الجامعة الاسلامية العالمية ماليزيا

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

اونيۏرسيتي اسلام انتارابڠسا مليسيا

KULLIYYAH OF ENGINEERING

DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

MICROWAVE LABORATORY
ECE 3203

EXPERIMENT NO.4

(Horn Antenna Investigations)

MICROWAVE TRAINER	**Assignment 5** **Horn Antenna Investigations**

CONTENT

A test bench is set up to investigate the radiation pattern of a rectangular waveguide pyramidal horn antenna. Polar radiation diagrams are plotted and the 3 dB beamwidth of the antenna is determined.

EQUIPMENT REQUIRED

Qty	Identifying Letter	Description
1	-	Control console
1	A	Variable attenuator
1	K	Resistive load termination
1	M	Diode detector
2	N	Horn antenna
1	P	X-band oscillator
4	-	Supports

OBJECTIVES

When you have completed this assignment you

- Will appreciated the directional radiation characteristics of a horn antenna and know how to plot its radiation pattern
- Know how to measure the beamwidth and gain of an antenna

KNOWLEDGE LEVEL

Before you start this assignment it would be an advantage

- To be familiar with the operation of the microwave bench
- Know that microwave signals can be detected using a diode detector and for low-level signals, that detected output is proportional to power
- To appreciate the role of antennas in the transmission and reception of radio waves

INTRODUCTION

Antennas are essential components in the transmission and reception of radio waves. In the microwave range, highly directive antennas capable of producing the narrow beams required for the line-of-sight links and satellite communications can be designed. The horn antenna, whose radiation characteristics are investigated in this assignment, plays an important role as a radiator of microwave energy in its own right and also as a primary feed for reflector antennas employed in microwave radio links and radar.

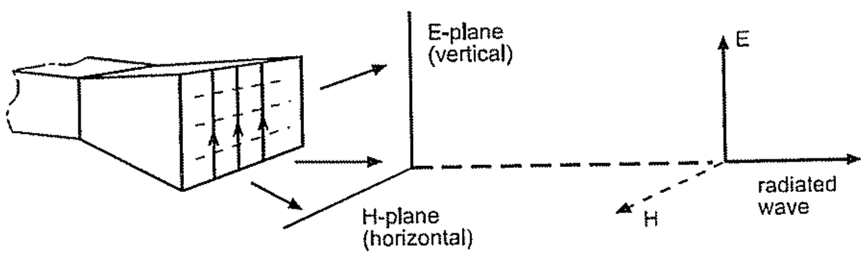
The directional characteristics of an antenna - the directions it radiates energy into space - can be visualised graphically by plotting radiated power density versus angular direction. These polar plots are known as far-field radiation diagrams, the latter qualifying the condition that measurements are taken at a sufficiently far distance from the antenna to represent the characteristics as dependent primarily on angular direction. Close to an antenna the radiation pattern is very complex and seldom used in practice. The far-field conditions are satisfied at distances,

$$r \geq 2D^2/\lambda$$

where D = largest antenna dimension

λ = transmitted wavelength

To fully describe the directional properties of an antenna two radiation diagrams are normally required: one in the horizontal plane, in the case of the horn antenna this would be the H-plane with respect to the horn sketched in Figure 2-5-1, and one for the vertical plane, the E-plane in Figure 2-5-1.



E = Electric field
H = Magnetic field

Figure 2-5-1: Pyramidal Horn Antenna

A typical radiation diagram for an antenna with directional radiation (and receiving) properties such as a horn or a parabolic reflector fed by a horn is shown in figure 2.5.2. The angular spread on the main beam between points where the power drops to one-half or by 3 dB from the maximum is known as the 3-dB beamwidth and is an important measure of an antenna's directivity. Not all radiation is confined to the main beam and subsidiary beams at lower power levels and known as side-lobes occur. side-lobes and spill-over radiation can cause interference in microwave radio systems and their levels must be carefully controlled by antenna designers.

