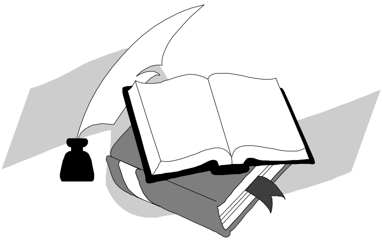
LONG REPORT

ANTENNAS & PROPAGATION

PREPARED BY:
ZULKIFLI B. HJ. MOHD SIDI

For:
Telecommunication Laboratory



CONTENTS

ANTENNAS & PROPAGATION

OBJECTIVE

When you have completed this exercise, you will be familiar with, and be able to measure, the gain and directivity of an antenna. You will also be able to plot the radiation pattern of an antenna.

INTRODUCTION

Antennas

An antennas, as a noise source, is characterized by a noise temperature. The two ports of a receiving system, so far as their noise generation is concerned, are characterized by equivalent input noise temperatures or by noise figures. In term of these characterizations, we may determine the signal power required to be available from a receiving antenna to ensure an acceptable signal-to-noise ratio. Refer to briefly to the manner in which the transmission performance of an antenna system is characterized, so that given the required available power at the receiving antenna, these will determine the power required to be radiated by the transmitting antenna.

Consider a transmitting antenna which radiates a power P_t, and assume that the power is radiated uniformly in all directions, that is isotropically. The power incident on an area A oriented perpendicularly to the direction of power flow and at a distance d from the transmitting antenna is;

$$P_R = \frac{P_T A}{4\pi d^2}$$

Equation above, may be used to define an effective area A_e of an antenna. Thus, if the available power from a receiving antenna is P_R when the antenna is a distance d from an isotropic antenna transmitting a power P_T, then the effective area of the receiving antenna is

$$A_e = \frac{4\pi d^2 \; P_R}{P_T}$$

The effective area of an antenna is related principally to the physical shape and dimensions of antenna. For example; a parabolic disk antenna the effective area is generally in the range 0.5 to 0.6 of the physical area of the disk.

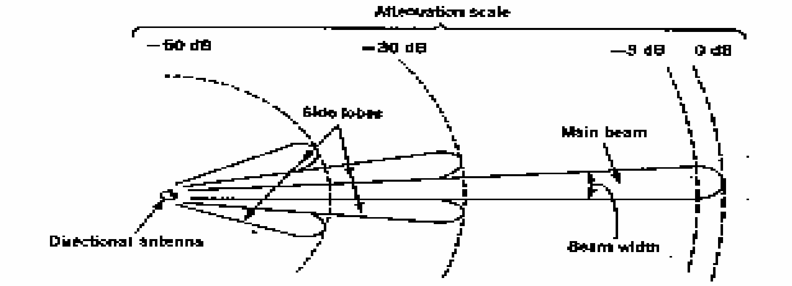


Fig. 1;Transmission pattern of a highly directional antenna.

Propagation Effects

Communication systems frequently use electromagnetic propagation to convey information from point to point. Because the choice of modulation may be influenced by the propagation, we briefly digress to investigate some of these effects. Electromagnetic radiation through space has its average power divided equally between an electric field and a magnetic field. In free space the directions of the electric field, the magnetic field, and the direction of propagation are all at right angles. The polarization of an electromagnetic wave is taken to be in the direction of the electric field. Hence a wave is said to be vertically polarized if its electric field is in the vertical direction. In the presence of a ground plane, vertical polarization is usually preferred when antennas are within a wavelength of the ground, while horizontal is prefer-red when antennas are several wavelengths above ground.

As a result of electromagnetic theory, the minimum dimension of an antenna for efficient radiation of radio frequency energy is one-half the wavelength of the radio frequency. At low frequencies, this length becomes excessive and for vertical polarization the earth is used as one half of the antenna, as shown in *Fig. 2.* This type of antenna is used, for example, in the commercial AM broadcast band. At higher frequencies (i.e., shorter wavelengths), horizontally polarized half-wave antennas are commonly used, often in arrays to improve their performance. At very high frequencies, physical dimensions of the antenna become large compared to a wavelength, and optical approximations can be used.

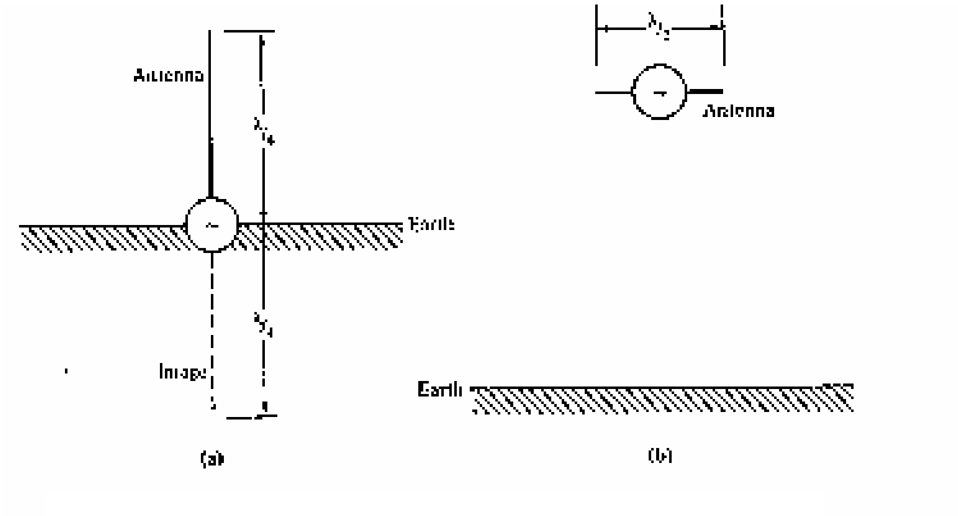


Fig. 2; The basic half wave antenna: (a) vertical polarization, low frequency;
(b) horizontal polarization , high frequency

In general, an electromagnetic wave radiated from an antenna is composed of a ground wave that arises from currents induced in the earth and travels along the earth's surface and a sky wave that is propagated through space. At very low frequencies, the ground wave can be used to communicate reliably over long distances while sky-wave propagation is generally used at high frequencies.

The ground wave loses energy as a result of dispersion along the earth's surface and energy dissipated in the earth. These losses vary directly with frequency and the resistance of the earth. The attenuation above 10 MHz is so high that ground wave propagation is of little practical value at these frequencies. Because the tangential component of the electric field cannot exist along the ground interface, vertical polarization is used where propagation via ground wave is desired.

The sky wave leaves the antenna and travels essentially in a straight path. Some of the sky wave's energy leaves the antenna at an angle to the horizontal and travels upward until it enters an ionized layer, known as the ionosphere, about 30-70 miles above the earth's surface. In this region the path of the wave is altered by refractive effects that are dependent on the intensity of ionization and the wave frequency. Depending on the conditions, the path of the sky wave may be bent downward enough to cause the radiated energy to return to earth, as illustrated in *Fig. 3*. The losses in this mechanism are small and the signal strength of the sky wave may be very strong. As a result, long-distance communications can be accomplished by use of the sky wave.

The ionization within the ionosphere varies with solar activity so that these effects vary with the time of day and season of the year. These effects are more pronounced at night and it is not unusual to receive strong signals in the AM broadcast band over a thousand-mile distance at night while the ground wave signal strength is weak after a few hundred miles. To avoid undue interference from these effects, some AM stations are permitted to operate only during daylight hours.

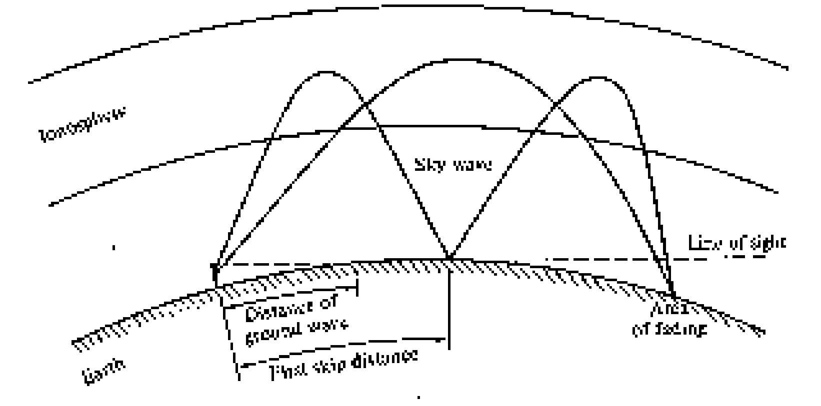


Fig. 3; Propagation of ground wave and sky wave from an antenna. *(not by scale)*

When two or more radio waves arrive at a point of reception along different paths, their phase relations may not be the same. The results of this multipath propagation can cause wide variations in signal intensity at the point of reception. Cancellation of one wave by another results in a loss of signal strength and is called *fading.* If the fading is highly sensitive to the frequency of propagation, different parts of the spectrum of a signal may undergo different amounts of fading. This effect is called *selective fading.*

The effects of fading can be minimized by proper choices of carrier frequency and modulation, the use of several different carrier frequencies (frequency diversity), and the use of several different antennas (space diversity) or highly selective antenna arrays.

