and workplaces, on our cars and aircraft, while our ships, satellites and spacecraft bristle with them. Even as pedestrians, we carry them.

Although antennas may seem to have a bewildering, almost infinite variety. They all operate according to the same basic principles of electromagnetics. The aim of this book is to explain these principles in the simplest possible terms and illustrate them with many practical examples. In some situations intuitive approaches will suffice while in others complete rigor is needed. The book provides a blend of both with selected examples illustrating when to use one or the other.

This chapter provides an historical background while Chap. 2 gives an introduction to basic concepts. The chapters that follow develop the subject in more detail.

1-2 THE ORIGINS OF ELECTROMAGNETIC THEORY AND THE FIRST ANTENNAS

Six hundred years before Christ, a Greek mathematician, astronomer and philosopher, Thales of Miletus, noted that when amber is rubbed with silk it produces sparks and has a seemingly magical power to attract particles fluff and straw. The Greek word for amber is *elektron* and from this we get our words *electricity, electron* and *electronics*. Thales also noted the attractive power between pieces of a natural magnetic rock called loadstone, found at a place called *Magnesia,* from which is derived the words *magnet* and *magnetism.* Thales was a pioneer in both electricity and magnetism but his interest, like that of others of his time, was philosophical rather than practical, and it was 22 centuries before these phenomena were investigated in a serious experimental way.

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Maxwell unified electromagnetics in the same way that Isaac Newton unified mechanics two centuries earlier with his famous Law of Universal Gravitation governing the motion of all bodies both terrestrial and celestial,

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Early in the 1880s the Berlin Academy of Science had offered a prize for research on the relation between electromagnetic forces and dielectric polarization. Heinrich Hertz considered whether the problem could be solved with oscillations using Leyden jars or open induction coils. Although he did not pursue this problem, his interest in oscillations had been kindled and in 1886 as professor at the Technical Institute in Karlsruhe he assembled apparatus we would now describe as a complete radio system with an end-loaded dipole as transmitting antenna and a resonant square loop antenna as receiver. When sparks were produced at a gap at the center of the dipole, sparking also occurred at a gap in the nearby loop. During the next 2 years. Hertz extended his experiments and demonstrated reflection, refraction and polarization, showing that except for their much greater length, radio waves were one with light. Hertz turned the tide against Maxwell around.

Hertz's initial experiments were conducted at wavelengths of about 8 meters while his later work was at shorter wavelengths, around 30 centimeters. Figure 1-1 shows Hertz's earliest 8-meter system and Fig. 1-2 a display of his apparatus, including the cylindrical parabolic reflector he used at 30 centimeters.

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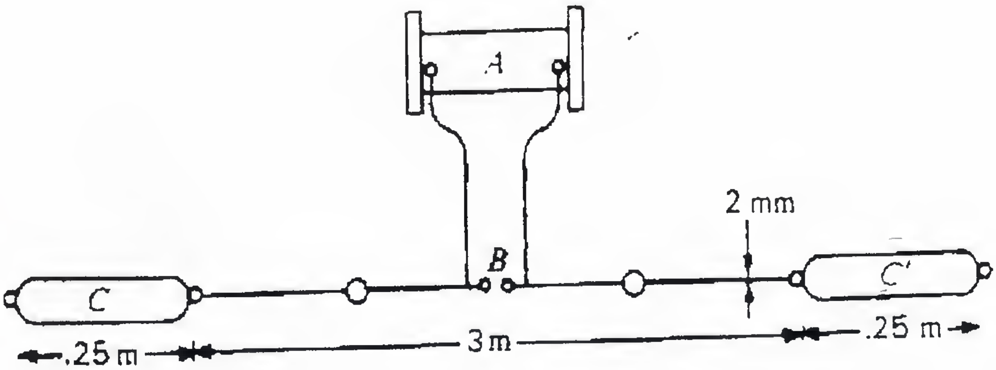

Figure 1-1 Heinrich Hertz's complete radio system of 1886 with end-loaded dipole transmitting antenna

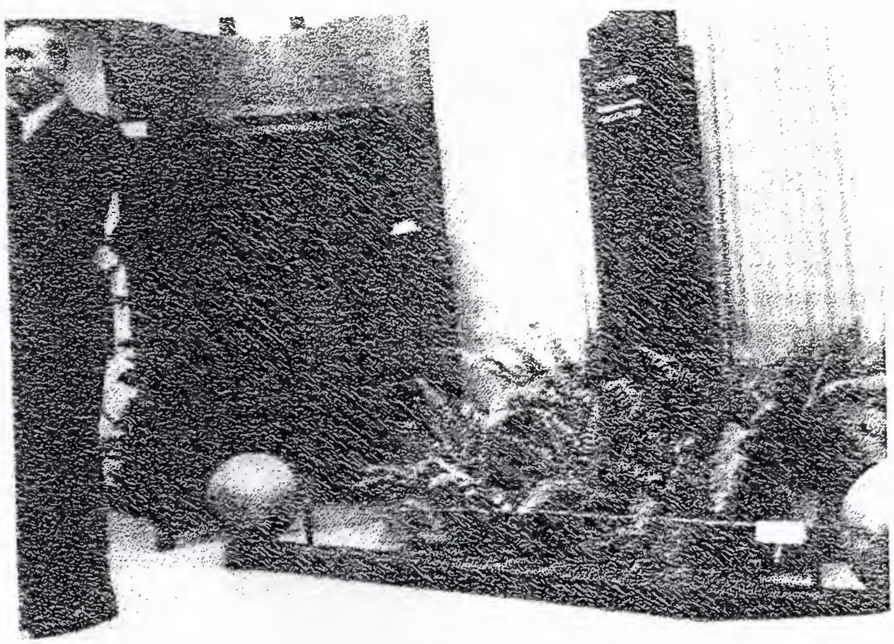

Figure 1-2 Hertz's sphere-loaded λ/ 2 dipole and spark gap (resting on floor in foreground) and cylindrical parabolic reflector for 30 centimeters (standing at left). Dipole with spark gap is on the parabola focal axis.

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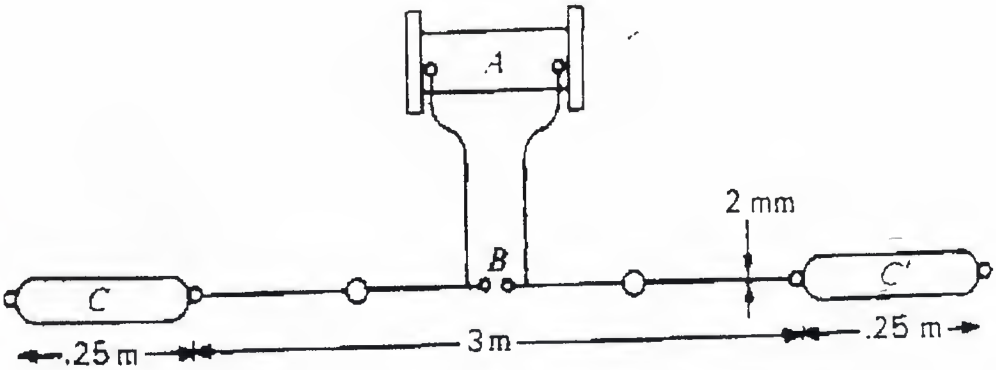

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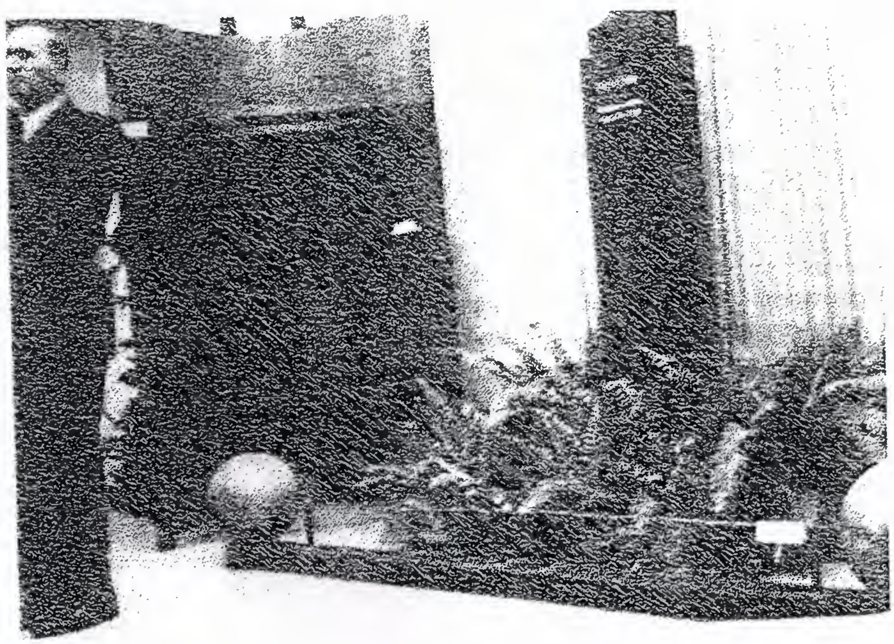


Figure 1-2 Hertz's sphere-loaded λ/ 2 dipole and spark gap (resting on floor in foreground) and cylindrical parabolic reflector for 30 centimeters (standing at left). Dipole with spark gap is on the parabola focal axis.

Marconi quickly went on to add tuning, big antenna and ground systems or longer wavelengths and was able to signal over large distances. In mid-December 1901, he startled the world by announcing that he had received radio signals at St. John's, Newfoundland, which had been sent across the Atlantic from a station he had built at Poldhu in Cornwall, England. The scientific establishment did not believe his claim because in its view radio waves, like light, should travel in straight lines and could not bend around the earth from England to Newfoundland. However, the Cable Company believed Marconi and served him with a writ to cease and desist because it had a monopoly on transatlantic communication. The Cable Company's stock had plummeted following Marconi's announcement and it threatened to sue him for any loss of revenue if he persisted. However, persist he did, and a legal battle developed that continued for 27 years until finally the cable and wireless groups merged.

One month after Marconi's announcement, the American Institute of Electrical Engineers (AIEE) held a banquet at New York's Waldorf-Astoria to celebrate the event. Charles Protius Steinmetz, President of the AIEE, was there, as was Alexander Graham Bell, but many prominent scientists boycotted the banquet. Their theories had been challenged and they wanted no part of it.

Not long after the banquet, Marconi provided irrefutable evidence that radio waves could bend around the earth. He recorded Morse signals, inked automatically on tape, as received from England across almost all of the Atlantic while steaming aboard the SS Philadelphia from Cherbourg to New York. The ship's captain, the first officer and many passengers were witnesses.

A year later, in 1903, Marconi began a regular transatlantic message service between Poldhu, England, and stations he built near Glace Bay. Nova Scotia, and South Wellfleet on Cape Cod.

In 1901, the Poldhu station had a fan aerial supported by two 60-meter guyed wooden poles and as receiving antenna for his first transatlantic signals at St. John's, Marconi pulled up a 200-meter wire with a kite, working it against, an array of wires on the ground. A later antenna at Poldhu, typical of antennas at other Marconi stations, consisted of a conical wire cage. This was held up by four massive self-supporting 70-meter wooden towers (Fig. 1-3). With inputs of 50 kilowatts, antenna wires crackled and glowed with corona at night, Local residents were sure that such fireworks in the sky would alter the weather.

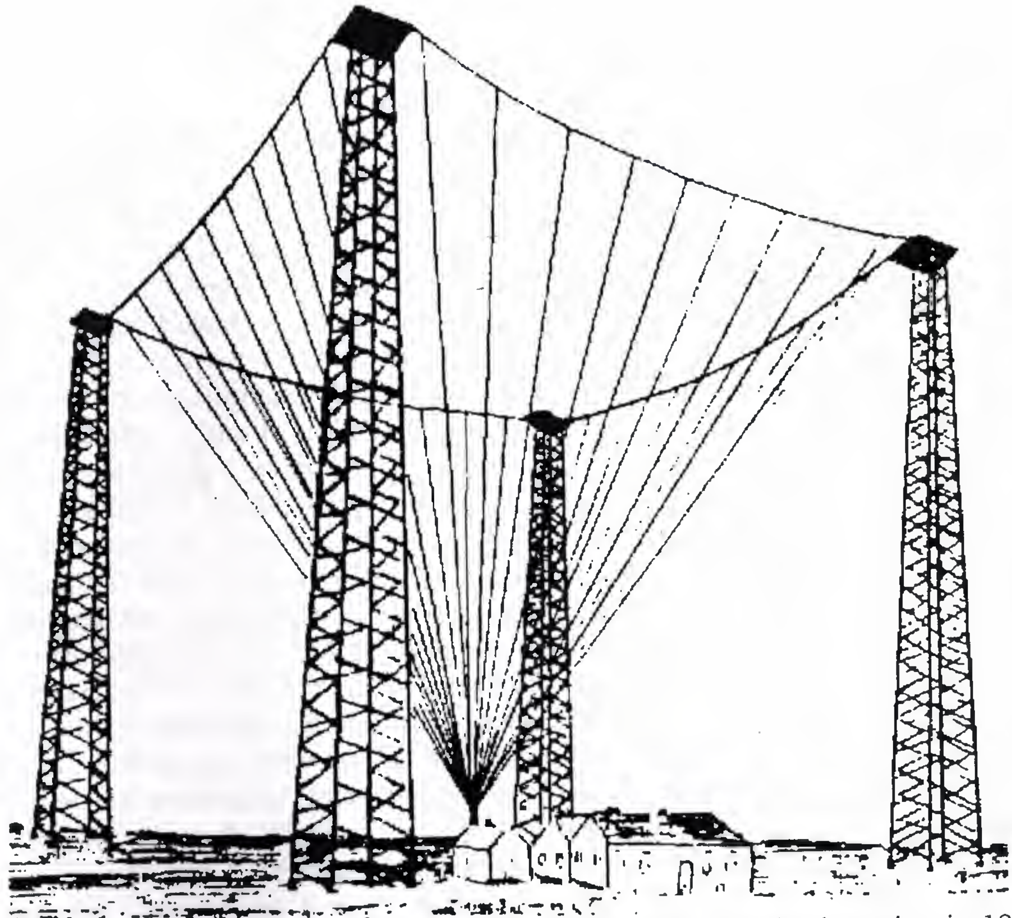


Figure 1-3 Square-cone antenna at Marconi's Poldhu, England, station in 1905. The 70-meter wooden lowers support a network of wires which converge lo a point just above the transmitting and receiving buildings between the towers.