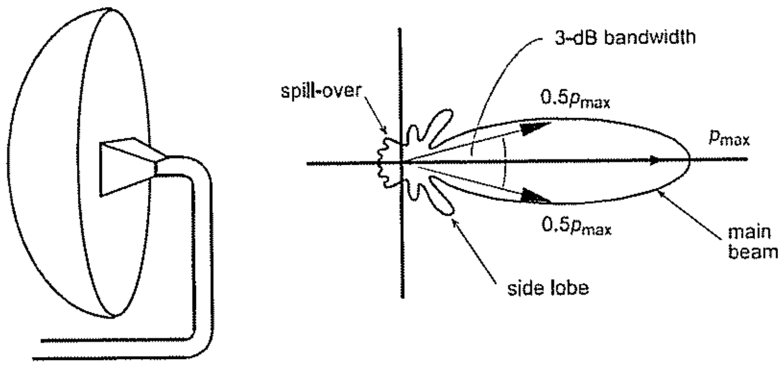


Figure 2-5-2: A Typical Radiation Diagram for a Directional Microwave Antenna

One of the most important parameters of an antenna is its gain. Antenna gain compares the power radiated in the direction of the main beam with that of a hypothetical antenna radiating equally in all directions. Antenna gain is defined as:

G = p/pi

where p = power density W/m^2 radiated by antenna in given direction

pi= power density radiated equally in all directions

= P/4pr^2

P= total power radiated

r= distance from antenna

4pr^2= surface area of sphere radius r

For aperture type antenna such as horns and parabolic reflectors, gain is given by the formula:

$$G = \eta \frac{4\pi}{\lambda^2} A$$

where A = area of antenna aperture

η = aperture illumination efficiency (typically between 0.5 and 0.8)

Gain is very often expressed in decibels, dB:

G dB = 10 log (p/pi) dBi

The i qualifying, isotropic, the fact that the reference antenna radiates isotropically (equally in all directions). The product of antenna gain G and radiated power P is known as the effective isotropic radiated power normally abbreviated to EIRP:

EIRP = G x P

The power received in a line-of-sight radio link can be expressed in terms of transmitted power and antenna gains; the received power

$$P_R = P_T \; G_T \times \left(\frac{\lambda}{4\pi r}\right)^2 \times G_R$$

where P_T = transmitter radiated power

G_T = gain of transmitter antenna

G_R = gain of receiver antenna

l = wavelength

r = link distance

The above formula is extremely useful in power budget calculations for microwave radio links. It may also be used to measure experimentally the gain of an antenna. If P_R is measured for a given transmitted power and a reference antenna is used over a link of known length, G_T can be determined:

$$G_r = \frac{\left(\frac{P_R}{P_T}\right) \times \left(\frac{4\pi r}{\lambda}\right)^2}{G_R}$$

or in dB $\quad G_r \text{ dB} = 10 \log \left(\frac{P_R}{P_T}\right) + 20 \log \left(\frac{4\pi r}{\lambda}\right) - G_R \text{ dB}$

