Antenna measurements

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→ we have discussed antenna through various analytical methods uptill now.

→ we have also studied differnt methods of computing various parameters of antenna such as gain, directivity, rad. characteristic, antenna impedance & radiation resistance. and also studied differnt theorems.

→ But this discussion requires validation through the actual measurement of various parameters of the antenna.

→ There are some complex antenna structure, which can not be studied analytically investigated.

→ For such complex antennas, the measurments are necessary.

→ The antenna measurements are carried out using the test antenna in the receiving mode.

→ The test antenna is a reciprocal antenna.

→ If the test antenna is reciprocal, then the receiving mode characteristics of such reciprocal antennas are identical to the characteristics in the transmitting mode.

→ The distance between test antenna and source antenna (R) must be greater than or equal to $\frac{2d^2}{\lambda}$.

→ These test antennas are affected by reflections for the ground & near by objects such as tall buildings, trees hills.

→ The drawbacks of the experimental investigations.

– In some cases, the size, weight and volume of antenna is It impractical to move it from operating environment the measuring site.

– For large antennas pattern measurements at far field region becomes very difficult because the $\left(r \geq \frac{2d^2}{\lambda}\right)$ becomes too large

→ The outside measuring equipments are not capable of handling unctrolled all-weather environment.

→ The cost factor in the measurement techniques is too high.

→ These drawbacks are overcome by using special techniques & modern commercial equipment & computer assisted techniques, these are

– Compact and ~~extra~~ extrapolation ranges
– Improved polarization Technique.
– Near field probing Technique
– Indirect measurement of antenna characteristics
– Automated test systems.

→ For exploring the performance of antennas, the parameters such as D, G, Zi, Rad pattern are measured by using above techniques.

Basic concept of Antenna measurement

In general, the important measurement parameters of the antenna are gain, directivity, radiation pattern etc.

→ The typical set-up for the measurement of radiation properties of antenna is as shown in fig.

→ The Antenna under test is considered to be located at origin of the coordinate system.

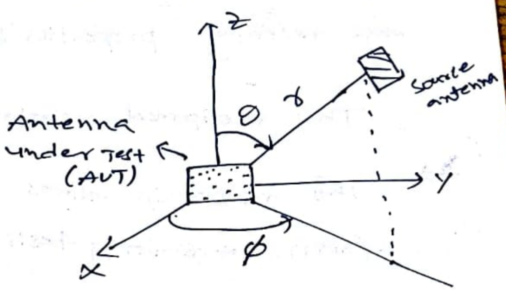

Fig.– Configuration for measurement of radiation properties.

→ The source antenna is placed at different locations wrt AUT.

→ The source antenna may be transmitting or receiving.

→ At different locations, the no. of samples of the pattern are obtained.

→ To achieve different locations, generally AUT is rotated.

→ To achieve sharp sample of pattern, it is necessary that there exists single direct signal path b/w the AUT & source antenna......

Reciprocity (Reciprocal Relationship b/w Tring Rxing properties of

→ Generally antenna can act either as a tr (or) Rr.

→ There exists a reciprocal relationship b/w the transmitting and receiving properties of the antenna.

→ This reciprocal relationship is very useful in the antenna measurements

→ This relationship allows us to obtain the characteristics of an ante from transmitting tests or receiving tests, whichever is most convenient during the measurement.

→ It is necessary to study 2 important consequences helpful in antenna measurements.
i.e

① The transmitting & receiving patterns of antenna are same.

② The power flow is the same in transmitting & Receiving mode.

→ when the AUT is used in tr or Rr, the direction of the signal can be defined easily.

→ practically while using reciprocity relationship; the following conditions must satisfy

— The e.m.f.s at the terminal of Tring or receiving antennas should be of same freq.

— The power flow should be equal to that due to matched impedance.

— The media should be linear, isotropic and ~~passive~~ passive.

Field and

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region.

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Near Field and Far Field

→ There are 3 main regions of the radiated field of the antenna.

→ The region very close to antenna is called reactive near field region.

→ The region next to the reactive near field region which is called radiating near field region.

