A NOVEL DUAL FREQUENCY S -BAND RECTANGULAR MICROSTRIP ANTENNA FOR RADAR AND SPACE COMMUNICATION

[1]VIJAY SHARMA, [3]BRAJRAJ SHARMA [2]K.B. SHARMA, [3]V.K. SAXENA, [3]D. BHATNAGAR
[1]Department of Physics, Govt. Women Engg. College, Ajmer – 305002 India
[2]Department of Physics, S.S. Jain Subodh P.G. College, Jaipur – 302004 India
[3]Microwave Lab, Department of Physics, University of Rajasthan, Jaipur- 302004 India

ABSTRACT

A novel technique for obtaining a single-layer single-feed dual frequency rectangular microstrip antenna with protruding semi ellipse for s-band communication is proposed and demonstrated. By protruding semi ellipse of appropriate dimension close to one of the edge, the rectangular patch has been shown to realize dual-frequency broadside radiations. This dual frequency operation increases its applications in radar and space communications. The range of the frequency ratio (FR) can be varied from 1.03 to 1.30 by changing the dimension of semi minor axis of protruding semi ellipse. Several optimizations are performed to attain the optimum values of the antenna physical parameters and then a prototype is fabricated. The presented antenna is compact having an area reduction greater than 15% and shows enhanced radiation characteristics compared to the standard rectangular patch. Details of the antenna design and experimental results are presented.

Keywords: *Microstrip patch antenna***,** *Dual Frequency, S band, Radar and Space communication.*

1. INTRODUCTION

In radar and space communication applications patch antennas have attracted much interest due to their compactness and dual-frequency operation. They are inexpensive to fabricate, light in weight, and can be made conformable with planar and nonplanar surfaces. Unfortunately, they have some shortcomings, including relatively low gain, narrow bandwidth, and sensitivity to fabrication errors [1-2]. Typically, dual-frequency operations have been attained by multilayer stacked patches [3] and little attention has been paid to single-layer microstrip antennas [4]. The detailed inspection of double frequency microstrip-antennas is given in literature. By cutting a square slot at the centre of a rectangular microstrip patch, both compactness and dual-frequency operation can be achieved [5]. By loading a pair of narrow slots parallel and close to the radiating edges of a bow-tie patch dual-frequency operation with tunable frequency-ratio can be achieved [6].A circularly polarized, dual-frequency, slotted square patch with probe feeding mechanism is reported to operate as the telemetry, telecommand and control (TT&C) antenna for satellite spacecrafts at 2.25 GHz and 3.0 GHz [7]. A compact patch design for circular polarization application based on third iteration minkowski-like pre fractal geometry to be used in dual band application was reported by Ali Jalal [8]. Two short-circuited microstrip patch antennas can radiate at dual frequencies was reported by Roy and Thomos [9]. In present communication, a new single-layer dual frequency patch antenna with protruding semi ellipse is introduced. This protruding semi ellipse significantly changes both the resonance frequencies and radiation pattern of the patch.

2. DESIGN OF SINGLE PATCH RECTANGULAR MICROSTRIP ANTENNA

In first step single patch rectangular microstrip antenna is designed and in next step a semi ellipse is protruding on one of the edge of the patch. The parameters for the design of rectangular microstrip antenna are:

2.1. Frequency of operation (f_0):

S-band is that part of the frequency spectrum between 2GHz to 4GHz. Many satellites transmit at S-band frequencies. The resonant frequency selected for rectangular patch is 2.56 GHz which lays in S-band. A novel design a rectangular microstrip patch antenna with protruding semi ellipse is designed such that it may resonant at two frequencies lies in S - band.

2.2. Selection of the substrates:

The FR4 glass epoxy substrate has dielectric constant ε_r = 4.4 and thickness h =1.59 mm is used for the simulation and fabrication of antenna.

2.3. Theory:

The dimension of the antenna for a chosen resonant frequency can be calculated using Cavity Model (10). Element width is given by the following equation:

$$W = \frac{c}{2.fr.\sqrt{\varepsilon_0 . \mu_0}} . \sqrt{\frac{2}{\varepsilon_r + 1}} \qquad ....(1)$$

Here fr = Resonant frequency,

ε_r = Relative dielectric constant

The length of the resonant element is given by –

$$L = \frac{c}{2.fr.\sqrt{\varepsilon_{eff}}\sqrt{\varepsilon_0 . \mu_0}} - 2.\Delta l \qquad ....(2)$$

