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Design of Conformal Log Periodic Dipole Array Antennas Using Different Shapes of Top Loadings

Swetha Velicheti*, Santosh Pavada, P. Mallikarjuna Rao, and M. Satya Anuradha

Abstract—Planar and conformal log periodic dipole array (LPDA) antennas are proposed in this paper with circular patch and hexagonal patch top loadings for multiband applications. Due to these top loadings, the size of the antennas is reduced, and the total dimensions of the two antennas are 44 mm × 40 mm. These antennas are fabricated on polyimide material with a dielectric constant of 3.3 and thickness of 0.1 mm. These two antennas resonate at 3.5 GHz, 5.7 GHz, 7.5 GHz, and 9.3 GHz frequencies in both planar and conformal modes. The antenna characteristics of the proposed antenna models such as reflection coefficient, VSWR, radiation pattern, and gain are analyzed, and the measured results are in good agreement with simulation ones.

1. INTRODUCTION

Recent researches have focused on low profile and conformal configurations because of the demand for wearable devices, 5G technology, internet of things (IOT), wireless sensor networks, and wireless communication devices. Log periodic dipole array antenna is a multi-element, directional antenna. It was initially proposed by DuHamel and Isbell in 1957 [1] and then developed by Carrel in 1961 [2]. Due to their wide bandwidth, high gain, and planar profile, planar log-periodic dipole array (LPDA) antennas [3, 4] have been widely used for a number of communication applications. Those are also designed for dual-band and multiband applications [5, 6]. However, rigid substrates, such as FR4, Arlon, and Rogers are not considered because they are not possible to integrate into curved surfaces. Numerous flexible substrates have been researched as a solution to this [7–9]. However, designing a single antenna with the advantages of multiple operating bands and compactness is a big challenge for researchers working with flexible antennas.

In this paper, two LPDA antennas with different top loadings are designed using CST MW studio suit 2019. They are fabricated on a very thin polyimide substrate having the thickness of 0.1 mm. The designed antenna models are also conformal models, and their radiated fields are satisfied for curvature 45°.

2. ANTENNA DESIGN MODELS

Two antenna models are designed in this paper. The first one is a printed log periodic dipole array (PLPDA) with circular patch top loading, and the second one is a PLPDA with hexagonal patch top loading. These antennas are designed in both planar and conformal forms which are fabricated on a polyimide substrate. Each antenna contains 6 elements, and they are fabricated on both sides of the substrate along with feed line. The total dimensions of the two antennas are 44 mm × 40 mm.

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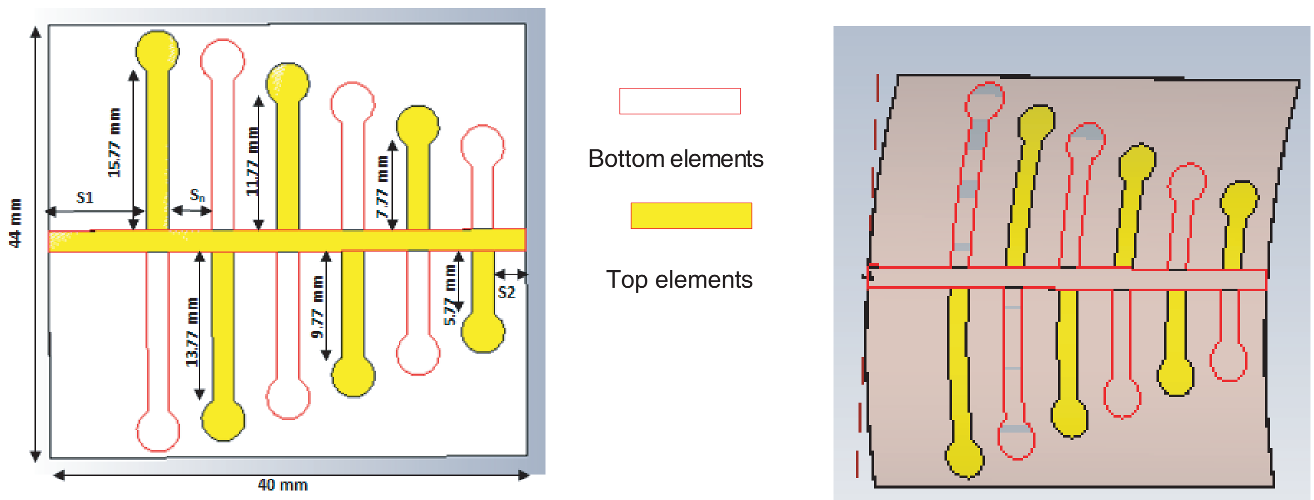
* Corresponding author: Swetha Velicheti (swethaphd7@gmail.com).
The authors are with the Department of ECE, Andhra University College of Engineering, Visakhapatnam, India.

