Chapter 3 Assignment 9

CONTENT

The construction and operating characteristics of a horn antenna is investigated.

EQUIPMENT REQUIRED

Qty	Ident. letter	Description
1	–	Control Console
1	A	Variable Attenuator
1	K	Resistive Terminator
1	M	Diode Detector
2	N	Horn Antenna
1	P	X–Band Oscillator

Chapter 3 Assignment 9

OBJECTIVES

When you have completed this assignment you will:

- Be able to describe the operation and characteristics required of a horn antenna.
- Know what is meant by beam–width and gain with reference to a horn antenna.

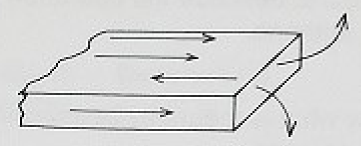
KNOWLEDGE LEVEL

Before you start this assignment you should:

- Have completed Assignment 2 'Measurement of Voltage Standing Wave Ratio'.

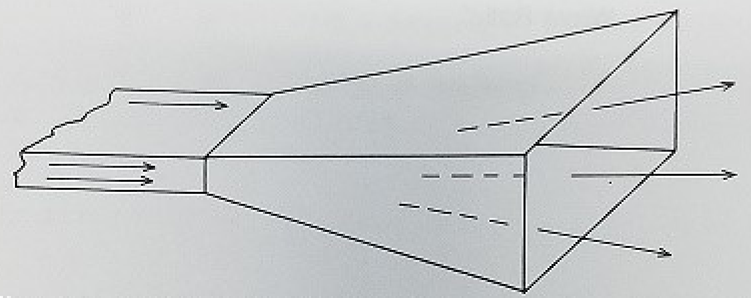
Chapter 3 Assignment 9

Fig 9.1



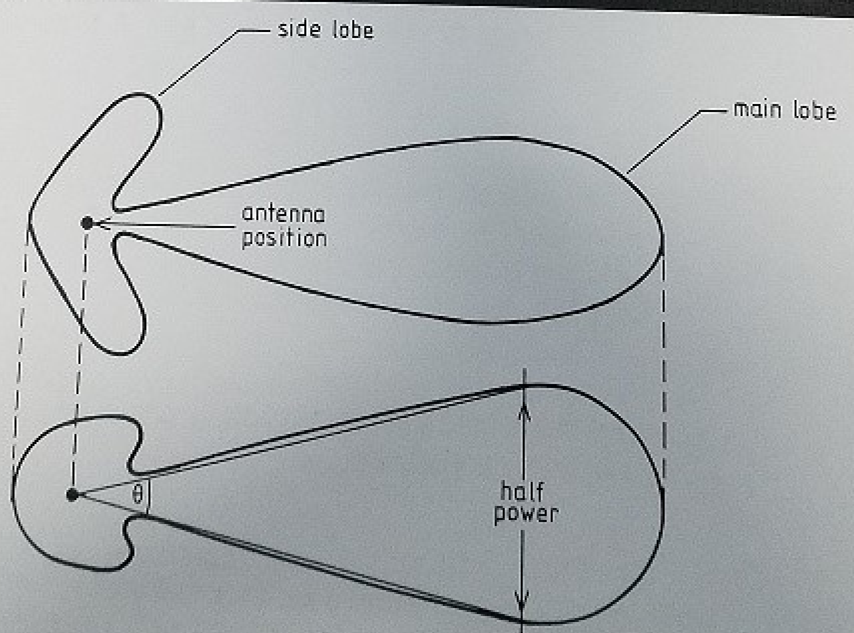
Energy Radiated and Reflected from an Open Waveguide End

Fig 9.2



Energy Radiated from a Horn Antenna (more concentrated in one direction)

Fig 9.3



Two Sections of a Three-dimensional Radiation Pattern

Chapter 3 Assignment 9

INTRODUCTION

If a waveguide which is propagating a signal is left with an open end,some of the signal energy will escape into space (Fig 9.1). Some will be reflected because the end is not well matched to free space, so a VSWR of about 2 will typically result.