For a dielectric substrate of thickness h, an antenna operating frequency of fr, and for an effective radiator, a practical width W is:

$$\frac{\Delta l}{h} = 0.412.\frac{(\varepsilon_{eff} + 0.3)}{(\varepsilon_{eff} - 0.258)} . \frac{(\frac{W}{h} + 0.264)}{(\frac{W}{h} + 0.8)} \qquad ....(3)$$

Using above equations a prototype of the antenna was designed (fig. 1), and characteristics are verified with theory and simulation results. The antenna with the calculated dimension of 28 mm and 27 mm when printed on FR4 substrate ε_r = 4.4 with substrate height h=1.59 mm resonates at 2.56 GHz when coaxially fed at (x_o, y_o) to excite the patch. An excellent return loss approx -35 dB has been achieved at the resonant frequency 2.56GHz (fig. 2).

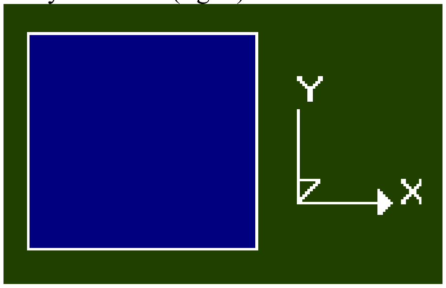

Figure 1 Top View of the Patch

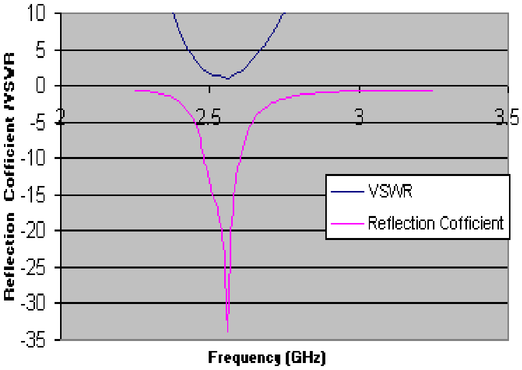

Figure 2 Variation of reflection coefficient/VSWR with Frequency

3. DESIGN OF RECTANGULAR PATCH MICROSTRIP ANTENNA WITH PROTRUDING SEMI ELLIPSE

The methods of designing dual frequency antenna discussed in introduction have their own merits and demerits. But the method used in this paper for designing the dual frequency microstrip antenna is easier in manufacture compared with the ordinary methods, because it only has to do some basic modification on the ordinary coplanar microstrip-antenna to achieve the dual-frequency property.

In this paper, an interesting phenomenon is observed that by a simple amendment on the regular coplanar microstrip antenna the new antenna geometry can work with dual-frequency. One of the resonant frequency is similar to the frequency with conventional patch while the other is originate due the alteration in geometry. The radiation doesn't change for first frequency but get some improvement with new resonant frequency. The radiation mechanism, design procedure and experimental results of the dual frequency geometry are presented in the following section.

The structure consists of a rectangular patch of length L = 28mm and width W = 27mm, with a protruding ellipse of dimension semi major axis a = 14mm and semi minor axis b = 3mm with its origin at (x = 14 mm, y = 20 mm) etched on a substrate of dielectric constant ε_r = 4.4 with thickness 1.59 mm is shown in Figure 3. Since there are no analytical models to solve the design problems, a simulation tool (IE3D) is used to solve all the cases in this paper .The IE3D (Zeland Software) is an integrated full wave electromagnetic simulation and optimization package for the analysis and design of microstrip antennas based on method-of-moments is used to solve the problems assigned to it (11).

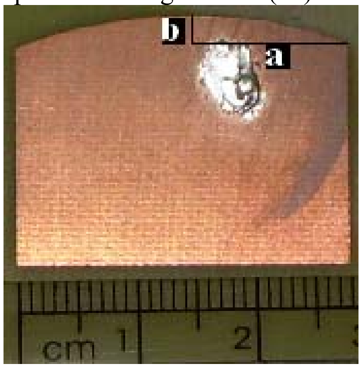

Figure 3 (a) Top View of the proposed Patch

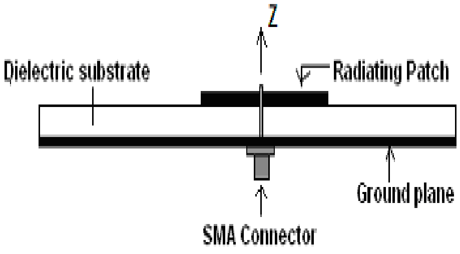

Figure 3 (b) Side view of the antenna structure with feed network

The antenna is coaxially fed to a 50 ohm system interfacing via a single coaxial SMA female connector with radius 0.62mm at an optimized feed location(x_o= 19.6mm,y_o=16.4mm) to excite the patch. The measured and computed variation of return loss for the proposed antenna with frequency is shown in figure 4(a) and 4(b) respectively.

