BVM Engineering College, VV Nagar

Gujarat Technological University

MICROWAVE ENGINEERING

SEM 7
PRESENTATION

Measurement of Antenna Parameters

Electronics & Communication Dept.

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Measurement of Antenna Parameters

13.16 MICROWAVE ANTENNA MEASUREMENTS

The most important parameters required to be measured to determine the performance characteristics of microwave antennas are radiation amplitude patterns, radiation phase patterns, absolute gain, directivity, radiation efficiency, beam width, input impedance, bandwidth and polarisations. The accurate measurement methods for these parameters require standard antenna test ranges.

In this presentation, we'll discuss about …

1. Test Range
2. Radiation Patterns
3. Gain
4. Phase
5. Directivity
6. Radiation Efficiency
7. Polarization

Test Range

13.16.1 Antenna Test Ranges

There are two basic antenna test ranges used for antenna measurements. These are indoor and outdoor test ranges. Usual indoor test range is an anechoic chamber which consists of a rectangular volume enclosed by microwave absorber walls. These walls reduce reflections from the boundary walls and increases the measurement accuracy. Microwave absorbers are carbon impregnated polyurethane foam in the shape of pyramids. The materials are expensive for lower frequency ranges because the typical the size of pyramid is nearly 5′– 6′ for 100 MHz. Most of the antenna placed at a far field distance from a transmitting antenna. Consequently the requirement of a large space limits the use of the costly indoor facility. Special indoor ranges such as compact range and near field range could be used where the former produces a plane wave field in a smaller distance by means of an offset fed reflector antenna having a special edge geometry. The latter one uses mathematical computations of the near field measurement data to obtain the far field information. Both these methods are very costly and have several limitations. In this section, far field outdoor test range is discussed for antenna parameter measurements.

Outdoor Test Range

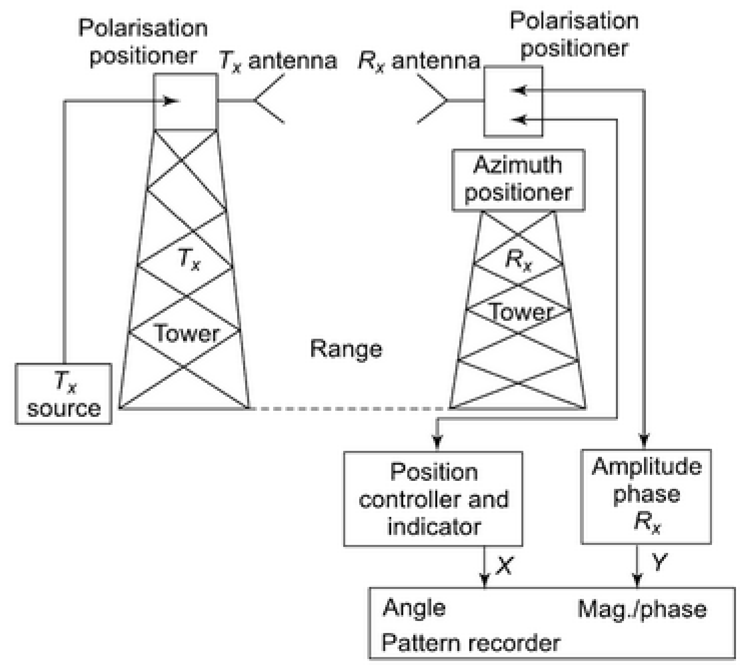


Fig. 13.39 *Outdoor antenna test range*

Outdoor Antenna Test Range

The most popular microwave antenna test range is the free space outdoor range in which the antennas are mounted on tall towers as shown Fig. 13.39. The reflections from the surrounding environment are reduced by

1. Selecting the directivity and side lobe level of the transmitting antenna.
2. Making line-of-sight between the antennas obstacle free.
3. Absorbing or redirecting the energy that is reflected from the range surface or from any obstacle.

