ANTENNA GAIN MEASUREMENT

Objective: To measure the gain of wave guide horn.

List of Equipment:

1. Microwave source with square wave modulation
2. Isolator
3. Variable attenuator
4. Two identical waveguide horns
5. Antenna test bench
6. Tunable Detector
7. VSWR meter

Theory:

The ability of an antenna to concentrate the radiated power in a given direction, or conversely to absorb effectively incident power form that direction, is specified variously in terms of its gain, power gain, directive gain, or directivity. The precise significance of each of these terms is most readily stated by first defining a quantity known as radiation intensity.

Radiation intensity is defined a power radiated per unit solid angle. Thus,

$$\bar{\phi}(\theta,\phi) = \frac{E^2}{\eta} r^2 \text{ watts per unit solid angle} \qquad (1)$$

where $\bar{\phi}(\theta,\phi) =$ radiation intensity in the direction (θ,ϕ)

E = far electric field intensity

η = intrinsic impedance of the medium

r = distance form the antenna

The average radiation intensity is defined as

$$\bar{\phi}_{av} = \frac{w_r}{4\pi}, \qquad w_r = \int \bar{\phi}\, d \qquad (2)$$

where w_r is the total power radiated. $\overline{\phi}_{av}$ may be considered to be the radiation intensity of an isotropic radiator, radiating same total power. The directive gain, g_d, in a given direction is defined as the ratio or radiation intensity in that direction to the average radiation intensity, i.e.

$$g_d(\theta,\phi) = \frac{\overline{\phi}(\theta,\phi)}{\overline{\phi}_{av}} = \frac{4\pi\,\overline{\phi}}{\int \overline{\phi}\, d} \tag{3}$$

Often the directive gain is expressed in decibels as

$$G_d(dB) = 10\log_{10} g_d \tag{4}$$

Clearly, g_d *or* G_d is a function of direction (θ,ϕ). Maximum directive gain is called directivity. In practice, it is power gain g_p, defined as

$$g_p = \frac{4\pi\,\overline{\phi}}{wt} \tag{5}$$

which comes into play. Here, $wt = wr + wl$ is the total power including losses, fed to the antenna.

Although these definitions have been framed by considering a transmitting antenna, these are applicable to receiving antennas too. Of course, the gain thus defines can be realized on a receiving antenna only when it is properly matched and an approximately polarized field is present. For receiving antennas, one defines the effective area A as

$$A = \frac{\lambda^2}{4\pi} G \tag{6}$$

where G is g_d for antennas with an efficiency of 100%, and G is g_p for lossy antennas.

Power density at a distance R from a point source fed with a power p_t is

$$\frac{P_t}{4\pi R^2} \tag{7}$$

If however, the radiator is an antenna with gain G, the power density increases to

$$\frac{P_t G_t}{4\pi R^2} \tag{8}$$

If an antenna with gain Gz is used to receive the signal, its effective aperture is

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

and the power received Pr is given by

Pr = power density × effective aperture

$$= \frac{\text{Pr } Gr}{4\pi R^2} \times \frac{\lambda^2}{4\pi} Gz$$

$$= Pt \left(\frac{\lambda}{4\pi R} \right)^2 G_1 G_2$$

If $G_1 = G_2 = G$

$$\text{Pr}/ Pt = \left(\frac{\lambda}{4\pi R} \right)^2 G^2$$

or $$R^2 = \left(\frac{\lambda G}{4\pi} \right)^2 Pt / \text{Pr} \qquad (9)$$

Measuring Pt/Pr by interesting an attenuator to maintain constant power detected with and without antenna system allows G^2 to be calculated. As several readings must be taken, it is best to plot Pt/Pr against R^2 and evaluate G from the slope of the graph.

Theoretical calculation of gain of waveguide horn antennas is given in [3] and [4]. For a well constructed horn, measured power gain values are quire close to the calculated values.

Procedure:

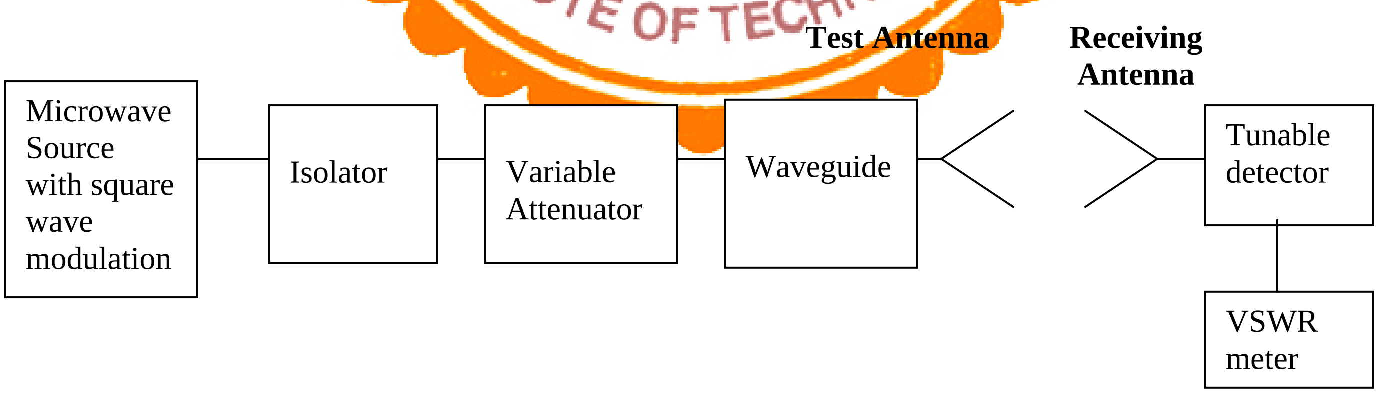

Fig 1. Experimental arrangement for Gain measurement

1. Set up apparatus as shown in fig.1. Set the source at 10 GHz by given slider. Fix the amplitude (maximum to get maximum power) and do square modulation using the modulator.
2. Isolator must be in "**forward direction**" and attenuation should be minimum, so that we get maximum power in output.
3. We can vary the distance between two horns by using "**Sample**" button. But the minimum distance should be $2D^2/\lambda$ where D is the largest dimension of the aperture of the horn and λ is the free space wavelength corresponding to 10 GHz.
4. A graph is plotted between the square of the distance between horns (R^2) along y-axis and the power ratio along x-axis in **GAIN Measurement window**. Where m shows the tangent of the slope and G is the gain.
5. We can verify the result by calculating the slope $(\lambda G/4\pi)^2$ form the graph. Knowing λ, G can be easily calculated.

Discussions:

1. What do you understand by antenna gain?
2. How do you know that antenna is tuned at the correct frequency?
3. Why the distance between both the horns should be more than $2D^2/\lambda$?
4. What will happen if both antennas are not aligned horizontally or vertically?

References:

1. E.C. Jordan and K.G.Balmain, 'Electromagnetic wave Radiating Systems' 1968.
2. R.E. Collin, 'Antennas and Radio Wave Propagation', 1985.
3. C.A. Balanis, 'Antenna Theory: Analysis and Design, 1982.
4. A.W. Cross, 'Experimental Microwaves', 1977.