will use the source antenna to illuminate the antenna under test with a plane wave from a specific direction. The polarization and antenna gain (for the fields radiated toward the test antenna) of the source antenna should be known.

Due to reciprocity, the radiation pattern from the test antenna is the same for both the receive and transmit modes. Consequently, we can measure the radiation pattern in the receive or transmit mode for the test antenna. We will describe the receive case for the antenna under test.

The test antenna is rotated using the test antenna's positioning system. The received power is recorded at each position. In this manner, the magnitude of the radiation pattern of the test antenna can be determined.

Measurement Example

An example should make the process reasonably clear. Suppose the radiation pattern of a microstrip antenna is to be obtained. As is usual, lets let the direction the patch faces ('normal' to the surface of the patch) be towards the z-axis. Suppose the source antenna illuminates the test antenna from +y-direction, as shown in Figure 1.

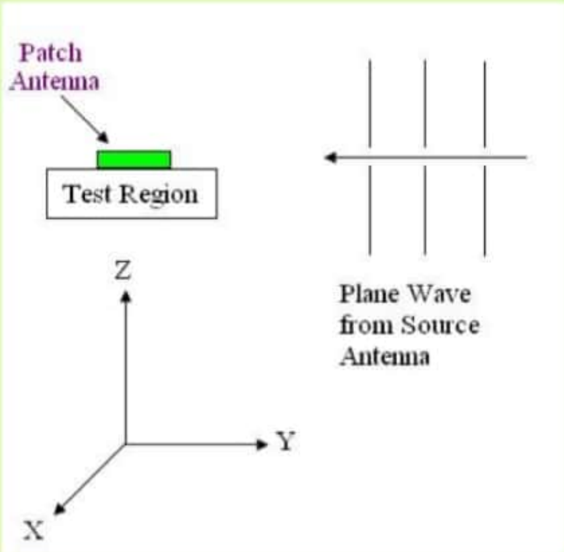

Figure 1. A patch antenna oriented towards the z-axis with a Source illumination from the +y-direction.

In Figure 1, the received power for this case represents the power from the angle: $(\theta,\phi) = (90°,90°)$. We record this power, change the position and record again. Recall that we only rotate the test antenna, hence it is at the same distance from the source antenna. The source power again comes from the same direction. Suppose we want to measure the radiation pattern normal to the patch's surface (straight above the patch). Then the measurement would look as shown in Figure 2.

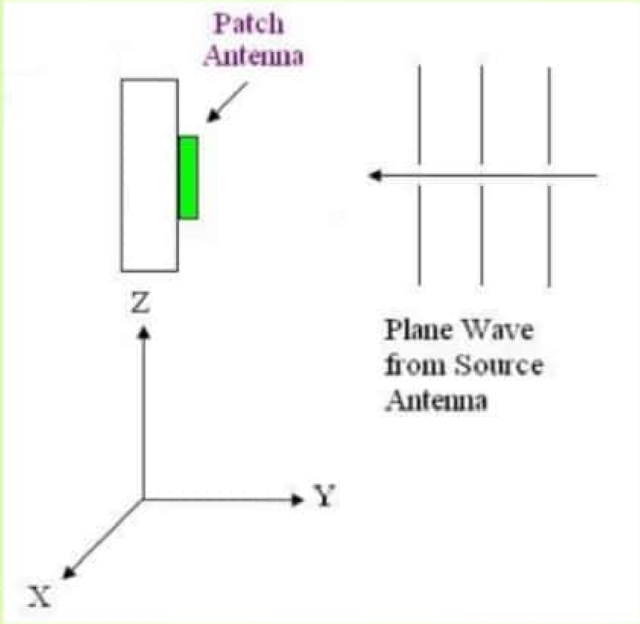

Figure 2. A patch antenna rotated to measure the radiation power at normal incidence.

In Figure 2, the positioning system rotating the antenna such that it faces the source of illumination. In this case, the received power comes from direction $(\theta,\phi)=(0°,0°)$. So by rotating the antenna, we can obtain "cuts" of the radiation pattern - for instance the E-plane cut or the H-plane cut. A "great circle" cut is when θ=0 and ϕ is allowed to vary from 0 to 360 degrees. Another common radiation pattern cut (a cut is a 2d 'slice' of a 3d radiation pattern) is when ϕ is fixed and θ varies from 0 to 180 degrees. By measuring the radiation pattern along certain slices or cuts, the 3d radiation pattern can be determined.

In addition, the radiation pattern is a function of frequency. As a result, the measured radiation pattern is only valid at the frequency the source antenna is transmitting at. To obtain broadband measurements, the frequency transmitted must be varied to obtain this information.