Radiation Patterns

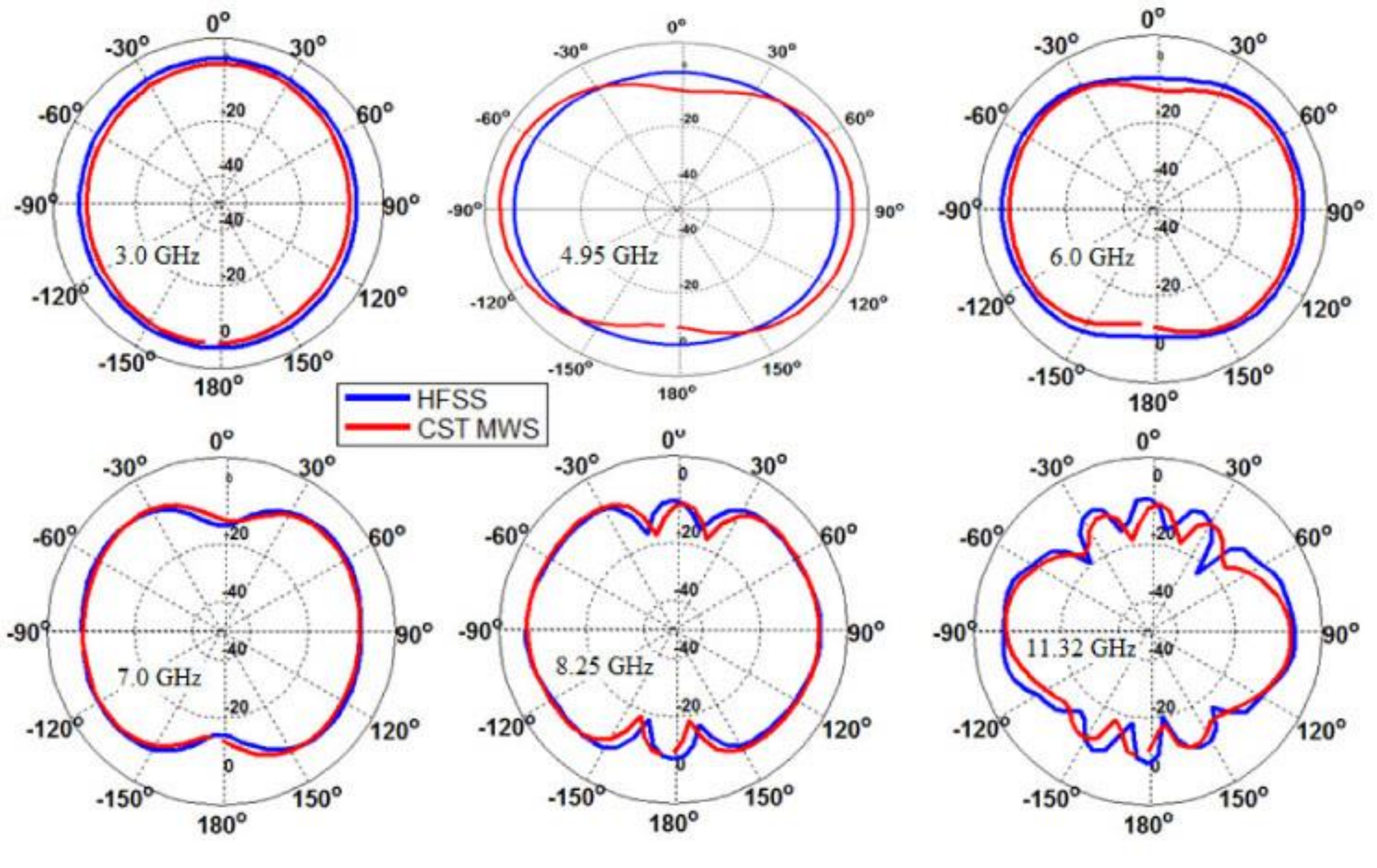


Fig. 13. Simulated radiation patterns in H – plane at 3.0, 4.95, 6.0, 7.05, 8.25 and 11.32 GHz