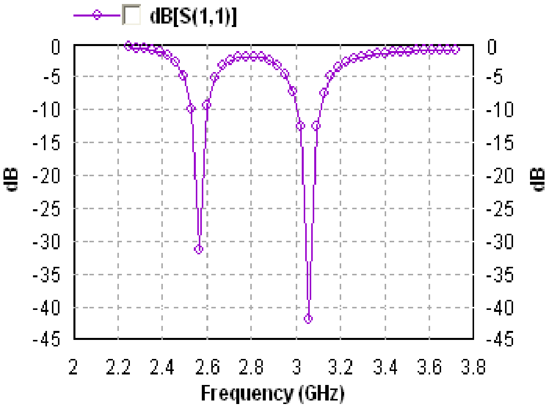

Figure 4 (a) Computed variation of return loss for the proposed antenna with frequency

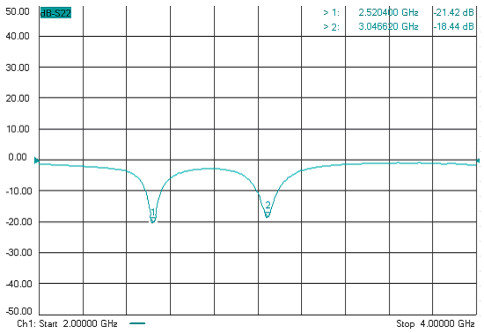

Figure 4 (b) Measured variation of return loss for the proposed antenna with frequency

The measured VSWR of this antenna for both the resonant frequencies are close to unity as shown in fig.5. This result confirms excellent matching of this antenna geometry with the feed network.

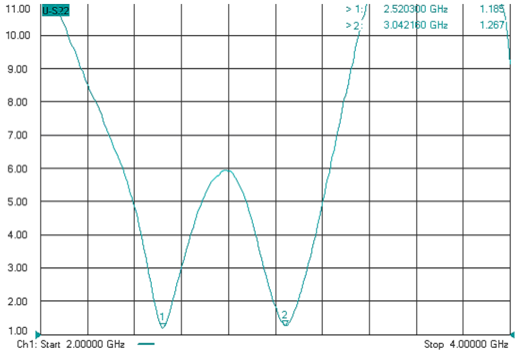

Figure 5 Measured variation of VSWR for the proposed antenna with frequency

The measured variation in input impedance of antenna with frequency is shown in figure 6. The input impedance at both the frequencies is close to 50 ohm and reactive parts are also close to desired values.

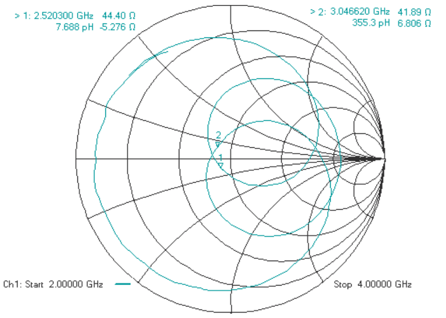

Figure 6 Measured variation of input impedance for the proposed antenna with frequency

The directivity of antenna is significantly large (around 6.5 dBi) and it is more or less unaffected within the frequency range as shown in Figure 7.

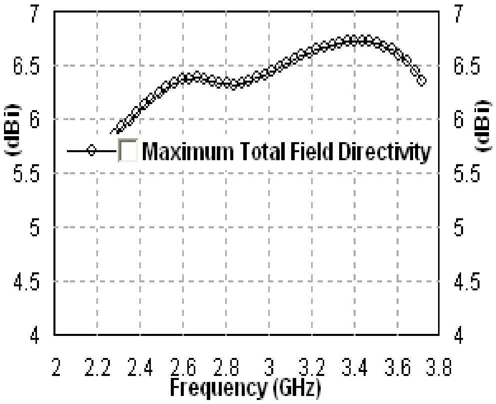

Figure 7 Computed variation of total field directivity for the proposed antenna with frequency

The computed elevation radiation patterns for both the frequencies are shown in figure 8(a) and 8(b) respectively. The patch antenna produces a cardoid pattern, with good gain along on boresight and dropping to 0 db. When mounted on a ground plane this pattern is flattened out producing less gain on boresight and more at higher elevations a useful feature for Space applications. The antenna gains of both frequencies f_1 and f_2 in the broadside direction ($\theta = 0^0$) are 1.12 dBi and 2.45 dBi, respectively.