→ Finally the region located far away from the antenna is called far field region.

→ According to Huygen's principle, the field with sufficient information is sampled at surface in any region of the radiated field

→ Most of the times far field measurement is preferred.

→ **Advantages** in the far field.

- At any point in the far field region, the field pattern measured is valid.
- In the far field region, only power measurements serves the purpose for obtaining power pattern.
- measurement errors are reduced when AUT is rotated.

dis

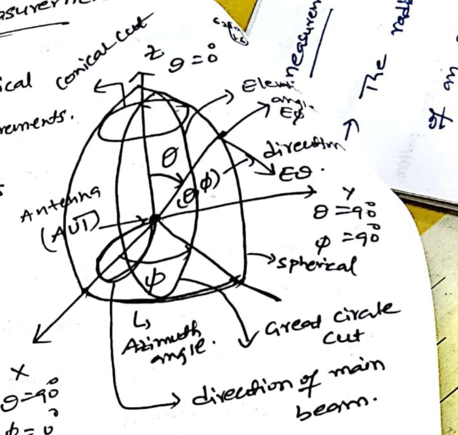
It reqires large distance between transmitting & Receiving antennas.

Coordinate system for antenna measurement

→ According to the IEEE standards, the spherical coordinate system is used for antenna measurements.

→ The angle measured from the z-axis is called elevation angle (θ)

→ The angle measured from the projection of the radius vector to the horizontal X–Y plane is called azimuth angle (ϕ).



→ when the source antenna is moved along lines of constant θ, the cuts obtained are called conical cuts (or) ϕ-cuts.

→ when the source antenna is moved along lines of constant ϕ, the cuts obtained are called great circle cuts (or) θ-cuts.

Sources of Error in Antenna measurement

→ For antenna measurements in far field region, the plane wave with uniform phase & amplitude is the ideal ~~instance~~ requirement.

→ But practically there are deviations in the plane wave

- Errors due to finite measurement distance b/w antennas
- Reflections from surroundings.
- Errors due to coupling in the reactive near field
- Errors due to misalignment of antenna.
- Errors due to manmade Interface.
- Errors due to Atmospheric effects
- Errors due to cables
- Errors due to Impedance mismatch
- Errors due to Imperfections of Instruments.

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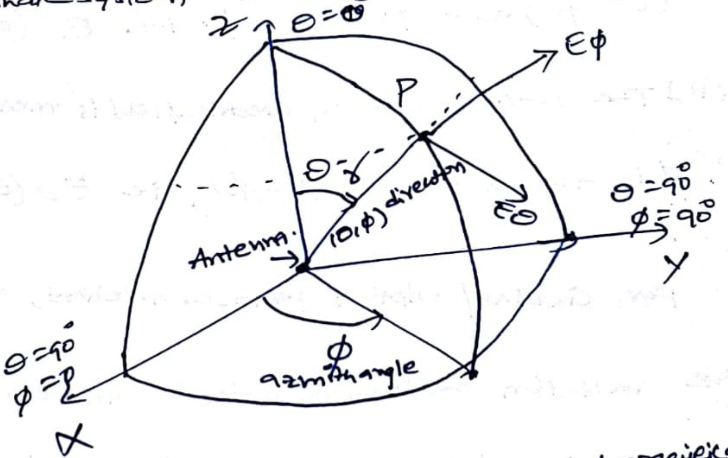
Measurement of Radiation pattern

→ The radiation capabilities are characterized by the characteristics of an antenna such as radiation pattern (including amplitude and phase patterns), polarization and gain.

→ All these parameters are measured on the surface of a sphere with constant radius.

→ Any point 'p' on such sphere can be described using spherical co-ordinate system as shown in below fig.



→ For representation of a point on the surface, only θ & φ specifications are sufficient because sphere with constant radius is considered.

→ Radiation pattern → It is a function of θ & φ and constant radius.

→ It is 3 dimensional representation but due to practical difficulties it is constructed by 2-dimensional i.e E-plane & H-plane patterns.

→ The required patterns are in horizontal plane i.e X-y plane and vertical pattern in X-z plane.