Rarely has an invention captured the public imagination like Marconi's wireless did at the turn of the century. We now call it radio but then it was wireless: Marconi's wireless. After its value at sea had been dramatized by the *SS Republic* and *SS Titanic* disasters, Marconi was regarded with a universal awe and admiration seldom matched. Before wireless, complete isolation enshrouded a ship at sea. Disaster could strike without anyone on the shore or nearby ships being aware that anything had happened. Marconi changed all that. Marconi became the Wizard of Wireless.

Although Hertz had used 30-centimeter wavelengths and Jagadis Chandra Bose and others even shorter wavelengths involving horns and hollow waveguides, the distance these waves could be detected was limited by the technology of the period so these centimeter waves found little use until much later. Radio developed at long wavelengths with very long waves favored for long distances. A Popular " rule-of-thumb " of the period was that the range which could be achieved with adequate power was equal to 500 times the wavelength. Thus, for a range of 5,000 kilometers, one required a wavelength of 10,000 meters.

At typical wavelengths of 2,000 to 20,000 meters, the antennas were a small Fraction of a wavelength in height and their radiation resistances only an ohm or less. Losses in heat and corona reduced efficiencies but with the brute power of many kilowatts, significant amounts were radiated. Although many authorities favored very long wavelengths, Marconi may have appreciated the importance of radiation resistance and was in the vanguard of those advocating shorter wavelengths, such as 600 meters. At this wavelength an antenna could have 100 times its radiation resistance at 6,000 meters.

In 1912, the Wireless Institute and the Society of Radio Engineers merged to form the Institute of Radio Engineers. In the first issue of the Institute's *Proceedings,* which appeared in January 1913, it is interesting that the first article was on antennas and in particular on radiation resistance. Another *Proceedings* article noted the youthfulness of commercial wireless operators. Most were in their late teens with practically none over the age of 25. Wireless was definitely a young man's profession.

The era before World War I was one of long waves, of spark, arc and alternators for transmission and of coherers. Fleming valves and De Forest audions for reception. Following the war, vacuum tubes became available for emission: continuous waves replaced spark and radio broadcasting began in the 200 to 600-meter range.

Wavelengths less than 200 meters were considered of little value and were deflated to the amateurs. In 1921, the American Radio Relay League sent Paul Godley to Europe to try and receive a Greenwich, Connecticut, amateur station operating on 200 meters. Major Edwin H. Armstrong, inventor of the super-heterodyne receiver and later of FM, constructed the transmitter with the help of several other amateurs. Godley set up his receiving station near the Firth of Clyde in Scotland. He had two receivers, one a 10-tube super-heterodyne, and a Beverage antenna. On December 12, 1921, just 20 years to the day after Marconi received his first transatlantic signals on a very long wavelength, Godley received messages from the Connecticut station and went on to log over 30 other U.S. amateurs. It was a breakthrough, and in the years that followed, wavelengths from 200 meters down began to be used for long-distance communication.

Atmospherics were the bane of the long waves, especially in the summer. They were less on the short waves but still enough of a problem in 1930 for the Bell Telephone Laboratories to have Karl G. Jansky study whether they came from certain predominant directions. Antennas for telephone service with Europe might then be designed with nulls in these directions.

Jansky constructed a rotating S-element Bruce curtain with a reflector operating at 14 meters (Fig. 1-4). Although he obtained the desired data on atmospherics from thunderstorms, he noted that in the absence of all such static there was always present a very faint hiss like noise or static which moved completely around the compass in 24 hours. After many months of observations, Jansky concluded that it was coming from beyond the earth and beyond the sun. It was a cosmic static coming from our galaxy with the maximum from the galactic center. Jansky's serendipitous discovery of extraterrestrial radio waves opened a new window on the universe. Jansky became the father of radio astronomy.

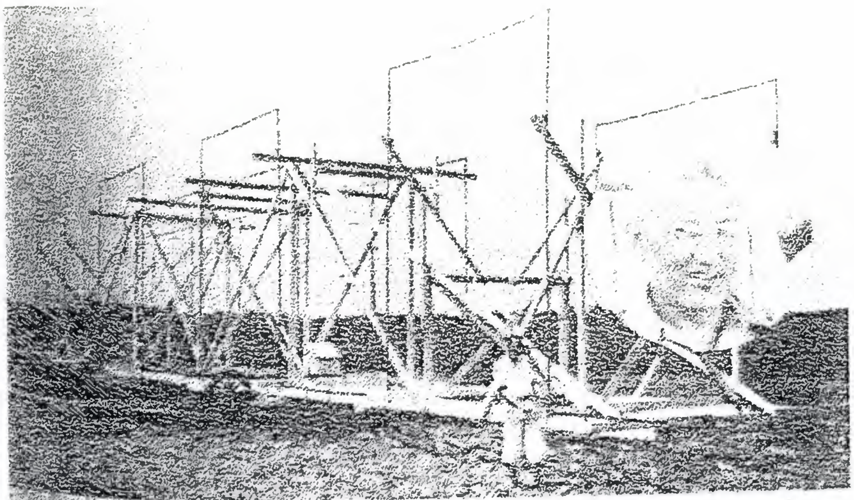


Figure 1-4 Karl Guthe Jansky and his rotating Bruce curtain antenna with which he discovered radio emission from our galaxy.

Jansky recognized that this cosmic noise from our galaxy set a limit to the sensitivity that could be achieved with a short-wave receiving system. At 14 meters this sky noise has an equivalent temperature of 20,000 kelvins. At centimeter wavelengths it is less, but never less than 3 kelvins. This is the residual sky background level of the primordial fireball that created the universe as measured four decades later by radio astronomers Arno Penzias and Robert Wilson of the Bell Telephone Laboratories at a site not far from the one used by Jansky.

For many years, or until after World War II, only one person, Grote Reber, followed up Jansky's discovery in a significant way. Reber constructed a 9-meter parabolic reflector antenna (Fig. 1-5) operating at a wavelength of about 2 meters which is the prototype of the modern parabolic dish antenna. With it he made the first radio maps of the sky. Reber also recognized that his antenna-receiver constituted a radiometer i.e., a temperature-measuring device in which his receiver response was related to the temperature of distant regions of space coupled to his antenna via its radiation resistance.

With the advent of radar during World War II, centimeter waves, which had been abandoned at the turn of the century, finally came into their own and the entire radio spectrum opened up to wide usage. Hundreds of stationary communication satellites operating at centimeter wavelengths now ring the earth as though mounted on towers 36,000 kilometers high. Our probes are exploring the solar system to Uranus and beyond, responding to our commands and sending back pictures and data at centimeter wavelengths even though it takes more than an hour for the radio waves to travel the distance one way. Our radio telescopes operating at millimeter to kilometer wavelengths receive signals from objects so distant that the waves have been traveling for more than 10 billion years.

With mankind's activities expanding into space, the need for antennas will grow to an unprecedented degree, Antennas will provide the vital links to and from everything out there. The future of antennas reaches to the stars.

1-3 ELECTROMAGNETIC SPECTRUM.

Continuous wave energy radiated by antennas oscillates at radio frequencies. The associated free-space waves range in length from thousands of meters at the long-wave extreme to fractions of a millimeter at the short-wave extreme. The relation of radio waves to the entire electromagnetic spectrum is presented in Fig. 1-6. Short radio waves and long infrared waves overlap into a twilight zone that may be regarded as belonging to both.

The wavelength λ of a wave is related to the frequency f and velocity v of the wave by $\lambda = v/f$.

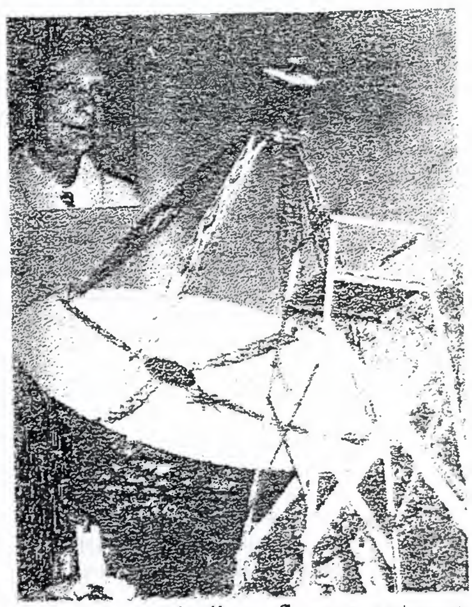


Figure 1-5 Grote Reber and his parabolic reflector antenna with which he made the first radio maps of the sky. This antenna, which he built in 1938, is the prototype of the modern dish antenna.

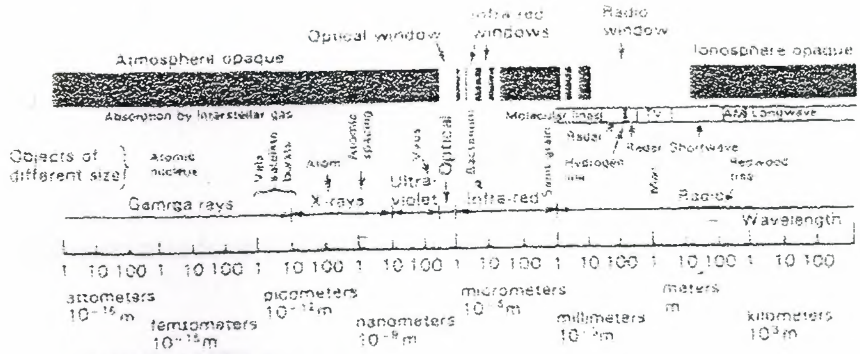


Figure 1-6 The electromagnetic spectrum with wavelength on a logarithmic scale from the shortest gamma rays lo the longest radio waves. The atmospheric-ionospheric capacity is shown at the top with the optical and radio windows in evidence.

Thus, the wavelength depends on the velocity v, which depends on the medium. In this sense, frequency is a more fundamental quantity since it is independent of the medium. When the medium is free space (vacuum) $v=c=3$ x 10s m/s.

A more detailed frequency use listing is given in Table 1-1.

Frequency	Wavelength	Band designation
30-300 Hz	10-1 Mm	ELF (extremely low frequency)
300-3000 Hz	1 Mm-100 km	
3-30 kHz	100-10 km	VLF (very low frequency)
30-300 kHz	10-1 km	LF (low frequency)
300-3000 kHz	1 km-100 m	MF (medium frequency)
3-30 MHz	100-10 m	HF (high frequency)
30-300 MHz	10-1 m	VHF (very high frequency)
300-3000 MHz	1 m-10 cm	UHF (ultra high frequency)
3-30 GHz	10-1 cm	SHF (super high frequency)
30-300 GHz	1 cm-1 mm	EHF (extremely high frequency)
300-3000 GHz	1 mm-100 μm	
Frequency	**Wavelength**	**IEEE Radar Band designation**
1-2 GHz	30-15 cm	L
2-4 GHz	15-7.5 cm	S
4-8 GHz	7.5-3.75 cm	C
8-12 GHz	3.75-2.50 cm	X
12-18 GHz	2.50-1.67 cm	Ku
18-27 GHz	1.67-1.11 cm	K
27-40 GHz	1.11 cm-7.5 mm	Ka
40-300 GHz	7.5-1.0 mm	mm

Table 1-1 Radio-frequency band designations

1-4 TYPES OF ANTENNAS

I will now introduce you to the various antenna types used at our present time.

1-4-1 WIRE ANTENNAS

Wire antennas, is one type of antenna that can't be missed. These types are situated everywhere you look. They are fixed on cars, buildings, planes, and spacecrafts, practically on every manmade object.

Wire antennas come in numerous shapes, the following is a list of it's types;

1) Straight Wire (dipole)
2) Loop
3) Helix

These three types of wire antennas are illustrated in figure 1-7. One point we should note is those loop wire antennas do not necessarily come in circular shapes. They can be in rectangular, square, ellipse or in any other shapes.

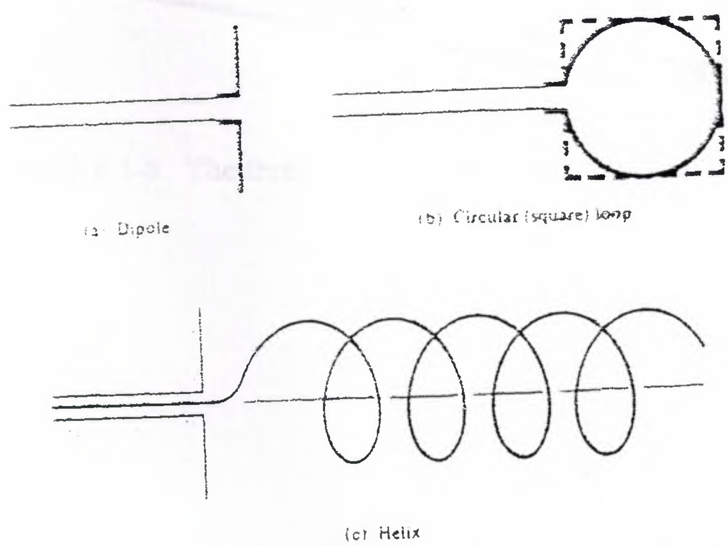


FIGURE 1-7 The different types of wire antenna configurartions.

1-4-2 APERTURE ANTENNAS

The aperture antenna is a sophisticated type of antenna. It is used in aircrafts and spacecrafts, and utilizes the higher frequency domain. The reasons for their use in aircrafts is because, they are easily flush mounted onto the body of the aircraft and are covered with a dielectric material, which protects them from the harsh environmental conditions. A few typical forms of aperture antennas are shown in figure 1-8.