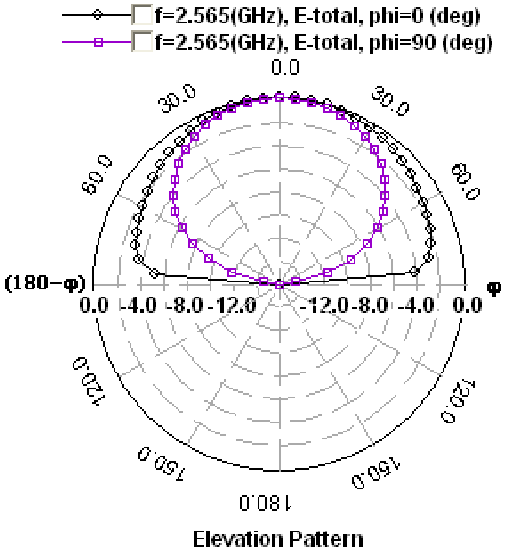

Figure 8 (a) Computed elevation radiation pattern for proposed geometry at frequency 2.565 GHz

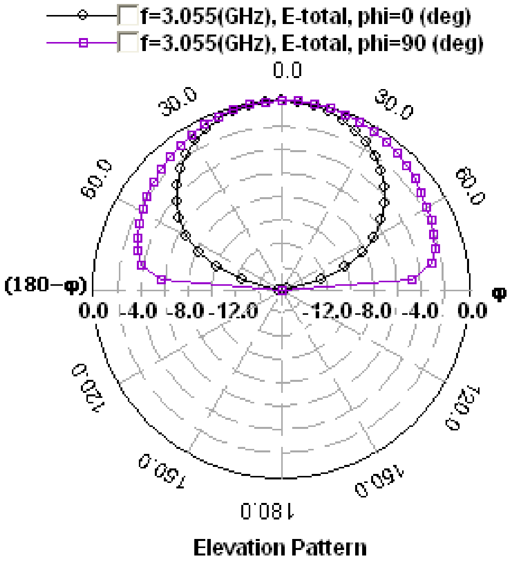

Figure 8 (b) Computed elevation radiation pattern for proposed geometry at frequency 3.055 GHz

The computed azimuthal radiation pattern for both the frequency is shown in fig. 9. The azimuthal patterns at both the frequencies are almost symmetric in nature.

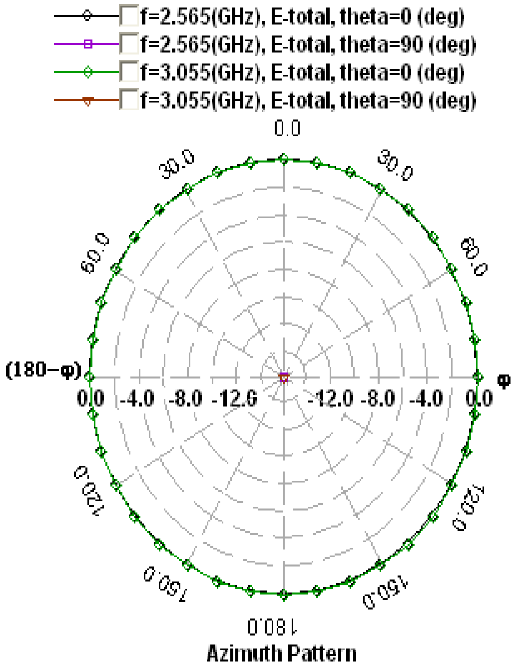

Figure 9 Computed azimuthal radiation pattern for proposed geometry at frequencies 2.55 GHz and 3.055 GHz

Figure 10 (a) and 10 (b) shows the true 3D radiation pattern at frequency 2.565GHz and 3.055GHz respectively.