Let us consider first the energy which does get radiated or transmitted into space. Suppose the transmitted power is P_t. If it were radiated in all directions equally, then at a distance r from the source the total power P_t would be spread evenly across the surface of a sphere of surface area $4\pi r^2$. A receiving antenna occupying area A of that sphere would receive a proportion of the transmitted power,

$$P_r = P_t \frac{A}{4\pi r^2}$$

When it is required to transmit energy efficiently into space, a device called an '*aerial*' or '*antenna*' is used. The horn is a very simple form of antenna, being no more than a flare-out of the shape of the waveguide walls. It improves the match between the waveguide and free space, and narrows the angle over which energy is radiated, fig 9.2.

By concentrating the radiation in a particular direction, the power radiated in that direction is increased (at the expense of reduced power in other directions). The factor by which it is increased is called the 'gain' of the transmitting antenna. Thus the power received by the receiving antenna of area A becomes:

$$P_r = P_t \frac{GA}{(4\pi r^2)}$$

The gain G is often expressed in decibels as:

$10 \log_{10} G$ dB, or dBi

(where the 'i' refers to an isotropic radiator; one which radiates equally in all directions).

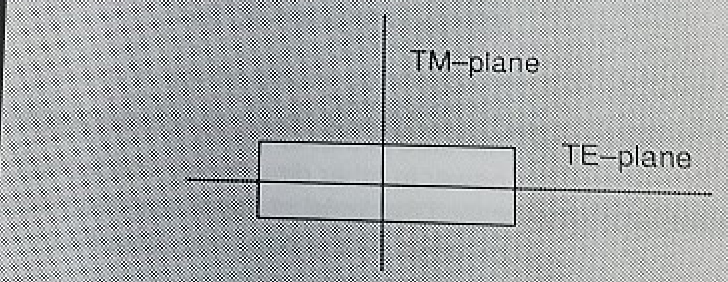
An alternative definition for gain compares the antenna's performance not with an isotropic radiator, but with a half-wave dipole. The gain defined in this way is about 2.2dB less than the gain in dBi.

In most microwave applications we require as much energy as possible to be radiated in a particular direction. This is often important not only for maximising the power received, but also because the system (a radar, perhaps) requires directional information.

The directional characteristics of an antenna would ideally be shown as a three-dimensional graph in which, for each direction, the radius from a central point is proportional to the power density at a given distance. This is called the '*radiation pattern*'. For practical reasons the radiation pattern is normally shown by two-dimensional graphs which show a section or sections of the three-dimensional pattern, like figure 9.3.

Fig 9.4 shows the planes used for a rectangular waveguide, designated TM–plane and TE–plane because they contain the directions of the electric and magnetic field respectively.

Fig 9.4



End-view of Waveguide Showing TM and TE Planes

As shown in fig 9.3, a radiation pattern usually has several 'lobes'. Generally, most energy is concentrated into the main lobe. Radiation in side and back lobes represents a waste of power. It can in some applications have serious effects by, for instance, producing false radar images.