The direction of the sky wave above a frequency of about 30 MHz is not altered enough to return to earth and propagation above this frequency is predominantly straight-line from transmitter to receiver. Multipath propagation is still present as a result of reflected waves from the earth and man-made structures but is not as frequency dependent (e.g., the "ghosts" in television video). The distance of communication is governed predominantly by the height of the transmitting and receiving antennas. Some refraction or bending of the path does occur for low elevation angles, and communications beyond the line of sight are still possible at very high frequencies, although not as efficient as at the lower frequencies. Multipath propagation and fading may vary as a function of meteorological conditions in this mode of propagation.

For line-of-sight propagation between terrestial stations the signal path must be above the horizon for a clear path. Actually, electromagnetic waves do not propagate in exactly straight lines even above 30 MHz because the refractive index of the atmosphere decreases with altitude, causing some known bending of the wave fronts. This effect can be compensated in line-of-sight path calculations by using an effective earth radius that is four-thirds that of the actual radius. The point of tangency to this four-thirds earth model, as illustrated in *Fig. 4,* is called the radio horizon. Using this geometry, we can write

$$d^2 + r^2 = (r + h)^2,$$

$$d = \sqrt{(2rh + h^2.)}$$

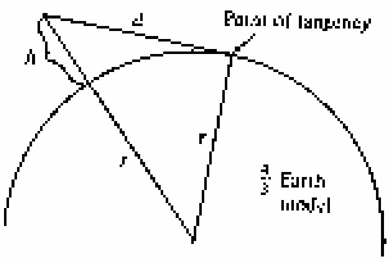


Fig. 4; Line of sight distance to the radio horizon.

Assuming that $h^2 << 2rh$, and using 3960 miles for the radius of the earth, $r = (4/3)(3960) = 5280$, and a convenient approximation for the distance d in miles to the radio horizon is

$$d = \sqrt{2h}$$

where *h* is the antenna height in feet. Thus a television station transmitting from 1000-ft tower has an effective listening area out to about $\sqrt{2000} = 44.7$ miles, this distance can be increased by additional tower height. It is for this reason television (and FM) stations prefer to position antennas on tall buildings and to extend their effective listening area.

At vhf and higher frequencies, multipath propagation continues to cause probe Because a major portion of the long-distance terrestial communication systems ate at these frequencies, multipath propagation at these frequencies has been studied extensively. In addition to the reflection and refraction of signals off the ground man-made objects, and the gradual decrease of the refractive index with altitude there may also be a layering effect of the lower atmosphere that causes sharp refractive index gradients. The result is that the transmitted signal is received via se paths with different characteristics, and these characteristics can change with time.

Recent work on multipath propagation at microwave frequencies has centered on fitting measured statistical data to mathematical models. One approach is to fit data to a two-path transfer function of the form:

$$H(\omega) = \qquad a(1 - be^{-j(\omega-\omega_o)\tau}) \qquad\qquad Eqn.\quad 1$$

where a, b are scale and shape factors, respectively, ω_o, is the frequency of a minimum in $|H(\omega)|$, and τ is the channel difference between the two paths. (In a similar manner, one could postulate a three-path model, etc.) It has been found that this two path model, when fitted against statistical propagation data, yields a usable channel transfer function for a relatively constant value of τ. Thus there is some advantage building a filter that will compensate for this multipath. Such compensation, purposely introduced in the system, is called *equalization.*

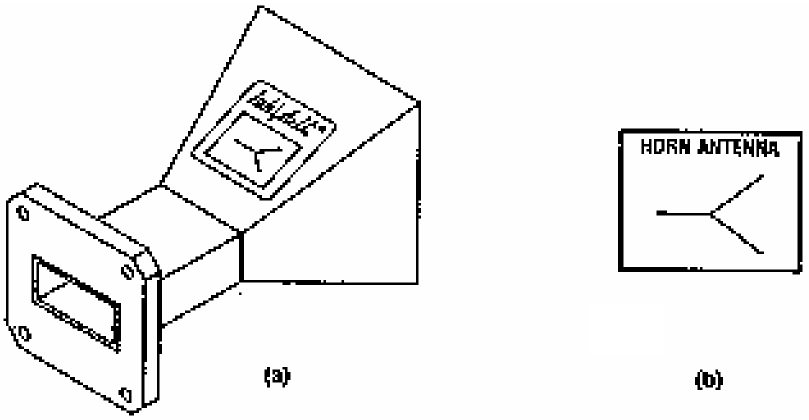
From an overall perspective, the transfer function $H(\omega) = \quad a(1 - be^{-j(\omega-\omega_o)\tau})$ can be consider as the product of a frequency-selective term (the bracketed term in the equation) a "flat-fade" term specified by the parameter a. Performance of angle modulation systems at vhf and higher frequencies can be characterized fairly well by a flat-fade margin. For example, the designer of an aircraft-to-aircraft or aircraft-to-ground FM system would specify an extra multipath margin (e.g., 20 dB) in the systems design to account for multipath propagation.

Digital transmissions (as well as AM) are more sensitive to frequency-selective fading. Frequency-selective fading causes severe amplitude and delay distortion which degrades the reliability of such systems beyond that expected from a flat-fade margin alone.

While both frequency diversity and space diversity are used in digital as well as analog transmission systems, the effects of multipath propagation are generally severe enough in digital systems to war-rant additional countermeasures. These include amplitude equalization and channel equalization. Amplitude equalization methods attempt to restore the correct magnitude transfer function by adjustment of the parameters of the model (e.g., the two-path model). It has been found that amplitude equalization alone is of limited value for digital systems, but amplitude equalization coupled with some space diversity can be quite effective. However, multipath propagation corrupts both amplitude and phase of the transmitted signal and therefore a better solution is to equalize a channel for both amplitude and delay distortion.

THEORY.

So far, we have only been considering guiding energy through waveguides. In this exercise, we will consider launching microwave power into free space. Antennas are the transition devices between waveguides or transmission lines and free space. They can be used either to receive free-space waves or radiate guided waves. Fig. 5, shows the Horn Antenna used in this exercise and its schematic representation used in this exercise.



(a)

(b)

Fig. 3;. (a) Horn Antenna and (b) its schematic representation.

The power received by an antenna decreases as the antenna is moved away from the transmitting antenna. The received signal power is inversely proportional to the square of the distance that separates the transmitting and receiving antennas. This power loss, due to the separation between the antennas, is called the free-space propagation loss PL. The mathematical expression for determining the free-space propagation loss is given in Equation 2.

$$PL\ (dB) = 10 \log \left(\frac{4 \pi r}{\lambda} \right)^2 = 20 \log \frac{4 \pi r}{\lambda} \qquad \textit{Eqn. 2}$$

where r represents the distance between the antennas (in meters) and
λ represents the wavelength in free space (in meters).

The wavelength in free-space is related to the frequency f of the transmitted signal by the relation $\lambda = c/f$ where c is the speed of light; that is, 3×10^8 m/s.

The free-space propagation loss is defined as the loss between two isotropic *radiators* in free space, expressed as a power ratio. It is usually expressed in dB, as in Equation 2. An isotropic radiator is a hypothetical antenna having equal radiator intensity in all directions. The concept of an isotropic radiator is very useful antenna studies as it gives a convenient reference for expressing the directive properties of actual antennas.

Note that the definition of free-space propagation loss is directly related to the concept of an isotropic radiator, bringing out the fact that it is independent of the directive properties of antennas.

For a given operating frequency, Equation 2 shows that PL depends only on the distance between the antennas. This relationship can be determined experimentally by transmitting a signal from one antenna and measuring the power received at another antenna for different separations. However, since the antennas used generally have directive properties, the same orientation must be kept between them when the experiment is performed. If the different antenna separations are known, the attenuation of the received signal power obtained at a greater distance relative that obtained at a near distance can easily be calculated with the use pf Equation 3.

$$A\ (\mathrm{dB}) = 20 \log \frac{r_2}{r_1} \qquad \textit{Eqn. 3}$$

where A is the attenuation in dB
r_2 is the greater distance between the antennas
r_1 is the smaller distance between the antennas.

