Design of Spheroidal Lens antenna excited by Rectangular Patch antenna for C-band applications

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Abstract— **Shaped dielectric lens antennas are effective in producing highly shaped beams that can enhance the performance of wireless broadband systems. This paper focuses on design of spheroidal dielectric lens antenna excited by rectangular patch antenna operating at 6.6GHz. The simulation of the designed antenna system is done to obtain s-parameters and the radiation pattern using HIGH Frequency Structural Simulator (HFSS) simulator. The designed antennas were fabricated and there is a close agreement between simulated and measured results.**

***Keywords*— lens antenna, dielectric lens, HFSS**

I. INTRODUCTION

Dielectric lens antennas are effective in producing highly shaped beams that can enhance the performance of wireless broadband systems. Dielectric lens-coupled antennas are commonly used as advanced receivers for THz spectroscopy systems, automotive radars and a number of other industrial and medical applications. Patch antennas are becoming increasingly popular due to their additional advantages of small size and its compatibility with planar, microwave, millimetre integrated circuits (MIC's) and monolithic microwave integrated circuits (MMIC's). However microstrip patch antenna has low gain, narrow bandwidth, and poor radiating efficiency but due to its extensive applications constant efforts are being made to modify its overall performance. To enhance the gain, dielectric lens are used since lens are inherently broadband, cost effective, easy to fabricate, have lower dimensional tolerances, and act as a radome for the primary radiators that are embedded inside or placed behind the lens.

The paper focuses on the design of shaped dielectric lens excited by rectangular patch antenna at 6.6GHz. The patch antenna is designed using empirical equations[2]. The rectangular patch antenna is simulated using electromagnetic simulation and optimization tool 'HFSS' to obtain S-parameters, VSWR and Radiation pattern. The dielectric lens is designed using the CAD model and the simulation of lens-antenna combination is carried out again in HFSS to obtain s-parameters, VSWR and radiation pattern. The comparison of gain, S-parameters and radiation pattern of rectangular patch with and without shaped lens is carried out. The fabricated spheroidal lens antenna combination is compared with simulated results and there is a very close agreement between them.

The reminder of paper is as follows: in Section II the design of single patch is achieved using empirical equations and dimension of spheroidal lens is optimised using HFSS. In section III HFSS simulation model with lens and without lens along with its respective results are presented. The fabricated antenna model and measured results are presented in section IV. the paper is concluded by comparison of simulated and fabricated results.

II. DESIGN

A. Design specifications of Patch

The rectangular patch antenna is designed for a resonant frequency of 6.6GHz. The material chosen for the substrate of the patch antenna is FR4 having dielectric constant of 4.4, tangent loss of 0.02 and the substrate height is 1.6 mm. The dielectric material is easily availability and cost effective. The length and width of patch are 13.83mm and 10.22mm respectively which were determined by considering the empirical equations of [1].

B. Design specifications of Dielectric Spheroidal lens

A prolate spheroid is formed by revolution of ellipse about its major axis. The equation of a prolate spheroid centred at the origin with semi-axes 'a' and 'b', is

$$\frac{x^2}{a^2}+\frac{y^2}{a^2}+\frac{z^2}{b^2}=1 \qquad (1)$$

The dielectric material chosen for the lens antenna is Teflon. It has a dielectric constant of 2.08 and tangent loss factor of 0.00037. The dimension of spheroid is chosen such that it is larger than few wavelengths greater than dimension of the patch antenna. The dimensions of the lens is optimized using HFSS simulator to obtain best performance wrt gain is major axis diameter(2a) is 120mm minor axis diameter(2b) is 85.7mm

III. SIMULATION AND RESULTS

HFSS is used for simulation of the designed patch/array and lens combination. HFSS is a commercial finite element method solver for electromagnetic structures from Ansys. A coaxial probe type feed is used for the rectangular patch array in this design. The feed point is

located at that point on the patch, where the input impedance is 50 ohms for the resonant frequency.

The rectangular patch structure is constructed by HFSS simulator at operating frequency of 6.6GHz. The dielectric substrate is FR4 with dielectric constant 4.4, tangent loss of 0.02 and the substrate height is 1.6 mm. The length and width of the patch is 10.22mm and 13.81mm respectively. The length and width of the ground plane were 20.32mm and 23.43mm. A coaxial probe type feed is used for the rectangular patch array the location of feed is optimised using HFSS. The HFSS model of patch antenna is presented in Fig. 1.the simulated radiation pattern at its resonant frequency is in Fig. 2.

