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# HORN ANTENNAS

In this experiment, the radiation pattern, half-power beamwidth, and gain of a pyramidal horn antenna will be investigated.

## Preliminary Information :

Horn antennas are specialized antennas used at very high frequencies. They are generally used for illuminating reflectors or in the measurement of antenna gains. Radiation occurs from the electromagnetic waves propagating out of the open aperture of the horn antenna. Horn antennas can be created by flaring the aperture of a rectangular waveguide in theE-plane (electric field) or H-plane (magnetic field). Commonly, pyramidal horns, which are formed by flaring the waveguide in both the E and H planes, are used (Figure 1).

**Radiation Pattern**: The angular variation of the power that an antenna radiates into or receives from space is called the radiation pattern. Generally, this variation can be plotted in three dimensions. However, in practice, two-dimensional plots are more common. For example, let the x and y axes be in the aperture plane and the z-axis be normal to the aperture. The radiation pattern of a horn antenna is given in Figure 2. As seen in the figure, the radiated power varies depending on the direction. The direction of maximum radiation is approximately at $\theta=0^{\circ}$. Additionally, there are secondary maxima in the radiation pattern, which are called sidelobes. The angle between the directions where the power drops to half of its maximum value is called the half-power beamwidth or the 3-dB beamwidth.

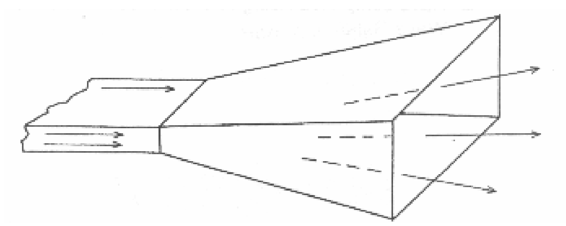
Figure 1: A pyramidal horn antenna

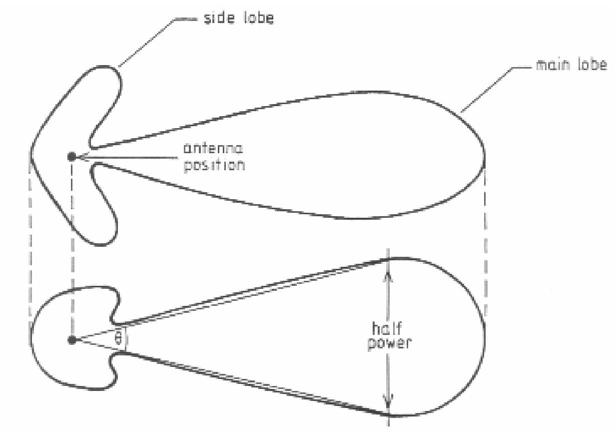

Figure 2: Radiation pattern of a pyramidal horn

Gain of a Horn Antenna: Antenna gain is defined as the ratio of the power radiated by the antenna per unit solid angle to the power radiated per unit solid angle by an isotropic antenna (which radiates equally in all directions), assuming equal input power.

$$G(\theta,\emptyset)=\frac{U(\theta,\emptyset)}{U_o}=\frac{U(\theta,\emptyset)}{P_t/4\pi}=4\pi\frac{U(\theta,\emptyset)}{P_t}$$

$U(\phi,\theta)$ : Power radiated by the antenna per unit solid angle (W/sr)
$U_o$ : Power radiated by an isotropic antenna per unit solid angle (W/sr)
$P_t$ : Power supplied to the input of the antenna (W)

Gain is generally direction-dependent. Let $G_t$ be the gain of the transmitting antenna in the direction of maximum radiation. The power density at a distance R from this antenna is:

$$W_t = \frac{P_t G_t}{4\pi R^2}$$

If the gain of the receiving antenna is $G_r$ and the antennas are aligned, the power received by the receiving antenna is given by the Friis transmission equation:

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2 \quad (1)$$

If the horn antennas used for transmitting and receiving are identical, then $G_t = G_r = G$. In this case, the antenna gain can be calculated from the following formula:

$$G = \frac{4\pi R}{\lambda}\sqrt{\frac{P_r}{P_t}} \quad \text{(dimensionless)} \quad (2)$$

It is important to note that the values of $P_r$ and $P_t$ in this formula must be in linear units (e.g., Watts), not in dB. The gain in dB is calculated as

$$G(dB) = 10\log(G)$$

**Experimental Procedure :**

**1.** Experimental Procedure

**1.1.** Assemble the experimental setup as shown in Figure 3. A Gunn oscillator will be used as the microwave signal source.