Equation 3, clearly shows that if the distance is doubled ($r_2 = 2r_1$), 6 dB less power will be received, which means that the received power has been reduced to one-fourth of the transmitted power. This is just another way of expressing the inverse-square law response of the power with distance.

In general, a given antenna can be used to transmit or receive a signal. When an antenna is used to receive a signal, the power that it receives will depend on its orientation with respect to the transmitting antenna: in certain orientations, the receiving antenna is able to receive a stronger signal than in other orientations. Similarly, if the same antenna is used to transmit a signal, the radiated power is stronger in some directions than in others. As it turns out, for the same antenna, the direction of maximum power transmission coincides with the direction of maximum power reception. Obviously, when transmitting a signal from one antenna to another, it is preferable to have the two antennas aligned so that the transmitting antenna is transmitting most of the signal towards the receiving antenna, and so that the receiving antenna is aligned for the best reception of the signal.

A radiation pattern is a three-dimensional, graphical representation of the far-field radiation properties of an antenna as a function of space coordinates. The far-field , region is a region far enough away for the radiation pattern to be independent of the distance from the antenna. A radiation pattern represents the energy distribution transmitted by the antenna. Although the term radiation pattern is used, k applies just as well to receiving antennas. The reception pattern of an antenna is identical to its radiation pattern, except that it indicates the relative signal level of received power as a function of direction.

Although the radiation pattern of an antenna is a three-dimensional function, for reasons of presentation, one or two radiation patterns, plotted in polar coordinates, are generally used to characterize the directional properties of an antenna. Although a radiation pattern plotted in polar coordinates represents the power distribution of energy in only one plane of rotation around the antenna, it often gives a sufficient indication of the radiation characteristics of the antenna if the plane is correctly chosen.

To characterize an antenna more completely, two radiation patterns, usually selected to be at right angle to each other, are necessary. One of the two patterns, often called the E-plane pattern, is defined as the plane parallel to the electric field in the direction of maximum radiated power. The other pattern, called the H-plane pattern, is defined in the same way except that it is parallel to the magnetic field.

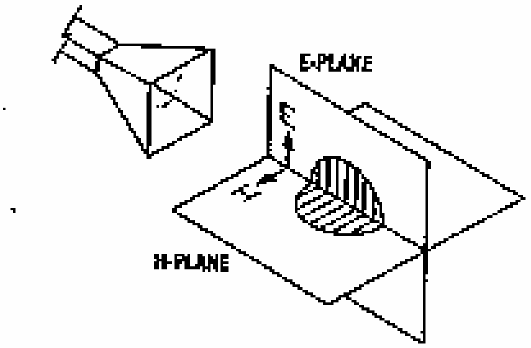


Fig. 4; Definition of E- and H-planes.

To plot a radiation pattern in the H-plane, the antenna must be rotated in such a way that its direction of maximum radiated is situated in the H-plane.

Generally, radiation patterns are measured by rotating an antenna while measuring the level of received power as a function of the orientation of the antenna. To obtain a valid radiation pattern, the measurement environment must be free from all obstacles. Walls, buildings, and even the ground can act as reflectors-and cause errors in the measurement of the radiation pattern.

To characterize numerically the directional properties of antennas, the concept of *directive gain* is most often used. For a given point in space, the gain of an antenna is the ratio of the power produced by the antenna at the given point to the power that would be produced by an isotropic radiator radiating the same total power. Fig. 5, illustrates this definition. The same total power is radiated by the two antennas but antenna A produced 20 dB more power in its direction of maximum radiation than antenna 0. Antenna A is said to be a 20-dB gain antenna. When antenna gain is specified with no mention of direction, the direction of maximum radiation is always assumed.

There are different for measuring the gain of an antenna. The simplest method of comparing the power received by a reference antenna P_{Ref}. to the power received by the antenna being tested P_{Test}. The gain of the unknown antenna is given by the following equation:

$$G_{Test} = \frac{P_{test}}{P_{Ref.}} G_{Ref.}$$

or, if all measurements are in dB relative to an arbitrary reference:

$$G_{Test}\ (dB) = P_{test}\ (dB) + G_{Ref.}\ (dB) - P_{Ref.}\ (dB)$$

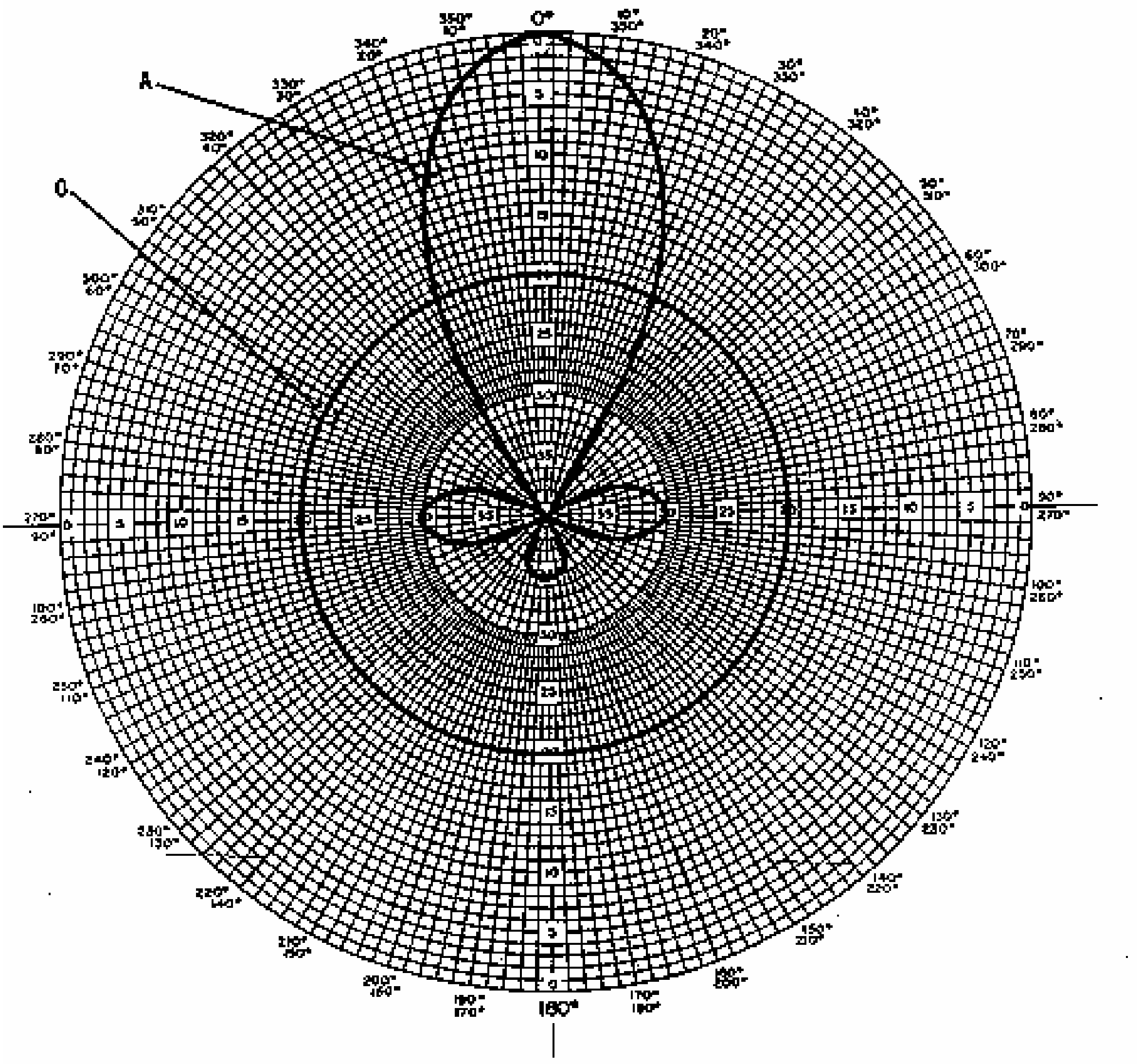


Fig. 5; Radiation pattern (in dB) of a directional antenna A and an isotropic antenna o.

It should be noted that if absolute power measurements are made, dbm's can replace the dB's in the above equation. For example, if the power received by the antenna under test is - 15 dBm, and the power received by the reference antenna whose gain is 10 dB is - 12 dBm, the gain of the antenna under test will be 7 dB.