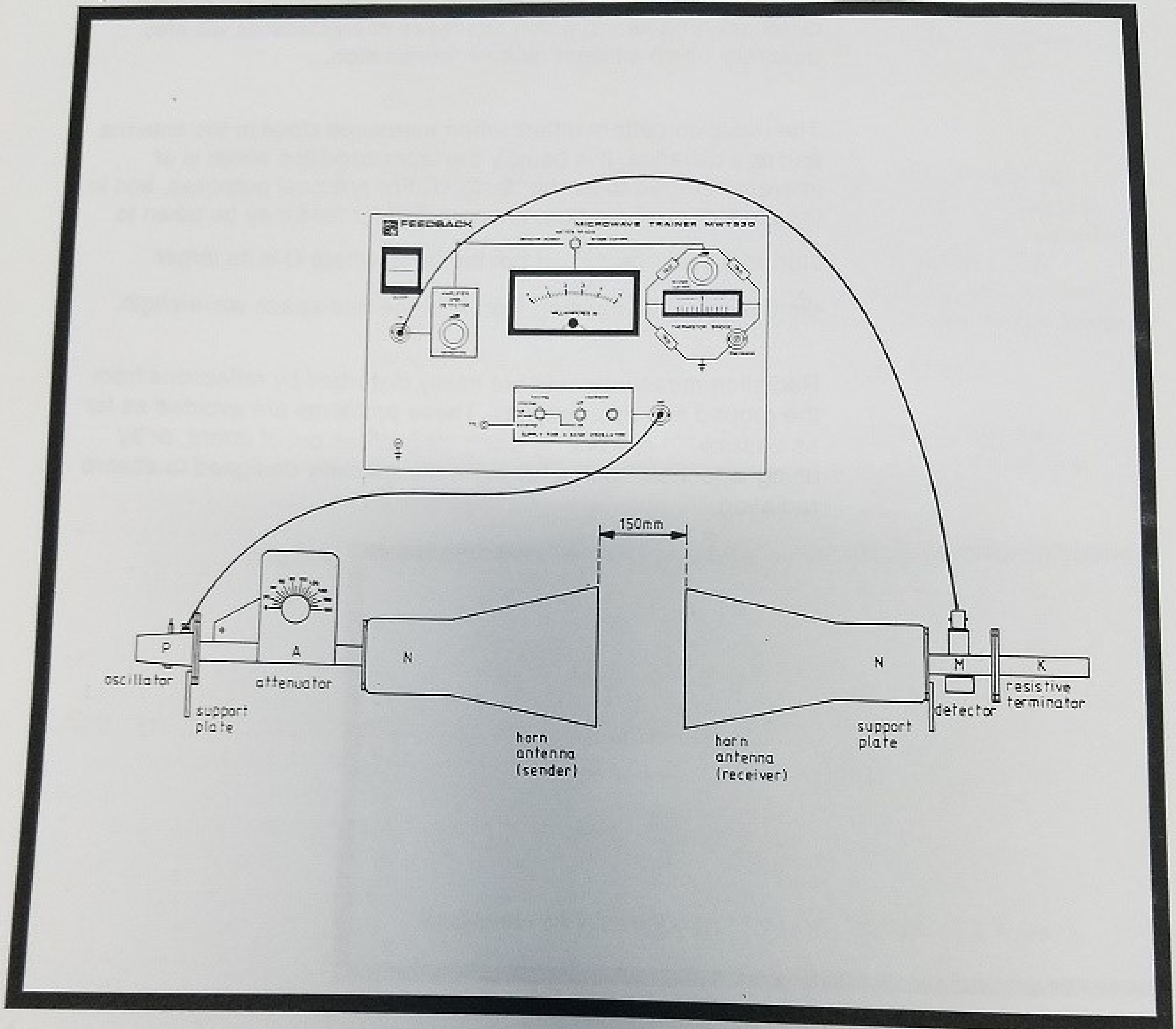
The '*3-dB beam width*' is often used as a measure of the directivity of an antenna. It is the angle (θ in fig 9.3) between the two points on the main lobe at which the radiated power density is half the maximum.

The gain is generally highest if the beam width is narrow and the side lobes are small, so that all the power is sent in the desired direction. An antenna which has these characteristics will also generally be an efficient receiver of radiation.

The radiation pattern differs when measured close to the antenna and at a distance. It is usually the latter condition which is of interest, referred to as the '*far field*'. For practical purposes, and in the case of a simple horn antenna, the far field may be taken to start at a distance $\frac{2D^2}{\lambda_0}$ from the horn, where D is its larger dimension at the opening, and λ_0 is the free-space wavelength.

Radiation measurements are easily disturbed by reflections from the ground and other objects. These problems are avoided as far as possible in practice by using clear areas out of doors, or by using 'anechoic' rooms having walls specially designed to absorb radiation.