→ For horizontal antenna following patterns are requi[red]

(i) The ϕ component of electric field as a function of ϕ is mea[sured] in X-Y plane $(\theta = 90^\circ)$ i.e $E_\phi(\theta = 90^\circ, \phi) \rightarrow$ E-plane pa[ttern]

(ii) The ϕ component of electric field as a function of θ is measur[ed] in X-Z plane $(\phi = 0^\circ)$, i.e $E_\phi(\theta, \phi = 90^\circ) \rightarrow$ H-plane pattern[s]

→ For vertical antenna following patterns are required.

(i) The θ-component of the electric field is measured in X-Y plane $(\theta = 90^\circ)$ as a function of ϕ, i.e $E_\theta(\theta = 90^\circ, \phi) \rightarrow$ H-plane pattern

(ii) The θ-component of electric field is measured as a function of ϕ in the X-Z plane $(\phi = 90^\circ)$, i.e $E_\theta(\theta, \phi = 90^\circ) \rightarrow$ E-plane pattern.

→ For circular/ eliptical polarized antennas, ~~att~~ all the 4 patterns are neces-sary.

→ The radiation pattern of antenna can be measured either in transmitting mode (or) reciving mode. (Receiving mode is selected for reciprocal antenna).

Basic procedure for Radiation pattern measurement

→ For the measurement of radiation pattern, 2 antennas are required.

→ one of the antenna in the system is the antenna under test (Receiving mode) ~~and~~ and another antenna is source antenna (Tr mode) which is located away from the AUT.

(5) (6)

According to the reciprocity principle, radiation pattern will be same in both the modes (TX, RX).

→ The procedures for the measuring Radiation pattern in a particular plane as follows.

(a) In the first procedure, the antenna under test i.e primary antenna is kept stationary, while the secondary antenna is moved around the primary antenna along a circular path uniform radius.

→ If the secondary antenna is directional one, it is always aimed at primary antenna.

→ In this procedure, usually the primary antenna is transmitting.

→ ~~At~~ At different points, along the circular path, the readings of the field strength and direction w.r.t the primary antenna are recorded.

→ Then from these readings a plot of the radiation pattern of a primary antenna is plotted as rectangular / polar plot.

(b) In the second procedure, both the antennas are kept stationary with suitable spacing between them.

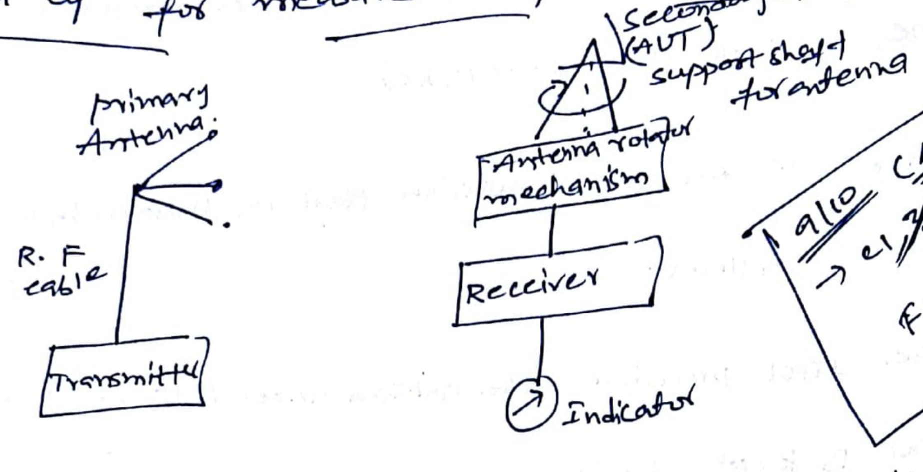
→ The secondary antenna is aimed at primary antenna.

→ The primary antenna is rotated about a vertical axis.

→ In this procedure, the secondary antenna is used in Transmitting mode, so that the field strength reading and direction of the primary antenna w.r.t secondary antenna is made and continuous readings at different points during rotation can be made using pattern recorder.