13.16.2 Radiation Pattern Measurements

The radiation pattern is a representation of the radiation characteristics of the antenna as a function of elevation angle θ and azimuthal angle ϕ for a constant radial distance and frequency. The three-dimensional pattern is decomposed into two orthogonal two-dimensional patterns in **E** and **H** field planes where the *Z-axis* is the line joining the transmitting and receiving antennas and perpendicular to the radiating apertures. Due to the reciprocal characteristics of antennas, the measurements are performed with the test antenna placed in the receiving mode. The source antenna is fed by a stable source and the received signal is measured using a receiver. The output of the receiver is fed to *Y*-axis input of an *XY* recorder. The receiving antenna positioner controller plane and the angle information is fed to *X*-axis input of the *XY* recorder. Thus the amplitude vs angle plot is obtained from the recorder output.

Initially two antennas are aligned in the line of their maximum radiation direction by adjusting the angle and height by the controller and antenna mast. Effects of all surroundings are removed or suppressed through increased directivity and low side lobes of the source antenna, clearance of LOS, and absorption of energy reaching the range surface.

The following precautions are taken for better accuracy in the measurements:

1. Effects of coupling between antennas–inductive or capacitive–causes error in measurement. The former exists at lower microwave frequencies and negligible if range $R \geq 10\ \lambda$. Mutual coupling due to scattering and reradiation of energy by test and source antenna causes error in measurement.
2. Effect of curvature of the incident phase front produces phase variation over the aperture of test antenna and this restricts the range R. For a phase deviation at the edge $\leq \pi/8$ radians, $R \leq 2D^2\lambda$, where D is the maximum size of the aperture.
3. Effect of amplitude taper over the test aperture will give deviation of the measured pattern from the actual. This occurs if the illuminating field is not constant over the region of the test aperture. Tolerable limit of amplitude taper is 0.25 dB, for which decrease in gain is 0.1 dB.
4. Interference from spurious radiating sources should he avoided.

Gain Measurement

Absolute

2-Antenna Method

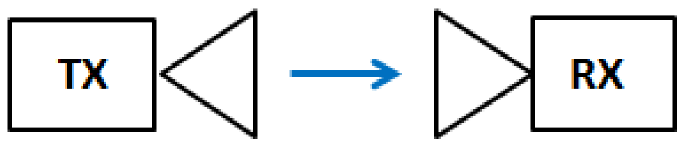
3-Antenna Method

Relative (Comparison)

Friss Formula

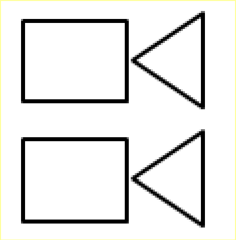
Friss Formula:

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



$$G_t + G_r = 20\log\left(\frac{4\pi r}{\lambda}\right) + 20\log\left(\frac{P_r}{P_t}\right)$$

Absolute Method

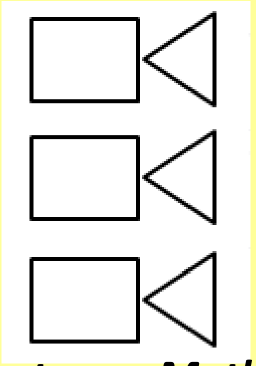


2-Antenna Method

$$G_t = G_r$$

$$G_t = G_r = \frac{1}{2}\left(20\log\left(\frac{4\pi r}{\lambda}\right) + 10\log\left(\frac{P_r}{P_t}\right)\right)$$