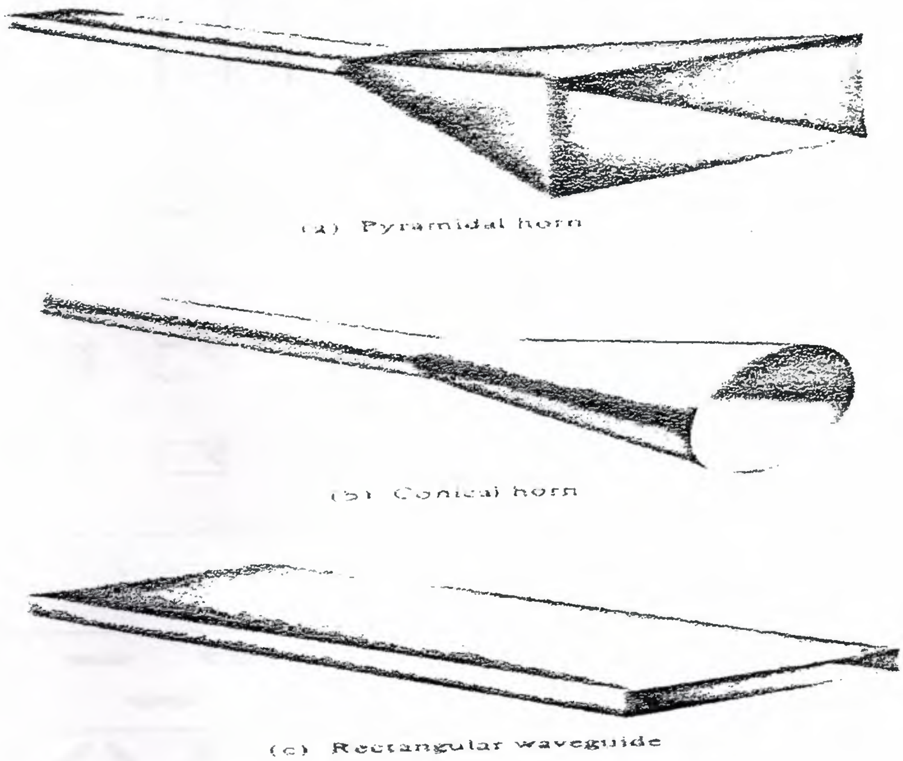


FIGURE 1-8. The three types of aperture antennas.

1-4-3 ARRAY ANTENNAS

The array antenna consists of numerous elements, that are arranged in such a way that they achieve a radiation maximum in a particular directions, while a minimum in others. A few typical examples of such antennas are shown in figure 1-9.

Figure 1-9(a) is known as the yagi-uda array. This is a very simple, but effective design that probably almost everyone is familiar with. It is used for receiving t.v. frequency signals, and is placed on top of everyone houses.

Note that the term array can also be used to describe an assembly of radiators mounted on a continuous structure, shown in figure 1-9(c).

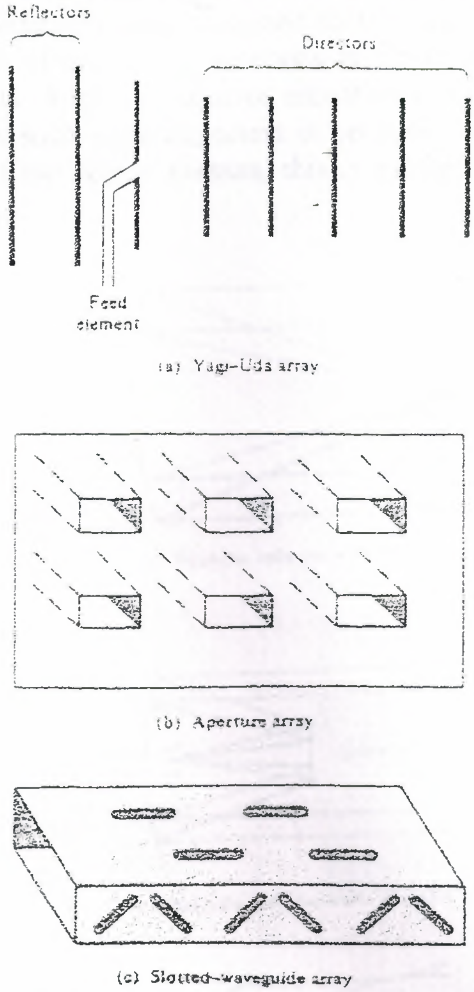


FIGURE 1-9 These are the basic types of wire and array antennas.

1-4-4 REFLECTOR ANTENNAS

The reflector antennas were developed as a result of the exploration of outer space. These antennas were designed to transmit and receive signals over distances that covered millions of miles. The antennas in figure 1-10(a) and (b) are some examples of reflector antennas. A typical reflector antenna has a diameter of 305m, the reason for these antennas to have such large diameters is because of the high gain needed. The antenna in figure 1-10(c) is the corner antenna, this is another form of the reflector antenna, which is not that common.

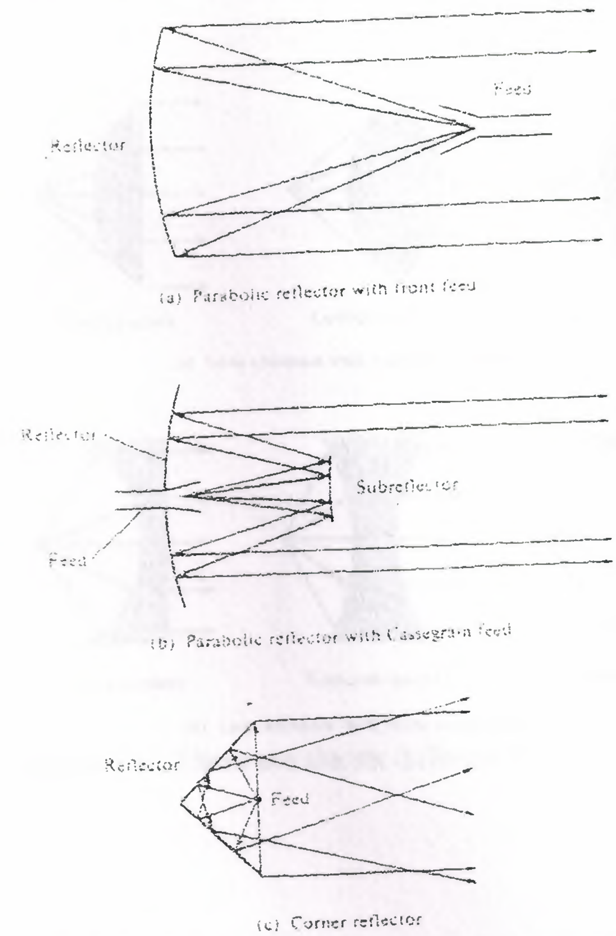


FIGURE 1-10 These are the three different kinds of reflector antennas.

1.4.2 LENS ANTENNAS

The lens antennas are used to converge the energy of the signal, in order it from spreading in undesired directions. When designing an antenna of this type, the geometrical shape and the material used are the two key factors that the designer has to keep in mind. These antennas are classified according to the material of construction and its shape. These antennas are used for similar purposes as the parabolic antennas.

A few examples of such are shown below in figure 1.11.

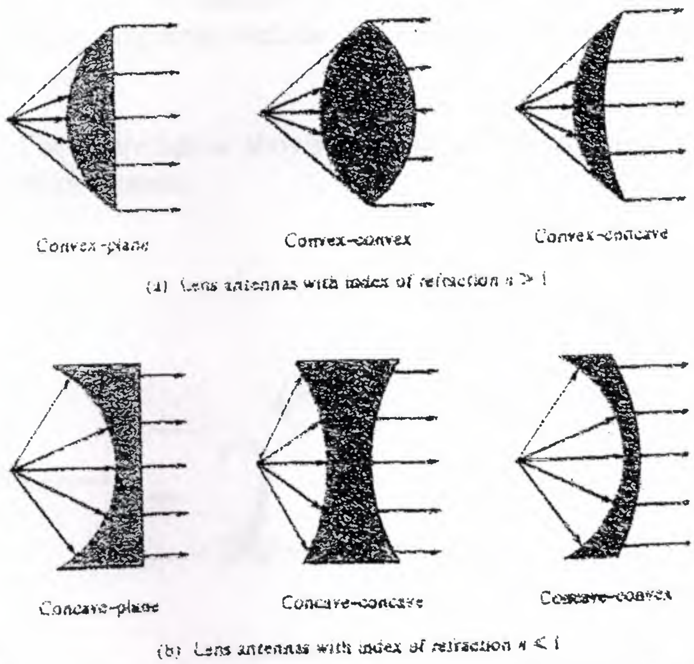


Figure 1.11 These are the six different kinds of lens antennas.

CHAPTER 2 FUNDAMENTAL PARAMETERS OF ANTENNAS

2-1 RADIATION PATTERN

The radiation pattern of any antenna can be described best as a graphical representation of the radiation properties of the antenna as a function of space coordinates. The radiation properties include radiation intensity, field strength, phase or polarization and constant radius.

The figure below shows the basic coordinate system used for analyzing the radiation pattern of an antenna.

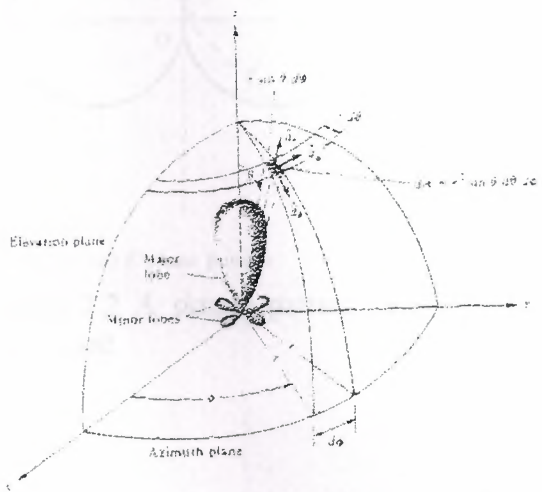


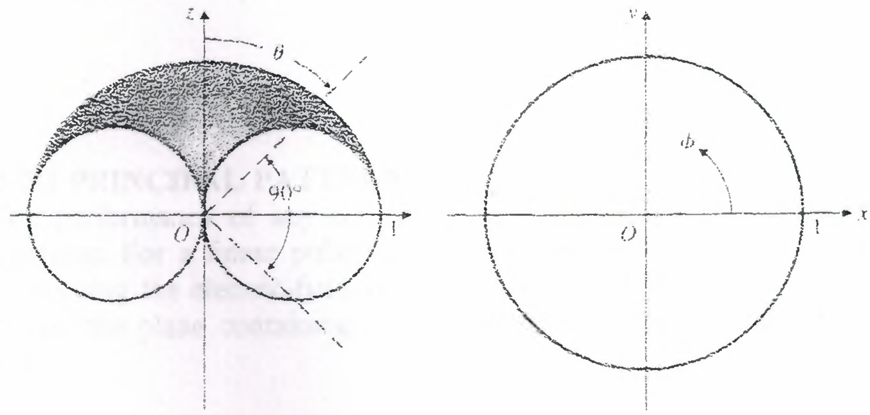
Figure 2.1 The coordinate system for antenna analysis.

The radiation pattern also called as the antenna pattern. These patterns are three-dimensional plots. Even though 3D plots are quite interesting to look at, the immense difficulty of drawing one can be avoided by splitting it into two 2D plots. These 2D plots represent the radiation pattern when looked at horizontally and vertically.

1) E-Plane/Vertical plane pattern - this plane represents the magnitude (r) versus θ for a constant Φ.

2) H-Plane/Horizontal plane pattern – this plane represents the magnitude (r) versus Φ for θ=π/2.

The two figures below illustrate the horizontal and vertical designs



(a) E-plane pattern. (b) H-plane pattern.

Figure 2.2 A simple pattern of a Hertzian dipole showing how the E and H-plane pattern are used.

2-2 ISOTROPIC, DIRECTIONAL AND OMNIDIRECTIONAL PATTERNS

The radiation patterns can be divided into three categories, which are, isotropic, directional and omnidirectional.

Isotropic patterns are basically the pattern of a hypothetical antenna having equal radiation in all directions, an example of such a radiator is a point source, although such a source cannot be physically realized, we use it as a reference for expressing the directive properties of practical antennas.

Directional patterns are made by antennas that have the property of radiating or receiving electromagnetic waves in some directions more effectively than in others.

An omnidirectional pattern is a specialized type of directional pattern.

2-2-1 PRINCIPAL PATTERNS

The performance of any antenna is normally described by it's principal E- and H-plane patterns. For a linear polarized antenna, the E-plane pattern can be defined as "the plane containing the electric-field vector and the direction of maximum radiation", and the H-plane as "the plane containing the magnetic-field vector and the direction of maximum radiation".

2-2-2 RADIATION PATTERN LOBES

The numerous parts of the radiation pattern are referred to as the lobes which fall into four categories;

1) Major Lobes
2) Minor Lobes
3) Side Lobes
4) Back Lobes

A radiation lobe refers to a portion of the radiation pattern bounded by regions of relatively weak radiation intensity. The following figure 2.3(a) illustrates all four lobe parts of a simple symmetric three-dimensional polar pattern. The second part of the figure shows the same lobe characteristics in a two-dimensional form.

The main lobe is called the major lobe and is defined as the radiation lobe containing the direction of maximum radiation. In both parts of figure 2.3, the main lobe is pointing in the direction of $\theta=0°$, there are some antennas that have more than one main lobe; one example is the split-beam antenna.

The minor lobe can be classified as any lobe other than the major lobe, so in the figure 2.3 all radiation lobes other than the major lobe can be called the minor lobes.

The side lobe is classified as a minor lobe which is any radiation lobe that is pointing in the any direction other than the intended, while a back lobe is a radiation lobe that occupies the hemisphere in a direction opposite to the direction of the major lobe.