Scanned by CamScanner

Set up for measurement of Radiation pattern of an ~~Secondary Antenna~~ non-uniform



also (ACOP)
→ c1, ~~3~~, D3, E4, F4, F6, A4, H4, U5

→ The simple arrangement for the radiation pattern measurement consists primary antenna is transmitting mode, secondary antenna as antenna under test (Receiving mode)

→ The secondary antenna is coupled with shaft and it is rotated using antenna rotator mechanism.

→ To measure the relative amplitude of the received field an indicator is used along with the receiver as shown in above fig.

→ The AUT is properly illuminated by the stationary primary antenna

→ The secondary antenna is rotated about vertical axis.

→ For E-plane pattern measurement, the antenna support shaft is rotated with both the antennas horizontal.

→ while for H-plane pattern measurement, the shaft is rotated with both the antennas vertical.

{uniform distance required
{ " Amplitude "

Uniform distance Requirement

→ For accurate far-field radiation pattern, the distance between primary and secondary antenna must be very large.

→ If this distance is smaller, then near field radiation pattern is obtained.

→ The basic requirement for the far-field pattern, the secondary antenna must be illuminated by a plane wavefront.

→ The plane wavefront is possible only at infinite (max) distance.

→ The phase difference between the centre and edge of the antenna should not be greater than $\lambda/16$.

→ But according to standard condition the distance b/w 2 antennas should be

$$r \geq \frac{2d^2}{\lambda}$$

r = distance b/w Tr & Rr

λ = wavelength

d = maximum dimension of either of the antenna.

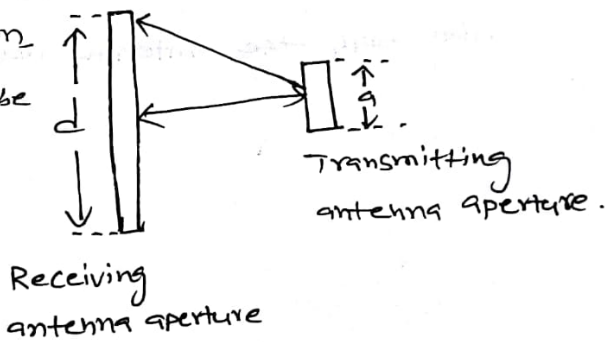


Fig: phase difference b/w centre & edge of the receiving antenna for uniform distance requirement.

→ From fig

$$(r+\delta)^2 = \left(\frac{d}{2}\right)^2 + r^2$$ where δ is phase difference error.

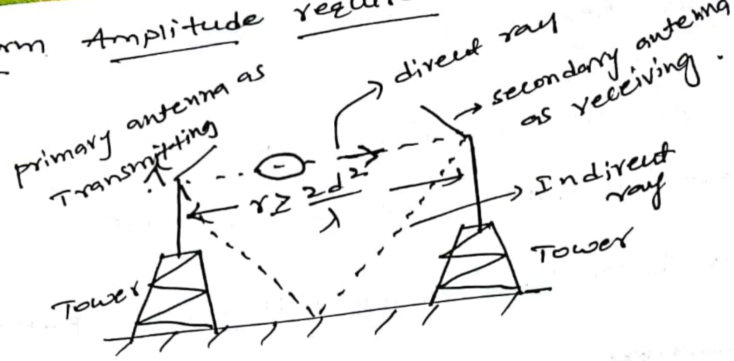
$$r^2 + 2r\delta + \delta^2 = \frac{d^2}{4} + r^2$$

As δ is very small, neglecting δ^2

$$2r\delta = \frac{d^2}{4} \Rightarrow \boxed{r = \frac{d^2}{8\delta}}$$

→ It is clear that the minimum distance required depends on the aperture of the receiving antenna & λ.

Uniform Amplitude requirement



→ For accurate field radiation pattern, the transmitting antenna should produce a plane wave with uniform amplitude and phase over distance r.

→ As far as possible, the interference b/w direct rays and indirect reflected rays should be minimized.

→ For this both the antennas must be mounted on higher towers & also both the antennas must be highly directional.