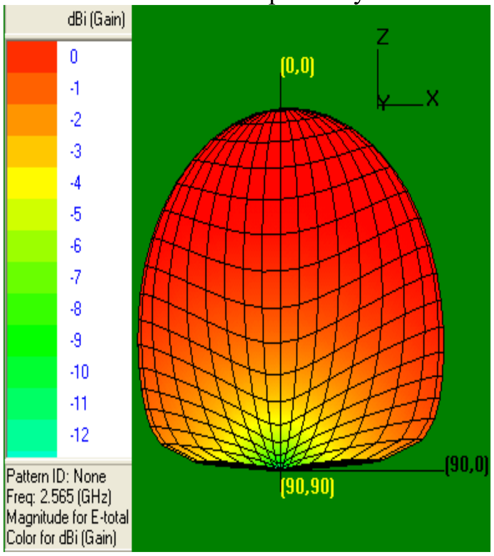

Figure 10 (a) Computed True 3D radiation pattern for proposed geometry at 2.565 GHz

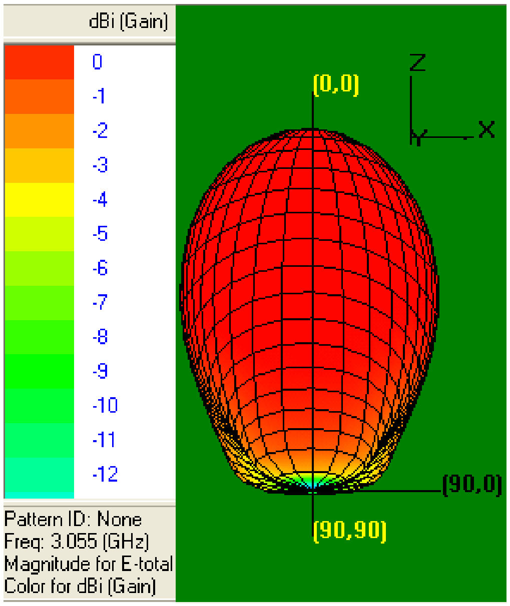

Figure 10 (b) Computed True 3D radiation pattern for proposed geometry at 3.055 GHz

The variation of return loss versus resonant frequency with the variation in dimension of semi minor axis of protruding semi ellipse 'b' is shown in fig.(11).

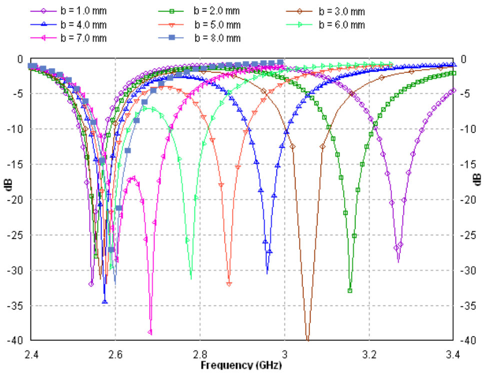

Figure 11 Computed variation of return loss versus resonant frequency with the variation in dimension of semi minor axis of protruding semi ellipse

It is observed that first resonant frequency shows no significant change whereas the second resonant frequency decreases with increase in dimension of semi minor axis of protruding semi ellipse. At b = 7 mm both the frequency merges to give a relatively wider bandwidth 6.32% with respect to center frequency which is twice of the conventional patch of same dimension.

The variation in resonant frequency with dimension of semi minor axis of protruding semi ellipse is shown in fig (12). It is observed that when dimension of semi minor axis of protruding semi ellipse is 7 mm both the frequency merge.

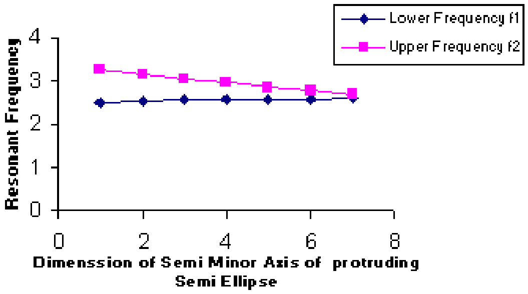

Figure 12 Resonant frequency versus dimension of semi minor axis of protruding semi ellipse

Figure (13) shows the variation of frequency ratio with dimension of semi minor axis of protruding semi ellipse which indicates that frequency ratio can be controlled by changing the dimension of semi minor axis of protruding semi ellipse.