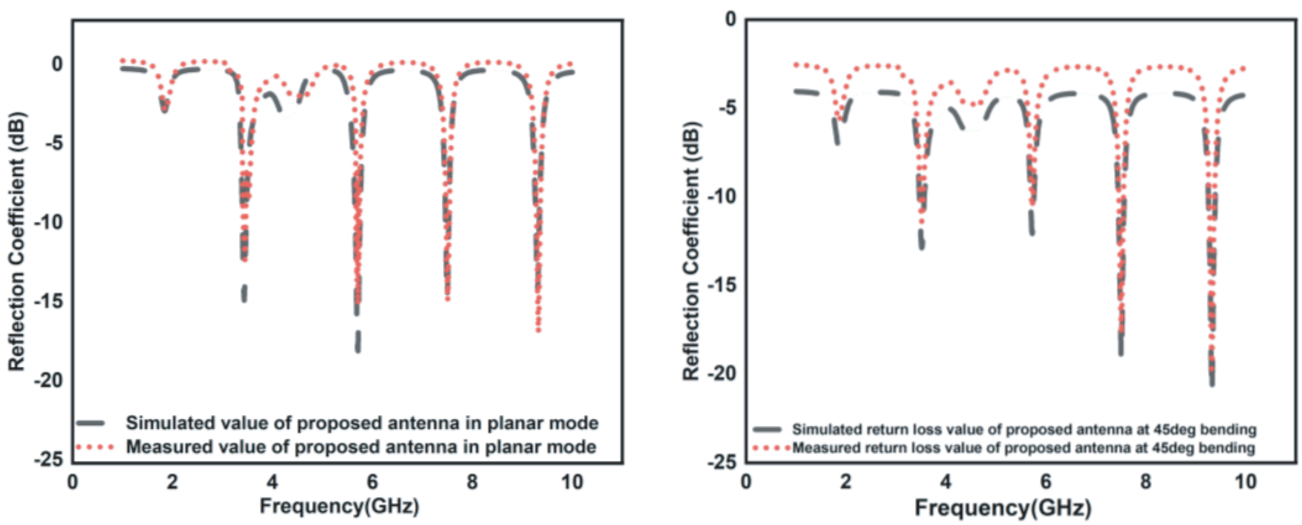
2.1. Antenna I: PLPDA with Circular Patch Top Loading

Figure 1 shows the planar and conformal PLPDA with circular patch at top loading. In this configuration, the top of each dipole element is attached to the circular patch. Basically, the antenna is designed as per the carrel [2] method, but here in addition to that multi-tau technique [10] is employed which means that it uses variable tou (τ) values. Here $\tau_n = 0.87$, 0.85, 0.83, 0.79, and 0.74, where $n = 1, 2, 3, 4, 5$, respectively. Therefore, the lengths of the LPDA antenna elements are calculated by $L_n + 1 = L_n x \tau_n$, and the lengths of the antenna are represented in Figure 1. This antenna uses uniform width and spacing between the elements, and the values are width $W = 2$ mm and spacing $S_n = 4$ mm. In addition to that $S1 = 9$ mm, $S2 = 3$ mm, and radius of the circular patch is 2 mm for all the elements.



(a) (b)

Figure 1. Schematic view of planar and conformal LPDA with circular patch top loading. (a) Planar model. (b) Conformal model.

