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Design and Development of Compact Conformal Microstrip Antenna at S-Band

V. Srinivasa Rao[#,*], D.R. Jahagirdar[#], and Girish Kumar[@]

[#]*DRDO-Research Centre Imarat, Hyderabad - 500 069, India*
[@]*Indian Institute of Technology, Bombay, Powai, Mumbai - 400 076, India*
[*]*E-mail: varanasi0205@gmail.com*

ABSTRACT

A compact microstrip antenna at S-Band is described in this work. This paper presents the theoretical and experimental investigations on conformal 90° Sectoral circular microstrip antenna using shorting wall. The performance of antenna characteristics is obtained using FEM based HFSS software and the computed results are verified by measurement. Here, microstrip antenna is loaded with shorting wall to achieve frequency reduction of about 75 per cent. The antenna characteristics were studied with radome surrounded by metallic ring. The radiation characteristics of antenna mounted on vehicle body is carried out. The antenna has moderate gain and wider coverage in roll plane as well as azimuth plane and may be used as small, compact antenna for onboard telemetry applications.

Keywords: Metallic ring; Shorting wall loaded microstrip antenna; Compact antenna; Radome; Conformal antenna

1. INTRODUCTION

In many airborne applications, antennas are required to be conformal[1-4], low profile, light weight, compact and rugged enough to minimise and withstand the aerodynamic drag during the flight[5-6]. Microstrip antennas (MSA) are preferred for such onboard applications as conventional monopole antennas and their variants protrude from the surface of the body leading to aerodynamic drag in real time dynamics. One of the major advantages of microstrip patch antenna is that it can be flush mounted to a curved host surface such as an aircraft, UAV, missile and satellite. It provides omni-directional coverage (when number of elements are used) for onboard application to ensure uninterrupted link between ground station and space vehicle.

There are a few methods presented in the literature to reduce the size of the patch antennas by using slots, shorting posts, walls and plates[7-13], but constraints with respect to missile platform like aerodynamic drag have not been addressed.

This paper addresses the conformal antenna design for missile requirements. The size of circular microstrip antenna (CMSA) is reduced by half, if a semicircle MSA (SCMSA) is designed. The area is further reduced to one fourth of a circle by shorting along zero field lines, resulting in shorted 90° sectoral MSA[7].

The radiation characteristics of this antenna mounted on metallic square-cylindrical body having each side of 200 mm is presented as the pattern and coverage alters by the shape of the mounting body.

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2. ANTENNA DESIGN

The shorted 90° Sectoral MSA is as shown in Fig. 1. The substrate used for antenna is RT 5870 with relative permittivity, $\varepsilon_r = 2.33$ with 3.2 mm thickness and loss tangent, $\tan\delta = 0.0012$. The antenna was fed using a 50 Ω co-axial feed to match the input impedance of the patch antenna. A special arrangement of adding metallic ring of width d2 has been made around the radiating patch for enhancing the coverage, which is critical for on board Telemetry applications.

In most of the onboard applications, the environmental conditions are stringent and requires a dielectric material i.e. radome with a customised design. It is used over the radiating element as a cover to protect from external constraints like temperature, heat, pressure, leakage etc. The study of the antenna along with the radome is done. Due to dielectric loading, the resonance frequency of the antenna changes. This change in the frequency is due to the relative permittivity and thickness of the dielectric layer given[14-15] as:

$$\frac{\Delta f_r}{f_r} = \frac{f_r(d=0) - f_r(d)}{f_r(d=0)} \tag{1}$$

$$\frac{\Delta f_r}{f_r} = \frac{\sqrt{\varepsilon_e} - \sqrt{\varepsilon_{eo}}}{\sqrt{\varepsilon_o}} \tag{2}$$

where f_r is the resonance frequency, $f_r(d=0)$ is the resonance frequency when unloaded and $f_r(d)$ is the resonance frequency when loaded.

