Chapter 3

METHODOLOGY - EXPERIMENTAL SETUP, MEASUREMENT TECHNIQUES AND THEORETICAL APPROACH

This chapter describes the fabrication techniques employed for the microstrip antennas. A brief description of the experimental setup and measurement techniques used for the study of various antenna characteristics are also given in this chapter. This chapter concludes with description of the theoretical approach employed to predict different antenna characteristics.

3.1 FABRICATION OF MICROSTRIP ANTENNA

For the fabrication of the microstrip antennas, two different techniques are employed depending upon the dimensional tolerance.
3.1.1 Photolithographic Technique

Most commonly used method for the fabrication of microstrip antenna is photolithographic technique [7, 10]. A step-by-step procedure of this technique is shown in Figure 3.1. As the figure is self-explanatory and the technique is most popular, it is not elaborated here.

This technique is employed for the fabrication of L-band antennas where fabrication tolerance is more critical.

![FIGURE 3.1 Step-by-step procedure of photolithographic technique](image)

3.1.2 Fast fabrication process

For fast and reasonably accurate fabrication of microstrip antennas, an alternate method is used. The different steps in this process are shown in Figure 3.2. Here, the copper clad substrate is cleaned thoroughly (1) and a drawing of the antenna is made on one side (2). The entire top and bottom metallisation regions are covered with transparent cellophane tape (3). The tape is then selectively removed from the top metallisation layer (4) by means of a sharp diamond tipped
cutting tool in such a manner that tape over the antenna geometry is unaltered. The exposed metallisation regions(5) are etched out. After the etching process, tape is removed from both the surfaces and cleaned (6) once again to get the antenna ready to test. This simpler and faster technique is used for the fabrication of UHF antennas, since, at higher wavelengths this technique yields fabrication tolerance within acceptable limits.

FIGURE 3.2 Different steps in the fast fabrication process

This method is very fast and simple compared to the photolithographic technique mentioned earlier. The validity of this technique has been established by fabricating conventional
rectangular patch antennas. In the case of the drum-shaped antenna, periphery is constituted by few line segments and can be easily fabricated by this method with fabrication tolerances in acceptable limits.

3.2 EXCITATION TECHNIQUES

Two types of feeding mechanisms are used for the excitation of the present microstrip antenna. They are

a. microstrip feed
b. coaxial feed

The general nature of these feeding mechanisms are already discussed in section 1.1.2 (Chapter 1). As in the case of a rectangular microstrip antenna, the input impedance of the drum-shaped antenna varies from zero to a maximum value as we move from the centre towards the edges (see section 4.2) and thereby provides a simple means for matching of 50Ω feed line. In this thesis, coaxial type feed is employed in most of the cases.

3.3 MEASUREMENT OF RETURN LOSS, RESONANT FREQUENCY AND BANDWIDTH

The HP8510B Network Analyzer is used for the measurement of return loss, resonant frequency and bandwidth. The block diagram of the experimental setup for the automatic measurement controlled by an IBM PC interfaced to the Network Analyzer is shown in Figure 3.3.

Network Analyzer is calibrated for one full port (PORT 1) and the test antenna is connected to PORT 1 of the S-parameter test set. The measured $S_{11}$ LOGMAG data in the Network Analyzer is acquired and stored in ASCII format in the computer using MERL Soft (A software indigenously developed by the microwave group of the Department for antenna studies).
The resonant frequency of the antenna for a particular mode is determined from dip of the return loss curve for that mode. The bandwidth can be directly obtained from the return loss data by noting the range of frequencies ($\Delta f_r$) over which the return loss is $\leq -10$dB. Now percentage bandwidth is given by, 

$$ \frac{\Delta f_r}{f_c} \times 100 \% $$

where $f_c$ is the centre frequency of the operating band. The stored return loss data in ASCII format is analysed for bandwidth and resonant frequency using MERL Soft.