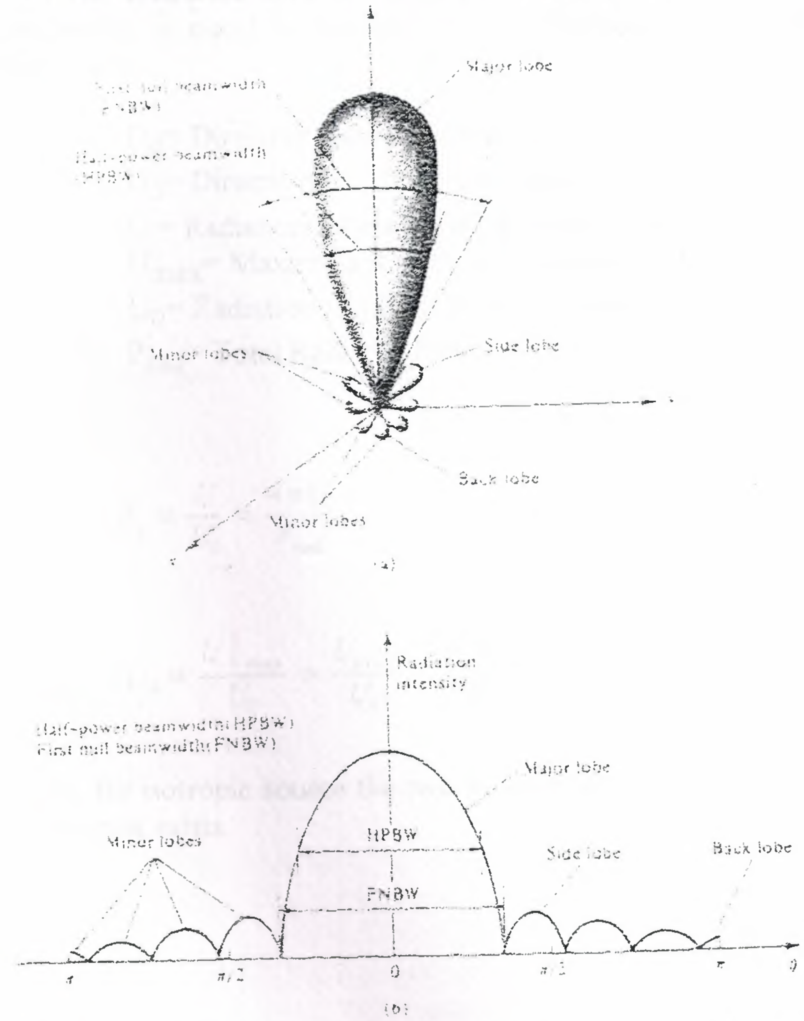


FIGURE 2.3 (a)Shows the beamwidth and the radiation lobes while,(b) shows the power pattern in two dimensional form.

2-3 DIRECTIVITY OF AN ANTENNA

The directivity simply is the directional property of an antenna. The directivity of an antenna can be defined as "the value of the directive gain in the direction of it's maximum value", when converted into more simple terms it actually means that directivity is an isotropic source is equal to the ratio of it's maximum radiation intensity over that of an isotropic source.

D_g= Directive Gain (dimensionless)
D_0= Directivity (dimensionless)
U = Radiation Intensity (W/unit solid angle)
U_{max}= Maximum Radiation Intensity (W/unit solid angle)
U_0= Radiation Intensity of Isotropic source (W/unit solid angle)
P_{rad}= Total Radiated Power (W)

$$D_g = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}} \tag{2-1}$$

$$D_0 = \frac{U|_{max}}{U_0} = \frac{U_{max}}{U_0} = \frac{4\pi U_{max}}{P_{rad}} \tag{2-2}$$

Note, for isotropic source the two equation above will be equal to unity, but in reality, no such antenna exists.

2.4 GAIN OF AN ANTENNA

The gain is another unit for measuring the performance of an antenna, it is closely related to the directivity. The gain measures the efficiency as well as the directional properties of an antenna and is controlled only by the antenna pattern.

The power gain in a given direction of an antenna is defined as "4π times the ratio of the radiation intensity in that direction to the net power accepted by the antenna from a connected transmitter". The following equation is a mathematical representation of the above statement.

Note that when the direction of the antenna is not stated, the power gain is usually taken in the direction of maximum radiation.

$$\text{GAIN} = \frac{\text{radiation intensity}}{\text{total input power}} = 4\pi \frac{U(\theta,\varphi)}{Pin} \qquad (2\text{-}3)$$

The relative gain is what we mostly deal with, in actual cases. It is defined as "the ratio of the power gain in a given direction to the power gain of a reference antenna in it's referenced direction".

2.5 EFFICIENCY OF THE ANTENNA

The factors that effect the efficiency of the antenna are the input terminals and the structure of the antenna. The cause of such losses are due to two factors.

1) Reflection caused by the mismatch between the transmission line and the antenna.
2) I^2R losses (conduction and dielectric)

$$e_t = e_r e_c e_d \qquad (2\text{-}4)$$

Where,

e_1= Total Efficiency (dimensionless)

e_r = Reflection (mismatch) Efficiency = $(1- |\Gamma|^2)$ (dimensionless)

e_c = Conduction Efficiency (dimensionless)

e_d = Dielectric Efficiency (dimensionless)

2.6 HALF-POWER BEAMWIDTH

The half-power beamwidth of an antenna can be defined as “The plane containing the direction of the maximum of a beam, the angle between the two direction in which the radiation intensity is one-half the maximum value of the beam”.

Normally the term beamwidth is used to describe the angle between any two points on the pattern, for example the angle between the 10 dB points.

Note that the term beamwidth by itself is usually reserved to describe the 3 dB beamwidth.

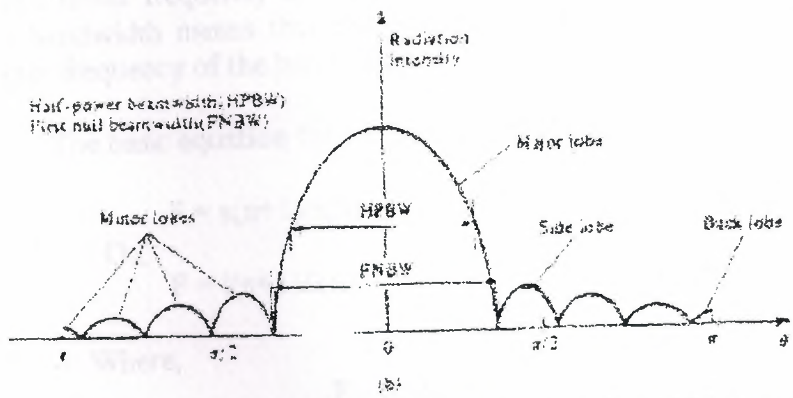


Figure 2.4 A two-dimensional graph showing the half-power beamwidth.

2-7 BANDWIDTH

The bandwidth of an antenna can be described as "the range of frequencies within which the performance of the antenna, with respect to some characteristics, conforms to a specified standard".

The bandwidth of an antenna can be considered to be the range of frequencies, on either side of a center frequency, usually the center frequency is taken as the resonance frequency for a dipole. The antenna characteristics such as the input impedance, pattern, beamwidth, are within an acceptable value of those at the center frequency.

A broadband antenna has a bandwidth expressed in a ratio of the upper-to-lower frequencies of operation. An example of a broadband bandwidth would be 10:1, which means for this particular broadband antenna, the upper frequency is 10 times greater than the lower frequency.

For narrowband antennas, the bandwidth is expressed as a percentage, of the upper minus lower frequency divided by the center frequency of the bandwidth. For example, a 5% bandwidth means that the frequency difference of acceptable operation is 5% of the center frequency of the bandwidth.

The basic equation for the bandwidth of an antenna is;

$$F = s(n+1)/s(n) \qquad (2\text{-}6a)$$

Or,

$$F = l(n+1)/l(n) \qquad (2\text{-}6b)$$

Where,

F - Bandwith.
s(n), s(n+1) - Distances between dipoles.
l(n), l(n+1) - Length of the dipole.

2-8 POLARIZATION

The polarization of any antenna in a given direction is defined as the polarization of the radiated wave, when the antenna is excited. To put it into simple terms, the polarization of an incident wave from the given direction, which results in maximum available power at the antenna terminals.

One point that you should be aware of, is that if the direction of polarization is not stated, in such a situation the direction of the maximum gain is taken as the direction.

Normally the polarization of a radiated energy varies with the direction from the center of the antenna, which implies that the different parts of the pattern have different polarizations.

The polarization of a radiated wave is considered as the property of a radiated electromagnetic wave that describes the time varying direction and the relative magnitude of the electric-field vector.

CHAPTER 3 LOG-PERIODIC ANTENNA

The log-periodic antenna is a special type of an array antenna. These antenna are frequency independent and cannot be completely specified by angles. There are three types of log- periodic antennas. The first is the planer, wire surface log-periodic antenna and the third is the dipole array.

3-1 Planer and Wire Log Periodic Antenna

The structure of the planer log-periodic antenna is shown in figure 3-1. This type of log-periodic antenna is made of a metal strip whose edges are specified by the angle α/2. For specifying the length from the origin to any point on the structure, a distance characteristic are to be added. In this case, the spherical coordinates (r,θ,φ) are used to define the structure of the planer antenna.

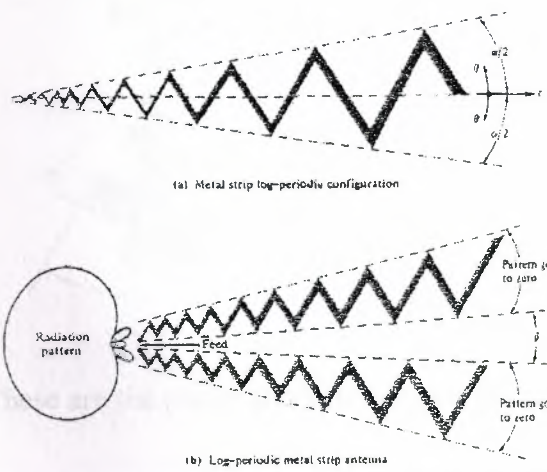


Figure 3-1 This is a common metal strip log-periodic configuration and antenna structure.

The function of the spherical coordinate θ, of the planer log-periodic antenna is defined below:

$$\theta = \text{periodic function of } [b\ln(r)] \qquad (3\text{-}1)$$

As the equation above states, that in general the angle θ is equal to a periodic function, for example $\theta = \theta_0 \sin[b\ln(r/r_0)]$.

The name log-periodic antenna was given by its behavior of θ that repeats itself whenever the logarithmic of the radial frequency $\ln(\omega)=\ln(2\pi f)$ differs by $2\pi/b$. This performance of the system is then periodic as a function of the logarithm of the frequency; thus the mane logarithmic-periodic or log-periodic.

A common log-periodic antenna is shown in figure 3-1(b), which is made of two coplanar arms. The pattern is unidirectional toward the apex of the cone formed by the two arms and is linearly polarized.

Even though the patterns of these and other log-periodic structures are not completely frequency independent, the amplitude variation of certain designs are very slight, meaning that they are practically frequency independent.

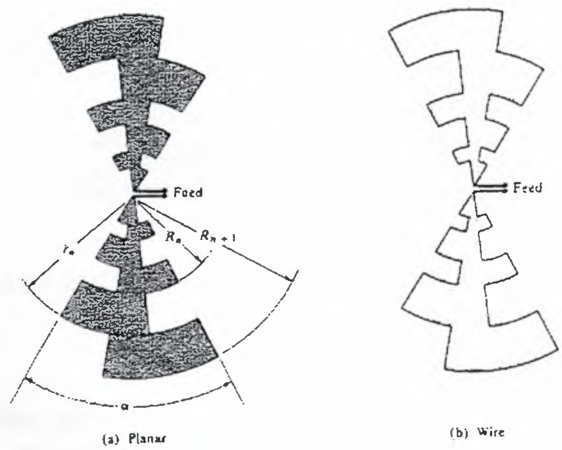


Figure 3-2 These are the planer and wire log-periodic antennas.

DuHamel was the person, who discovered the log-periodic antenna. While investigating the current distribution on log-periodic surface structures of the type shown in figure 3-2, he discovered that the fields on the conductors attenuated very sharply with distance, which suggested that perhaps there was a strong current concentration at or near the edges of the conductors.

By removing part of the inner surface to form a wire antenna as shown in figure 3-2(b), should not seriously degrade the performance of the antenna. To verify this a wire antenna with geometrical shape identical to the pattern formed by formed by the edges of the conducting surface, was built and it was investigated experimentally. The result was that the performance of this antenna was almost identical to that of figure 3-2(a). Nonplaner geometries in the form of a V, formed by the bending of one arm relative to the other.

If the wires or the edges of the plates are linear (instead of curved), the geometries of figure 3-2, are reduced respectively to the trapezoidal tooth log-periodic structures shown in figure 3-3.

These simplifications result in more convenient fabrication geometries with no loss in operational performance. There are many other strange but practical configurations of log-periodic structures including log-periodic arrays.

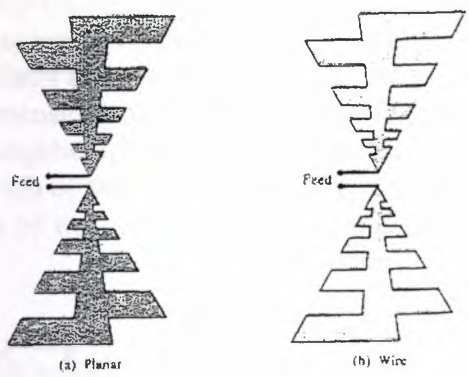


Figure 3-3 Planar and wire trapezoidal toothed log-periodic antennas.

Studies on the performance of the antenna of figure 3-2 have been performed. These structures performed almost as well as the planer and conical structures. The only difference is that the log-periodic configurations are linearly polarized instead while these are circularly polarized.

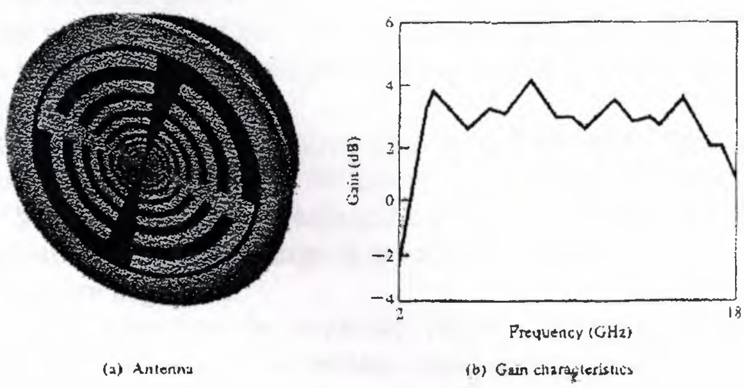


Figure 3-4 (a) Linearly polarized flush-mounted cavity-backed log-periodic slot antenna, (b)Gain characteristics.

The above figure shows a commercial lightweight, cavity-backed, linearly polarized, flush-mounted log-periodic slot antenna and its maximum diameter of the cavity is about 2.4in., the depth is 1.75in., and the weight is near 0.14kg.