As shown in Fig. 1, the patch is covered with a teflon radome of thickness 5 mm and a metallic ring is placed along the edges of radome at a height of 5 mm and a distance d1 from the patch.

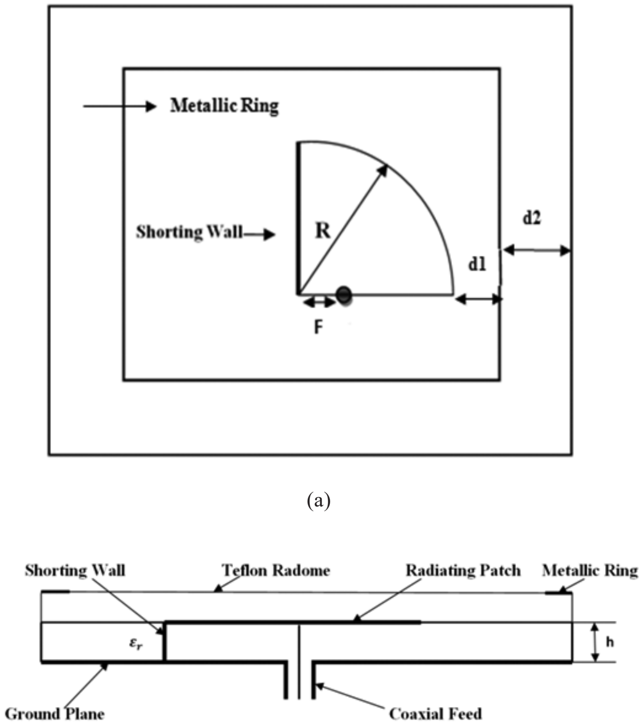


Figure 1. Shorting wall loaded 90° Sectoral microstrip antenna with radome and metallic ring (a) Top view (b) Side view.

The width of this metallic ring is d2=10 mm. The resonance frequency of the antenna is same as that of a circular microstrip antenna (CMSA). A CMSA with diameter (*D*=2R) of 50.25 mm, when fed at *F*= 7 mm from the centre of the patch has a resonance frequency of 2.25 GHz for the fundamental TM11 mode and its bandwidth is 34 MHz and Half Power Beam Width (HPBW) of 98° in E-Plane and 82° in H-Plane. Its size is reduced by using shorted 90° sectorial MSA with *R*= 25.1 mm. 14 shorting pins of diameter 0.8 mm spaced 1 mm apart are placed in place of a shorting wall. When fed at 3 mm from the center of the patch, it resonates at the same frequency. A radome of 5 mm thick teflon is placed over the radiating patch to sustain high temperature of the order of 400^{o}C, which occurs due to aerodynamic friction. However, when teflon radome surrounded by metallic ring placed, the resonance frequency of the antenna decreases.

The final optimised dimensions of the proposed antenna is *R*=24 mm and feed location is 3 mm away from the centre. Thus the size of the radiating patch has been reduced by around 75 per cent than conventional CMSA.

The antenna performance has been studied by placing the radome over 90° sectoral MSA with finite ground plane having metallic cavity using HFSS software. Figure 2 shows the simulated reflection co-efficient and radiation pattern at *f*=2.25 GHz of proposed antenna. The 10 dB returnloss bandwidth is 23 MHz and half power beam width (HPBW) is 130° in E-Plane and 100° in H-Plane with a peak gain of 4.51 dBi.