1. Theoretical Background:

Radiation Pattern: Practical antennas do not radiate uniformly in all directions. The radiation pattern is a graphical representation of the distribution of radiation energy as a function of angle about the antenna in the three-dimensional space and is generally measured in the **far field region**. The strength of radiation is usually measured in terms of field strength relative to some reference level, and this reference level is usually the peak of the main beam. Radiation pattern plots, however, can be shown in terms of field strength, power density or decibels (dB). Thus a complete radiation pattern gives relative field strength (or power radiated) at all angles of 'θ' and 'φ' in spherical coordinate system and requires a 3-dimensional presentation. However, in practice, it is common to present cross sections of the radiation pattern in two principal planes of interest. For linearly polarized antennas, these planes are **E- and H-planes**.

Far Field Region: The far field region is defined as that region of space where the angular field distribution of the antenna is essentially independent of the distance from the antenna. If the maximum overall dimension of the antenna is D, then the far field region is commonly taken to exist at distances greater than $2D^2/\lambda$ from the antenna where λ is the wavelength.

E-plane: The E-plane is the plane passing through the antenna in the direction of beam maximum and parallel to the far-field E vector.

H-plane: The H-plane is the plane passing through the antenna in the direction of beam maximum and parallel to the far-field H vector.

Beam Width: The radiation pattern of a typical antenna consists of a main beam and a few minor lobes. Minor lobes usually represent radiation in the undesired directions and they are sensitive to the surroundings in which the radiation pattern is measured. The beam width is a measure of sharpness of the main radiated beam. The 3dB beam width is the angular width of a pattern between the half-power points; that is, 3dB points with respect to the maximum field strength. In the electric field intensity pattern it is the angular width between points that are 1/2 times the maximum intensity.

2. Experimental Procedure:

Block Diagram:

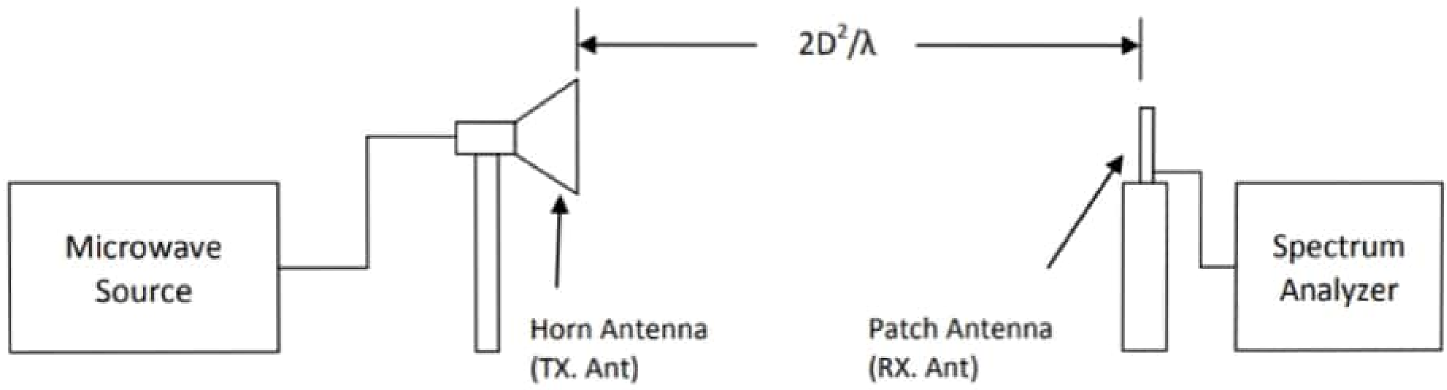

Fig. 1. Antenna radiation pattern measurement set up.

Procedure:

1. Experimental set up is made as shown in Fig 1. Microwave source is connected to the transmitting antenna (Horn Antenna). The antenna under test (patch antenna) is used as a receiving antenna and fixed to the stand whose rotation can be controlled by stepper motor controller. The distance between the horn antenna and patch antenna is kept as $2D^2/\lambda$, where maximum overall dimension of the antenna is D, and λ is the operating wavelength. The patch antenna and horn antenna are placed in line of sight aligned to each other. The receiving antenna is connected to spectrum analyzer (SA) to measure the received power.
2. Patch antenna's resonant frequency is measured from the return loss measurement using vector network analyzer (VNA) .
3. Frequency in the microwave source is set to resonant frequency of the patch antenna and power level is kept at 0 dBm.
4. Set the centre frequency of SA to the operating frequency and span to 1 MHz.
5. Observe the peak reading in the SA consider this reading for 0°.
6. Rotate the receiving antenna stand from 0 to 360 degree on its axis in steps of 10° a[illegible] down the power reading from SA. After completing 360° rotate the antenna back to 0°.
7. Repeat the measurement for radiation pattern in another plane (E-plane) by rotating both Tx. and Rx. antenna by 90°.
8. Draw the rectangular radiation pattern for E Plane and H-Plane in the graph sheet.
9. Measure the half power beam width in both the planes $(HPBW)_E$ and $(HPBW)_E$ from the radiation pattern.
10. The directivity (D) of antenna can be find by $D = \frac{4\pi}{(HPBW)_E \times (HPBW)_H}$.