3-2 Dipole Array

The most recognized log-periodic antenna structure is the shown in figure 3-5. This antenna consists of a sequence of side-by-side parallel linear dipoles forming a coplanar array. This antenna has similar directivities as the Yagi-Uda array, but there are still big differences between them.

The geometrical dimensions of the Yagi-Uda array elements do not follow any set patterns, lengths (l), spacing (R), diameter (d) and even gap spacing at dipole centers (d) of the log-periodic array increase logarithmically as defined by the inverse of the geometric ratio (τ).

$$\frac{1}{\tau}=\frac{l_2}{l_1}=\frac{l_{n+1}}{l_n}=\frac{R_2}{R_1}=\frac{R_{n+1}}{R_n}=\frac{d_2}{d_1}=\frac{d_{n+1}}{d_n}=\frac{s_2}{s_1}=\frac{s_{n+1}}{s_n} \qquad (3\text{-}2)$$

A Yagi-Uda array has only one element directly energized by the feed line, while the others operate in a periodic in a parasitic mode, all the elements of the log-periodic array are connected. There are two basic methods of connections which are shown in figure 3-5 (b) and (c), which could be used to connect and feed the elements of a log-periodic dipole array. In these two cases, both antennas are fed at the small end of the structure.

The currents in the elements of figure 3-5(b) have the same phase relationship as the terminal phases. If in addition the elements are closely spaced, the phase progression of the currents is to the right, this produces an endfire beam in the direction of the longer elements and interference effect to the pattern result.

Mechanically crisscrossing or transposing the feed between adjacent elements as shown in figure 3-5(c), a 180° phase is added to the terminal of each element. The phase between the adjacent closely spaced short elements is almost in opposition, very little energy is radiated by them and their interference effects are negligible.

However, at the same time the longer and larger spaced elements will radiate, the mechanical phase reversal between these elements produces a phase progression so that the energy is beamed endfire in the direction of the shorter elements. The most active elements for this feed arrangement are those that are near resonant with a combined radiation pattern toward the vertex of the array.

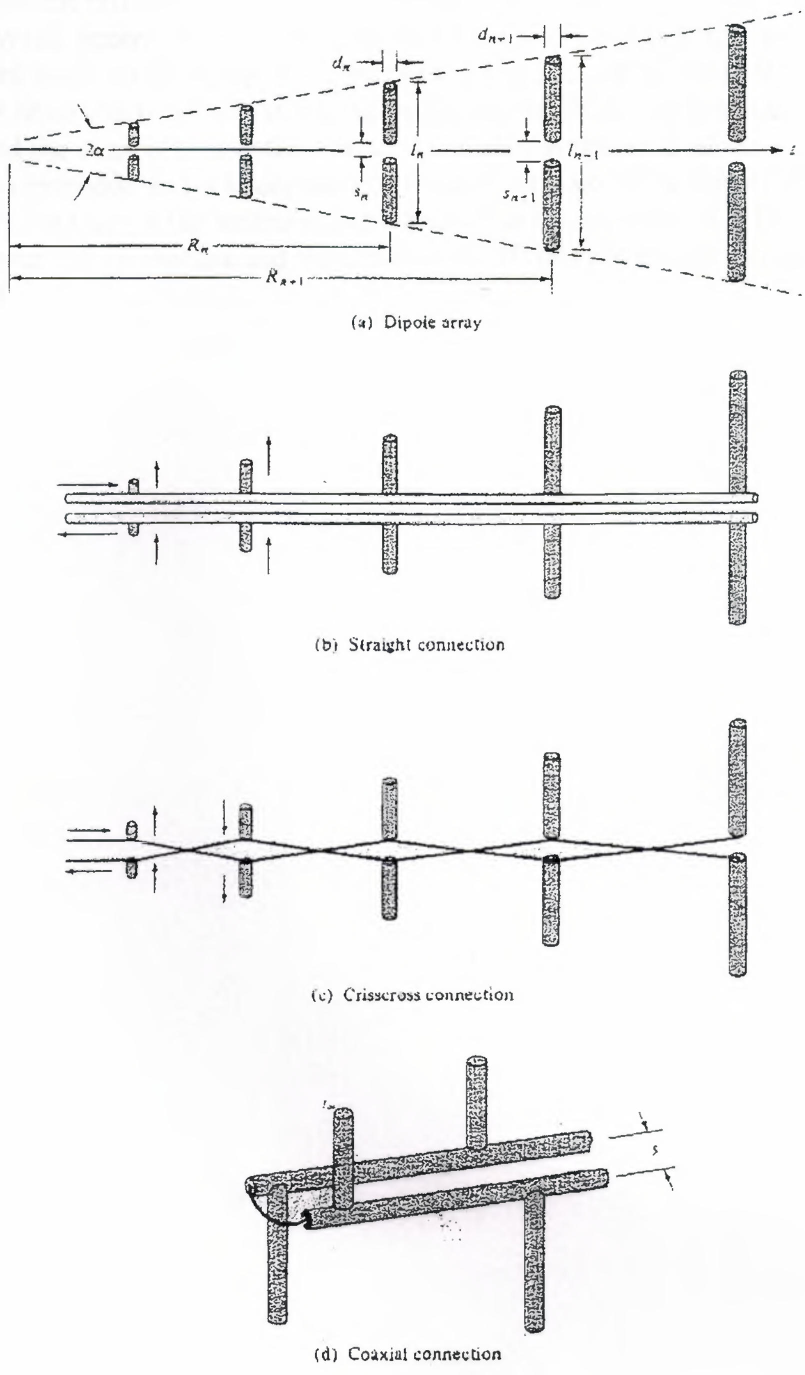


Figure 3-5 Log-periodic dipole array associated connections.

The feed arrangement of the figure 3-5(c) is convenient provided the input feed line is a balanced line like a practical method to achieve the 180° phase reversal between adjacent elements is shown in figure 3-5(d). This feed arrangement provides a built-in broadband balun resulting in a balanced overall system. The coaxial cable is brought to the feeder line of this array are made up of piping. The coaxial cable is brought to the feed through the hollow part of one of the feeder line pipes. While the outside conductor of the coax is connected to that conductor at the feed, its inner conductor is extended and it is connected to the other pipe of the feeder line.

This is the type of the antenna that was used in the experiment. The actual antenna had 16 dipoles and the dimensions of the antenna are shown in chapter 4.

CHAPTER 4 EXPERIMENTS IN B.R.T

The experiment was conducted by using an UHF antenna as the transmitting antenna and UHF panel as the receiving antenna. A single device called the 'TV Transcope-MUF2' was used for the generation and measurement of the signal.

The MUF2 is a device that measures and checks the transmission characteristics of TV transposer systems in cable TV and community antenna systems. It can also be used as an analyzer and selective sweeper for VHF transposer and antenna systems and is suitable for transposer servicing as well as laboratory work.

The MUF2 has the following measuring instruments:

1) Sweep Generator and selective receiver
2) VSWR meter (with VSWR bridge)
3) Vision/sound/sideband carrier generator
4) Display section
5) Microvoltmeter
6) Power meter
7) Analyzer
8) Wideband demodulator

The frequency used for the transmitting signal was 470Mhz, this frequency was ideal for both the transmitting and receiving antennas to operate in.

The UHF antenna was attached to a rod. This rod was then clamped to a table, thus insuring that the antenna will not move in any other direction except in a 360° rotation horizontally. On top of the antenna, a double-D protractor was placed for measuring the angle.

The receiving UHF panel was placed 0.5m away from the transmitting antenna. It was placed right in front of the antenna.

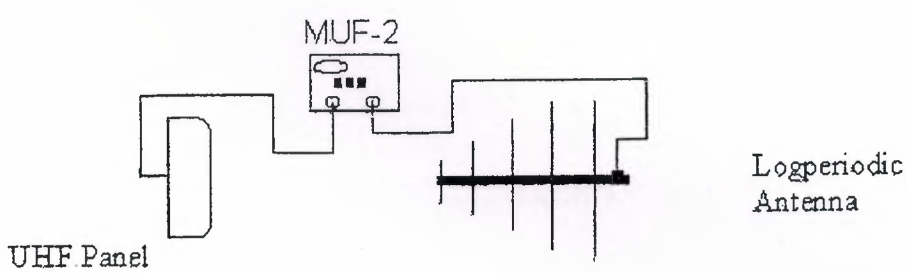
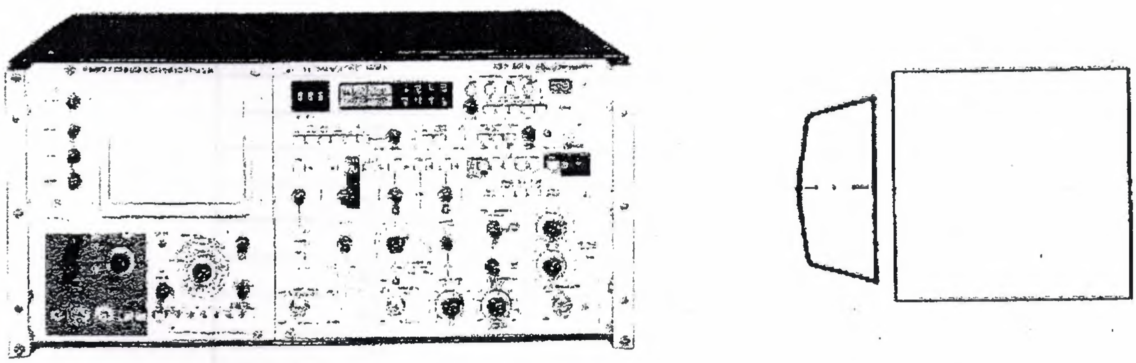


Figure 4.1 A simple diagram of the experiment conducted at the B.R.T station.

Both antennas were then connected to the MUF2 and then set to the transmitting frequency. The angle at which both antennas were facing each other was taken as our initial 0° angle. The transmitting antenna was then rotated in a clockwise direction, starting from the initial angle up to 180°. The radiation level was recorded at a 10° interval.

In the following pages, I have provided the data recorded during the experiment and a radiation pattern of the transmitting antenna.



(a) (b)

Figure 4-1 (a) The MUF2 transposer, (b) UHF panel.

4.1 RADIATION PATTERN

The readings taken in the table below, ranges from 0° to 180° and the values were taken almost after every 5° interval.

These reading are taken for the H-plane, i.e. they are the values of the radiation pattern taken in the horizontal plane.

Angle(Degrees)	Radiation Level (dB)
0	0
5	-0.2
10	-0.7
15	-0.9
20	-1
25	-1.5
30	-2
35	-2.5
40	-3
45	-3.5
50	-4
55	-5
60	-6
70	-9
80	-12.5
90	-15
95	-17.5
100	-19
105	-22
110	-24
115	-25
120	-27
135	-28.5
150	-30
180	-30

Table 4.1 Table contains the radiation values recorded for the log-periodic antenna.

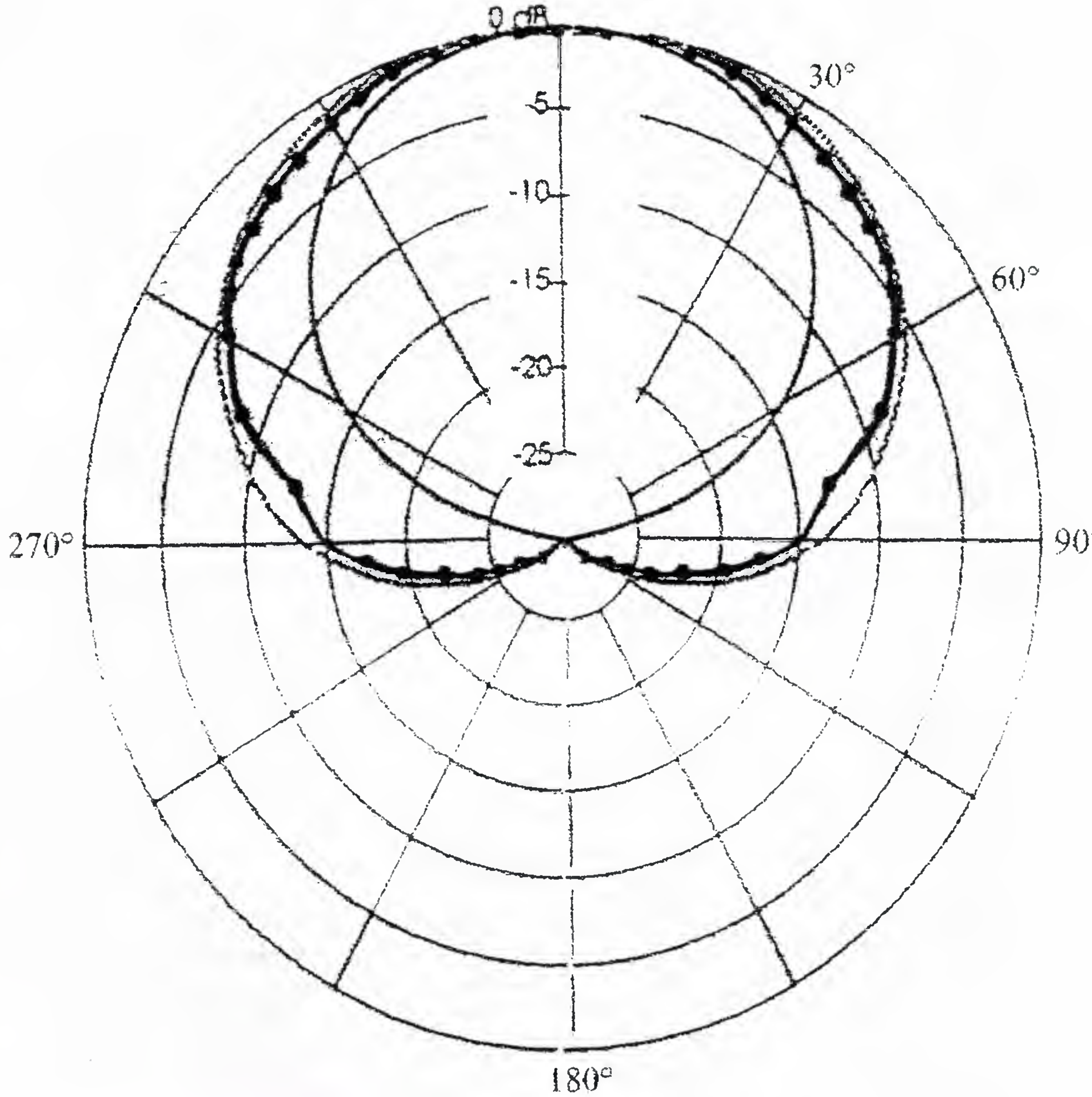


Figure 4.2 Shows the ideal and experimental radiation pattern in the H-plane v.s φ.