Fig 9.5


FEEDBACK
MICROWAVE TRAINER MWT530
150mm
P
A
N
N
M
K
oscillator
support plate
attenuator
horn antenna (sender)
horn antenna (receiver)
support plate
detector
resistive terminator

Chapter 3 Assignment 9

EXPERIMENTAL PROCEDURE

Connect the apparatus as shown in fig 9.5, with one sending antenna and one receiving antenna. On the Control Console, switch on the supply to the oscillator and set its left-hand switch for internal keying; set the METER READS switch to 'detector output'.

Results will be improved if the sending and receiving antennas are each mounted so that no solid material is near the path between them. They may each for instance be mounted on the edge of a box, or on the edge of a table, leaving an open space between them. A space of about 150mm betwen the antennas may be tried for a start.

WARNING

Keep your eyes AWAY from the space in front of the transmitting antenna.

Set the amplifier to maximum sensitivity. Align the Antennas '0°' direction. Adjust the attenuator to give a meter deflection near maximum. Make a note of this reading in the 0° column of a table like fig 9.6. (Do not stand close to the transmisson path while taking readings, as they will be affected).

Notice that the antennas must be similarly 'polarised'. That is, the receiving antenna must be sensitive to electric field in the same direction as the electric field from the sending antenna. Try turning the receiving antenna on its side and note the effect.

Fig 9.6

Meter reading (mA)	Attenuator setting				
	0°	10°	20°	30°	40°
left side					
right side					

Chapter 3 Assignment 9

Using a protractor (or a copy of fig 9.7) to measure angles, rotate the receiving antenna about the centre of the broad edges of its aperture (opening). Set the angle to 10°, 20° 30° and 40° in each direction. Record the meter readings in each case. Plot them on a graph sheet like fig 9.7.

Use the graph to find the 3dB beam-width of the antenna.

Fig 9.7

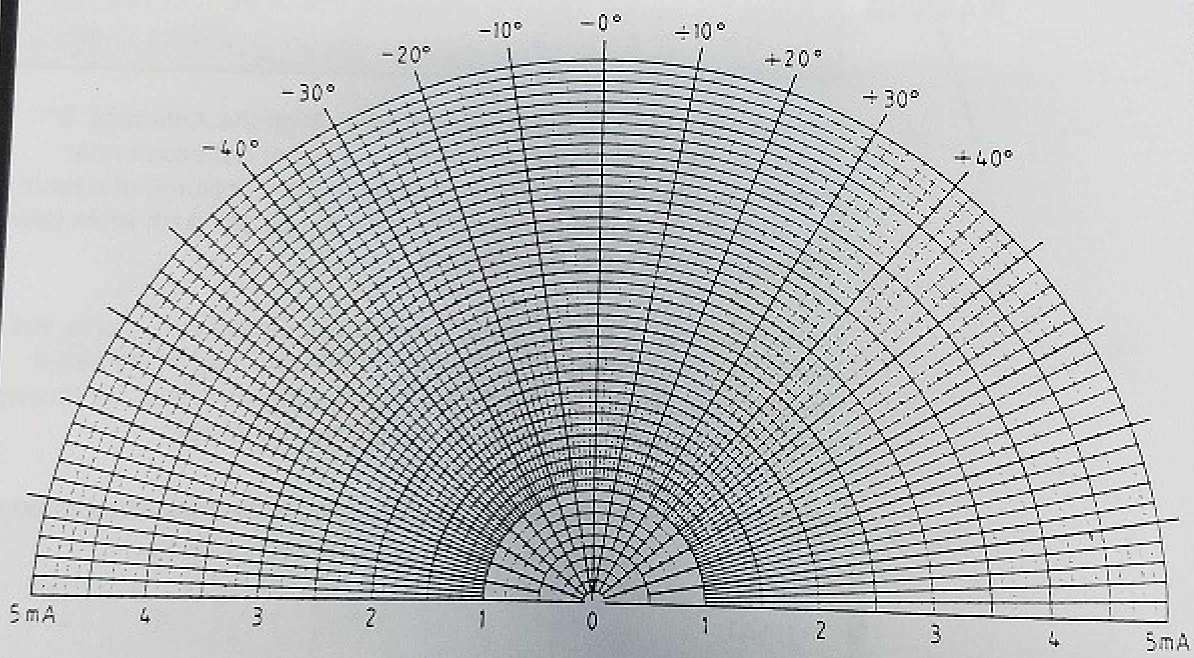


Chart for Plotting Radiation Patterns

Chapter 3 Assignment 9

SUMMARY

R.f energy reaching the open end of a waveguide will be partly radiated into space and partly reflected back into the waveguide. When it is desired to radiate the energy, an antenna is used. An antenna should:

- Provide a good match to the waveguide, thus avoiding reflections and standing waves in it.
- Launch radiation into space in required directions, not in others. This also increases the gain, which is the ratio between power radiated in a preferred direction and that which would be radiated by an isotropic (or omnidirectional) radiator.

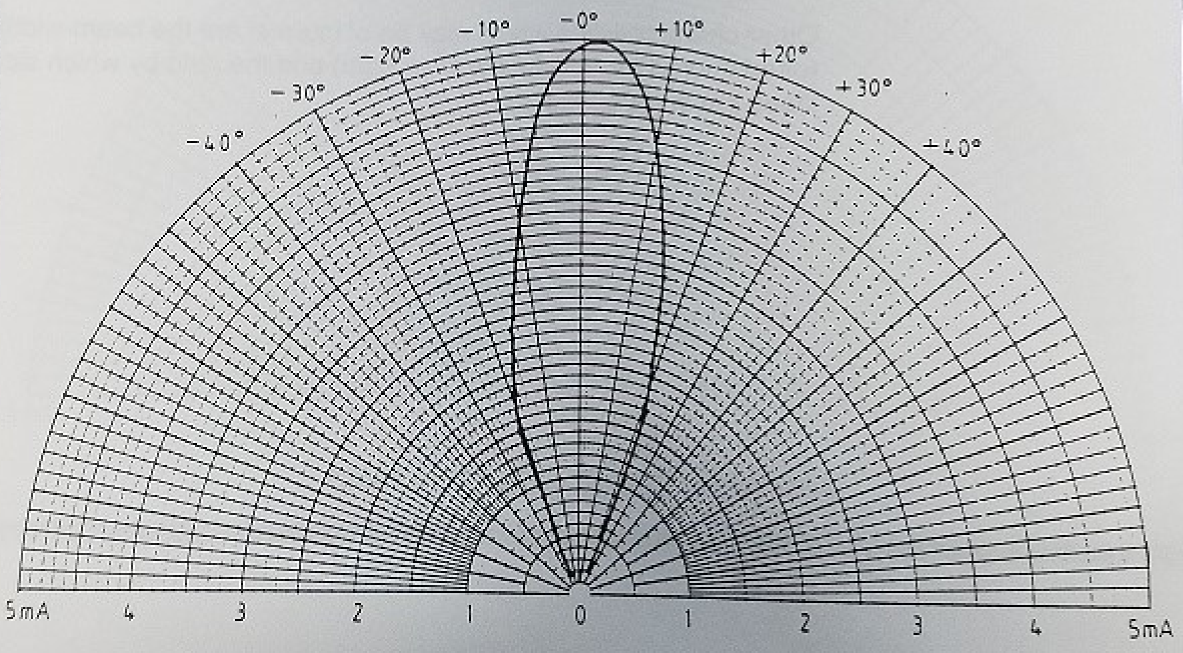
An antenna may also be used to receive energy radiated from elsewhere in space. In general the properties of receiving antennas are closely related to those of the same antenna when used for transmitting.

Other characteristics which may be of interest are the beam-width (often quoted for 3dB below peak gain) and the ratio by which side-lobes are suppressed.

Ref. fig 9.6

Meter reading (mA)	Attenuator setting				
	0°	10°	20°	30°	40°
left side	5	3.4	1.8	0.6	0.1
right side	3	4.2	1.7	0.6	0.015

Fig E9



Since maximum power corresponds to 5mA, half power corresponds to 2.5mA. From a graph the 3dB beamwidth can be estimated as 26°.