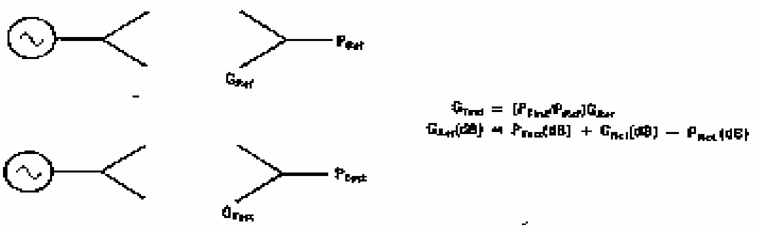


Fig. 6; Illustration of antenna gain measurement with reference antenna

Another method allows the gain of two identical antennas to be evaluated. Once the transmitted and received powers P_T and P_R, respectively, have been measured, the gain can be calculated with Equation 4.

$$G = ((4\pi r)/\lambda)\sqrt{(P_R/P_T)} \qquad \textit{Eqn. 4.}$$

where λ is the signal wavelength in free space. (it should be in the same units as r, the antenna separation.)

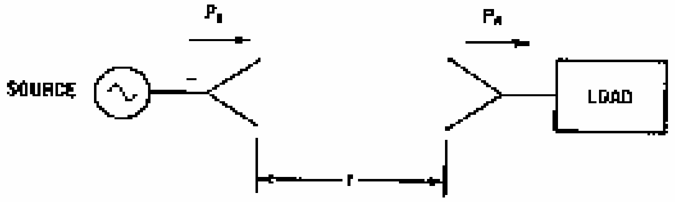


Fig. 7. Illustration of identical-antenna gain measurement technique.

EQUIPMENT REQUIRED

DESCRIPTION	*MODEL*
Gunn Oscillator Power Supply	9501
SWR Meter	9502
Gunn Oscillator	9510
Crystal Detector	9522
Variable Attenuator	9532
Horn Antenna (2)	9535
Microwave Accessories	9536
Connection Leads and Accessories	9590
Waveguide Support (2)	9591
Antenna Azimuth Indicator	9592

PROCEDURE SUMMARY

In this exercise, you will be using the SWR Meter to make relative power measurements as ft is more sensitive than the Power Meter. Absolute power measurements can not be made with the SWR Meter, but relative powers can be determined using the dB scale.

In the first part of this exercise, you will determine the relationship between the power of the received signal and the distance between two horn antennas. You will transmit a signal from one horn and use the SWR Meter to measure the strength of the signal received by the other horn for various antenna separations. Relative signal powers will be determined by subtracting the received signal strength (in dB) from a reference measurement. You will plot these results against the horn separation and use this curve to determine the relationship between the two variables.

Then, you will determine the gain of two identical horn antennas using the identical antenna gain-measurement technique. First, you will put the Variable Attenuator between the Gunn Oscillator and the Crystal Detector connected to the SWR Meter, and adjust the Variable Attenuator to set the transmitted power reference level. You will then insert the transmitting and receiving horns in the set-up and the SWR Meter reading will now represent the received signal level. Subtracting the received signal level from the reference level will give the ratio of the received power to the transmitted power in dB. From this ratio and Equation 4, the gain of each horn will be determined.

Finally, in the last part of the exercise, you will plot the radiation pattern of a horn antenna and of a long triangular lens. The Antenna Azimuth Indicator will be used to the orientation of the receiving antenna under study. You will set a reference level on the SWR Meter with the receiving antenna aligned with the transmitting antenna. This value will be used to determine the relative power of the received signal as the receiving antenna is turned through 360°. Each relative power will be plotted to produce the radiation pattern.

Note: *Since you will be transmitting microwaves through free-space, it is suggested that you work in an open area clear from any obstacles that might reflect the transmitted signal. Reflected signals will change the results of the exercise. Also, set up the Gunn Oscillator Power Supply and the SWR Meter behind the Gunn Oscillafor, and avoid working between the transmitting and receiving antennas so that you do not interfere with the propagating signal.*

PROCEDURE

1. Make sure that all power switches are in the 0 (off) position and set up the modules as shown in Figure 8.

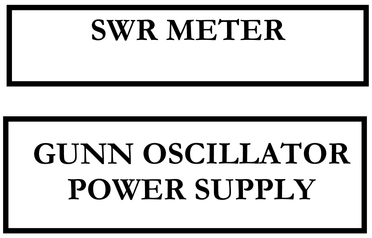


Fig. 8; Module Arrangement

2. Set up the components as shown in Fig. 9. Use the long support rods and the Antenna Azimuth Indicator.

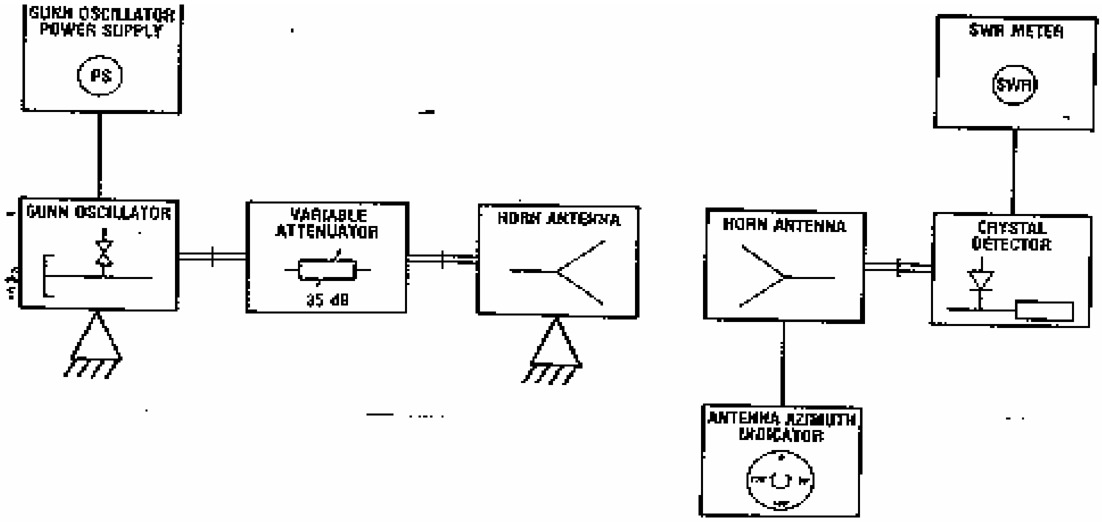


Fig. 9. Set-up used to measure propagation loss.

3. Place the receiving antenna next to the transmitting antenna. Adjust the height of the supporting rods so that the center of each antenna is about 30 cm above the working surface. Referring to Fig. 10, move the antennas a distance r = 60 cm apart. Adjust the horns so that they are at the same height and directly facing each other.

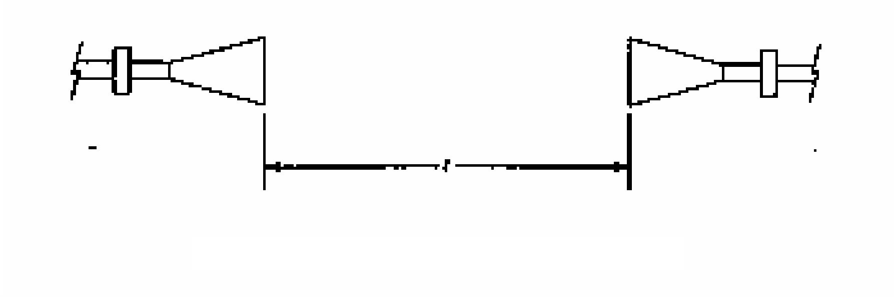


Fig. 10; Distance r between the antennas.

Note: *To make it easier to align the antennas later on in the exercise, lay a strip of masking tape along your working surface. On the tape, mark off separations of 60, 70, 80,* 90, 100, 1 *10 and 120 cm.*

4. Make the following adjustments:

On the Gunn Oscillator Power Supply

VOLTAGE : MIN
MODE : 1 KHz.
METER RANGE : 10 V

On the SWR Meter

RANGE : -30 dB
GAIN .... : 10 dB (Fully cw)
SCALE..................................... :NORMAL
BANDWIDTH......................... : 20 Hz

On the Variable Attenuator
Blade Position....................... : 11 mm

5. Power up the Gunn Oscillator Power Supply and the SWR Meter. Wait 1-2 minutes to allow the power supply to warm up. Adjust the Gunn Oscillator supply voltage to 8 V.

