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Design of High Gain B-Sandwiched Radome

Shruthi M[1] and Dr. Mahesh A[2]

[1]Department of Electronics and Communication,
RVCE, Bangalore, India

[2] Department of Electronics and Communication,
RVCE, Bangalore, India

Abstract: ***A high gain antenna is required to reduce the path losses that occur while operating in the high-frequency band. The radomes protect the antenna element from the external harsh environment. But it affects the electromagnetic property of the feed element. In order to prevent a significant change in the electromagnetic behavior of the feed element after integration with the radome, a B-sandwiched Radome with a 2x2 Microstrip Patch Antenna Array (MPAA) as a feed element, operating at 9.7 GHz, is proposed in this work. A Return loss of -27.58 dB, an increase in gain of 12.13 dB, and a peak gain of 23.13 dB are observed after integration.***

Keywords: High Gain, Low-profile, Dielectric lenses, non-Euclidean geometry, Radomes.

1. INTRODUCTION

The development of the fifth generation (5G) mobile and wireless technologies is prompted by the rising demand for faster data rates which in turn require a wider bandwidth. Although there are more mobile users and more data demand, 5G should be able to manage more traffic at considerably faster speeds than the base stations that comprise today's cellular networks. The millimeter wave systems are among the most favored solutions [1]. The operating frequency is very high in mm-wave systems due to which the path losses are very significant. A high gain is usually achieved by using the concept of antenna arrays. The Microstrip Patch Antenna Arrays (MPAA) have advanced significantly over the years, which makes them very popular in the field of communication. The evolution of MPAA makes them easier to integrate and fabricate. A high gain can be achieved using MPAA by applying various types of feeding techniques like line feeding [2], corporate feeding techniques, leaky wave technique, etc. Since the gain is proportional to the number of elements in the antenna array, achieving a high gain increases the number of elements in the array, which leads to an increase in the overall dimension of the antenna array system.

The radome structures are known to protect the antenna from the harsh environment. Radomes have a significant impact on the characteristics of large electrical size antennas such as reduced antenna gain, increasing sidelobes, boresight errors, and depolarization are the key characteristics [3]. There are various types and style of radomes which includes A-sandwiched, B-sandwiched, and C-sandwiched [4]. Depending on the application type, the radome configuration is selected. The A-sandwich radome consists of two high-density skin and a lower-density core. B-sandwich radome is the dual of A-sandwich [5].

In this work, a high gain B-sandwiched radome design is discussed. Further analysis of various simulation results like gain, return loss, VSWR, and input impedance are illustrated. In the following section, the design of B-Sandwiched Radome is discussed followed by the simulation results and conclusion in further sections.

2. DESIGN OF B-SANDWICHED RADOME

The design and simulation of the B-sandwiched radome are performed in ANSYS HFSS. The B-sandwich radome shown in Figure 1, consists of a high-density core sandwiched between two low-density matching layers.

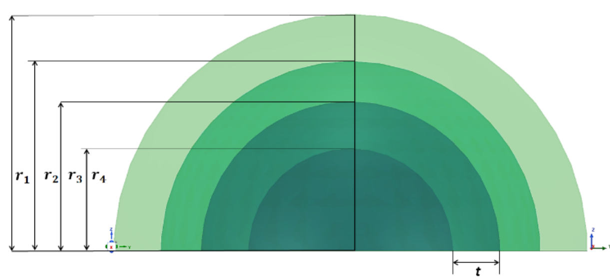

Figure 1 B-sandwiched radome (Front view)

The core is assigned with Acrylonitrile-Butadlene-Styrene (ABS) material which has a dielectric constant of 3 and the two matching layers with polypropylene material which has a dielectric constant of 2.2. The thickness (t) of each layer is calculated using (1).

$$t = \frac{\lambda}{2 \times \sqrt{\epsilon_r}} \quad (1)$$

where, λ is the wavelength and ϵ_r is the relative permittivity.

Using (1), the resultant matching layer thickness is 1.01 cm, and the core thickness is 0.866 cm. The dimension and material composition of the B-Sandwich Radome is tabulated in Table 1.