As you can see that the experimental values do differ from the ideal case. These differences are caused by the following:

1) Interference from UHF Television Signal
2) Electromagnetic interference from machinery
3) Measurement Error

B.R.T is a radio and television station, which broadcasts numerous programs through a range of frequencies. Therefore it is quite liking that one of it's channel frequencies was interfering with the experiment.

The electromagnetic interference was the main reason for the difference between the ideal and actual case. The interference was coming from within the laboratory.

The measurement error, was caused by taking readings from the measuring device itself. For those of you who are not familiar with the MUF2 device, the best description that I can provide is that it is a oscilloscope, with additional function, which means that the readings taken from this machine, is similar to how we take readings from an ordinary oscilloscope.

4.2 BANDWIDTH AND GAIN OF THE ANTENNA

4.2.1 BANDWIDTH OF ANTENNA

The bandwidth was also calculated by applying the equations2-6(a,b). These equations are in chapter 2.

Distance b/w Dipoles (cm)	Length of Dipole (cm)	Bandwidth: F=l{n+1}/l{1}	Bandwidth: F=s{n+1}/s{1}
2.8	4.8		
3	5.4	1.125	1.071428571
3.8	6.2	1.291666667	1.357142857
4	7.3	1.520833333	1.428571429
4.5	8.2	1.708333333	1.607142857
5.2	9.3	1.9375	1.857142857
5.2	10	2.083333333	1.857142857
6.2	12.3	2.5625	2.214285714
7	14.2	2.958333333	2.5
6	16.3	3.395833333	2.142857143
7.2	20.4	4.25	2.571428571
7	23.4	4.875	2.5
7.4	26.9	5.604166667	2.642857143
7.2	31.5	6.5625	2.571428571
9.2	35.2	7.333333333	3.285714286
9.3	38.5	8.020833333	3.321428571
	Aver of Bandwidth =	3.681944444	2.195238095

Table 4.1 The data collected above is of the antenna used in the experiment.

The table shows the length of the dipoles and the distances between the dipoles. From this data, the bandwidth was calculated for each and every dipole of the log periodic antenna. Then an average was taken, which rounds up to be approximately 2.9385. The actual bandwidth was 3.0.

Below is the an approximate diagram of the actual antenna used in the experiment.

Note that there is no fixed ratio between the lengths of the dipoles or even the distances between the dipoles.

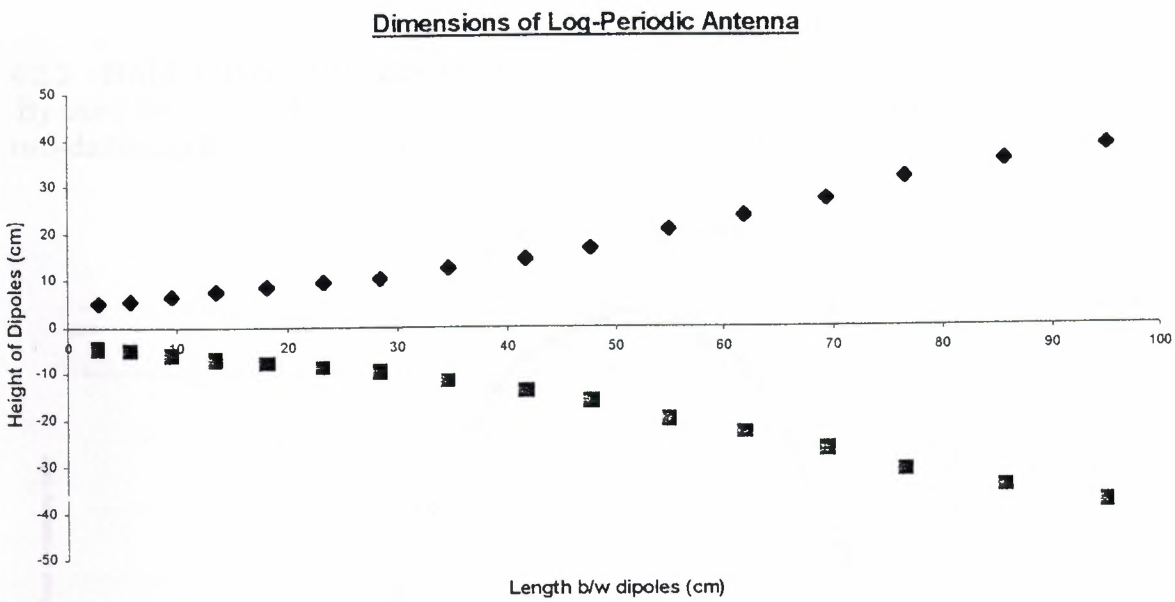


Figure 4-3 This figure shows the exact dimensions of the antenna used in the experiment.

4.2.2 GAIN OF ANTENNA

The gain of the antenna was the simplest experiment of all. The theoretical value was given on the instruction sheet of the antenna, which was 11dBi.

While the experimental gain was measured by the MUF2, which gave a reading of approximately 10.64 dBi.

4.2.3 HALF-POWER BEAMWIDTH

By using the definition in section 2.6, and the data collected in table 4.1, a two-dimensional radiation intensity pattern was constructed.

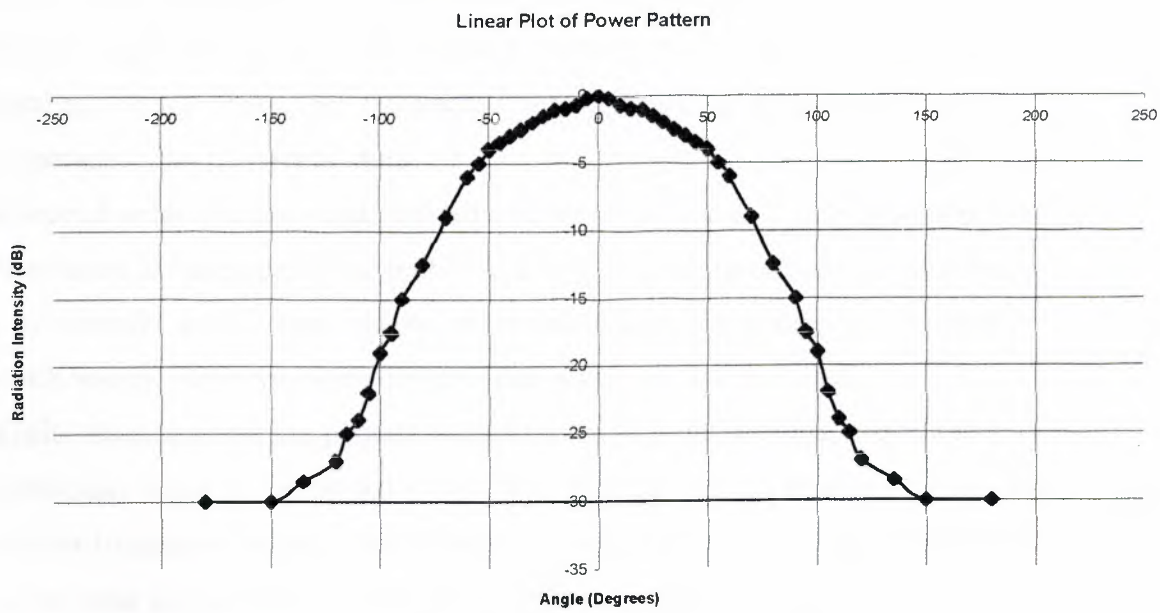


Figure 4.4 Graph of the linear power pattern.

The normalized maximum is 0 dB, the half of this power is –3 dB. So the HPBW is equal to (2*40°) = 80°.

CONCLUSION

When comparing the experimental results with the theoretical. I can conclude that the hard work rewarded me with very satisfactory results. The experimental part of this project has given results that are extremely close to the actual behavior of the antenna, with differences almost minimal.

Some very interesting points that were picked up during the completion of this project, which were;

1) By adding more dipole to the antenna, its directivity will proportionally increase.

2) The experiment that I conducted had errors, which are stated in chapter 3, but one type of error was undiscovered until later on.
   This error was the design flaw.

The first point is self explanatory, but the second point needs to be explained a little better.When the results of the experiments were first analyzed, the differences between the experimental and actual results were extremely different. This large difference led us to redo the experiments for the second time.

The second series of experiments yielded a better result, but with no explanation as to why the first series of experiments had such bad results. We had used the same machinery, the same environment and the same people, so the only logical explanation that we could come up with was the there was some designer flaw within the antenna itself.

A similar antenna to the log-periodic antenna is the yagi-uda antenna, even though both have the same shape, in performance they differ. For instance, comparing a 15 element yagi-uda to the 16 element log-periodic antenna. The yagi-uda has a equal input impedance of 50Ω, but in other properties they differ. Here are some of them for log/yagi:

Gain: 6dB/9.2dB (relative to $\lambda/2$ dipole)

Front-to-Back Ratio: 30dB/15dB

So you can see that there is a big difference between these two antennas, even though they may seem to be similar in shape.

REFERENCE

1) Principles of Antennas: Wire and Aperture,
   T.S.M. Maclean
   Cambridge University Press

2) Antenna Theory and Design
   Warren L. Strutzman, Gary A. Thiele

3) Antennas,
   John D. Kraus,
   Second Edition, McGraw Hill

4) Antenna Theory, Analysis and Design
   Constantine A Balanis

5) http://D&MQ114CollinearDipoleAntenna.htm
6) http://D&M Q115LogPeriodicAntenna.htm
7) http://LogPeriodicAntennaANS.htm

APPENDIX I

AZIMUTH –is the position measured by an angle round some fixed point or pole.

DIRECTIVE GAIN {$G_D(\theta, \Phi)$} –of an antenna pattern is the ratio of the radiation intensity in the direction (θ, Φ) to the average radiation intensity.

DIRECTIVITY –of an antenna can be defined as "the value of the directive gain in the direction of it's maximum value".

E-PLANE PATTERN - this plane represents the magnitude (r) versus θ for a constant Φ.

EFFICIENCY –is only concerned with ohmic losses in the antenna, i.e. in transmitting these losses, involve power fed to the antenna, which is not radiated but heats the antenna structure.

ELECTRIC CHARGE –is a fundamental property of matter and exists only in positive or negative integral multiples of the charge on an electron.
{e=1.60*10^{-19} (C) }

ELECTRIC DIPOLE –is a positive electric charge q separated a distance from an equal but negative charge.

ELECTROMAGNETICS –is the study of the electric and magnetic phenomena caused by electric charges at rest or in motion.

ELECTROMAGNETIC WAVE –is a wave consisting of electric and magnetic field propagating through space.

FIELD –is a region where both electric and magnetic forces act.

GAIN –of an antenna is referred as an lossless isotropic source that depends on both it's directivity and efficiency.

H-PLANE PATTERN – this plane represents the magnitude (r) versus Φ for $\theta=\pi/2$.

ISOTROPIC –is a body that has the same properties in all direction.

ISOTROPIC RADIATOR –is defined as a hypothetical antenna having equal radiation in all directions.

APPENDIX I

PHOTON –is the quantum unit of electromagnetic energy equal to hf.
(h=6.63*10^{-34} Js and f= frequency{Hz})

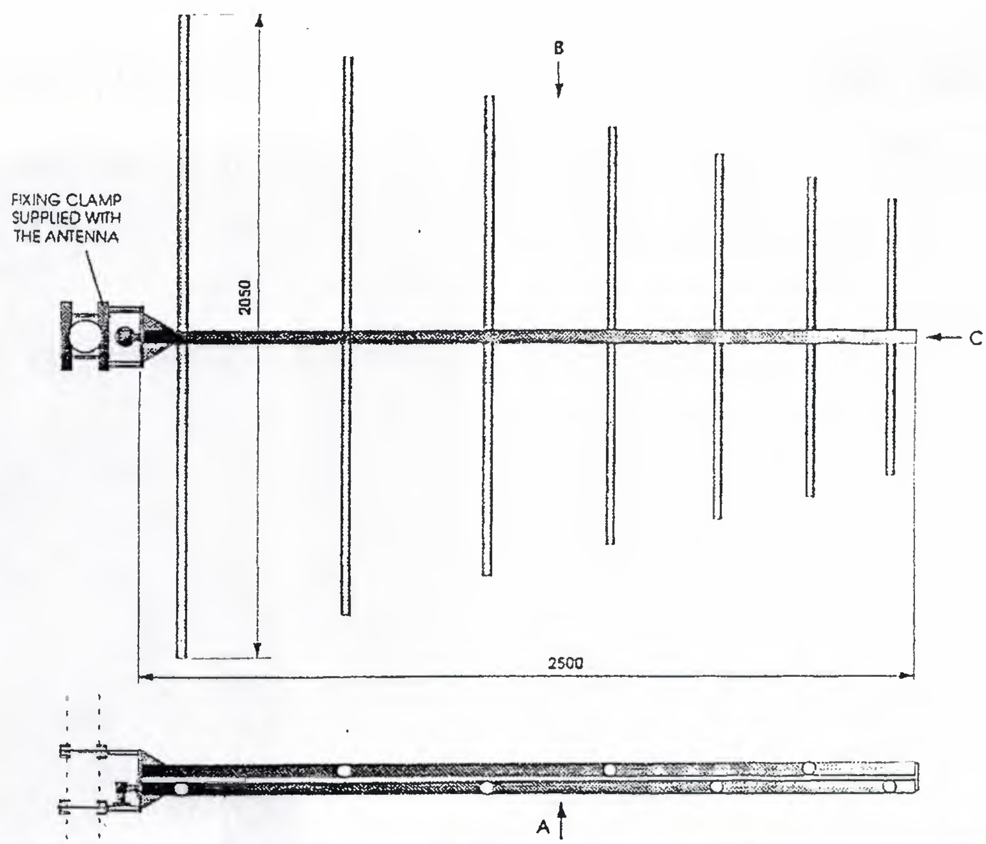
RADIO ANTENNA- may be defined as the structure associated with the region of transition between a guided wave and a free-space wave, or vice versa.