WARNING

For your safety, do not look directly into the waveguides or Horn Antennas while power is being supplied to the Gunn Oscillator.

6. Adjust the Variable Attenuator to obtain a reading of about - 35 dB. Adjust the *CENTER FREQUENCY* control to maximize the reading.

7. Vary the supply voltage to maximize the reading on the SWR Meter, and adjust the Variable Attenuator to obtain a reading of - 30 dB. This is the reference level; it is already recorded in the first row of Table 1.

8. For each ANTENNA SEPARATION r in Table 1, do the following:

   a. Align the receiving antenna a distance r from the transmitting antenna.

   b. Record the SWR Meter reading SR(r) in the RECEIVED SIGNAL LEVEL column of Table 1.

   c. Calculate SR(r) - SR(60), the difference in dB between the received signal level and the reference received signal level for an antenna separation of 60 cm, as indicated in the RELATIVE RECEIVED SIGNAL LEVEL column in Table 1, and record the value in that column.

RESULT

ANTENNA SEPARATION	**RECEIVED SIGNAL LEVEL**	**RELATIVE RECEIVED SIGNAL LEVEL**
r	$S_R(r)$	$S_R(r) - S_R(60)$
cm	dB	dB
60	-30.00	0.00
70	-31.20	-1.20
80	-32.25	-2.25
90	-33.00	-3.00
100	-34.00	-4.00
110	-34.60	-4.60
120	-35.50	-5.50

Table 1; Determining the received signal level relative to $S_r(60)$ for various antenna separations.

9. From the values in table 1. The curve of the RELATIVE RECEIVED SIGNAL LEVEL $S_R(r) - S_R(60)$ are plotted as a function of the ANTENNA SEPARATION, r in figure 11.

   Answer;

The relationship between the power of the received signal and the antenna separation is proportional.

10. The Gunn Oscillator Power Supply cable are disconnected from the Gunn Oscillator Power Supply. The connections is made in figure 12.

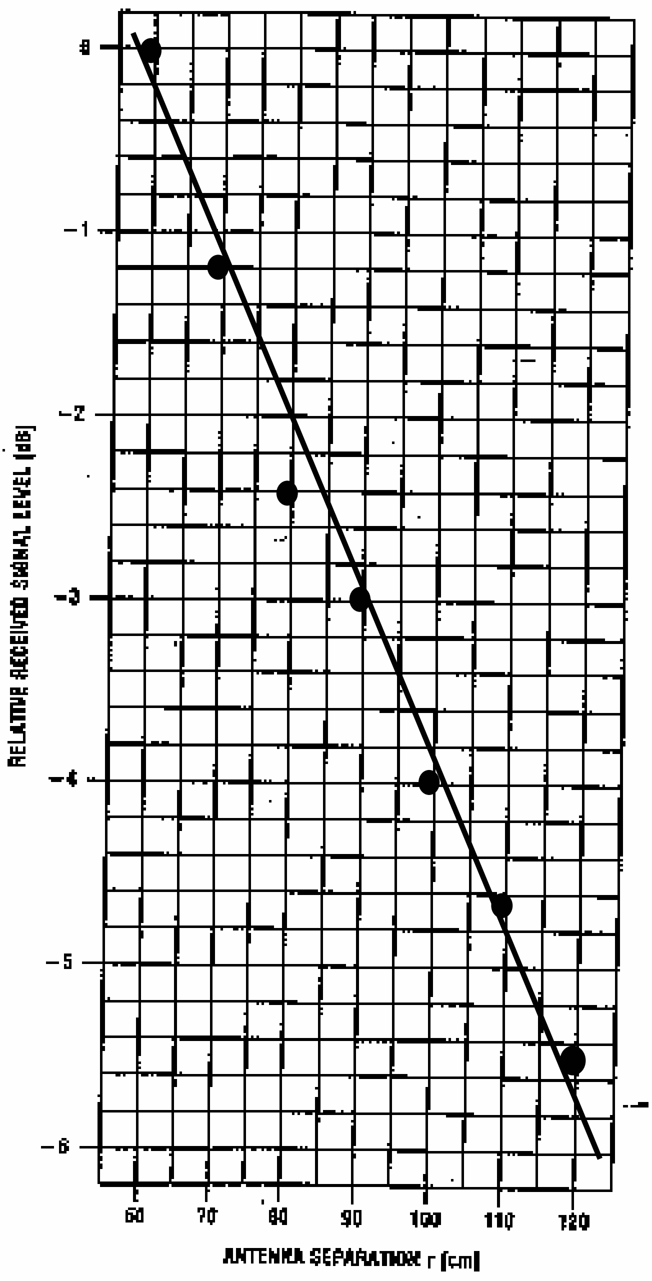


Fig. 11; Curve of RELATIVE RECEIVED SIGNAL LEVEL as a function of the ANTENNA SEPARATION r.

11. The Variable Attenuator`s blade position are adjusted to about 11 mm. The Gunn Oscillator 's Power Supply Cable connected to the Gunn Oscillator Power supply.

12. Adjust the Variable Attenuator are adjusted to obtain a reading of 30dB on the SWR Meter. This is the reference level; it corresponds to the transmitted power PT.

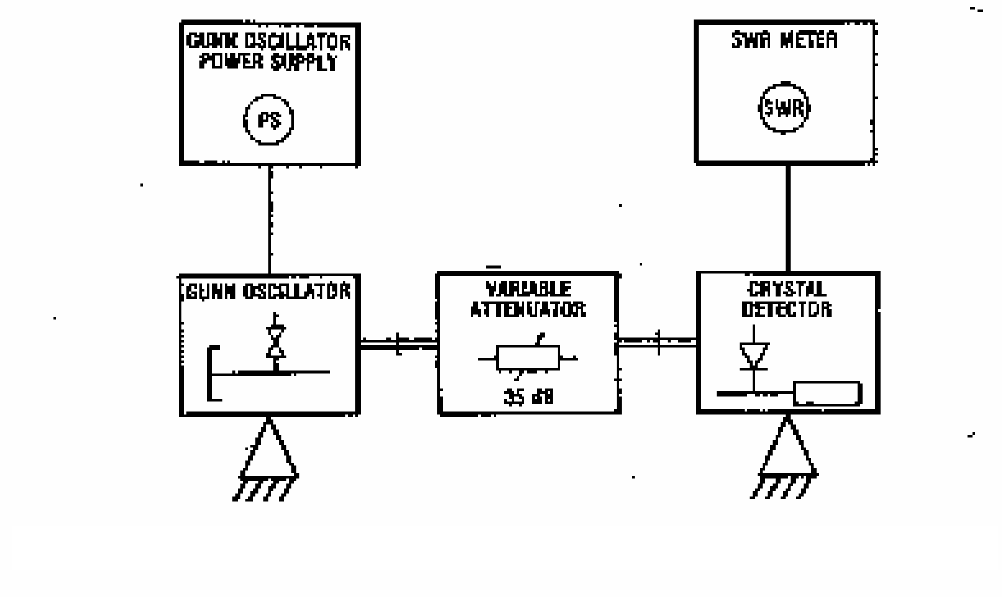


Fig.12; Set up used to obtain a reference level for determining the gain of the Horn Antenna .

Disconnect the Gunn Oscillator Power Supply Cable from the Gunn Oscillator Power Supply is disconnected. Without changing the setting of the Variable Attenuator, make the connections shown in figure 13.