Table 1: Dimension and material composition of B-Sandwiched Radome

Shell	Dimension (cm)		Material
	Inner Radius	Outer Radius	
Shell 1	2.2	3.21	Polypropylene
Shell 2	3.21	4.07	ABS
Shell 3	4.07	5.08	Polypropylene

For the design of 2x2 MPAA, RTDuroid (5880) substrate is considered with the dimension of 6.8cm x 6.8cm. The considered substrate has a thickness of 0.1575cm, a relative permittivity of 2.2, and a low loss tangent of 0.0009. As per the requirement, the inter-element spacing considered is 0.5λ. Further, the B-Sandwiched radome is integrated with the 2x2 MPAA and the schematic of the structure is shown in Figure 2.

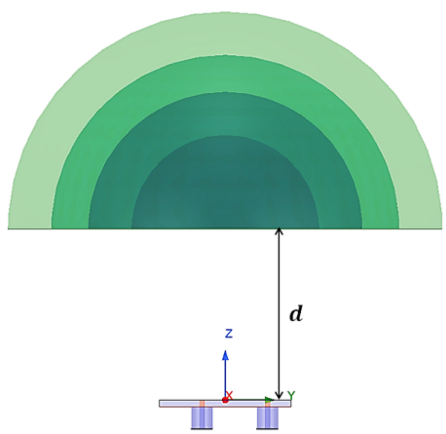

Figure 2 B-sandwiched radome with feed element

The distance between the feed element and the radome (*d*) is identified by the parametric analysis during the simulation. The radome's inner shell is designed to enclose the entire 2x2 MPAA.

3. Simulation Results and Discussions

The designed 2x2 MPAA and the integrated structure are simulated in ANSYS HFSS software which provides fast and accurate results.

3.1 Simulation results of 2x2 MPAA

The gain plot of 2x2 MPAA which is used as the feed element is shown in Figure 3 and it is observed that the peak gain obtained is 11.01 dB with HPBW of 52.08° and 53.41°, in E-plane and H-plane respectively.

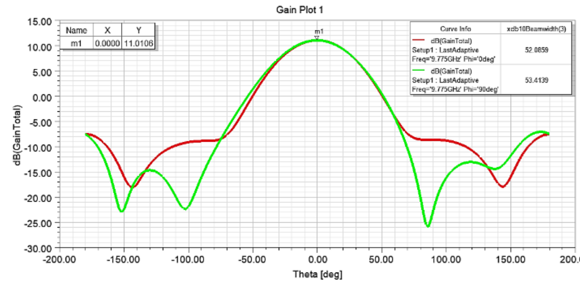

Figure 3 Gain (dB) plot of 2x2 MPAA

The return loss for the 2x2 MPAA is depicted in Figure 4, and the obtained value is -28.51dB.

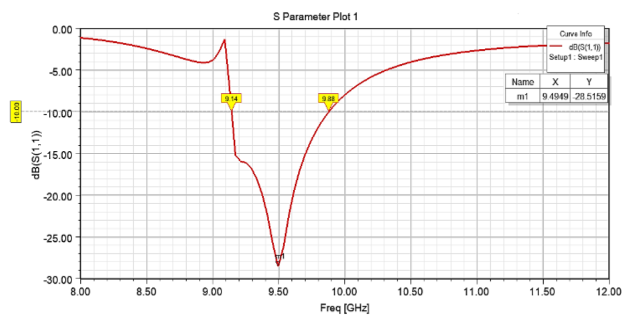

Figure 4 Return Loss of 2x2 MPPA

The 10 dB bandwidth is, 740 MHz. A high negative value indicates fewer reflections and no impedance mismatch.

3.2 Radome integrated with 2x2 MPAA

The gain value obtained after integrating the radome structure with the 2x2 MPAA is 23.13 dB and shows a normalized Peak Side Lobe Level (PSLL) of -12dB which is depicted in Figure 5. It is observed that there is an increment of 12.13 dB in gain in comparison with the gain of the feed element since the radiation is collimated by the radome structure.