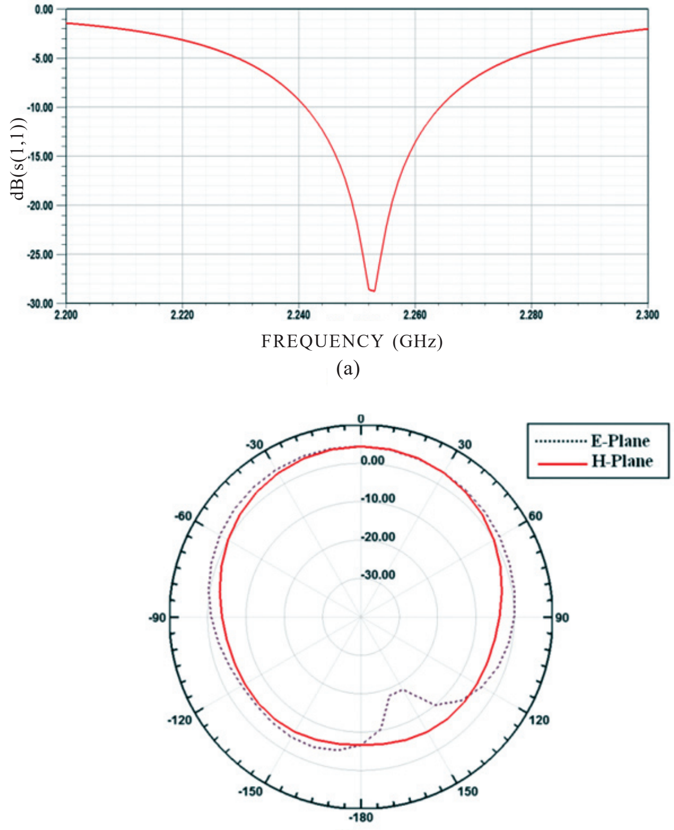


Figure 2. (a) Reflection coefficient plot (b) 2D Patterns at 2.25 GHz of 90° Sectoral MSA with radome.

3. ANTENNA MOUNTED ON SQUARE CYLINDER

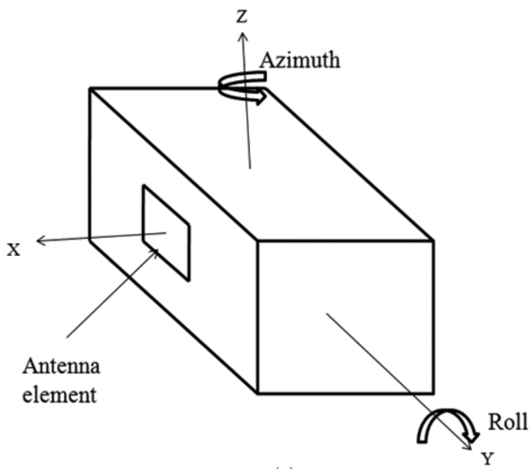
The radiation characteristics of the proposed antenna mounted on square cylinder have been presented in this section. The analysis of single antenna mounted on body is essentially required so that the number of elements can be decided to get omni-directional coverage. The geometry of the antenna mounted on a section and corresponding simulated radiation patterns for azimuth and roll planes are as shown in Fig. 3.

From the simulated results, it is observed that the antenna provides similar return loss characteristics as earlier. However a higher gain of 5.85 dBi is obtained at 2.25 GHz and HPBWs of 115° in azimuth plane and 90° in roll planes, respectively. The simulated results for all three antennas are summarised in Table 1.

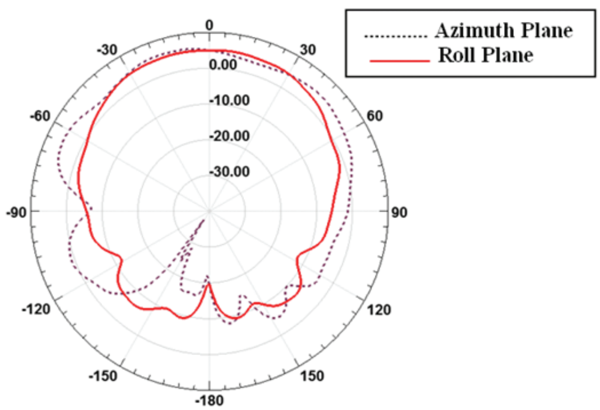
Table 1. Performance comparison

Type	Beam width (°)		Gain (dBi)
	E-Plane	H-Plane	
CMSA	98°	82°	5.8
Proposed antenna	130°	100°	4.51
Proposed antenna mounted on body	115°	90°	5.85

The proposed antenna has better coverage and reduced gain than the conventional CMSA. But when mounted on the body, the gain has increased by 1.34 dBi, with not much compromise on the coverage.