Knowing $r, \lambda, \frac{P_r}{P_t}$, **Gain** can be determined



3-Antenna Method

$$G_t \neq G_r$$

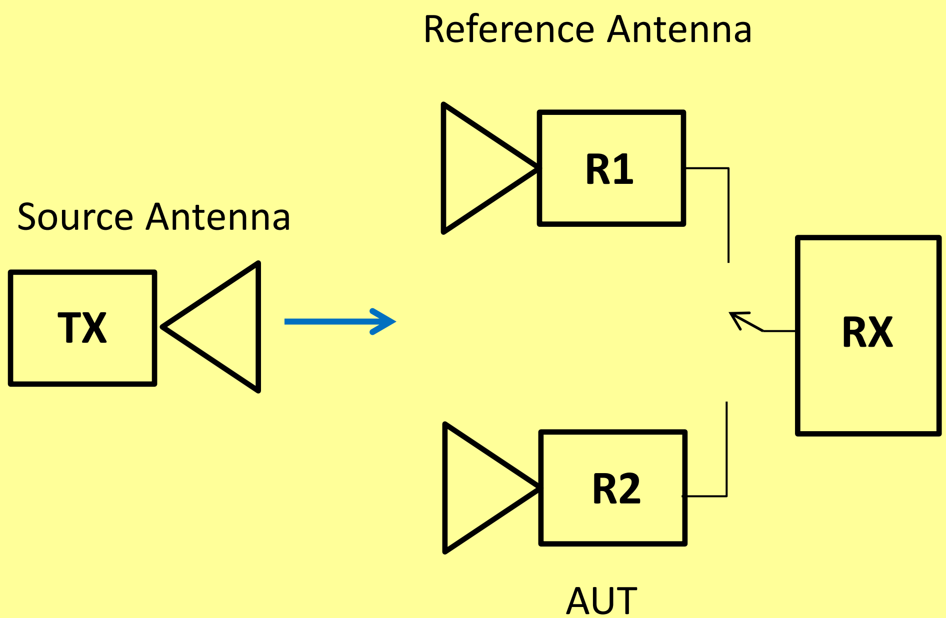
$$G_1 + G_2 = 20\log\left(\frac{4\pi r}{\lambda}\right) + 10\log\left(\frac{P_{r2}}{P_{t1}}\right)$$

$$G_2 + G_3 = 20\log\left(\frac{4\pi r}{\lambda}\right) + 10\log\left(\frac{P_{r3}}{P_{t2}}\right)$$

$$G_1 + G_3 = 20\log\left(\frac{4\pi r}{\lambda}\right) + 10\log\left(\frac{P_{r3}}{P_{t1}}\right)$$

Knowing $r, \lambda, \frac{P_r}{P_t}$, **Gains** can be determined

Comparison Method



$$P_{r1} = \left(\frac{\lambda}{4\pi r}\right)^2 P_t G_t G_{r1} \qquad P_{r2} = \left(\frac{\lambda}{4\pi r}\right)^2 P_t G_t G_{r2}$$