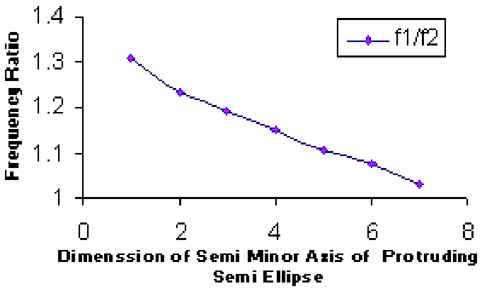

Figure 13 Frequency ratio versus dimension of semi minor axis of protruding semi ellipse

4. CONCLUSIONS

The proposed patch antenna is a rugged, low cost, moderate gain antenna solution for Radar and Space applications. It is compact, having an area reduction of 15% and similar radiation characteristics compared to the standard rectangular patch accessible to small spacecraft. This antenna resonates at two frequencies 2.565 GHz and 3.055 GHz in S band. This dual frequency behavior increases its applications in radar and satellite communications. The frequency ratio (FR) can be varied from 1.03 to 1.30 by changing the dimension of semi minor axis of protruding semi ellipse. Measured results display exemplary accuracy with simulated results thereby justifying the use of such techniques for synthesis of single element as well as antenna array structure for Radar and Satellite Communication. Although the gain of the antenna design is low, this is attributed to the loss tangent of the FR4 substrate material, with higher gain expected from the use of lower-loss substrate materials.

5. ACKNOWLEDGEMENT

Authors express their sincere thanks to DST, New Delhi for supporting this research work.

REFERENCES

[1].Garg.R.,Bhartia.P.,Bahl I.and Ittipiboon A. “Microstrip Antenna Design Hnadbook”Artech House Norwood 2001.

[2]. Wong, K. L. “Compact and Broadband Microstrip Antennas”. NewYork: J. Wiley and Sons, 2002.

[3].Wang, I., Pralich, R., w, c., and Lina, I. “Multifunctional Aperture Coupled Stack Antenna”, Electron. Lett. 1990, 26, (25). PP.2067-2068.

[4].Croq, F., and Pozar D. “Multifrequency Operation Of Microstrip Antennas Using Aperture Coupled Parallel Resonators”, IEEE Tram., 1992, AP-40, (ll), pp. 1367-1374

[5].Wen-Shyang Chen “Single-Feed Dual-Frequency Rectangular Microstrip Antenna with Square Slot” Electronics Letters. Vol.34 No.3 1998.

[6].K. L. Wong and W. S. Chen, “Slot-Loaded Bow-Tie Microstrip Antenna for Dual-Frequency Operation,” Electron. Lett. 34, 1713–1714, Sept. 3, 1998.

[7].A. M. El-Tager, M. A. Eleiwa, and M. I. Salama “A Circularly Polarized Dual-frequency Square Patch Antenna for TT&C Satellite Applications” Progress in Electromagnetics Research Symposium, Beijing, China, March, 2009.

[8].Ali Sadeq Abdulhadi Jalal “A New Compact Patch Design For Circular Polarization Application Based On Third Iteration Minkowski-Like Pre Fractal Geometry” journal of Engineering and applied sciences 3(9):729-734,2008.

[9].J. S. Roy, N. Chattoraj, N. Swain “New Dual-Frequency Microstrip Antennas for Wireless Communication” Romanian Journal Of Information Science And Technology Volume 10, Number 1, 2007.

[10]. Antenna Theory, Chapter 14.C.Balanis, Wiley, 2nd edition (1997).

[11]. IE3D User's Manual, Release 3. Zeland Software, Inc.,Fremont. C

BIOGRAPHY:

Mr. Vijay Sharma received the M.Sc. degree in Physics from University of Rajasthan, Jaipur in 2002. He is a research scholar of University of Rajasthan, Jaipur. Currently, he is a Lecturer at Govt. Women Engineering College, Ajmer. His research interest includes the design and development of dual frequency compact broadband antenna.

Mr. Brajraj Sharma received the M.Sc. degree in Physics from University of Rajasthan, Jaipur in 2002. He is a research scholar of University of Rajasthan, Jaipur. Currently, he is a Lecturer at SKIT, Jaipur.

Dr. K.B. Sharma received the Ph.D. degree in Physics from the University of Rajasthan, Jaipur, in 1987. Currently, he is a Principal at S.S. Jain Subodh P.G.College, Jaipur. He is a distinguished Fellow of IETE. His research interests include design and development of new antennas for radar and satellite communication.

Dr. V.K. Saxena received the Ph.D. degree in Physics from the University of Rajasthan, Jaipur, in 1991. Currently, he is an Assistant professor at University of Rajasthan. His research interests include patch antenna and RF communication.

Dr. D. Bhatnagar received the Ph.D. degree in Physics from the University of Rajasthan, Jaipur, in 1986. Currently, he is an Associate professor at University of Rajasthan Jaipur. He is Chair, IEEE MTTS India council & guided several Ph.D. students. His research interests include Space Communications, Electromagnetics, Antennas and Satellite Navigation.