Chapter III  METHODOLOGY

3.1 Introduction

The methodology adopted and the facilities used for the study of antenna characteristics of the hexagonal shaped dielectric resonator antenna are discussed in this chapter. The details regarding the different sophisticated equipments used to analyse the performance of the antenna are presented. Description of the fabrication of the hexagonal pellet is also given. The chapter also includes the methods and experimental set up used to study the important characteristics of the antenna such as reflection characteristics, radiation pattern, gain, polarisation and other associated parameters.

3.2 Basic facilities utilized

A full description of the equipments and amenities utilized for the measurement of antenna characteristics is presented.

3.2.1 HP 8510C Vector Network Analyzer

HP 8510 C Vector Network Analyzer (VNA) is versatile equipment capable of making rapid and accurate measurements in the frequency and time domain. It consists of the 32 bit micro controller MC68000 and has 1MB RAM and 512 KB ROM. The NWA can measure the magnitude and phase of scattering (S) parameters for frequencies up to 50 GHz with a resolution of 1Hz. It has the optional ability to take inverse Fourier transform of the measured frequency data to give the time domain response. The NWA consists of a microwave generator, S parameter test
set, signal processor and the display unit, as shown in figure 3.1. The synthesized sweep generator, HP83651B, uses an open loop YIG tuned element to generate the RF stimulus. It can synthesize frequencies from 10 MHz to 50 GHz. The frequencies can be synthesized in step mode or ramp mode depending on the desired measurement accuracy [1].

Figure 3.1 Schematic diagram of HP8510 C Network Analyzer
The antenna under test (AUT) is connected to the two-port S parameters test unit HP8514B. This module isolates the incident (test), reflected and/or transmitted signals (namely a1, b1, a2, b2) at the two ports. The signals are then down converted to an intermediate frequency of 20MHz and fed to the IF detector. These signals are suitably processed to display the magnitude and phase information of S parameters in Log magnitude, linear magnitude, smith chart or polar formats. These constituent modes of the NWA are connected using HPIB system bus. A completely automated data acquisition is made possible using the MATLAB\textsuperscript{TM} based software, developed by the Center for Research in Electromagnetics and Antennas, Department of Electronics, CUSAT.

### 3.2.2 Anechoic chamber

The anechoic chamber provides a quiet zone needed to simulate space environment required in pattern measurements. The absorbers used for building the chamber are made from high quality, low-density form impregnated with dielectrically/ magnetically lossy medium. The wall of the chamber (24' X 12' X 10' ) used for the measurements is properly shaped (tapered chamber) and covered with carbon black impregnated poly urethene (PU) foam based pyramidal, wedge, or flat absorbers of appropriate sizes. The PU foam structure gives the geometrical impedance matching while the dispersed carbon gives the required attenuation (up to -40 dB) for a wide frequency (500 MHz to 18 GHz) range. The chamber is made free of EMI by surrounding with thin aluminium sheet.
3.2.3 Automated turn table assembly for far field measurements

The turntable kept in the quiet zone consists of a stepper motor driven rotating platform, for mounting the antenna under test (AUT). The microcontroller based antenna positioner, STIC 310 C is used for rotating the AUT, for studying the radiation characteristics. The AUT is used as a receiver and a standard wideband (1-18 GHz) ridged horn antenna is used as transmitter for measurements of radiation pattern. Properly shielded cables connect the antennas to NWA. Antenna positioner is interfaced to the computer and the antenna can be rotated 360° in CW or CCW direction with any stepping angle (>=1°) using the software.

3.3 Experimental set up

Fig. 3.2 and Fig. 3.3 respectively shows the schematic set up used to measure the reflection and radiation characteristics of the antenna. A thorough investigation of the input characteristics followed by pattern measurement inside anechoic chamber.
Fig. 3.2 Setup for measuring the reflection characteristics using HP8510C Network Analyzer
Fig. 3.3 Set up for measuring radiation pattern using 8510 C Network Analyzer

3.4 Measurement procedure

The experimental procedure followed in determining various antenna parameters is discussed below:
3.4.1 S-parameters, Resonant frequency and Bandwidth

The Network analyzer is calibrated for full 2 ports by connecting the standard short, open and through loads suitably. Proper phase delay is introduced while calibrating, to ensure that the reference plane for all measurements in the desired band is actually at zero degree, thus taking care of probable cable length variations. The one port of the Hexagonal antenna is then connected to the port of S parameter test unit as shown in Fig. 3.3. The magnitude and phase of $S_{11}$ and $S_{21}$ are measured and stored in ASCII format using the software. $S_{11}$ indicate the return loss at the one port of the antenna geometry and $s_{21}$ indicates the isolation between the ports of the antennas. The resonant frequencies ($f_r$) at the port is determined from the return loss curves in Log Mag form by identifying those frequencies for which the curve shows maximum dip. It can be noted from the stored data also.