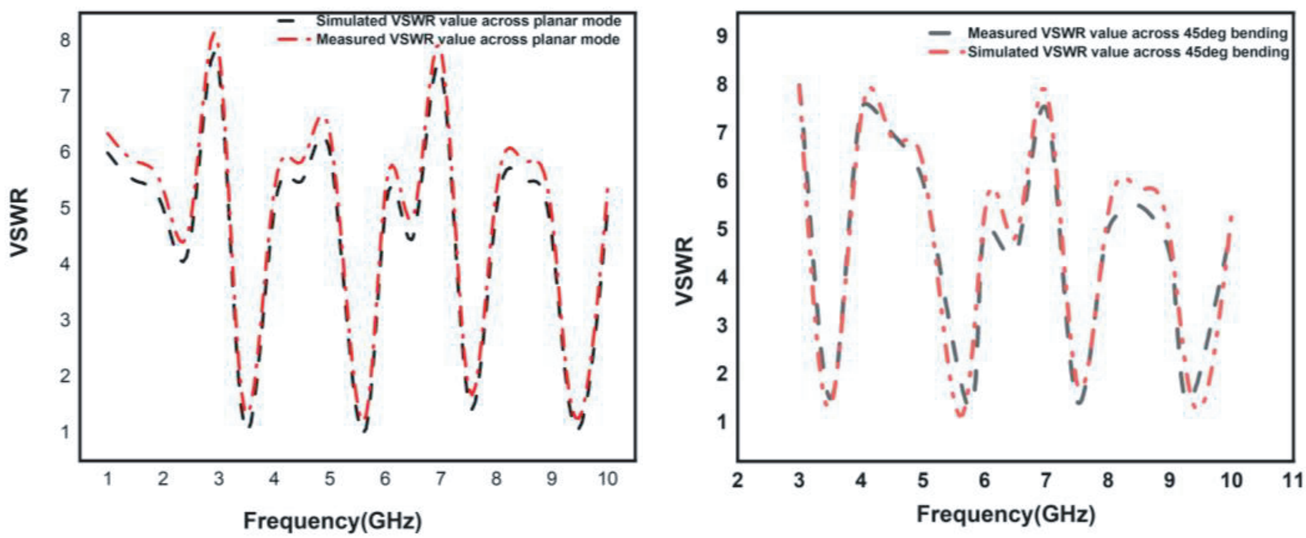


(a) (b)

Figure 2. Measured and simulated reflection coefficient for planar and conformal models. (a) Planar model. (b) Conformal model.

2.1.1. Results & Discussions of Antenna I

The proposed antenna model reflection coefficient and voltage standing wave ratio (VSWR) plots, in both planar and conformal forms, are shown in Figures 2 and 3, respectively. The findings show that both planar and conformal models resonate at frequencies of 3.5 GHz, 5.7 GHz, 7.5 GHz, and 9.3 GHz.



(a) (b)

Figure 3. Measured and simulated VSWR for planar and conformal models. (a) Planar model. (b) Conformal model.

Figures 4, 5, 6, & 7 show measured and simulated normalized E & H plane patterns for planar mode at 3.5 GHz, 5.7 GHz, 7.5 GHz, and 9.3 GHz, respectively.

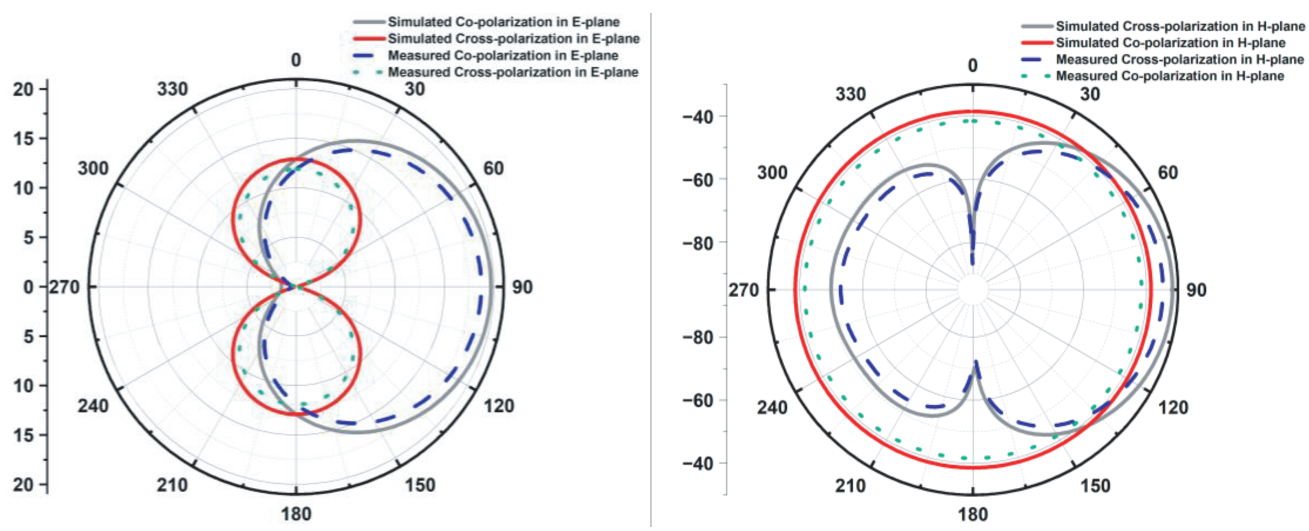


Figure 4. Planar model E & H plane patterns at 3.5 GHz.