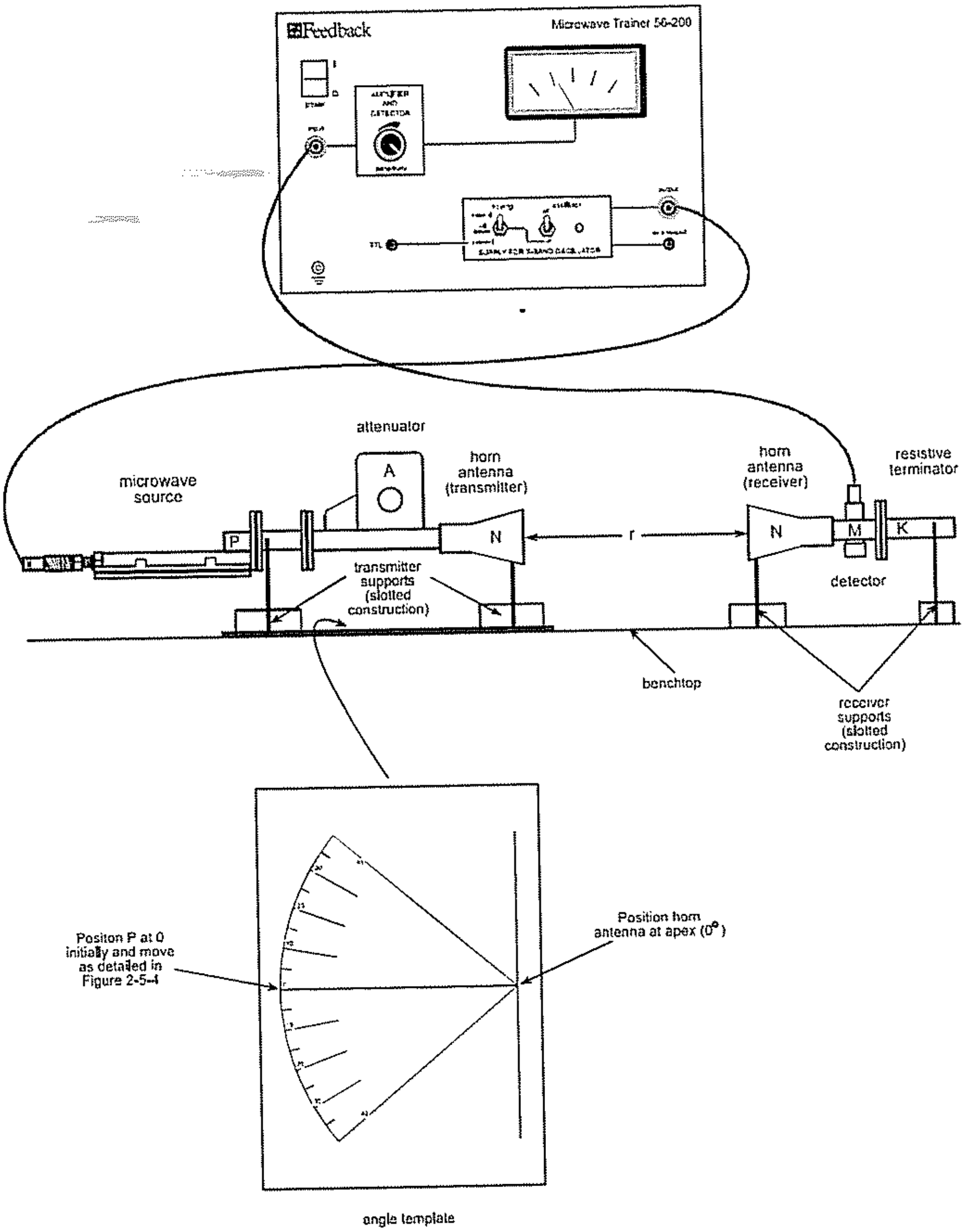

Feedback
Microwave Trainer 56-200
attenuator
A
microwave source
P
horn antenna (transmitter)
N
r
horn antenna (receiver)
N
M
K
resistive terminator
detector
transmitter supports (slotted construction)
benchtop
receiver supports (slotted construction)
Positon P at 0 initially and move as detailed in Figure 2-5-4
Position horn antenna at apex (0°)
angle template

Figure 2-5-3

EXPERIMENTAL PROCEDURE

> WARNING:
>
> Do NOT look directly into the transmitter antenna when taking measurements in this experiment.
> Remember, although the power levels produced by the microwave source in the Trainer are low, microwave radiation can cause harm and eyes are particularly sensitive.

1. Connect up the equipment as shown in Figure 2-5-3. Switch the X-band source to internal keying and the meter to detector output.

2. Ensure that the distance r between transmitter and receiver horns is about 30 cm. This distance partially satisfies the conditions that measurements are taken in the far-field, whilst providing sufficient scope for the received signal levels to be detected. The far-field condition is

$$r \geq \frac{2D^2}{\lambda}$$

where D = maximum dimension of horn aperture = 8 cm

λ = wavelength = 2.88 cm for f = 10.425 GHz

so $r = 2D^2/\lambda \cong 44$ cm

Thus the condition is not quite satisfied. However, reasonably accurate results for plotting a radiation diagram can be obtained with r = 30 cm. It is also important to ensure that the radio path between the antennas and their surrounds are free from obstacles, particularly metallic structures, which could cause reflections into the antennas and give rise to false results.

3. Switch on the console power supply and X-band oscillator source. Set the attenuator to a low attenuation setting, typically 40° on the attenuator scale, and turn the amplifier-detector control up to maximum sensitivity.

Align the antennas for the line-of-sight 0° position. In this position the transmitter antenna will be radiating directly in line with the receiver and correspond to maximum antenna gains and maximum received signal.

Adjust attenuator and detector-amplifier sensitivity to obtain a meter reading close to full scale deflection. Record this reading.

4. The radiation diagram for the transmitter horn can now be obtained by rotating the transmitter section from the 0° position through steps of 5° up to 40° either side of the 0° position, using the template provided (on the Manual CD or from the Feedback Website: www.fbk.com/).

Record measurement of received signal level as indicated on the detector meter in a table such as that given below.

The angle of rotation θ° can be set by use of the template, aligning the supports with the template lines as indicated on the template.