Measurement of Gain of an antenna

- Depending upon the frequency of operation various methods can be used for the measurement of gain of an antenna.
- Typically to measure gain above 1GHz, free space ranges used
- To measure gain b/w 0.1 – 1GHz, the ground reflection ranges are used.
- Basically there are 2 methods used for the measurement of gain of antenna such as

(i) gain-Transfer (gain comparison) method (or) direct comparison method.

(ii) absolute gain method.

Gain measurement by direct comparison method

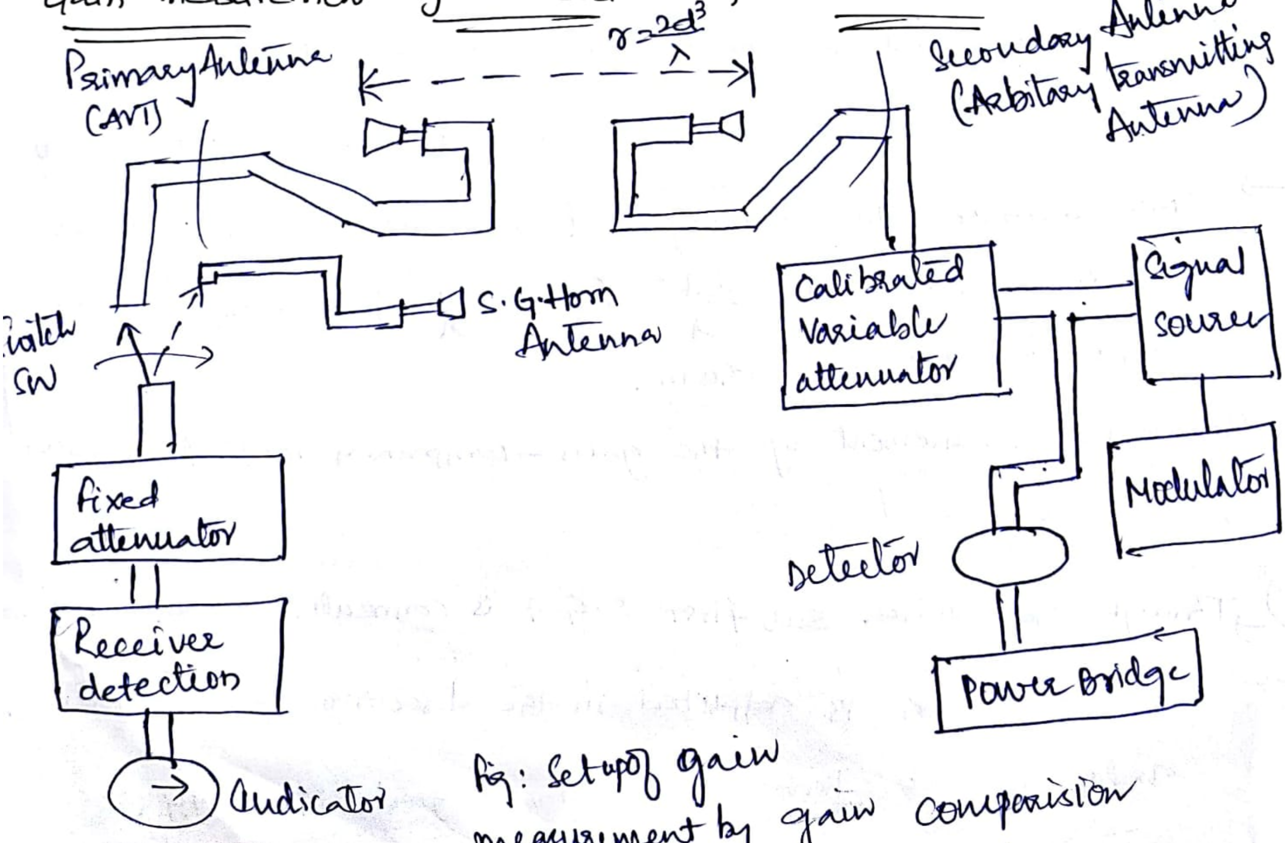


Fig: Setup of gain measurement by gain comparision method

→ At high frequencies, the gain measurement is done using direct comparison method.