RADIATION PATTERN –is the graphical representation of the radiation properties of the antenna as a function of space coordinates, i.e. it describes the relative far-zone field strength versus direction at a fixed distance form the antenna.

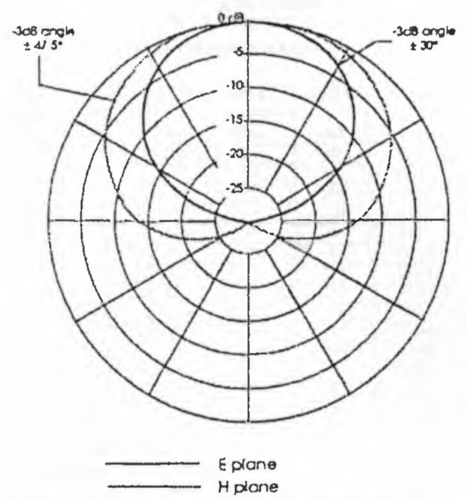
RADIATION RESISTANCE {R} –is not associated with any resistance in the antenna proper but is a resistance coupled from the antenna and its environment to the antenna terminals.

TRANSMISSION LINE- is a device for transmitting or guiding radio-frequency energy from one point to another. Usually it is desirable to transmit the energy with a minimum of attenuation.

APPENDIX II



Radiation pattern at mid-band



Electrical and mechanical characteristics

Frequency range		87.5÷108 MHz
Gain (ref. to λ/2 dipole)		4 times (6 dB)
Front to back ratio		≥ 30 dB
Impedance		50 Ω
V.S.W.R.		< 1.2
Max.input power		5 KW
Polarization		horizontal or vertical
Input connector		7/8" EIA standard
Weight of the antenna		27 Kg
Wind load 160 Km/h	A	620 N
	B	380 N
	C	186 N
Material		stainless steel

For severe conditions of ice and snow, it is foreseen the employment of dielectric tension ropes (supplied on request).

All dimensions are in millimeters   1/95   *Normalizzazione NMC0147*

APPENDIX II

UHF PANEL:

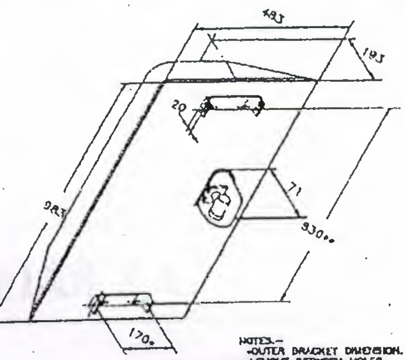
AT15-240 (HOR. POL)
AT15-241 (VER. POL)

TECHNICAL CHARACTERISTICS	
ELECTRICAL	
Frequency range (Mhz)	470-860
Gain (dB, ref. half wave dip.)	11.3
Polarization AT15-240	Horizontal
Polarization AT15-241	Vertical
Impedance (Ohms)	50
V.S.W.R.	<1.1:1
Max. Avg.Power Kw : (DIN 13/30)	4
: (DIN 7/16)	1
MECHANICAL	
Dimensions (mm.)	985x485x200
Max. wind speed (Km/h)	200
Wind load at 200 Km/h (N):Front	1275
:Side	400
Approx. weight (Kgms)	13
Clamp (1)	Standard
Colour	white/red
Materials : Reflector	Hot Galv.steel
: Dipoles	Cast alum.
: Radome.	Fiberglass
ENVIRONMENTAL	
Temperature range (°C.)	-40 to +60
Relative humidity	100%
Lightning protection	DC grounded
(1)Other type of clamp.	On request

RADIATING SYSTEM CHARACTERISTICS AT15-240/241

N° of BAYS	ANTENNA PER BAY	GAIN (dBd)	MAX POWER (Kw)	WEIGHT (Kg)	WIND LOAD (N)	SYSTEM HEIGHT (mm)
4	2	14.3	32	104	6700	4000
	3	12.6	48	156	8300	
	4	11.3	64	208	10000	
6	2	16.1	48	156	10050	6000
	3	14.3	72	234	12450	
	4	13.1	96	312	15000	
8	2	17.3	64	208	13400	8000
	3	15.6	96	312	16600	
	4	14.3	128	416	20000	
12	2	19.1	96	312	20100	12000
	3	17.3	144	456	24900	
	4	16.1	192	624	30000	
16	2	20.3	128	416	26800	16000
	3	18.6	192	624	33200	
	4	17.3	256	832	40000	

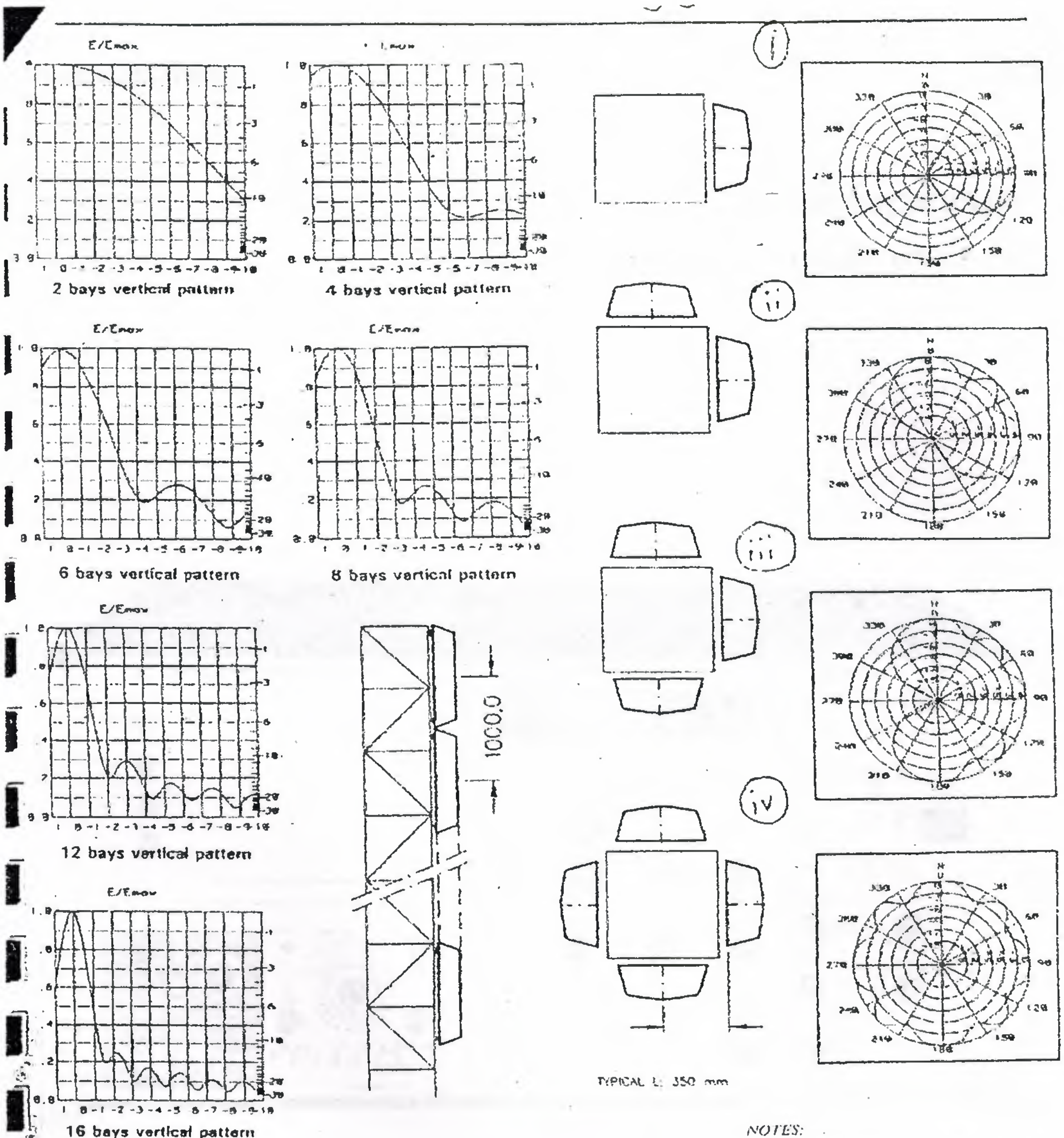
Power based on DIN 13/30 connector.
Null filling, beam tilt or feeder loss not include.



NOTES.-
-OUTER BRACKET DIMENSION.
-HEIGHT BETWEEN HOLES.

RYMSA

APPENDIX II



NOTES:

- *Other beam tilts or null filling on request.*

RYMSA will reserve the right to make any changes without notice.

RADIACION Y MICROONDAS S.A.

CTRA. CAMPO REAL KM. 2,100
28500 ARGANDA DEL REY (MADRID)
ESPAÑA (SPAIN)

NACIONAL/NATIONAL
TEL. 91-871 14 06
TELEFAX 871 17 31
E-Mail: rymsa.rf@mad.servicom.es

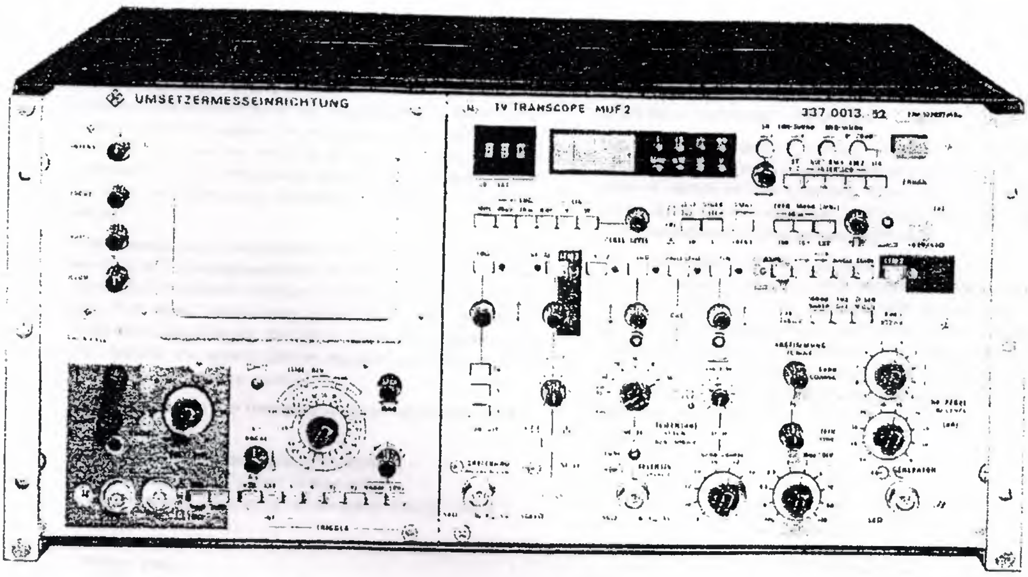
INTERNACIONAL/INTERNATIONAL
TEL. 341-871 14 06
TELEFAX 341-871 17 31
E-Mail: rymsa.rf@mad.servicom.es

APPENDIX II

ROHDE & SCHWARZ

6

transposer test equipment



Checking and adjustment of transposers involves measurements on both receiver and transmitter stages. The Rohde & Schwarz line offers for this purpose signal generators, receivers, demodulators and display units in the form of compact systems combining the required functions – especially for monitoring and servicing – as well as individual instruments.

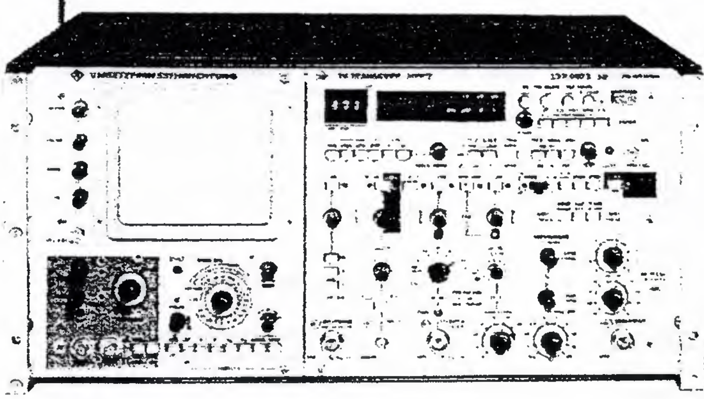
APPENDIX II

6 TV TRANSPOSER MEASUREMENT

transposer

MUF 2

TV Transcope MUF 2 • 3 to 1000 MHz



- Complete measuring and checking capability for TV transposers
- Compliance with IEC Publication 244 and with ARD and FTZ standard specifications for measurements on TV transposers
- Measurement of vision and sound carrier power
- Built-in microprocessor to handle readings

The **TV Transcope MUF 2** measures and checks the transmission characteristics of TV transposers and of transposer systems in cable TV and community antenna systems. It can also be used as an analyzer and selective sweeper for VHF transposers and antenna systems and is suitable for transposer servicing as well as laboratory work.

The measurement procedures for the electrical characteristics of **TV transposers** are described in the IEC Publication 244: "Methods of Measurement for Radio Transmitters. Part Nine: Transposers for Monochrome and Colour Television. Sections Six to Eight." Following these recommendations, the specifications required by DBP and ARD standards can also be measured.

MUF 2 combines the following measuring instruments in a compact unit:

Sweep generator and selective receiver,
VSWR meter (with VSWR bridge only),
Vision/sound/sideband carrier generator (IF region),
Display section,
Microvoltmeter,
Power meter,
Analyzer,
Wideband demodulator.

The unit is suitable for use in conjunction with the Group-delay Measuring Set LFM 2.

Sweep generator

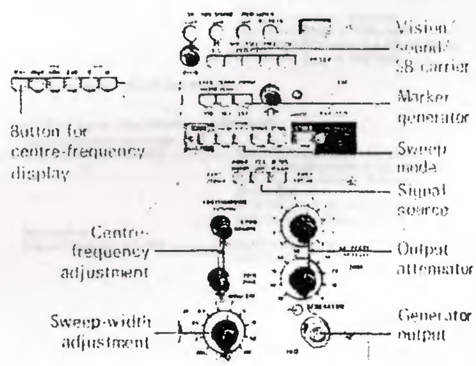
Swept signal. With its built-in YIG oscillator the sweep generator enables swept-frequency measurements from 3 to 1000 MHz to be performed in a single-sweep mode or with seven adjustable subranges with any desired centre frequency; manual tuning is possible. The centre frequency is displayed at the push of a button.