(a)



(b)

Figure 3. (a) Geometry of the antenna mounted on square cylinder and its and (b) 2D Patterns at 2.25 GHz.

4. RESULTS AND DISCUSSIONS

The antenna is fabricated as shown in Fig. 4 and tested. The antenna is characterised by measuring the resonance frequency, return loss, gain and beam width and its results are discussed in this section.

Figure 5 shows the simulated and measured reflection co-efficient (S_{11}) of antenna. The $|(S_{11})|$ of the antenna was measured using a vector network analyser. The simulated impedance bandwidth for $|(S_{11})| \leq$ -10 dB is from 2241 MHz to 2264 MHz (23 MHz) whereas the measured bandwidth is from 2234 MHz to 2263 MHz (29 MHz).

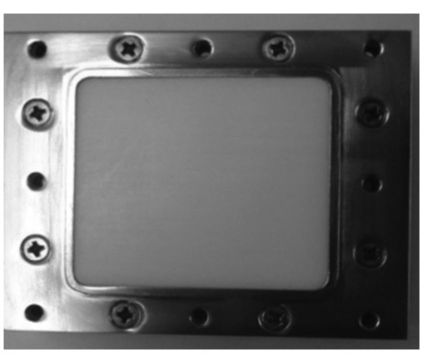


Figure 4. Fabricated compact antenna with radome.

The radiation pattern measurement has been carried out in compact antenna range facility with proper separation between transmitting and receiving ends meeting the far field condition. The radiation patterns of proposed antenna mounted on the square body are as shown in Fig. 6.

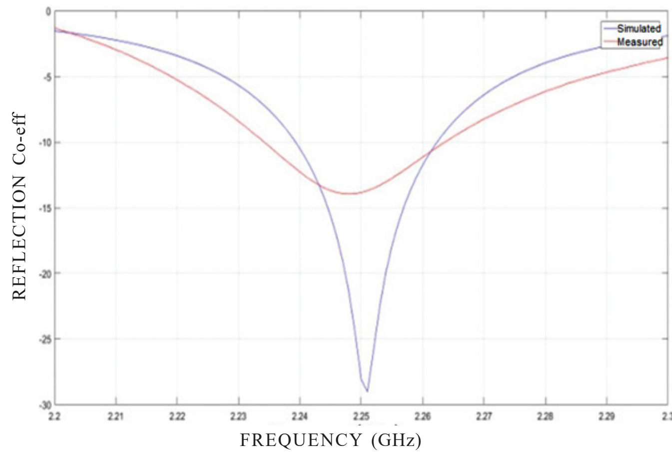
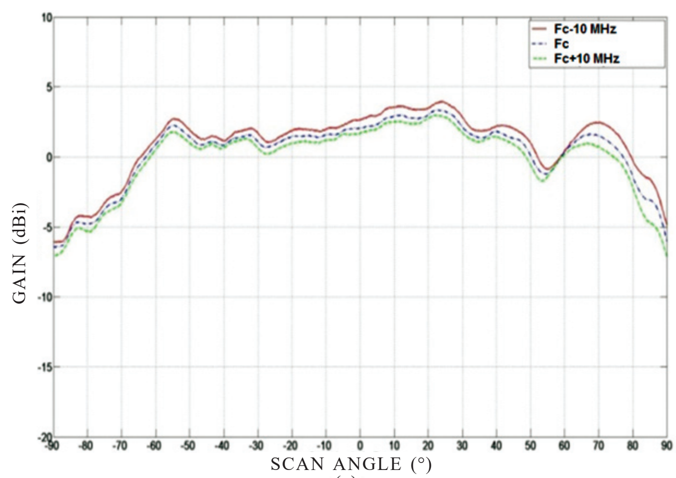
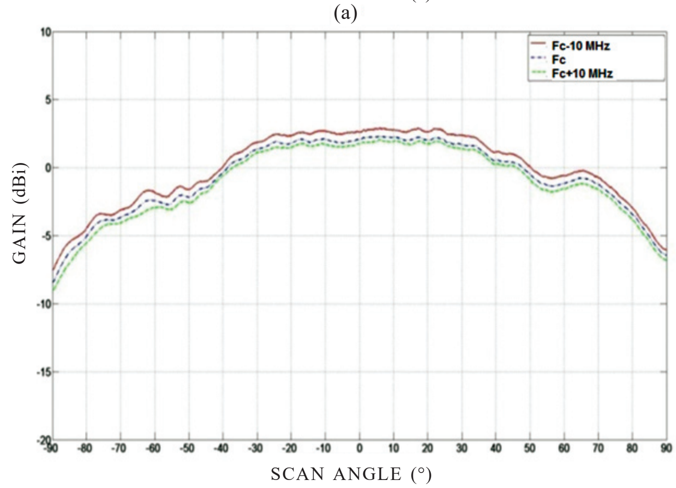