Figure 8 represents the measured and simulated gain values of proposed planar and conformal antenna models, from which it is shown that planar antenna produces 8.1 dBi, 7.8 dBi, 8.1 dBi, and 9.1 dBi gain values whereas its conformal model produces gain values 8.5 dBi, 8.3 dBi, 8.1 dBi, and

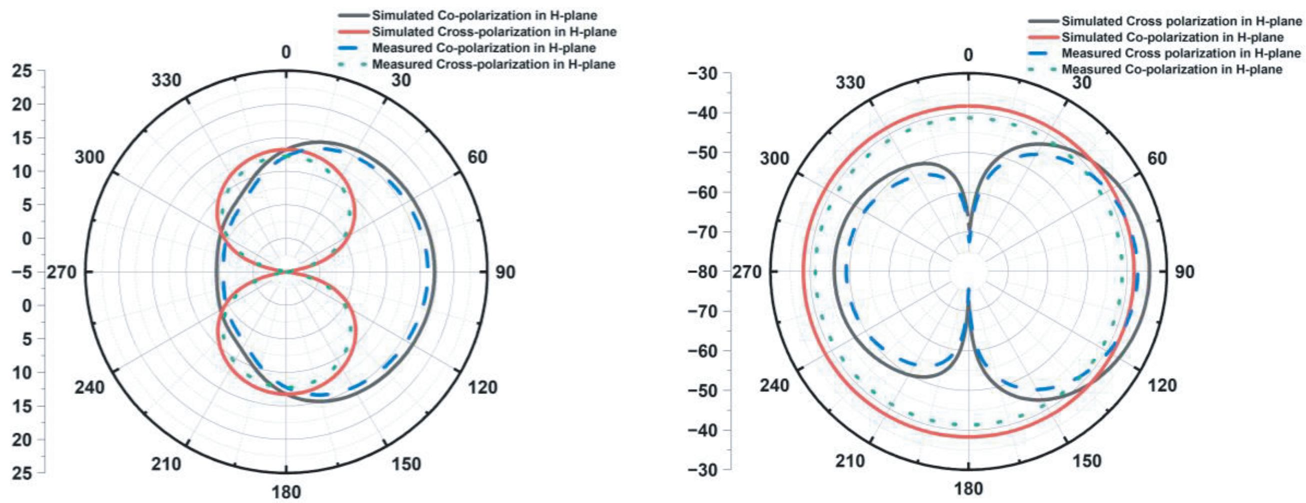


Figure 5. Planar model E & H plane patterns at 5.7 GH.

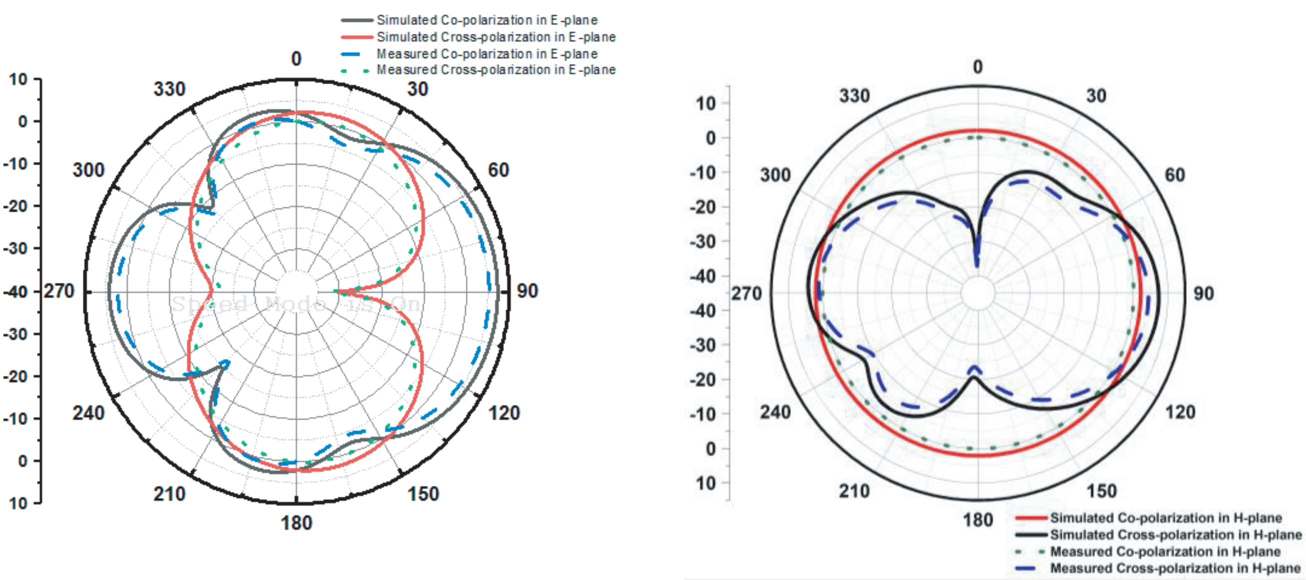


Figure 6. Planar model E & H plane patterns at 7.5 GHz.

10.7 dBi at 3.5 GHz, 5.7 GHz, 7.5 GHz, and 9.3 GHz resonant frequencies, respectively.

The front view and back view of a fabricated LPDA with a circular patch top loading are shown in Figure 9. It consists of two parallel microstrip lines fed at the edge with the inner conductor of the SMA connector connected at upper conducting microstrip, while the outer conductor connected at the lower conducting microstrip as ground. Figure 10 shows its measurement setup in an anechoic chamber with combinational analyzer.

