GAIN & DIRECTIVITY MEASUREMENT

There are two ways to measure gain

(i) Absolute method

(a) Two antenna method

(b) Three antenna method

(ii) Comparision method

(i) Absolute Method

Two antenna method

* 2 Identical antennas - one is transmitter and the other is a receiver.

Gain = Maximum radiation intensity of test antenna / Maximum radiation intensity of reference antenna.

$G_o = KD$

$G \rightarrow$ Gain of the antenna

$D \rightarrow$ Directivity

$K \rightarrow$ efficiency factor $(0 \leq K \leq 1)$

In two antenna method, Gain is measured using Friis transmission formula of received power.

$$P_R = P_T G_T G_R \left(\frac{\lambda}{4\pi R}\right)^2 \rightarrow (1)$$

where

$P_R \rightarrow$ Received power

$P_T \rightarrow$ Transmitted power

$G_T \rightarrow$ Gain of the transmitting antenna

$G_R \rightarrow$ Gain of the receiving antenna

$\lambda \rightarrow$ wavelength

$R \rightarrow$ spacing between the two antennas.

By taking log on both sides of equation ① we get,

from equation ①

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

$$(G_T)_{dB} + (G_R)_{dB} = 10 \log_{10}\left(\frac{P_R}{P_T}\right) + 10 \log_{10}\left(\frac{4\pi R}{\lambda}\right)^2$$

$$(G_T)_{dB} + (G_R)_{dB} = 10 \log_{10}\left(\frac{P_R}{P_T}\right) + 20 \log_{10}\left(\frac{4\pi R}{\lambda}\right) \rightarrow ②$$

Two antennas are identical, so in equation ②

$$(G)_{dB} = (G_T)_{dB} = (G_R)_{dB} \rightarrow ③$$

Therefore equation ② becomes,

$$2\,(G)_{dB} = 10 \log_{10}\left(\frac{P_R}{P_T}\right) + 20 \log_{10}\left(\frac{4\pi R}{\lambda}\right)$$

$$\boxed{(G)_{dB} = \frac{1}{2}\left[10 \log_{10}\left(\frac{P_R}{P_T}\right) + 20 \log_{10}\left(\frac{4\pi R}{\lambda}\right)\right]} \rightarrow ④$$

From equation ④, Gain is calculated.

Three antenna Method

When two identical antennas are not available, we use three antenna method to measure the gain.

considering three antennas with gain G_1, G_2 & G_3.

(i) using antenna 1 as a transmitting antenna & antenna 2 as the receiving antena.

Then from Friis Transmission formula,

$$(G_1)_{dB} + (G_2)_{dB} = 20 \log \left(\frac{4\pi R}{\lambda}\right)^2 + 10 \log \left(\frac{P_{R_2}}{P_{T_1}}\right) \rightarrow (5)$$

(ii) using antenna 2 as the transmitting antenna and antenna 3 as the receiving antenna

$$(G_2)_{dB} + (G_3)_{dB} = 20 \log \left(\frac{4\pi R}{\lambda}\right)^2 + 10 \log \left(\frac{P_{R_3}}{P_{T_2}}\right) \rightarrow (6)$$

(iii) using antenna 1 as a transmitting antenna and antenna 3 as a receiving antenna

$$(G_1)_{dB} + (G_3)_{dB} = 20 \log \left(\frac{4\pi R}{\lambda}\right)^2 + 10 \log \left(\frac{P_{R_3}}{P_{T_1}}\right) \rightarrow (7)$$

By solving equations (5), (6) & (7) we, calculate the unknown gain of the antennas.

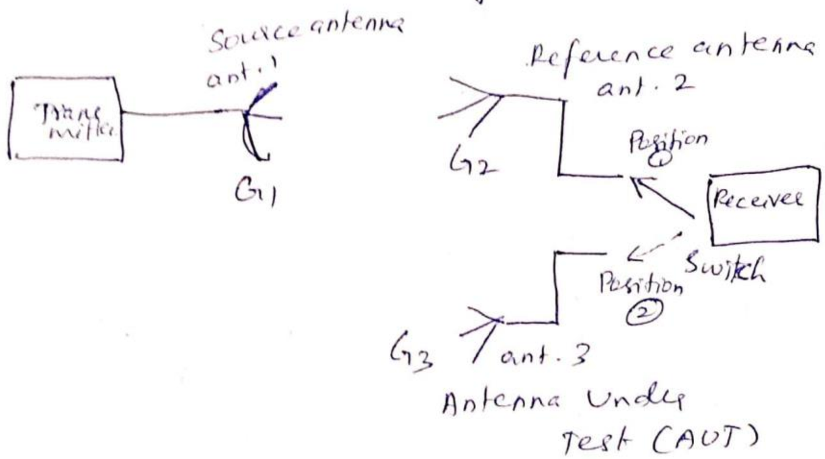
ii) Comparision Method

Comparision method need 3 antennas of gain G_1, G_2 & G_3.

$G_1 \rightarrow$ Gain of Source antenna

$G_2 \rightarrow$ Gain of reference antenna (antenna with known gain)

$G_3 \rightarrow$ Gain of antenna under test (The antenna to which the gain is going to be calculated)



When switch is at position ①, from Friis transmission formula, [Antenna 1 — Tx, antenna 2 — Rx]

$$P_{R2} = P_T G_1 G_2 \left(\frac{\lambda}{4\pi R}\right)^2 \rightarrow (8)$$

& when switch is at position ②,

[antenna 1 — Tx, antenna 3 — Rx]

$$P_{R3} = P_T G_1 G_3 \left(\frac{\lambda}{4\pi R}\right)^2 \rightarrow (9)$$

From equations (8) & (9) [eq (8) ÷ eq (9)]

$$\frac{P_{R2}}{P_{R3}} = \frac{G_2}{G_3}$$

$$\boxed{G_3 = \left(\frac{P_{R3}}{P_{R2}}\right) G_2} \rightarrow (10)$$

Equation (10) is used to measure the unknown gain of the antenna.

Directivity Measurement

→ Directivity of the antenna → maximum Directive gain.

→ obtained from the radiation pattern of the antenna.

The directivity can be estimated from the formula,

$$D = \frac{4\pi}{\Omega_A}$$

$$\simeq \frac{4\pi}{\theta_E \theta_H}$$

(or)

$$D = \frac{41,253}{\theta_E^{\circ} \ \theta_H^{\circ}}$$

θ_E° & θ_H° are → Half power beamwidths of E & H planes expressed in degrees.

where

Ω_A = Beam solid angle

$\Omega_A = \Omega_M + \Omega_m$
= Main lobe solid angle + side lobe solid angle

$\Omega_A \approx \Omega_M \approx \theta_E \theta_H$

Directivity can also be computed from the formula

$$D = 4\pi \frac{U(\theta, \phi)}{P_{rad}}$$

P_{rad} → power radiated
$U(\theta, \phi)$ → radiation intensity in the direction (θ, ϕ)

The radiated power Prad can be obtained by integrating the radiation intensity of an antenna over a closed sphere.

For a lossless antenna,

Gain = Directivity