Figure 5. Simulated and measured reflection co - efficient plot of compact antenna with radome.



(a)



(b)

Figure 6. Measured radiation patterns of shorted 90° Sectoral MSA with radome and cavity mounted on body (a) Azimuth plane and (b) Roll plane at S-band frequencies (Fc±10MHz).

The simulated and measured HPBWs of antenna mounted on section in both azimuth and roll planes are 115° x 90° and 111° x 92°, respectively. The fabricated antenna's measured peak gain is 3.8 dBi.

5. CONCLUSIONS

A compact shorted 90° sectoral MSA was successfully designed and fabricated considering radome and metallic ring for airborne Telemetry applications at S-Band. The proposed antenna with 14 shorting pins has 75 per cent size reduction as compared to CMSA. The realised antenna provides HPBWs of 111° x 92° in Azimuth and Roll planes, respectively with moderate gain. The effect of antenna mounted on square cylindrical body has been studied and reported. There is good agreement between the simulated and the measured results. The antenna is well suited to be used in missiles, fighter aircrafts and UAV to maintain uninterrupted link.

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CONTRIBUTORS

Mr V. Srinivasa Rao completed BE (Electronics and Communication Engineering) from GITAM, Vishakhapatnam, in 1999 and MTech (MSS) from Indian Institute of Technology, Kharagpur, in 2001. Currently working as a scientist at DRDO-Research Centre Imarat, Hyderabad. His fields of interest includes microstrip antennas, conformal antennas, arrays, RF and Microwave circuits.

Dr D.R. Jahagirdar received his MTech (Microwave Engineering) from Indian Institute of Technology, Kharagpur, in 1992 and PhD from the Department of Electronics and Computer Science, University of Southampton, UK, in 1997. Currently working as Scientist at DRDO-Research Centre Imarat, Hyderabad. He received 'Young Scientist Award' at Intl Radar Symposium Bangalore in 2005. He received 'Laboratory scientist of the year award' in 2007 and 'DRDO Scientist of the year' in 2010. He has 52 paper published in various international conferences and journals.

Dr Girish Kumar received PhD in (Electrical Engineering) from IIT Kanpur in 1983. Currently a Professor in the Electrical Engineering Department, IITB, Mumbai. His areas of interest are: Antennas, microwave circuits and systems. He has written more than 300 paper in journals and conference proceedings. He is author of four books and has filed 7 patent. He has been working on hazards of microwave radiation for the last one decade. Has written several reports and given presentations at various forums on the topic related to cell phone and tower radiation hazards and solutions.