**1.2.** Position the antennas at the same height, directly facing each other.

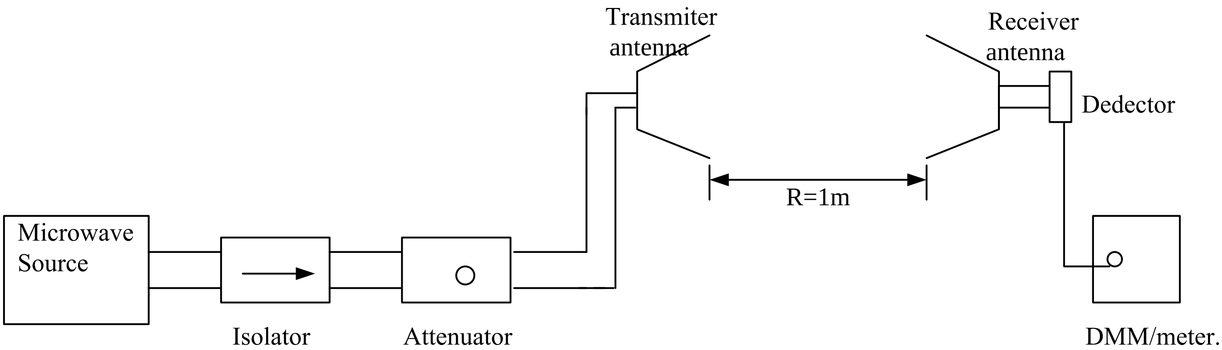


Figure 3: Experimental setup for measuring the radiation pattern and gain of a horn antenna

**2.** Plotting the Radiation Pattern
**2.1.** Set the frequency of the microwave signal generator to 10 GHz.
**2.2.** With the antennas perfectly aligned (direction of maximum radiation), take a reference reading on the meter.
**2.3.** Rotate the receiving antenna to the right and left in 10° intervals, recording the reading from the meter each time in Table 1.
**2.4.** Normalize the measured values with respect to the maximum radiation value and plot the radiation pattern on a polar coordinate system.
**3.** Determining the Half-Power Beamwidth
**3.1.** Realign the receiving antenna with the transmitting antenna for maximum signal and read a reference value on the meter.
**3.2.** Slowly rotate the receiving antenna to the right until the reading on the meter drops by 3 dB from the reference value. Record the angle of rotation.
**3.3.** Repeat step 3.2 by rotating the antenna to the left.
**3.4.** Add the two angles you recorded. The result is the half-power beamwidth of the antenna.
Table-1

| Rotation Angle | | 10° | 20° | 30° | 40° | 50° | 60° |
|---|---|---|---|---|---|---|---|
| f=10 GHz<br>Reading (dB) | Right | | | | | | |
| | Left | | | | | | |

**4.** Measuring Antenna Gain
**4.1.** With the antennas perfectly aligned, record the value shown on the meter.
**4.2.** Measure the distance between the antennas (from aperture to aperture).
**4.3.** Place the transmitting and receiving antennas aperture-to-aperture and record the new value shown on the meter.

**Questions**
**1.** Derive the Friis transmission equation (1).
**2.** Express equation (2) in terms of dB.
**3.** Calculate the gain using the approximate formulas of Kraus and Tai & Pereira. Assume the horn antenna's efficiency is 80%.
**4.** The gain of the horn antennas used in the experiment is given as approximately 16 dB at 10 GHz. If there is a difference between your experimental results and this value, what do you think could be the reason? Explain.