### 3.4 MEASUREMENT OF RADIATION PATTERN

The principal $E$- and $H$-plane radiation patterns (both co-polar and cross-polar) of the test antenna are measured by keeping the test antenna inside an anechoic chamber in the receiving mode. The experimental arrangement for the measurement is shown in Figure 3.4. A standard wideband (1-18GHz) ridged horn is used as the transmitter.
HP 8510B Network Analyzer, interfaced to an IBM PC, is used for the pattern measurement. The PC is also attached to a STIC 310C positioner controller. The test antenna is mounted on the antenna positioner kept inside the chamber. The test and the standard transmitting antennas are connected to PORT 2 and PORT 1 respectively of the Network Analyzer.

The radiation pattern of the antenna at multiple frequency points can be measured in a single rotation of the test antenna positioner by using MERL Soft. The positioner will stop at each step angle and will take $S_{21}$ measurements till it reaches the stop angle. The entire measured data are stored in ASCII format and can be used for further processing like analysis and plotting. The different pattern characteristics like half power beamwidth, cross-polar level, etc., are obtained after analysis of the stored patterns.

FIGURE 3.4 Set up for measuring the radiation pattern of the antenna
3.5 MEASUREMENT OF GAIN

The set up for the measurement of gain is same as that used for pattern measurement. A comparative measurement of gain of the new antenna is made with standard rectangular patch antenna operating at the same frequency and fabricated on the same substrate.

The standard rectangular antenna is kept inside the chamber and connected to PORT 2 of the Network Analyzer. PORT 1 is connected to the transmitting antenna. The antenna is bore-sighted and a THRU RESPONSE calibration is performed in the Network Analyzer and stored in the CAL SET. This will act as the reference gain response. The standard antenna is now replaced by the corresponding drum-shaped antenna and the plot displayed on the Network Analyzer will directly give the relative gain of the new antenna.

3.6 MEASUREMENT OF ELECTRIC FIELD INTENSITY

The probe assembly used for sampling the field intensity over the patch is shown in Figure 3.5. The probe is fabricated by removing the outer conductor and the dielectric from a 2 mm section at the end of a long semirigid cable as given in [135]. The probe assembly is now mounted on a precision XY positioner, which can position the probe at any point over the patch surface with an accuracy of 1 mm. The length of the probe \( P_L \) is 2 mm and the height of the probe above the patch surface \( s \) is 2.5 mm. The dimensions of the probe plate are 5 cm x 5 cm.

For the measurement of electric field variation, the probe is connected to PORT 2 and the test antenna to PORT 1 of the Network Analyzer. The probe is moved over the entire patch area with a resolution of 1 mm and the entire \( S_{21} \) data at the resonant frequency is stored. The stored data are normalised and plotted to get the variation of electric field magnitude.
3.7 THEORETICAL ANALYSIS OF THE ANTENNA

Experimental results are verified theoretically using segmentation technique along with cavity model and spatial Fourier Transform technique. This method is selected because of the fact that, it is computationally more efficient compared to Finite Element Method (FEM) and Finite Difference Time Domain (FDTD) methods for geometries which can be readily divided into few regular geometrical shapes whose Green's functions are known.

The complicated geometry of the drum-shaped antenna is divided into triangular and rectangular segments as shown in Figure 3.6. Now the continuous interconnection between the segments are replaced by interconnection at discrete points. The impedance matrix elements of the different segments are computed and combined together to get the input reactance of the
lossless cavity (as we have not incorporated the radiation, dielectric and surface wave losses). A large value of this reactance shows the resonance. Now the electric field variation along the periphery of the antenna is computed and the mode is identified. This field variation along the periphery is used in the aperture model to get the radiation pattern, power radiated, stored energy, etc. Finally the radiation loss is incorporated in the Q-factor and this in turn modifies the dielectric constant to a complex value. This modified dielectric constant is used in the impedance matrix evaluation to get the actual input impedance of the antenna. The elaborate steps followed for the theoretical analysis are described in chapter 5.

![Segmentation of the drum-shaped antenna into four triangular and one rectangular segment](image)

**FIGURE 3.6** Segmentation of the drum-shaped antenna into four triangular and one rectangular segment

For the theoretical analysis of the antenna, the programmes are written in *MATHEMATICA* 3.0 [11]. From the geometrical dimensions and substrate parameters, the programme will compute the resonant frequency, electric field variation along the periphery, radiation pattern, input impedance, etc.