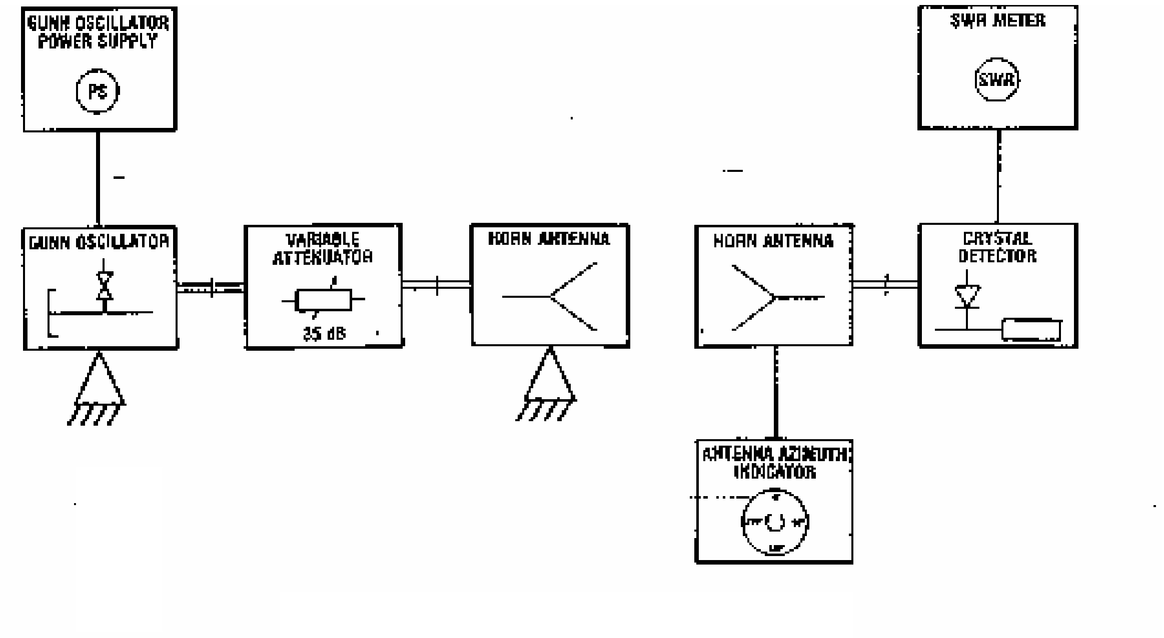


Fig. 13; Set up used to measure the gain of an antenna

13. Referring to figure 10, The antennas was separate by a distance of 60cm. The antennas are surely in line up correctly. The Antenna Azimuth Indicator are adjusted so that it indicates 0^o.
14. The Gunn Oscillator Power Supply Cable are reconnected to the Gunn Oscillator Power Supply.

    What is the relationship between the power of the received signal and the antenna separation?

    The level of the received signal are recorded as indicated by the SWR Meter.

    Received Signal Level, PR = ***-50.7 dB.*** *(answer)*

15. From the step 12, the PR = -30dB, the POWER RATIO are calculated, i.e. the ratio of the received power to the transmitted power:

$$\text{POWER RATIO } P_R/P_T \text{ in dB} = P_R\,(\text{dB}) - P_T(\text{dB}) = -50.7 + 30 = \underline{-20.7\text{ dB.}}$$

    Using Equation below, the value of this ratio are calculated.

$$P_R/P_T = 10^{(\text{POWER RATIO(dB)}/10)} = \underline{0.0085\ (\text{Ratio})}$$

16. By using equation below and the fact that microwave frequency is 10.5GHz, the gain of each Horn Antenna are calculated.

$$G = (4\,\pi r)/\,\lambda\,\sqrt{(P_R/P_T)}$$

$$G = \underline{\mathbf{24.34}}$$

    Using Equation below, the gain of antenna are calculated in Db.

$$G(\text{dB}) = 10\log_{10} 24.34 = \underline{\mathbf{13.86\text{ dB}}}$$

17. The -30dB RANGE on the SWR Meter are selected and the Variable Attenuator are adjusted to obtain a reading of -30dB. The antenna must be correctly aligned. The Antenna Azimuth Indicator are adjusted to read 0^o with the antennas correctly aligned. This is the reference level; it is already recorded in the first row of table 2.

18. For each direction given in the ANTENNA AZIMUTH INDICATION ,(column of table 2, the RECEIVED SIGNAL LEVEL, $S_R(0^o)$ are recorded and the POWER RATIO are calculated in dB with $S_R(0^o)$ as a reference, as indicated at the top of the column.

Antenna Azimuth Indication	**Received Signal Level S_R (θ)**	**Power Ratio S_R (θ) - S_R (0°)**	**Antenna Azimuth Indication**	**Received Signal Level S_R (θ)**	**Power Ratio S_R (θ) - S_R (0°)**
degrees	dB	dB	degrees	dB	dB
0	-30.00	0.00	180	-60.00	-30.00
10	-31.60	-1.60	190	-64.50	-34.50
20	-34.00	-4.00	200	-61.00	-31.00
30	-39.00	-9.00	210	-60.00	-30.00
40	-45.70	-15.70	220	-61.00	-31.00
50	-53.00	-23.00	230	-60.50	-30.50
60	-61.70	-31.70	240	-62.50	-32.50
70	-64.50	-34.50	250	-66.50	-36.50
80	-65.50	-35.50	260	-66.00	-36.00
90	-66.00	-36.00	270	-66.50	-36.50
100	-66.00	-36.00	280	-65.00	-35.00
110	-66.00	-36.00	290	-64.50	-34.50
120	-64.5	-34.50	300	-62.50	-32.50
130	-61.50	-31.50	310	-54.50	-24.50
140	-62.00	-32.00	320	-46.50	-16.50
150	-62.50	-32.50	330	-39.00	-9.00
160	-60.00	-30.00	340	-34.00	-4.00
170	-65.50	-35.50	350	-31.00	-1.00

Table 2: Determining the POWER RATIO with respect to the 0^o received signal level for the Horn Antenna.

19. From the results of table 2, the radiation pattern of the antenna are plotted in figure 14.

20. Disconnect the Gunn Oscillator's power supply cable from the Gunn Oscillator

Power Supply.

Remove the receiving Horn Antenna and insert the long triangular lens into the open end of the crystal detector . Adjust the antenna position indicator so that it indicates 0o when the lens is pointed directly towards the transmitting antenna.

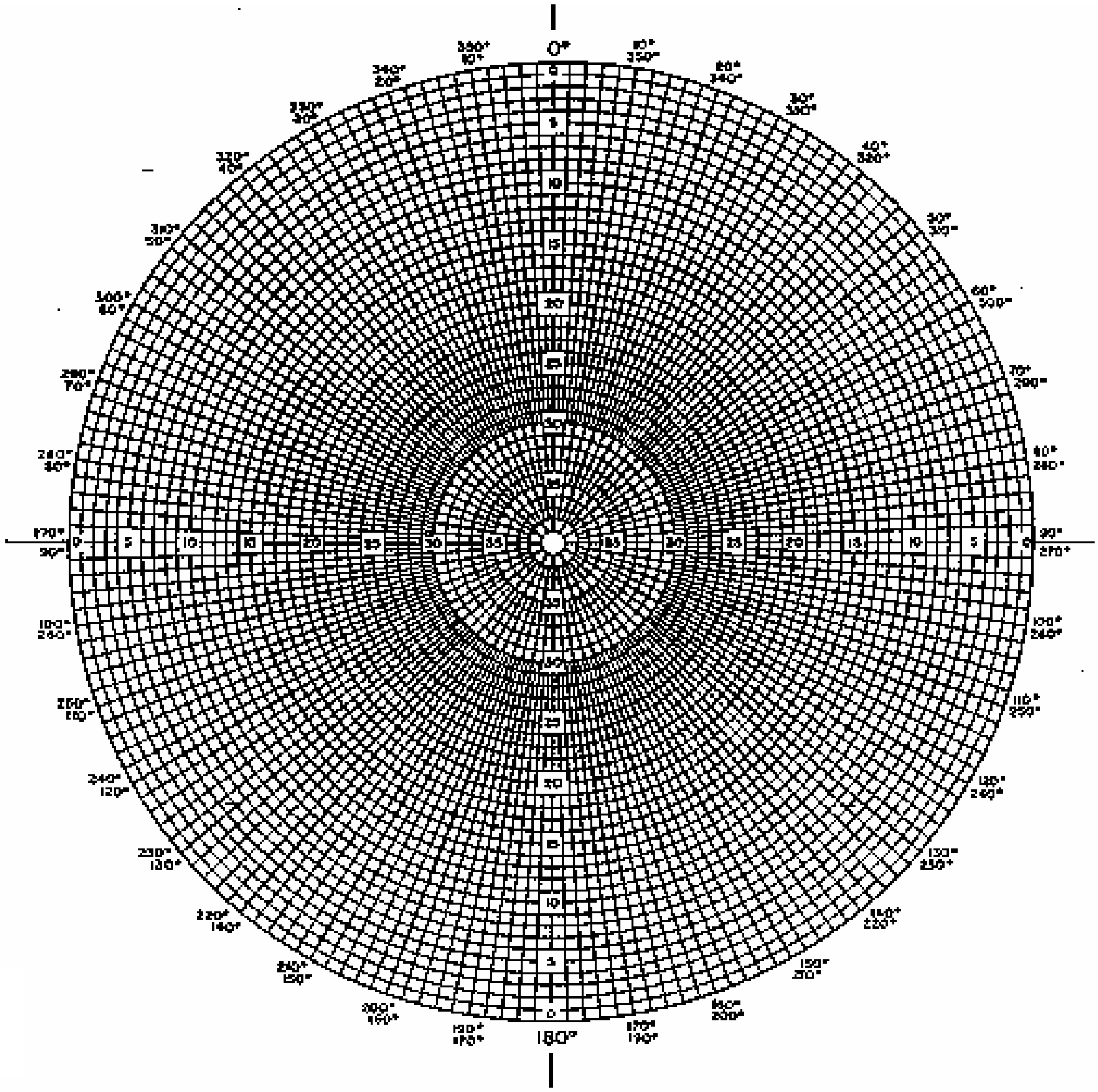


Fig. 14; Radiation pattern of the Horn Antenna.