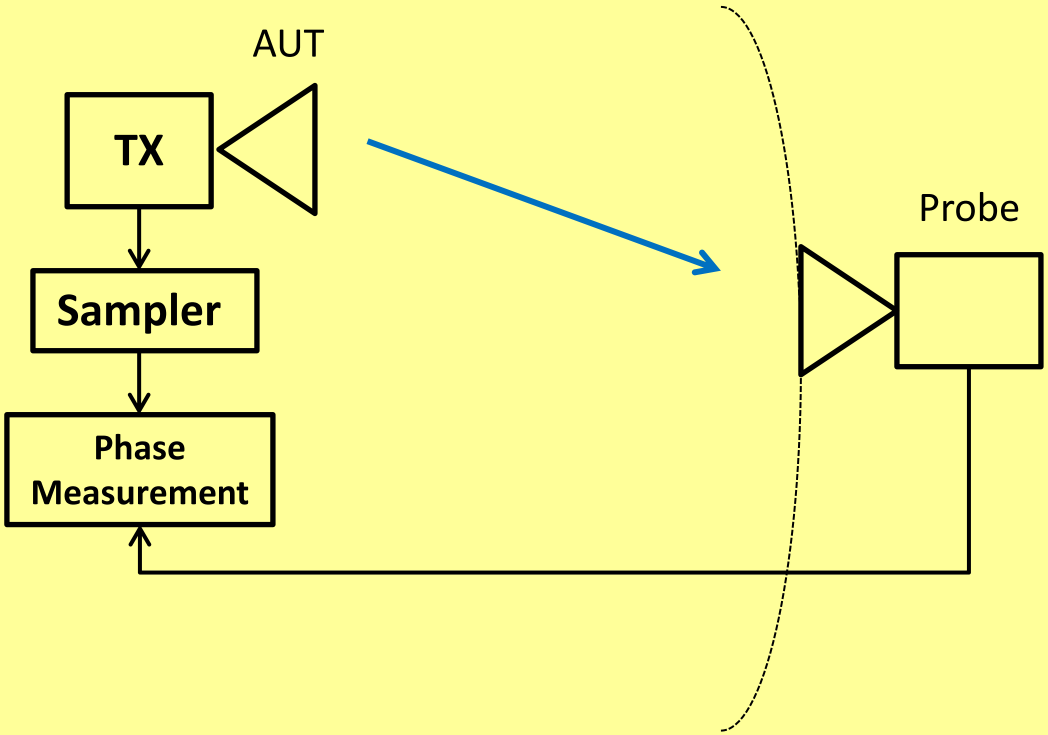
So, $\frac{P_{r1}}{P_{r2}} = \frac{G_{r1}}{G_{r2}}$ implies $G_{r2} = \frac{P_{r2}}{P_{r1}} G_{r1}$