2.2. Antenna II: PLPDA with Hexagonal Patch Top Loading

Figure 11 shows the PLPDA with hexagonal patch at top loading in planar and conformal configurations. In this configuration, the top of each dipole element is attached to the hexagonal patch. The variable tou (τ) values used to design this antenna are $\tau_n = 0.88$, 0.85, 0.83, 0.79, and 0.73, where $n = 1$, 2, 3, 4, 5, respectively, and the corresponding lengths of the antenna are represented in Figure 9. This antenna also uses uniform width and spacing between the elements, and the values are width $W = 2$ mm and

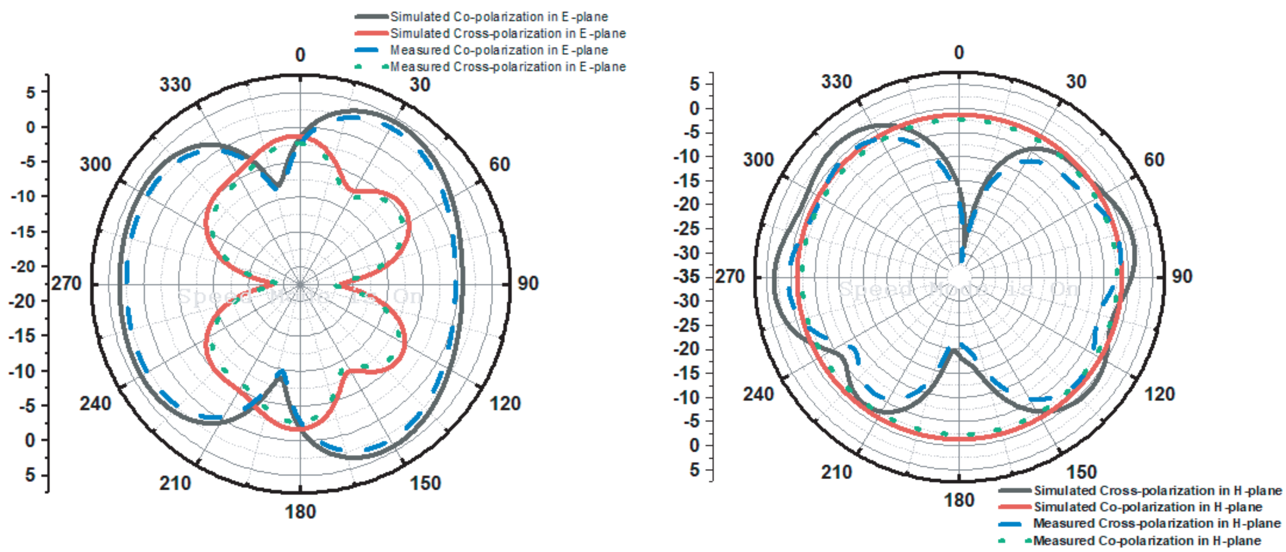
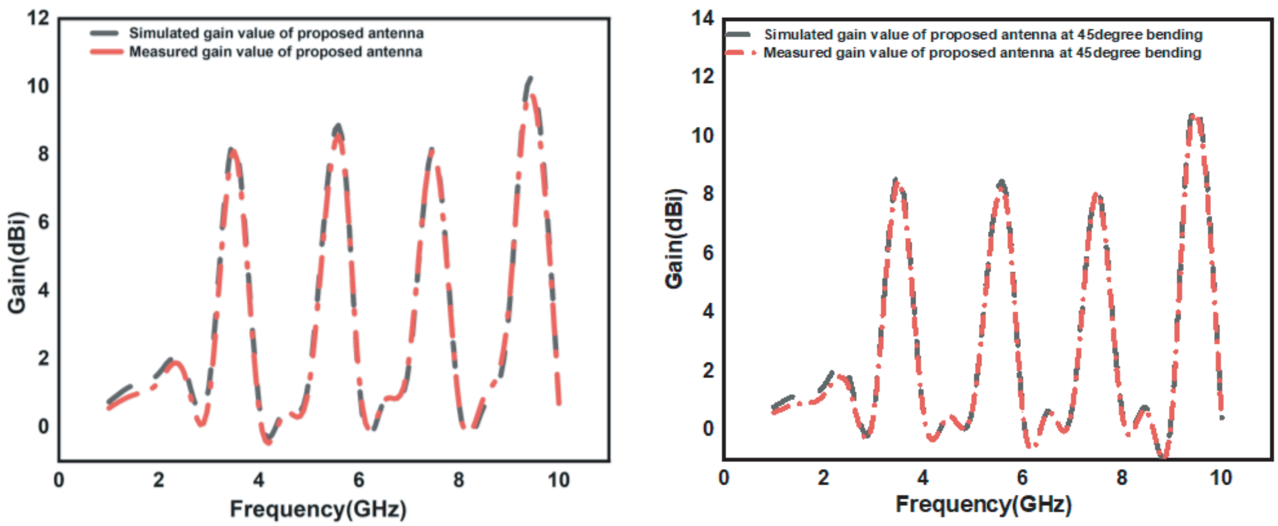
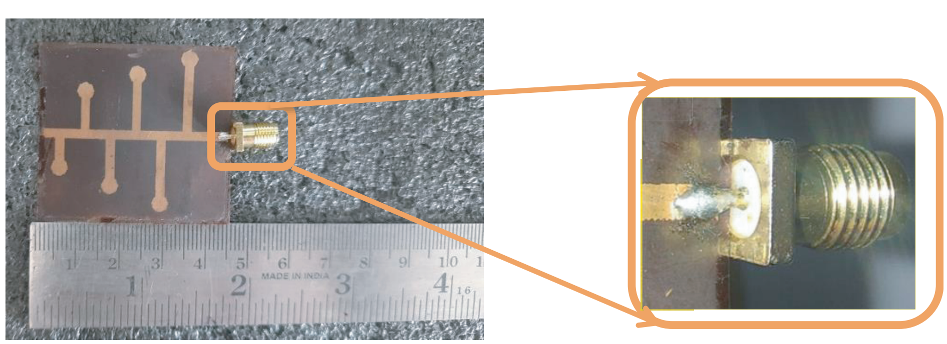