Reconnect the Gunn Oscillator's power supply cable to the Gunn Oscillator Power Supply.

21. Adjust the Variable Attenuator to obtain a reading of -30 dB on the SWR Meter. As before, this is the reference level; it is already recorded in the first row of table 3.

22. For each direction given in the ANTENNA AZIMUTH INDICATION θ column of table 3, the RECEIVED SIGNAL LEVEL, $S_R(\theta^o)$ are recorded and the POWER RATIO are calculated in dB with $S_R(0^o)$ as a reference, as indicated at the top of the column.

Antenna Azimuth Indication	**Received Signal Level S_R (θ)**	**Power Ratio S_R (θ) - S_R (0^o)**	**Antenna Azimuth Indication**	**Received Signal Level S_R (θ)**	**Power Ratio S_R (θ) - S_R (0^o)**
degrees	dB	dB	degrees	dB	dB
0	30.00	0.00	180	53.50	23.50
10	30.20	0.20	190	60.00	30.00
20	30.60	0.60	200	53.00	23.00
30	31.30	1.30	210	51.40	21.40
40	32.70	2.70	220	51.80	21.80
50	34.20	4.20	230	49.00	19.00
60	37.00	7.00	240	50.00	20.00
70	40.20	10.20	250	48.00	18.00
80	42.40	12.40	260	45.00	15.00
90	47.70	17.70	270	46.00	16.00
100	46.20	16.20	280	42.00	22.00
110	52.00	22.00	290	40.00	20.00
120	48.50	18.50	300	36.00	6.00
130	47.50	17.50	310	34.00	4.00
140	49.50	19.50	320	32.00	2.00
150	50.00	20.00	330	31.50	1.50
160	53.50	23.50	340	30.75	0.75
170	52.00	22.00	350	30.00	0.00

Table 3: Determining the POWER RATIO with respect to the 0^o received signal level for long Triangular Lens Antenna.

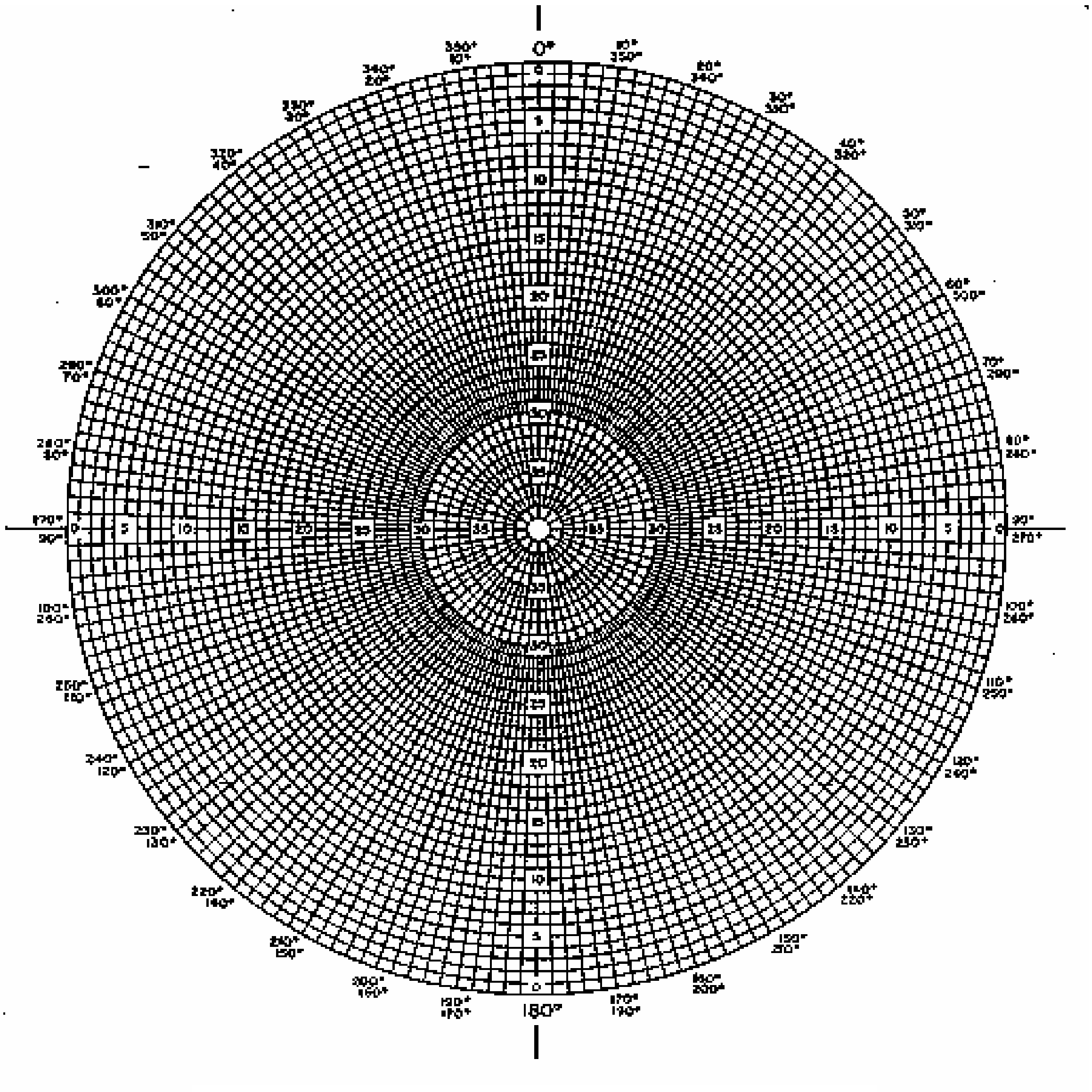


Fig. 14; Radiation pattern of the Long Triangular Lens antenna.