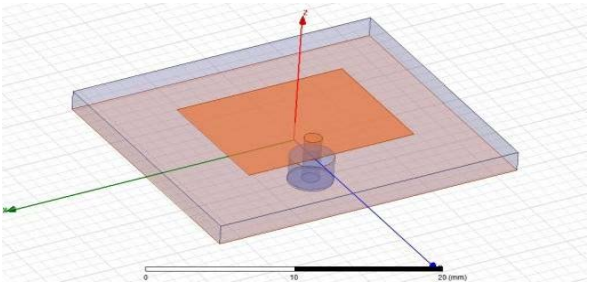

Fig. 1 HFSS model of patch antenna with dimension length=13.83mm and width = 10.22mm.

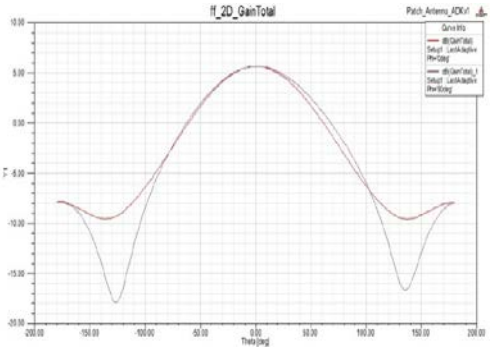

Fig. 2 Single patch Gain 2D plot the rectangular patch antenna with gain of 5.63dB

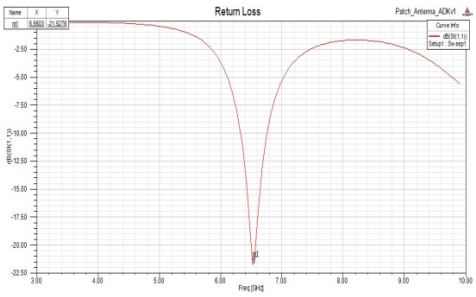

Fig. 3 The rectangular patch antenna with return Loss of -21.52 dB

The optimized rectangular patch structure has gain of 5.63dB, Return loss of -21.52dB and VSWR of 1.178.

The spheroidal lens antenna is designed for Teflon material having dielectric constant 2.08 and has a very low tangent loss factor of 0.00037.The spheroidal lens and patch antenna combination is simulated in HFSS to optimize the dimension of the lens and the separation distance between them. The optimised dimension of spheroid is major axis diameter of 120mm and a minor axis diameter of 85.7mm.

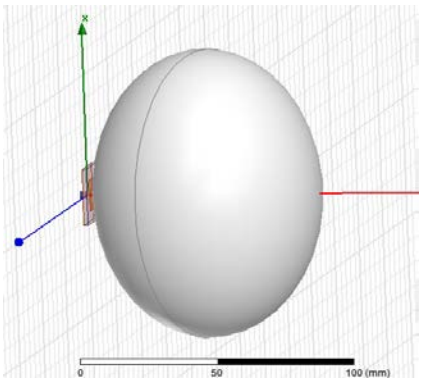

Fig.4 Spheroidal lens excited by single patch model patch dimensions w=13.81mm,l=10.22mm;lens dimensions major axis diameter=120mm,minor axis radius=85.68mm.

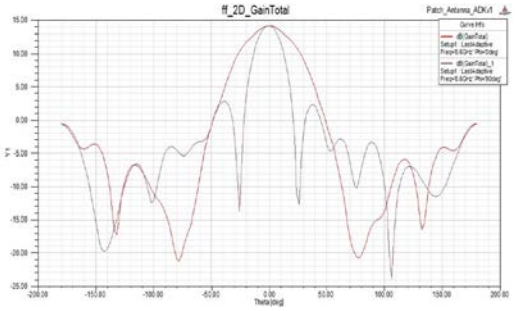

Fig.5 Gain 2D plot ,The Spheroidal Lens excited by rectangular patch antenna has Gain of 14.1 dB

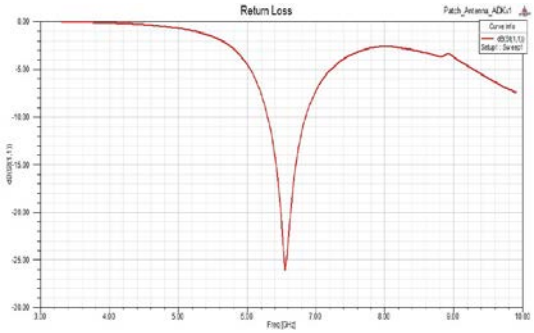

Fig.6 Return Loss plot ,The Spheroidal Lens excited by rectangular patch antenna has Return Loss of -26.02 dB

The lens array combination has gain of 14.1 dB, Return loss of -26.02dB and VSWR of 1.14 as shown in Fig 4, 5 and 6 respectively. The lens array combination has led to an increase of 8.5 dB. The comparison of performance of patch with and without lens is presented in Table 1

Parameters	Patch antenna	Spheroidal Lens excited by Patch antenna
Gain(dB)	5.63	14.1
VSWR	1.178	1.1456
Return Loss(dB)	-21.52	-26.02