Figure 7. Planar model E & H plane patterns at 9.3 GHz.

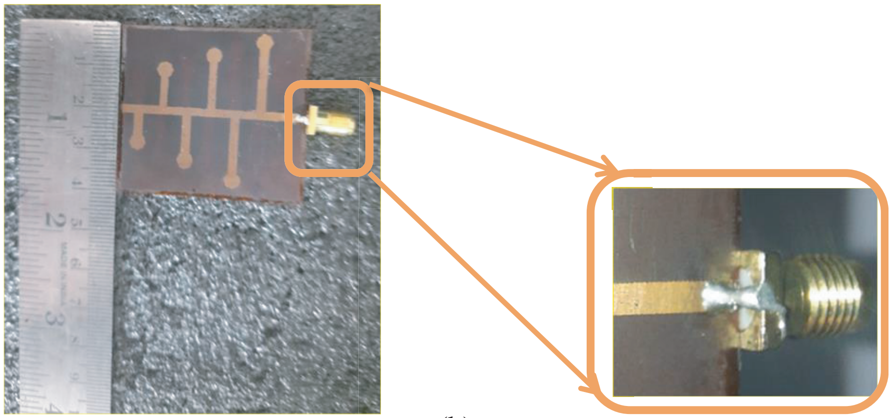


(a) (b)

Figure 8. Measured and simulated gain for planar and conformal models. (a) Planar model. (b) Conformal model.



(a)



(b)

Figure 9. Fabricated model of LPDA with a circular patch top loading. (a) Front view. (b) Back view.

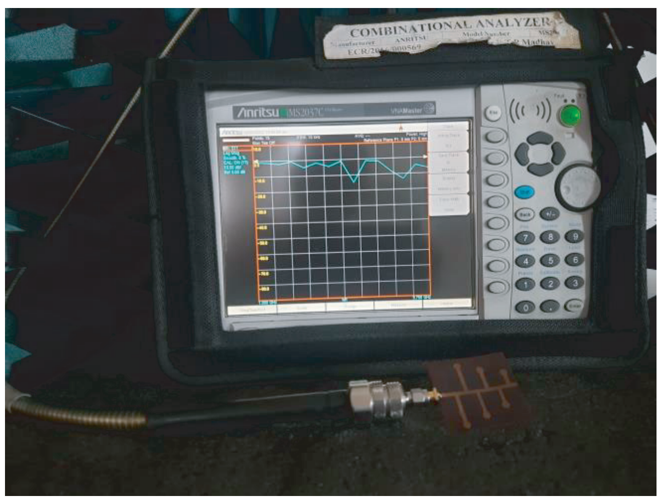
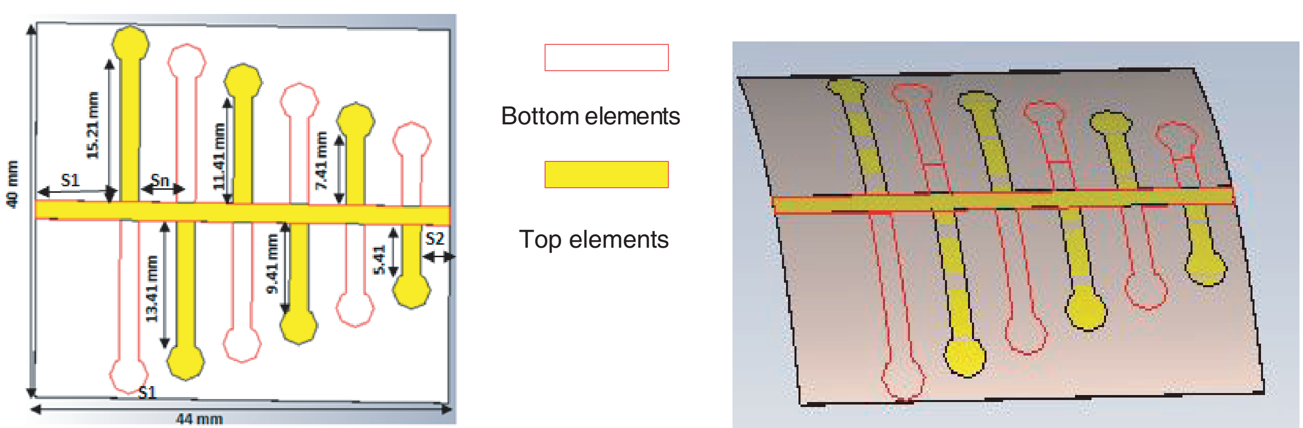