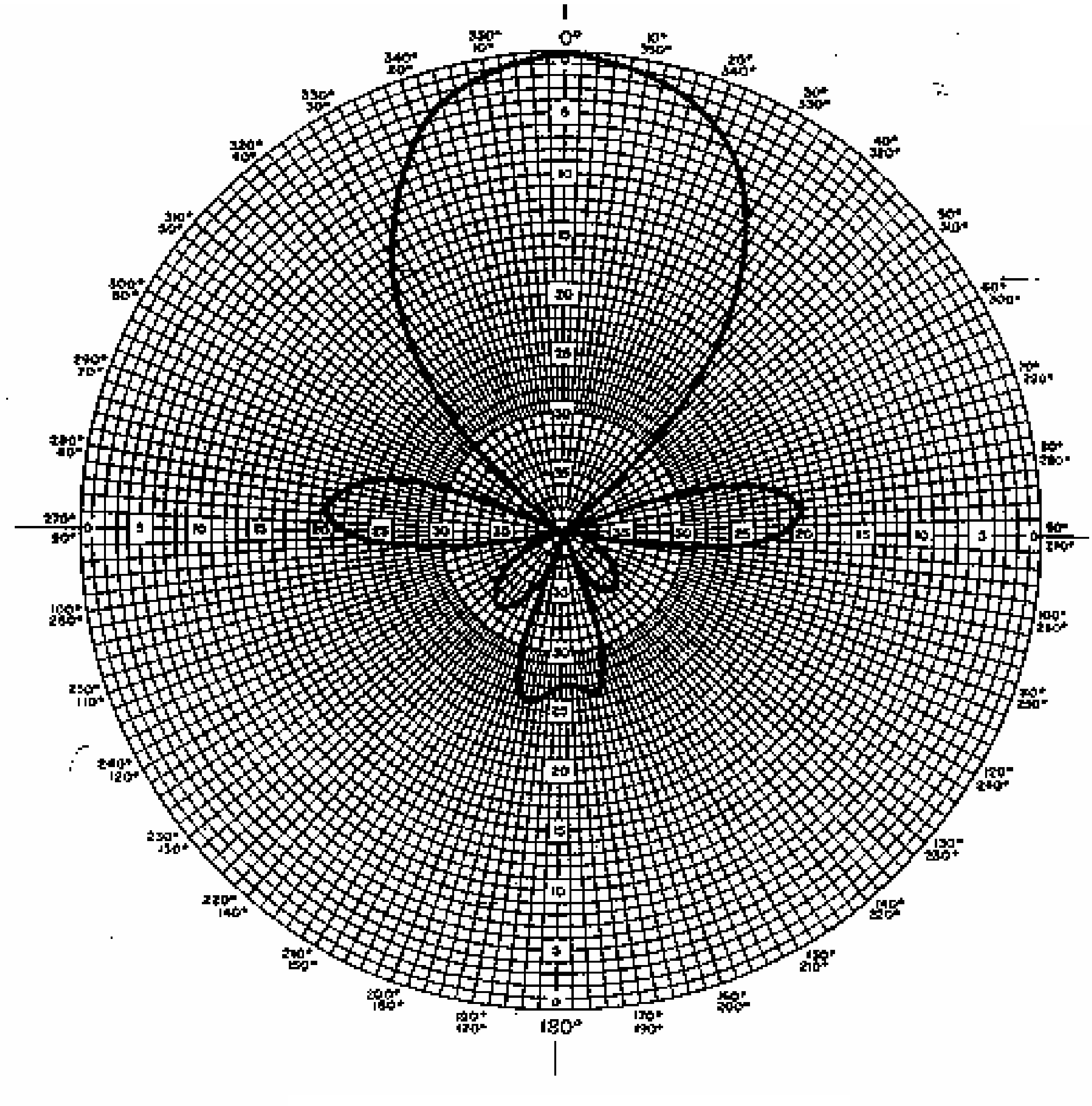


Fig. 15; Radiation pattern of the receiving antenna.

DISCUSSION

Antennas are the transition device between waveguides or transmission line and free space. They can either to receive free space waves or radiated guided waves. A waveguide, like a transmission line, is simply used to efficiently interconnect an antenna with the transceiver. An antenna couples energy from the output of the transmitter to Earth's atmosphere or from Earth's atmosphere to a receiver . An antenna is a passive reciprocal device, cannot amplify a signal, at least not in the true sense of the word and transmit or receive characteristics of an antenna are identical, except where feed currents to the antenna element are tapered to modify the transmit pattern.

Basic an antenna operation by looking at the voltage standing-waves patterns on the transmission line. Transmission line is terminated in an open circuit, which is represent an abrupt discontinuity to the incident voltage wave in the form of a phase reversal. The phase reversal results in some of the incident voltage to be radiated, not reflected back toward the source. The radiated energy propagates away from the antenna in the form of transverse electromagnetic waves.An antenna is used to interface a transmitter to free space or free space to the receiver waves guide , like transmission line, is simply used to efficiently interconnect an antenna with the receiver.An antenna couples energy from the output of the transmitter to Earth's atmosphere or from Earth's atmosphere to a receiver. Figure below shows the Horn Antenna and its schematic which one of the antenna type.

In this experiment we used horn antenna which is one of the type of an antenna. The horn is simply a flared piece of wavegiude material that is placed at the focus and radiates a somewhat directional pattern toward the parabolic reflector. When a propagating electromagnetic field reaches the mouth of the horn, it continues to propagate in the same general direction, except that, in accordance with Huygens' principle, at spreads laterally and the wave front eventually becomes spherical. The horn structure can have several different shapes, sectoral, pyramidal or conical. As with the center feed, a horn feed presents somewhat of an obtruction to waves reflected from the parabolic dish.

Refraction

Electromagnetic refraction is the change in direction of a ray as it passes obliquely from one medium to another with different velocities of propagation. The velocity at which an electromagnetic wave propagates is inversely proportional to the density of the medium in which it is propagating. Therefore, refraction occurs whenever a radio waves passes from one medium into another medium of different density.

Reflection

Reflection means to cast or turn back, and reflection is the act of reflecting. Electromagnetic reflection occurs when an incident wave strikes a boundary of two media and some or all of the incident power does not enter the second material. The waves that do not penetrate the second medium are reflected.

Diffraction

Diffraction is define as modulation or redistribution of energy within a wavefront when it passes north edge of an opaque object. Difraction is the phenomenon that allows light at radio waves to propagate (peek) around corners. However, the wave front continues in its original direction rather than spreading out, because cencellation of the secondary wave lets occurs in all directions except straight forward.

Interference

Interference means to come into opposition, and interference is the act of interfering. Radio wave interference occur when two or more electromagnetic waves combine in such a way that system performance is degraded.. Interference, on the other hand, is the subject to the principle of linear superposition of electromagnetic wave and occur whenever two or more waves simultaneously occupy the same point in space.

directive gain - gain of an antenna given by the ratio of the power produced by the antenna at given point to the power that would be produced by an asotropic radiator radiating the same total power.

Free space - empty space, or with no free electron or ions, which also contains no objects such as earth, building, and vegetation. Quite often, air is said to have the same electrical characteristics as free space.

isotropic radiator - hypothetical antenna having equal radiation power in all directions. It is a convenient reference for expressing the directive properties of Dual antennas

CONCLUSION

The propagation loss is function of the square of the distance between the transmitting and receiving antennas.

From the experiment, the ratio power between received power to the transmitted power is - 20.7 dB (Pr = -50.7 + Pt = 30) dB. The gain of each Horn antenna is equal to *13.86* dB.

From the plot curve, the relationship between the power of the received signal and the antenna separation is proportional to each other.

Antennas are the transition device between waveguide or transmission lines and free space. The radiation efficiency is the ratio of radiated to reflected energy and extremely low in open transmission.

A radiation pattern is a polar diagram or graph representing field strength or power densities at various angular positions relative to an antenna. The pattern is plotted on polar coordinate paper. If it plots field strength or power density with respect to the value at the reference point, it is called a relative radiation pattern.

To measuring the gain of an antenna, there are some different method.

I). The simplest method consists of comparing the power received by a reference antenna, P_{ref} to the power received by the antenna being tested, P_{test}.

II). Allows the gain of two identical antennas to be evaluated. Once the transmitted and received power Pt and Pr, therefore the Gain can be calculated

When we do our experiment, Don't look directly into the waveguide or Horn Antennas while power is being supplied to the Gunn Oscillator.

To reduce human mistake when do this experiment, lay a strip of masking tape along the working surface. Take the reading with directly propertional with the eyes make sure all equipment are good.

REVIEW QUESTION

The free-space propagation loss represented two isotropic radiator in free space, expressed as a power ratio usually in dB. Bringing out the fact that it is independent of the directive properties of antennas.

The reference antenna method of antenna gain measurement are describe by the simplest method consists of comparing the power received by a reference antenna. Prefer to the power received by the antenna being tested P test. The gain is given by

$$G_{test} = \frac{P_{test}}{P_{ref}} \cdot G_{ref}$$

The second method is allows the gain of two identical antennas to be evaluated . Once the transmitted and received power Pt & Pr should be measured by calculated with

The radiation pattern occur when the same antenna was used to transmit a signal was the field strength and power density will be less in energy and absolute radiation pattern cannot plotted exactly. Therefore polar coordinate with the heavy solid line cannot be equal to power density.

Distance between two successive measurement are:

Formula : $P_C\,(dB) = 20 \log (4\pi r)/\lambda$

assume $\lambda = c / f$ where $c = 3 \times 10^8$

$f = 10.5$ GHz

$\lambda = 28.57 \times 10\ 3$

if $P_C\,(dB) = 1$ dB,

$$1 = 20 \log (4\pi r)/\lambda$$

$$r = 25.50 \times 10^3$$

We preferable to move antennas away from the ground when making antennas pattern measurement because can be effect to wave propagation. The antenna is mounted an appreciable number of wavelength (height) above the surface of Earth. So it can reduce lower lobe and field strength directly upward is double.

REFERENCES

Modern Electronic Communication, 4 th Edition.
Gary Miller, 1993, New Jersey.

Electronic Communication System Faundamental Through
Advanced, 2 nd Edition . Wayne Tomasi
1994, United state.

Electronic Communications, 4 th Edition.
Dennis Roddy And John Coolent , New Jersey.

Electronic Communication System, 4 th Edition
Kennedy and Davis - Mc Graw Hill.

Introduction to Communication Systems, 3th. Edition.

Ferrel G. Stremler - Addison-Wesley Pub. Co.