Angular direction Θ°	Diode detector meter reading I mA	Angular direction Θ°	Diode detector meter reading I mA
0°		0°	
+5°		–5°	
10°		10°	
15°		15°	
20°		20°	
25°		25°	
30°		30°	
35°		35°	
40°		40°	

Table for logging radiation diagram results

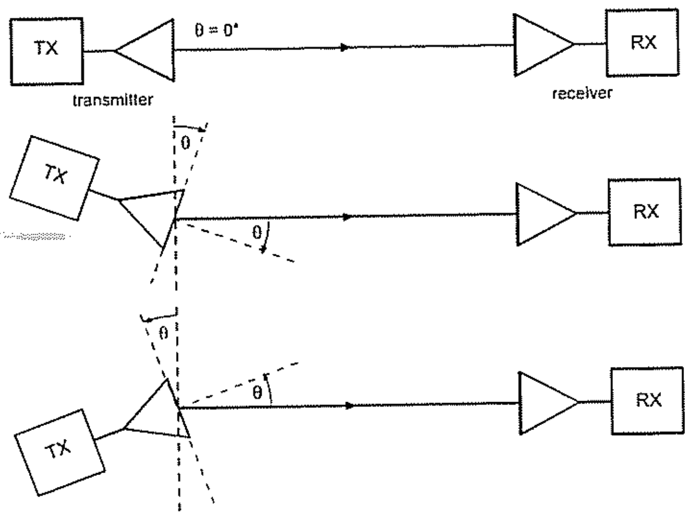


Figure 2-5-4: Measurement of Radiation Polar Diagram of an Horn Antenna

5. Plot the polar radiation diagram of the horn antenna on polar graph paper, an example of which is shown below in Figure 2-5-5. Θ° is the angular direction and I, the diode detector output current, is directly proportional to power for small signal levels. Thus a polar plot of I versus Θ represents the power radiation diagram.

From the radiation diagram, determine the beamwidth between half-power point (3 dB) levels; that is, the angle between points on the polar curve where the power drops to half of the maximum gain of the Θ = 0° position.

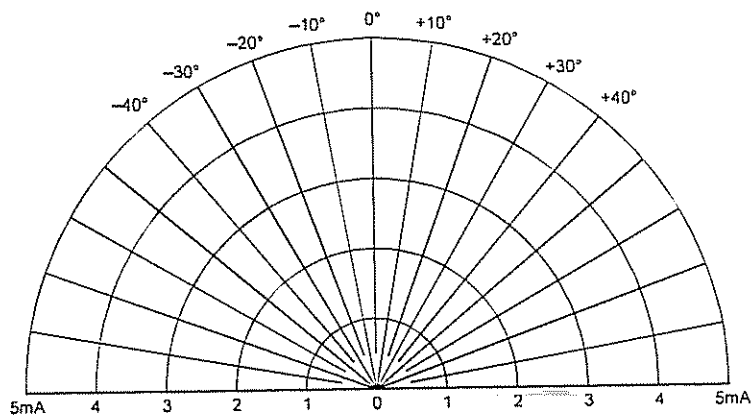


Figure 2-5-5 Polar Graph Paper for Plotting Radiation Diagram

6. Interchange transmitter and receiver antennas so their respective roles are changed and repeat the experiment to obtain the radiation diagram of the second antenna. Compare the two diagrams and their 3 dB beamwidth.

7. The gain of an aperture type antenna is given by the formula:

$$G = \eta \frac{4\pi}{\lambda^2} A$$

where η = aperture efficiency

A = aperture area

Assuming that the aperture efficiency of the horn antenna is 60%, estimate the gain of the horns used in the experiment at the 10.425 GHz source frequency.

8. The gain of the antennas may be measured experimentally by determining:

P_T = total power transmitted

P_R = power received

or the ratio P_R/P_T

and utilising the formula:

$$P_R = P_T \ G_T \times \left(\frac{\lambda}{4\pi r}\right)^2 \ G_R$$

where G_T, G_R = gain of transmitter, receiver antennas which in our case can be assumed equal.

Outline how you would measure gain G of the horn antennas and calculate G for the case

P_T = 2.0 mW

P_R = 0.05 mW

r = 0.5 m

f = 10.425 GHz

SUMMARY

The radiation diagram of horn antennas has been investigated experimentally using a basic microwave test bench. The polar radiation diagram has been plotted and the 3 dB beamwidth of the antenna determined. The measurements taken were in the H-plane and indicated the horn antenna to have a directive radiation pattern.

Notes