Figure 10. Measurement set up in anechoic chamber with proposed antenna model 1.



(a) (b)

Figure 11. Schematic view of planar and conformal LPDA with hexagonal patch top loading. (a) Planar model. (b) Conformal model.

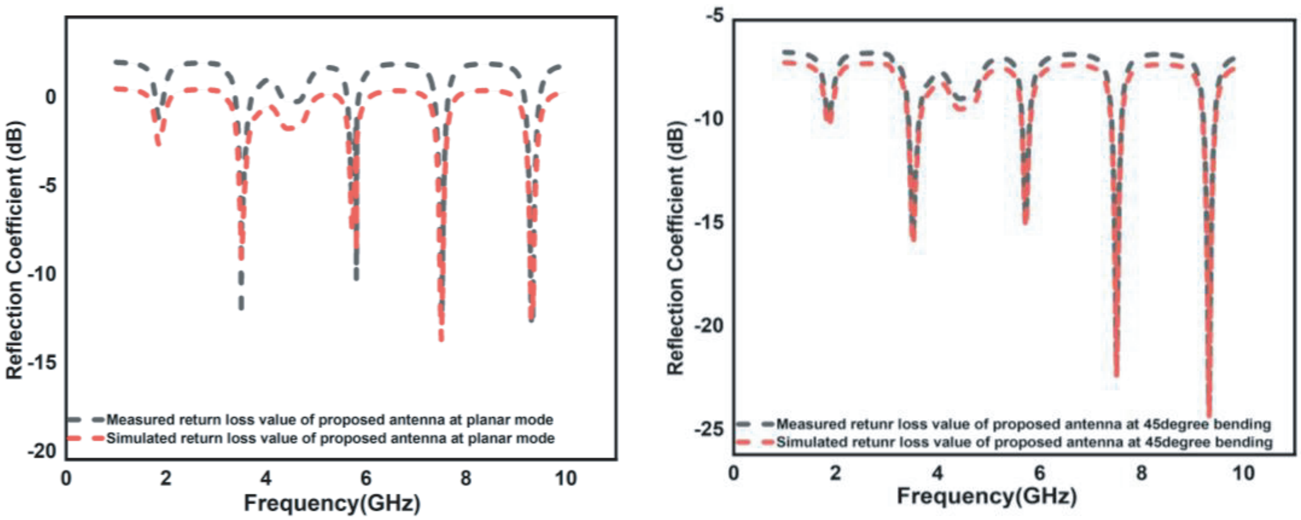
spacing $S = 4$ mm. In addition to that $S1 = 9$ mm, $S2 = 3$ mm, and each side of the hexagonal patch is 1.53 mm for all the elements.

2.2.1. Results & Discussions of Antenna II

The proposed antenna model reflection coefficient and VSWR plots, in both planar and conformal forms, are shown in Figures 12 and 13, respectively. The findings show that a planar and conformal model both resonate at frequencies of 3.5 GHz, 5.7 GHz, 7.5 GHz, and 9.3 GHz.