Knowing RHS, **Gain** can be determined

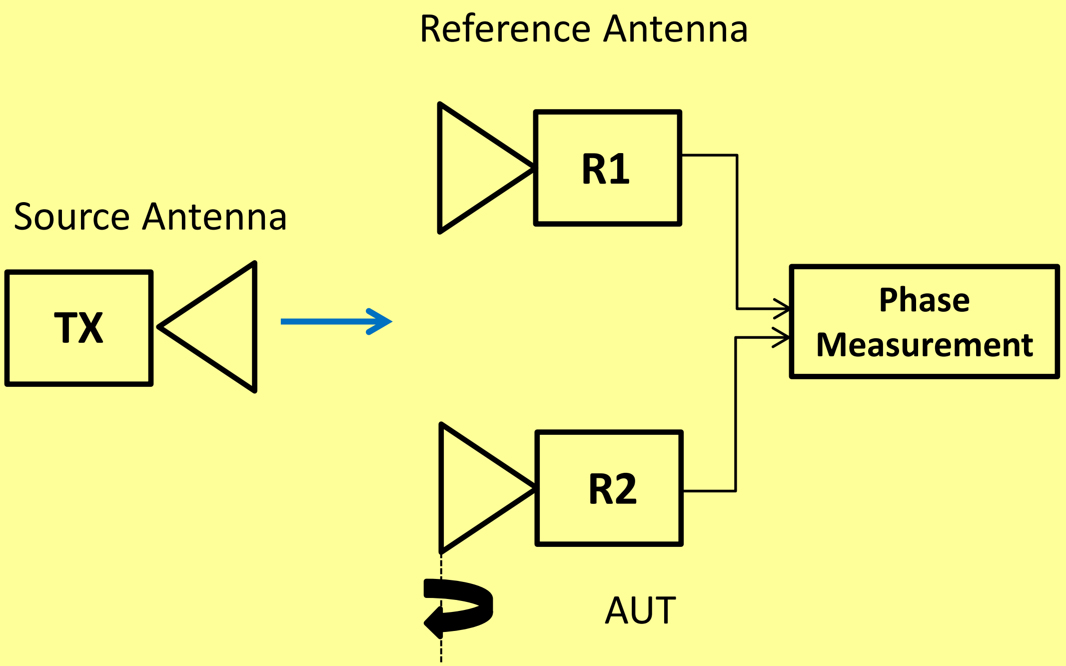
Gain Measurement

Direct Method
Reference Antenna Method
Differential Method

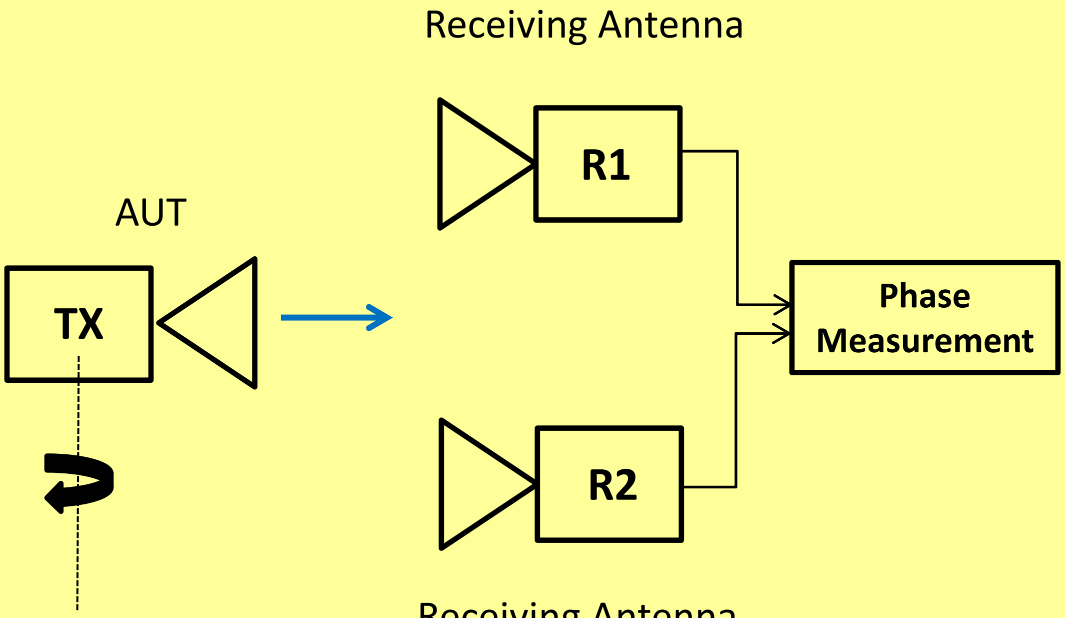
Direct Method



Reference Antenna Method



Differential Method



Directivity Measurement

13.16.7 Directivity Measurements

The directivity of an antenna can be determined from the measurements of its radiation pattern in two principal planes, E and H planes and finding the half-power beam widths θ_E and θ_H, degree in these planes, respectively.

$$D_0 = \frac{41{,}253}{\theta_E \, \theta_H} \quad \text{or,} \quad \frac{72{,}815}{\theta_E^2 + \theta_H^2} \tag{13.135}$$

This method is accurate for the antennas having negligible side lobes.

Radiation Efficiency Measurement

13.16.8 Radiation Efficiency

$$\text{Radiation efficiency} = \frac{\text{Total power radiated, } P_{\text{rad}}}{\text{Total power accepted at its input}}$$

$$= \frac{P_{\text{rad}}}{P_{\text{in}} - P_{\text{ref}}} = \frac{\text{Gain}}{\text{Directivity}} \tag{13.136}$$

where P_{in} is the input power and P_{ref} is the reflected power at the input. Therefore, the radiation efficiency can be determined from the measurement of gain and directivity.