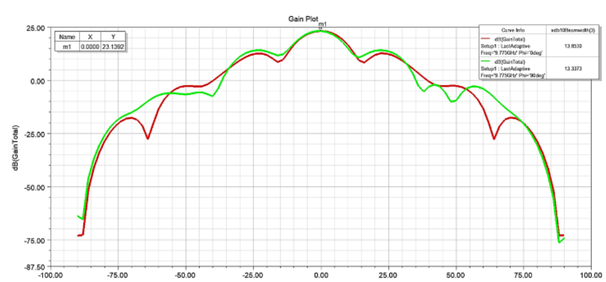

Figure 5 Gain (dB) plot of B-sandwiched radome integrated with 2x2 MPAA

The HPBW obtained is 13.85° and 13.33° in E-plane and H-plane respectively. The return loss which is depicted in Figure 6, is -27.58 dB.

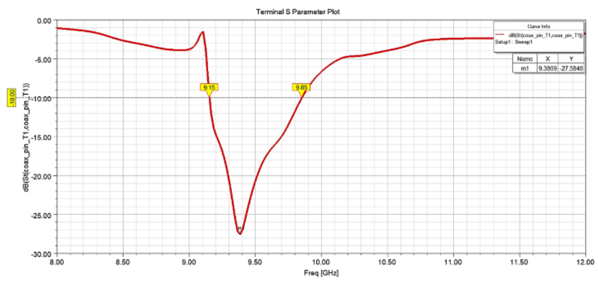

Figure 6 Return Loss (dB) plot of B-sandwiched radome integrated with 2x2 MPAA

In comparison with the 2x2 MPAA, there is a minor increase in return loss which is due to the total internal reflections which occur at each layer of the B-sandwiched radome when the angle of incidence is greater than the critical angle. The voltage standing wave ratio (VSWR) is depicted in Figure 7.

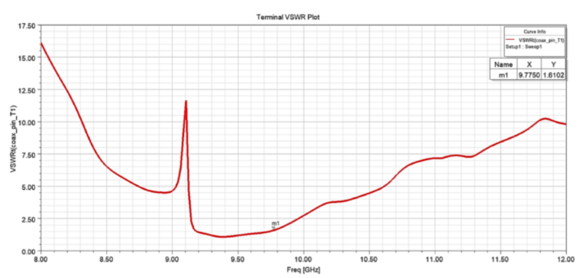

Figure 7 VSWR plot of B-sandwiched radome integrated with 2x2 MPAA

At a frequency of 9.7 GHz, VSWR is observed to be 1.6. A good impedance match is indicated by VSWR readings under 2. The smith chart is plotted in Figure 8 and it represents the normalized impedance value at 9.7GHz.

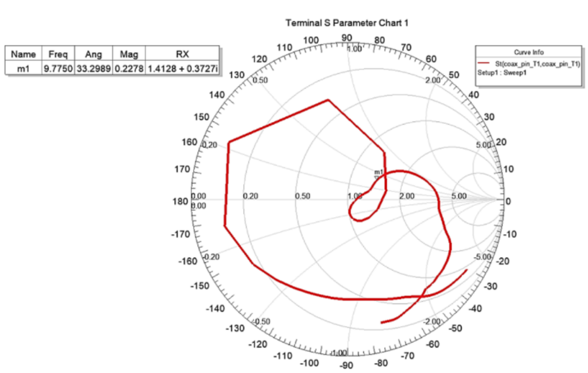

Figure 8 Smith Chart of B-sandwiched radome integrated with 2x2 MPAA

It can be inferred that the source and load impedance are perfectly matched and there is no degradation in antenna parameters.

4. CONCLUSION

A high gain antenna by integrating B-Sandwiched radome with 2x2 MPAA is designed and simulated. The return loss is -27.58 dB, which is slightly higher than the value obtained for the feed element, due to the total internal reflection caused by the dielectric materials used for the radome. The structure shows an increment of 12.13 dB in gain when compared to the feed element, which is suitable for space-borne applications, and satellite communication. Further, the work can be extended to control the PSLL and analysis on scanning performance.

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