OBJECTIVES

1. To plot the radiation pattern in E & H plane.
2. To determine 3-db beam with in both plane.
3. To compute approximate gain.
4. Using two identical horns determine gain & compare the value found in step b.

EQUIPMENTS

Klystron tube, Klystron power supply, Isolator, Frequency meter, Variable attenuator, Klystron mount, Waveguide stands, SWR meter, Detector mount, two horn antenna, turn table and accessories.

THEORY

In microwave communications, the transmission and reception of microwave power to/from space, is a primary necessity. The process is affected by an impedance transformer between the space and source, known as antenna. The basic characteristics of an antenna are expressed in terms of field pattern, directivity, bandwidth and gain. A transmission line shall act as an antenna if its output end is well matched to space. Such an antenna because of having shapes like horns are known as horn antenna.

Fig. 1   Energy radiated and reflected from an open waveguide end

RADIATION PATTERN

The Radiation pattern of an antenna is a diagram of field strength. Here 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. For practical reasons the radiation pattern is normally shown by two-dimensional graphs which show a section or sections of the three-dimensional pattern (Fig. 3).
If a waveguide which is propagating a signal is left with an open end, some of the signal energy will escape into space (Fig. 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,

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

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. 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:

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

The gain $G$ is often expressed in decibels as:

$$10 \log_{10} G \, \text{dBi}$$

where the ‘i’ refers to an isotropic radiator; one which radiates equally in all directions.

Fig. 4 shows the planes used for a rectangular waveguide, designated E-plane and H-plane because they contain the directions of the electric and magnetic field respectively.

![Fig. 4 End-view of waveguide showing E- and H- planes](image)

As shown in Fig. 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.

**3-dB BEAM WIDTH**

‘3-dB beam width’ is often used as a measure of the directivity of an antenna. It is the angle (θ in Fig. 3) between the two points on the main lobe at which the radiated power density is half the maximum. The gain is generally the 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 all these characteristic will also generally be an efficient receiver of radiation.

**FAR-FIELD PATTERN**

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 $2D^2/\lambda_o$ from the horn, where $D$ is its larger dimension at the opening, and $\lambda_o$ 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.
WARNING!

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

Fig. 5 Antenna test-bench set-up for radiation pattern measurement
PROCEDURE

A. Radiation Pattern Plotting:

1. Set the components and equipments as shown in Fig. 5.
2. Same type of transmitting and receiving antenna (horn antenna) are used, keeping the axis of both antennas in the same axis line. To satisfy the ‘Far-field Pattern’ a space of about 150 cm between antennas may be tried at the start.
3. The variable attenuator is set accordingly for maximum deflection at the VSWR Meter.
4. The amplifier (Klystron or Gunn diode) is set for maximum sensitivity.
5. Align the antennas at $0^\circ$ directions. Notice that antennas must be similarly ‘polarized’.
6. Attenuator is adjusted for deflection near maximum (possibly at 0-dB).
7. Using a protractor (or a copy of Fig. 6) to measure angles, rotate the receiving antenna about the centre of the broad edges of its aperture (opening). Set the angle to $10^\circ$, $20^\circ$, $30^\circ$ and $40^\circ$ in each direction. Record the meter reading in each case. They are plotted on a graph sheet like Fig. 6. The 3-dB beam-width of the antenna is found out from the graph (as the meter reading is proportional to received power, consequently 3 dB, half power, means that the meter reading is half the maximum reading).

B. Gain measurement:

1. Set up the equipments like we used in the previous experiment.
2. Keep the range dB switch of VSWR meter at 50 dB position with gain control full.
3. Energize the Gunn oscillator (or Klystron Amplifier) for maximum output at desired frequency.
4. Obtain full scale deflection at VSWR meter with variable attenuator.
5. Obtain the reading at the VSWR meter at the receiving antenna and record it.
6. Without touching gain control knob, replace the transmitting horn by detector mount and change the appropriate range dB position to get the deflection on scale. Note and record the range dB position and deflection of VSWR meter.
7. Calculate the difference in dB between the power measured in step 4 and 5.

EXAMPLE

Suppose that a deflection of 5 dB on 20 dB range dB position was obtained in step 5, the difference between 4 and 5 is-

$$50 - (20 - 5) = 25 \text{ dB}.$$  

Convert the dB into power ratio. As for above example it will come 316 which will be $P_t/P_r$. Calculate gain by following equation:

$$G = \frac{4\pi S}{\lambda_0} \sqrt{\frac{P_r}{P_t}}.$$
In our above example, suppose operating frequency is 9GHz. So, \( \lambda_0 = 3.33 \text{cm} \). Where \( c \) is velocity of light and is \( 3 \times 10^{10} \text{ cm/sec.} \) and distance between antennas is 150 cm. (suppose)

8. Convert G into dB in above example

\[
G \text{ dB} = 10 \log 318 = 15.02 \text{ dB}
\]

9. The same setup can be used for other frequency of operation.

Table for recording meter deflection for movement of antenna by respective degree

<table>
<thead>
<tr>
<th>Attenuator Setting</th>
<th>0(^{\circ})</th>
<th>10(^{\circ})</th>
<th>20(^{\circ})</th>
<th>30(^{\circ})</th>
<th>40(^{\circ})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meter reading (mA)</td>
<td>---</td>
<td>left side</td>
<td>---</td>
<td>right side</td>
<td>---</td>
</tr>
</tbody>
</table>

Fig. 6 Chart for plotting radiation patterns

Group No.:
Roll No.:
Name:

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