Polarization Measurement

13.16.9 Polarisation Measurements

The polarisation of an antenna is conveniently measured by using it in the transmitting mode and probing the polarisation by a dipole antenna in the plane that contains the direction of the electric field as shown in Fig. 13.42. The dipole is rotated in the plane of polarisation and the received voltage pattern is recorded and analysed as follows.

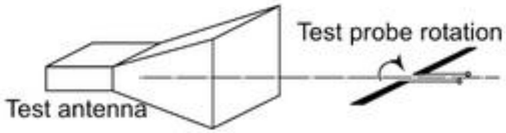


Fig. 13.42 *Polarisation measurements*

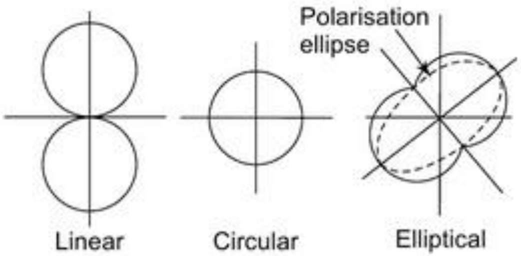


Fig. 13.43 *Polarisation patterns*

Linear Polarisation

For linear polarisation, the output voltage pattern will be a figure of eight.

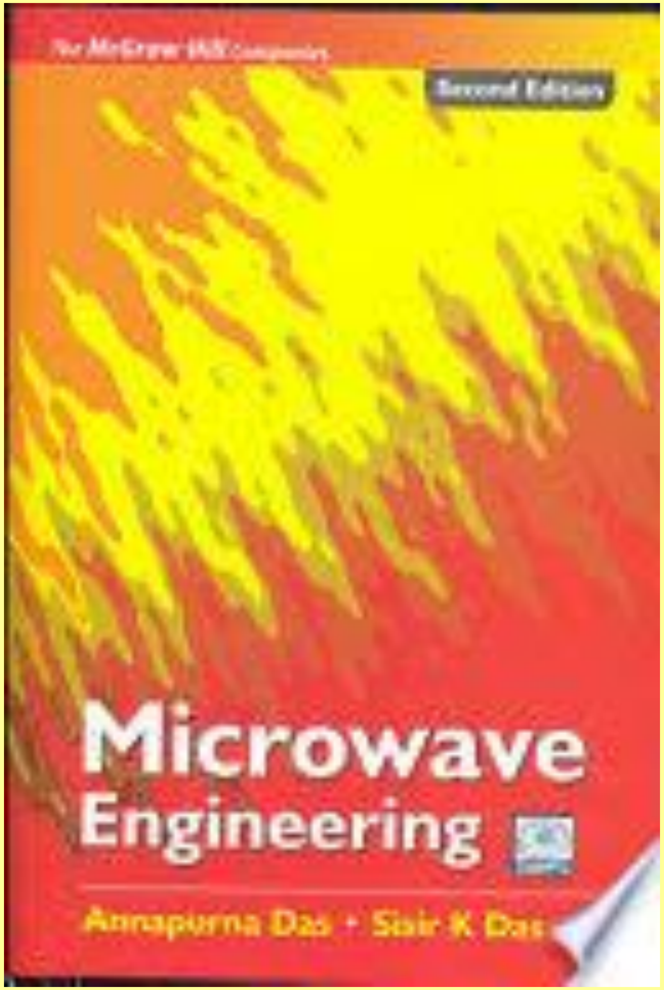
Circular Polarisation

For circular polarisation, the output voltage pattern will be a circle.

Elliptical Polarisation

For an elliptical polarisation, the nulls of the figure of eight are filled and a dumb-bell polarisation curve is obtained which will be tilted and a polarisation ellipse can be drawn as shown by dashed curve in Fig. 13.43. The sense of rotation of the circular and elliptical polarisations can be determined by comparing the responses of two circularly polarised antenna, one left and the other rightwise rotation. The polarisation of the test antenna will be the same as that of one of these two directions for which the response is larger.

Bibliography



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(Annapurna Das, Sisir K. Das)