The VSWR equal to 2, which corresponds to reflection coefficient, $ho = (\text{VSWR}-1)/(\text{VSWR}+1) = 1/3$, is the $\pm 10$dB $[(20 \log 1/\rho) = -9.5$dB] level in Log Mag display. Thus 2:1 VSWR bands and bandwidths at the one port is determined by observing range of frequencies ($\Delta f$) about the resonant frequency for which the return loss curves, show $\leq -10$dB. The fractional bandwidth is calculated as $\Delta f_r/f_r$. The input impedance at resonant frequency is determined directly from the smith chart display in the network analyzer, where the center point corresponds to 50Ω.
3.4.2 Radiation patterns

Radiation pattern measurement is performed within the anechoic chamber using the set up shown in figure 3.4. The hexagonal DR Antenna mounted on the rotating platform of the turntable assembly kept in the quiet zone. Measurements are performed in the receiving mode for the AUT, which is kept in the far field of the standard wideband ridged Horn antenna. The radiation patterns of the AUT at multiple frequency points can be measured in a single rotation of the positioner using the software. Before measurement is commenced, the transmitter (Tx) and receiver (Rx) are aligned such that the Rx is in the line of sight of the Tx. AUT is connected to port 1 and horn is connected to port 2 of the S parameter test. Analyzer is configured to make $S_{21}$ measurement in the Step mode with proper Averaging.

AUT is aligned in a near bore sight position with polarization matched; the boresight option in the software is invoked to rotate the AUT to accurately determine the direction of maximum radiation. With antennas aligned at bore sight for maximum reception, and through response calibration is performed for the frequency band of interest and saved in the Cal set. Switching to the time domain, gate is turned on in the analyzer with a gate span depending on the largest dimension of the AUT. This procedure eliminates the spurious reflections from neighborhood that are likely to corrupt the measured data. After the above sequence, the calibrate option prompts for the frequency band and the number of
frequency points within the band for which $s_{21}$ cal is to be done for pattern measurements of the AUT.

The position controller is then set to home. The analyzer switched back to frequency domain, and the controlling software for pattern measurement is invoked which prompts for the start, stop and step angle and the software sequences the operations:

a) Rotate the AUT in the horizontal plane by the specified step angle.

b) Measure $S_{21}$ at each frequency step within the specified start and stop frequency range.

c) Acquire data and rotate the AUT by the step angle to cover the full $360^\circ$

Measurements are repeated in the principal planes for both the co planar and cross polar orientations of the AUT and Horn, with calibration on. The gated response at each angular position is therefore normalized with respect to boresight trace. From the stored data, half power beam width, cross-polar level, back lobe level etc. in the respective planes are estimated.

3.4.3 Gain

The gain of the AUT is measured in the boresight direction. Gain transfer method utilizing a reference antenna of known gain is employed to determine the absolute gain of the AUT [2-4]. The experimental set up and measurement procedure for determining the gain is similar to radiation pattern measurement. A standard antenna with known gain $G_R$ operating in
the same band as AUT is used as reference antenna. $S_{21}$ measurements done using reference antenna (as receiver) and the wideband Horn (as transmitter), is saved as the reference power. A THRU RESPONSE calibration is performed for the frequency band of interest and saved in new Cal set. This acts as the reference (0 dB) gain response. The reference antenna is replaced with AUT, retaining the physical alignment. $S_{21}$ is measured then with the new calibration on and the power received ($P_r$ in dB) is recorded. Display on the network Analyzer indicates the relative power in dB of the AUT with respect to the reference antenna. The gain $G_r$ of the AUT is calculated from the stored data based on Friis transmission formula as

$$G_r (dB) = G_R (dB) + P_r (dB) \quad (3.1)$$

3.4.4 Polarization pattern

Polarization of an antenna in a given direction is the polarization of the wave radiated (or transmitted) by the antenna, which is that property of an electromagnetic describing the time varying direction and relative magnitude of the electric field vector at a fixed location in space, and the sense in which it is traced as observed along the direction of propagation [2-3]. The polarization a characteristic of an antenna is represented by its polarization pattern which is the special distribution of the polarization of the field vector radiated by an antenna measured over the radiation sphere.

To measure the polarization pattern along the axis of the antenna beam, the linearly polarized standard horn antenna and test antenna are
aligned so that orientation of AUTs co polar electric field matches with that of the Horn. The AUT connected to port 1 of the S parameter test setup is kept stationary, while the Horn antenna mounted on the turntable is rotated about its axis using the position controller. The horn antenna is connected to port 2 of the S parameters test set and $S_{21}$ measurement is performed after each rotation of the Horn. The data so acquired is plotted in polar coordinates with respect to angle of rotation to reveal the polarization pattern of the AUT. The ellipse drawn inscribed within the polarization pattern is the polarization ellipse for the antenna in the specified direction.

3.5 Ansoft HFSS™

HFSS [4] stands for High Frequency Structure Simulator is a high performance full wave electromagnetic field (EM) simulator for arbitrary volumetric passive device modeling. It employs Finite Element Method (FEM), adaptive meshing and brilliant graphics to give unparalleled performance and insight to all 3D EM problems. Since it is an interactive simulation system whose basic mesh element is tetrahedron, allows solving any arbitrary 3D geometry with complex curves and shapes and provides solutions to EM problems quickly and accurately. Hence HFSS is used to simulate the characteristics of the hexagonal dielectric resonator antenna which will be explained in Chapter V.
References

1. HP8510C network Analyzer, operating and service manual, Hewlett Packard company, Santa Rosa, CA, USA.
4. HFSS high frequency structure simulator 10, Ansoft Corporation.