Discrete frequencies can be identified by internal markers in decade steps and/or external **frequency markers**.

The **output signal** of 200 mV maximum can be attenuated by 99 dB in calibrated 1-dB steps.

Vision/sound/sideband carrier Instead of swept RF, generation of a vision/sound/sideband carrier in the television IF range can be selected. This feature is useful for measurements of modulation depth and harmonic distortion. The sideband is frequency-adjustable.

The combination of carriers and their levels that is required for spurious-frequency, intermodulation and linearity measurements can be selected with pushbuttons. The signals can be continuously varied by 3 dB. The vision carrier can be transmitted without any other components contained in the output. Its amplitude is adjustable from 0 to −20 dB to allow linearity measurements. The **output sum signal** can be attenuated by 99 dB in calibrated 1-dB steps.



Sweep generator

APPENDIX II

6 TV TRANSPOSER MEASUREMENT

TV Transcope MUF 2, continued

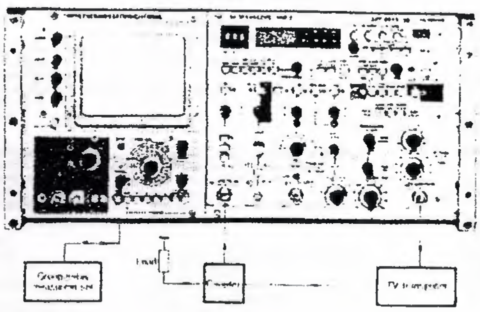
Measuring sync-pulse compression
3.8.2.2 of standard specifications
TV Test Transmitter SBUF and Video Test Signal Generator SPF 2 together produce a complete TV signal. Measurement with MUF 2 via selective demodulator (lin) using AFC and level line. Comparison of input and output signals provides optimum accuracy.

Measuring linearity
3.8.2.3 of standard specifications
Measurement as under 3.8.2.1. but using selective demodulator (lin).

Checking differential phase and intercarrier interference
3.8.2.4 and 3.8.2.5 of standard specifications
See after MUF 2 specifications on next page.

Measuring amplitude characteristic
3.8.3.1 of standard specifications
See under 3.5.4 of standard specifications on previous page.

Measuring group delay
3.8.3.2 of standard specifications



The MUF 2 is connected to the Group-delay Measuring Set LFM 2 via an adapter cable and operates as a probe-frequency modulated sweep generator. The test signal is applied via the selective or the wideband demodulator to the LFM 2 for evaluation. Amplitude and group-delay characteristics can be displayed simultaneously.

Video noise measurement
3.8.5 of standard specifications
MUF 2 is used as oscilloscope. Also necessary: Video Test Signal Generator SPF 2, TV Test Transmitter SBUF, TV Demodulator AMF 2, Video Noise Meter UPSF and Psophometer UPGR (see measuring instruments catalog).

Measuring antenna matching
The antenna is connected via a VSWR bridge to the sweep-generator output and the selective demodulator. The frequency range is swept through in the LOG mode. The return-loss curve is thus displayed continuously.

Determining RF S/N ratio
The transposer is driven by the vision carrier from the MUF 2 via the Broadband Mixer MUF 2-Z at the frequency of the received signal and its output power is measured. With the driving signal removed, the noise power output can be measured for determining the S/N ratio.

Specifications

Sweep generator

Frequency range	3 to 1000 MHz
Sweep width	100, 50, 10, 5, 2, 1, 0.2, 0.1, 0 MHz/cm; AFC
Centre frequency	adjustable
Display	digital, pushbutton-controlled
Sweep nonlinearity	≦1%
Spurious FM (Δf ≦2 MHz/cm)	≦3 kHz
Harmonics	≧40 dB (typ. 46 dB) down
Nonharmonic spurious	≧40 dB (typ. 50 dB) down
Frequency markers (pulse)	100, 100/10, 10/1; ext.
Marker input	0.1 V into 50 Ω; BNC female connector
RF suppression	during retrace
Test output (rear)	25 mV into 50 Ω (constant)
Ext. modulation (e.g. from LFM 2)	f_{mod} = 20 kHz, V_{pp} = 1 V (25-point female conn., rear)

Vision/sound/sideband carrier generator

Vision/sound/sideband frequency	38.9/33.4/33 to 40 MHz (standard B/G)[1]
Carrier selection (pushbuttons)	vision carrier/spurious/intermodulation/linearity measurement
Spurious signals	>70 dB down
Test output (rear)	50 mV into 50 Ω
Output	swept or vision/sound/sideband signal, switch-selected
Swept-frequency signal (V_{rms})	200 mV (into 50 Ω) ± ≦0.25 dB
Vision/sound/sideband carrier (V_{rms})	500 mV (into 50 Ω) each; all variable by 3 dB (vision carrier also 0 to −20 dB)
Level with LIN, KM, NW	depends on mode selected (see measurement examples)
Output attenuator	99 dB in 1-dB steps
Attenuator error	typ. ≦ ±0.25 dB
Connector	N female (50 Ω)
VSWR	≦1.3 (0 dB attenuation) ≦1.2 (≧10 dB attenuation)

Selective demodulator (receiver)

Frequency range	25 to 1000 MHz
Tuning	by YIG oscillator of sweep generator, switch-selected AFC
Maximum input (V_{rms}	≦10 V (input attenuator 40 dB)
Input sensitivity	<2 µV = −101 dBm (attenuator −10 dB, IF bandwidth 30 kHz, video bandwidth 1 kHz) = −116 dBm/kHz
Power range	0 to 2 W; with ext. attenuation (max. 60 dB) up to 2 kW depending on IF attenuator
Connector	N female (50 Ω)
Input attenuator	−10/to/+40 dB (10-dB steps)
VSWR	≦1.3 at ≧10 dB
Attenuator error	≦ ±0.2 dB/10 dB; max. ±0.5 dB
IF attenuator (lin display only)	0/to/50 dB (10-dB steps), continuous between steps
Attenuator error	≦ ±0.2 dB/10 dB; max. ±0.8 dB
Dynamic range with log display	>80 dB
Deviation	±0.25 dB/dB ≦ ±1 dB in total range
Dynamic range lin display	20 dB
Deviation	≦3% of fsd
Display range (V_{rms})	10 V to 2 µV (= 134 dB) depending on attenuator settings
IF bandwidth	30 or 300 kHz
Demodulator	for AM signals
Video bandwidth	150 kHz or ≦1 kHz
Usable screen area	limited by top horizontal graticule line with position control fully clockwise and Y × 1
Frequency response flatness	≦2 dB from 25 to 600 MHz ≦3 dB from 600 to 1000 MHz (0.04 dB/MHz; max. 0.4 dB/10 MHz)
LF output (rear)	0.1 V/div., f_{max} = 150 kHz

[1]) Other standards: please enquire.

Analyze mode (specifications continued)

Intermodulation products (input attenuation 0 dB)	≧64/≧70 dB down with vision carrier amplitude (rms) 100/30 mV (for vision/sound carrier ratio 0/−10 dB) >70 dB down for two carriers with equal amplitude ≦40 mV
Harmonics (input attenuation 0 dB)	≧40/≧60 dB down at 100/30 mV rms input

APPENDIX II

test equipment — TV TRANSPOSER MEASUREMENT 6

Wideband demodulator

Frequency range	3 to 1000 MHz
Display sensitivity	1/5/10 dB/cm
Max. input voltage	$V_{rms} \leq 5$ V, $V_{DC} \leq 10$ V
Connector	N female (50 Ω)
VSWR	≤ 1.2
Dynamic range	60 dB (5 V to 5 mV)
Error, V_{rms} 5 to 20 mV	± 0.8 dB/dB up to ± 2 dB max.
Error, V_{rms} 20 mV to 5 V	± 0.5 dB/dB up to ± 1.5 dB max.
Input requirement for measurement using LFM 2	$V_{rms} \geq 100$ mV
LF input	BNC female, $Z_{in} \geq 500$ kΩ
Frequency range	0 to 10 kHz
Deflection coefficient	0.5 mV/div.

Display section

CRT screen	80 mm × 100 mm; illuminated graticule
Colour/persistence	green/medium (GP)

Y axis

Deflection coefficient	10 mV/div. to 0.5 V/div.
Expansion (sweep mode)	× 2
Frequency range	0 to 12 MHz (DC coupling) 0.3 to 12 MHz (AC coupling)
Bandwidth (3 dB)	12 MHz (≤ ± 0.1 dB at 5 MHz)
Tilt 50 Hz/15 kHz	≤ ± 1%
Black level discontinuities	≤ ± 1%
Permissible DC voltage components	± 2.5 V at 100 mV/div.

Y input

Bridging filter input	75 Ω (switch-selected termination); suitable without termination for attenuator probe (1 MΩ shunted by 35 pF); BNC female
Return loss	≥ 34 dB (up to 10 MHz)
Attenuation, continuous	≥ 1:2.5
steps	1:1/2/5/10/20/50
Calibration squarewave generator (oscilloscope mode)	V_{pp} = 0.8 V
Amplitude error	≤ ± 1%
Duty cycle	1:1

Timebase

Scale (oscilloscope mode)	0.1 µs to 0.2 s/cm; external; manual
Expansion	× 20 (not for ≤ 0.5 µs/cm)
X input (rear)	0 to + 5 V, max. 50 Hz
Sweep control	automatic
Single (sweep mode)	triggered by pushbutton or external 5-V pulse

Triggering

Trigger level	normal AC supply freq.: adjustable, $V_1/V_2/H$: fixed
Trigger sources	ext./int./AC supply
Polarity	+ / − switch-selected
Threshold, internal	3 divisions
external (BNC female connector, rear)	V_{pp} = 1 to 4 or 4 to 20 V

Beam brightness

MAN/EXT mode	forward sweep and retrace on
Sweep and analyze modes	
⇉	forward sweep on retrace blanked
⇌	forward sweep and retrace on, zero line in retrace
Oscilloscope mode	forward trace on retrace blanked

Digital display

Level-line adjustable	manually
Digital display	3½ digits (LED)
Units	V, mV, µV, W, mW, dBµV, dBm, ΔdB (storage for forming difference), MHz
External attenuation setting	up to 60.0 dB taken into account by microprocessor

Calibration

Switch position CAL	10 dB input attenuation, sweep generator on, output level 100 mV ± 0.25 dB
Calibration procedure	connect generator output to receiver input, adjust lin or log display to level line

Specifications of recommended extras

Broadband Mixer MUF 2-Z

Frequency range	25 to 1000 MHz
Frequency-response flatness over any 10 MHz portion	≤ ± 0.1 dB
25 to 800/800 to 1000 MHz	≤ 1.5/≤ 3 dB
Conversion loss	20 ± 1 dB
Return loss	
Input (N male)	20 dB
Output (N female)	10 dB
Oscillator input level	100 to 250 mV
Mixer input level	≤ 100 mV
Intermodulation products; two-tone measurement (both carriers attenuated by 6 dB) at 100 mV/50 mV	typ. 70 dB/> 70 dB down
Spurious signals (at 50 mV)	≥ 70 dB down (vision/sound = 0/− 10 dB)
Cross-modulation products (at 100 mV)	≥ 70 dB down (vision/sound/SB = − 8/− 10/− 16 dB)
Supply voltage (from MUF 2)	+ 15 V (cable with 5-pin connector)
Dimensions	80 mm × 60 mm × 30 mm

VSWR Bridge (50 Ω)	SWOB 4-Z	ZRB
Frequency range	10 to 1000 MHz	5 to 2000 MHz
Connector: input and output	N female	N female
test item	N male	N female
Directivity	≥ 40 dB	≥ 46 dB
Insertion loss	6.5 dB	6.5 dB

Spark Voltage Protection SWOB 5Z5 (for RF input or output)

Threshold	4 V (DC or AC), approx.
Response time	≤ 3 ms

Demodulator SWOB 3-Z (probe with BNC male connector)

Frequency range	0.5 to 400 MHz (approx. measurement up to 1000 MHz)
Impedance at 50/200 MHz	≥ 30 kΩ shunted by 2 to 3 pF/≥ 10 kΩ
Input voltage	min. 50 mV (full display height), max. 5 V RF, DC component up to 100 V

General data

Rated temperature range	+ 5 to + 40 °C
Operating temperature range	0 to + 50 °C
Storage temperature range	− 20 to + 70 °C
AC supply	115/125/220/235 V + 10/ − 15%, 47 to 63 Hz (120 VA)
Dimensions, weight	492 mm × 250 mm × 530 mm, 24 kg

Ordering information

Order designation (50 Ω)	▶ TV Transcaper MUF 2 337.0013.52

Accessories supplied: RF connecting cable (100 cm, 50 Ω, N male connector) 155.0056.00, power cable, manual

Recommended extras

Broadband Mixer MUF 2-Z	349.8614.50	For specifications see above
VSWR Bridge SWOB 4-Z	912.7003.00	
VSWR Bridge ZRB	335.7613.50	
Spark-gap Voltage Protection SWOB 5Z5	333.9316.54	
Demodulator (probe) SWOB 3-Z	241.2116.00	

10:1 Attenuator Probe UTKS 241.0013.00 (compensation range 10 to 40 pF)
1:1 Probe UTKS 241.1310.93
Cameras: Steinheil (M 20, M 30, M 32); Tektronix

Further measurement on TV transposers

Measuring frequency stability

3.3 of standard specifications

Frequency counters of the following accuracy are required for measuring local-oscillator frequency stability:

Bands I and III:	5×10^{-7}/year
Bands IV/V:	1×10^{-7}/year

Checking differential phase and intercarrier interference ratio

3.8.2.4 and 3.8.2.5 of standard specifications

The TV transposer is driven by a complete television signal from TV Test Transmitter SBUF and Video Test Signal Generator SPF 2. TV Demodulator AMF 2 is used for demodulation. Differential phase can be measured by means of the Differential Phase/Gain Meter PVF, and Psophometer UPGR (see measuring instruments catalog) is required to measure intercarrier interference ratio.