→ In this method, the gain measurement is done by comparing strengths of the signals transmitted or received by the antenna under test and the standard gain antenna. (S.G.A)

→ The antenna whose gain is accurately known and can be used for the gain measurement of other antennas is called S.G.A

→ At high frequency, the universely accepted S.G.A is the horn antenna

→ The set up of gain measurement by the comparison method is as shown in the fig 1.

→ This method uses 2 antennas termed as primary antenna & secondary antenna.

→ The primary antenna consists of 2 different antennas seperated through a switch SW. (First primary antenna is S.G.A & other is A.U.T)

→ The distance b/w primary and secondary antennas is greater than or equal to $\frac{2d^2}{\lambda}$ $(r \geq \frac{2d^2}{\lambda})$ to minimize the reflection between them.

→ The gain measurement by the gain-comparison method in 2 step procedure.

i) → Through the switch SW, first S.G.A is connected to the receiver.

→ The antenna is adjusted in the direction of the secondary antenna to have maximum signal intensity.

I/P connected to the secondary (or) transmitting antenna is adjusted to required level.

For this I/P corresponding primary antenna reading at the receiver is recorded.

→ corresponding attenuator and power bridge readings are recorded as A_1 & P_1

(ii) secondly the antenna under Test (AUT) is connected to the receiver by changing the position of the switch SW.

→ To get the same reading at the receiver, the attenuator is adjusted. Then corresponding attenuator and power bridge readings are recorded as A_2 & P_2.

Now consider 2 different cases

case (i) If $P_1 = P_2$, then no correction need to be applied and gain of the subject antenna under test is given by,

power Gain $G_P = \frac{A_2}{A_1}$, A_1 & A_2 are relative power levels

log apply on both sides

$$\log_{10} G_P = \log_{10}\left(\frac{A_2}{A_1}\right) = \log_{10} A_2 - \log_{10} A_1$$

i.e $\underset{(db)}{G_P} = \underset{(db)}{A_2} - \underset{(db)}{A_1}$

case (ii) If $P_1 \neq P_2$, then the correction need to be included

Let $\frac{P_1}{P_2} = P$ then $\log_{10}\frac{P_1}{P_2} = P(db)$

Hence the $G = G_P \times \frac{P_1}{P_2} = \frac{A_2}{A_1} \times \frac{P_1}{P_2}$

$G = G_P \cdot \frac{P_1}{P_2}$

$\log_{10} G = \log_{10}\left(G_P \cdot \frac{P_1}{P_2}\right) = \log_{10} G_P + \log_{10}\frac{P_1}{P_2}$