Table 1: Comparison of performance of rectangular patch with and without lens at 6.6GHZ

IV. Fabrication And Measurements

The rectangular patch antenna array is fabricated for the simulated dimensions using high resolution photolithography process. The connectors are connected using a drill machine and drill feed, the feed positions and the feed network are marked and drilled to the diameters of the connectors. The connectors are soldered using flux, lead and soldering iron. The fabricated patch antenna is shown in Fig. 7

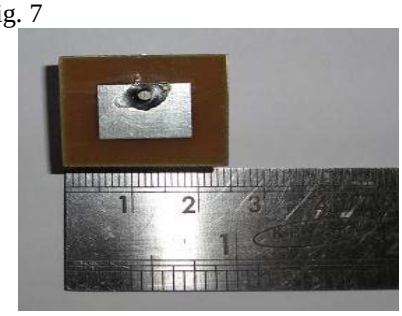

Fig. 7 Fabricated Rectangular Single patch antenna with dimension length=13.83mm and width = 10.22mm.

The spheroidal lens antenna is fabricated by accuracy computerized milling machinery like CNC lathe the cylindrical rod Teflon dielectric is shaped into spheroidal structure by coding the dimension of the structure to the machinery. The dimension of spheroid is major axis diameter of 120mm and a minor axis diameter of 85.7mm.The structure of Spheroid lens antenna is shown in Fig 8.

Fig. 8 CNC Lathe generated spheroidal lens antenna having major axis diameter of 120mm and a minor axis diameter of 85.7mm.

The antenna system is tested for the range 5 to 7 GHz and the various parameters are determined using network analyzer and radiation pattern is obtained with C-band source. Fig 9 shows the Experimental Setup to measure VSWR, S-parameter using Network Analyser and Fig 10 shows setup to measure the radiation pattern of patch with and without lens antenna

Fig. 9 Experimental Setup to measure VSWR , S-parameter using Network Analyzer

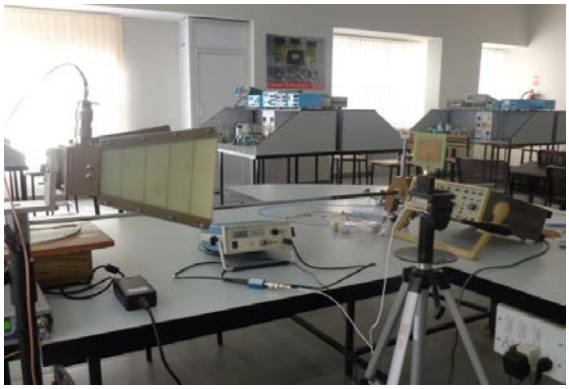

Fig 10 shows setup to measure the radiation pattern of patch with and without lens antenna

The measurements of parameters such as return loss and VSWR of fabricated lens antenna at 6.6 GHz is -16dB and 1.464. The plots of return loss and VSWR are presented in Fig 11 and 12 respectively

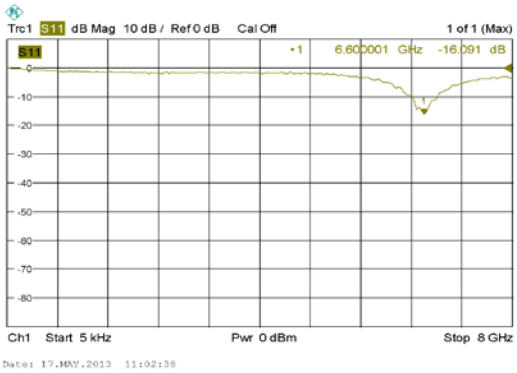

Fig. 11 Return loss plot of single patch antenna of the rectangular patch antenna with Return Loss of -16.091dB at 6.6GHz

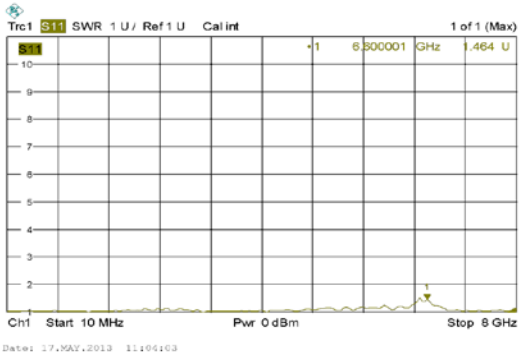

Fig. 12 Return loss plot of single patch antenna of the rectangular patch antenna with Return Loss of -16.091dB at 6.6GHz

V. Conclusion

The patch and lens antennas were designed using the empirical equations. The simulation of the designed antennas was done using the HFSS simulator tool. The antennas were then fabricated and tested using the Network Analyser. It can be seen that there is a considerable increase in the gain.

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