$G_{(db)} = G_P(db) + P(db)$ //

Measurement of Absolute Gain

Consider 2 Identical antennas seperated by distanle r as shown in

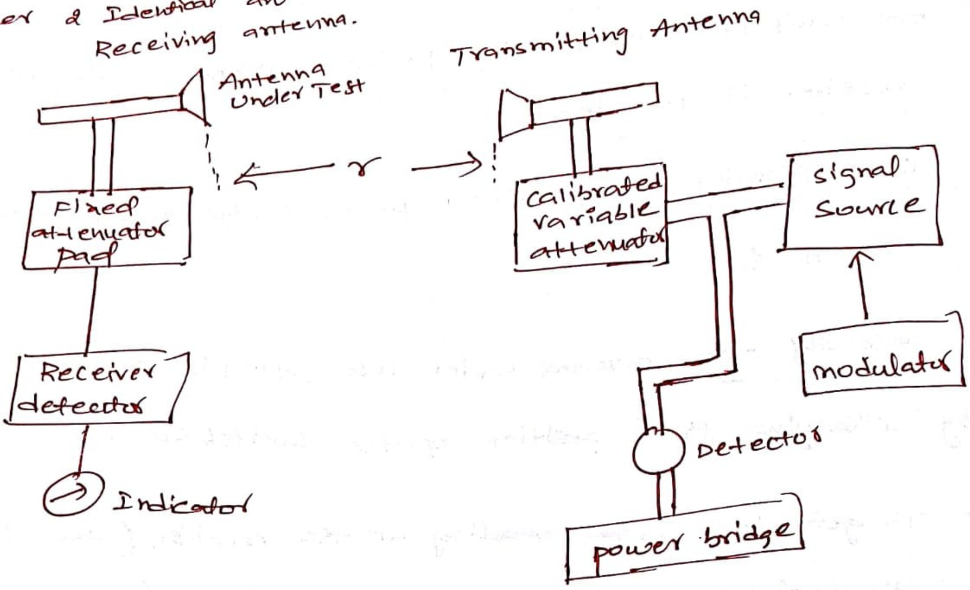


Fig: Transmitting & Receiving antennas for absolute gain measurement.

→ Let the transmited & Received power is P_t & P_r.

→ Let the effective apertures of the transmitting & receiving antennas be A_{et} & A_{er} respectively

→ As the 2 identical antennas, we can write

$$A_{et} = A_{er} = \frac{G_D \lambda^2}{4\pi}$$

From Friis's Transmission equation, we can write

$$\frac{P_r}{P_t} = \frac{A_{er} \cdot A_{et}}{\lambda^2 r^2} = \left(\frac{G_D \lambda^2}{4\pi}\right)\left(\frac{G_D \lambda^2}{4\pi}\right)\frac{1}{\lambda^2 r^2}$$

$$\frac{P_r}{P_t} = \left(\frac{G_D \lambda}{4\pi r}\right)^2 \Rightarrow \frac{G_D \lambda}{4\pi r} = \sqrt{\frac{P_r}{P_t}}$$

$$\boxed{G_D = \frac{4\pi r}{\lambda}\sqrt{\frac{P_r}{P_t}}}$$

as shown in

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Knowing λ, r and measuring the radiated and received powers, the absolute gain of the antenna can be obtained.

→ First the antennas are oriented for maximum signal.

→ Using the calibrated variable attenuator, the i/p signal level of the transmitting antenna is adjusted, then the corresponding receiver reading is recorded.

→ The corresponding attenuator & power bridge readings are recorded as A_1 & P_{t1} respectively.

→ Then the transmitter is disconnected from the antenna and is connected to the receiver through pad providing fixed attenuation.

→ Again attenuator dial is adjusted to get same reading at the receiver as obtained in first step.

→ Again corresponding attenuator & power bridge readings are recorded as A_2 & P_{t2}.

Measurement of Directivity (D)

→ The directivity of the antenna cannot be calculated using the analytical techniques alone.

→ So the directivity can be obtained from the radiation pattern of antenna.

→ The directivity of the antenna is defined as the ratio of maximum power density to the average power radiated

$$G_{Dmax} = \frac{P_{dmax}}{\left(\frac{P_{rad}}{4\pi r^2}\right)} = D$$

→ Let us be expressed interms of the electric field intensity as

$$D = G_{Dmax} = \frac{4\pi |E_{max}|^2}{\int_0^{2\pi}\int_0^{\pi} |E(\theta,\phi)|^2 \sin\theta \, d\theta \, d\phi}$$

$$D = G_{Dmax} = \frac{4\pi}{\int_0^{2\pi}\int_0^{\pi} f(\theta,\phi) \sin\theta \, d\theta \, d\phi}, \quad f(\theta,\phi) = \frac{|E(\theta,\phi)|^2}{|E_{max}|^2}$$

where $f(\theta,\phi)$ is the relative radiation intensity as a function of space angles θ & ϕ.

→ The directivity can be computed from the radiation pattern measurement.

→ In one of the simplest methods, first 2 principal patterns, namely E & H- plane patterns of the test antenna are measured

Then the half power beamwidths of the E & H-plane patterns are determined.

→ Then the directivity can be obtained by using one of the simplified expressions given by

$$D = \frac{41,253}{\theta_1 \cdot \theta_2} \quad (or) \quad D = \frac{72,815}{\theta_1^2 + \theta_2^2}$$

θ_1 = Half power beamwidth in one plane expressed in degree

θ_2 = Half power beamwidth in a plane right angle to the other expressed in degree.