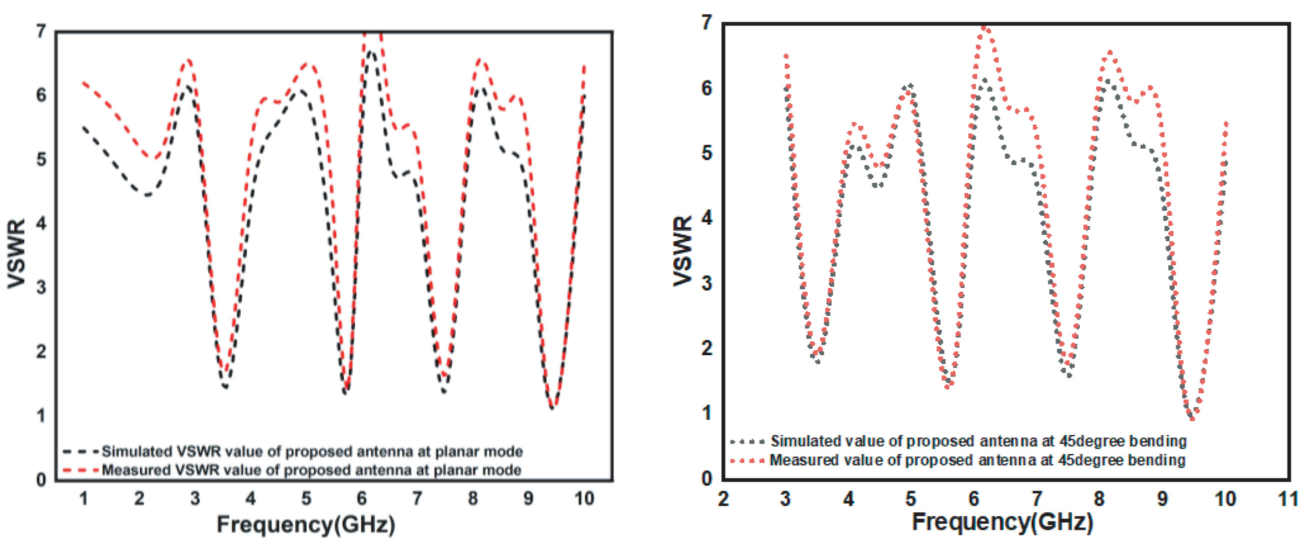
Figures 14, 15, 16, & 17 show simulated and measured normalized E & H plane patterns for planar mode at 3.5 GHz, 5.7 GHz, 7.5 GHz, and 9.3 GHz, respectively.

The simulated and measured gain values of proposed planar and conformal models are shown in



(a) (b)

Figure 12. Measured and simulated reflection coefficient for planar and conformal models. (a) Planar model. (b) Conformal model.



(a) (b)

Figure 13. Measured and simulated VSWR for planar and conformal models. (a) Planar model. (b) Conformal model.

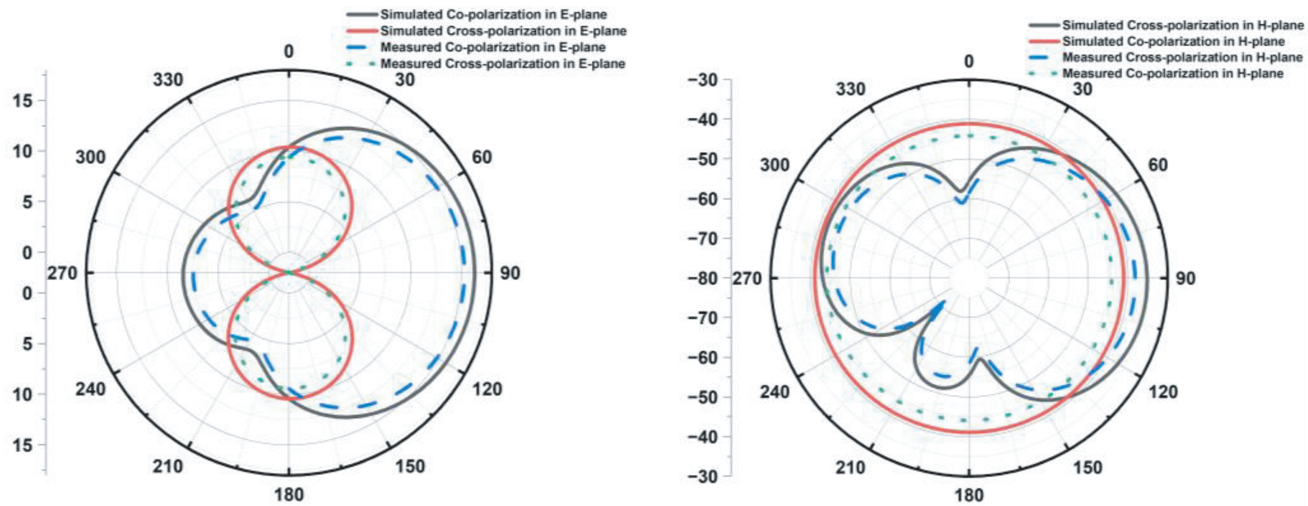


Figure 14. Planar model E & H plane patterns at 3.5 GHz.

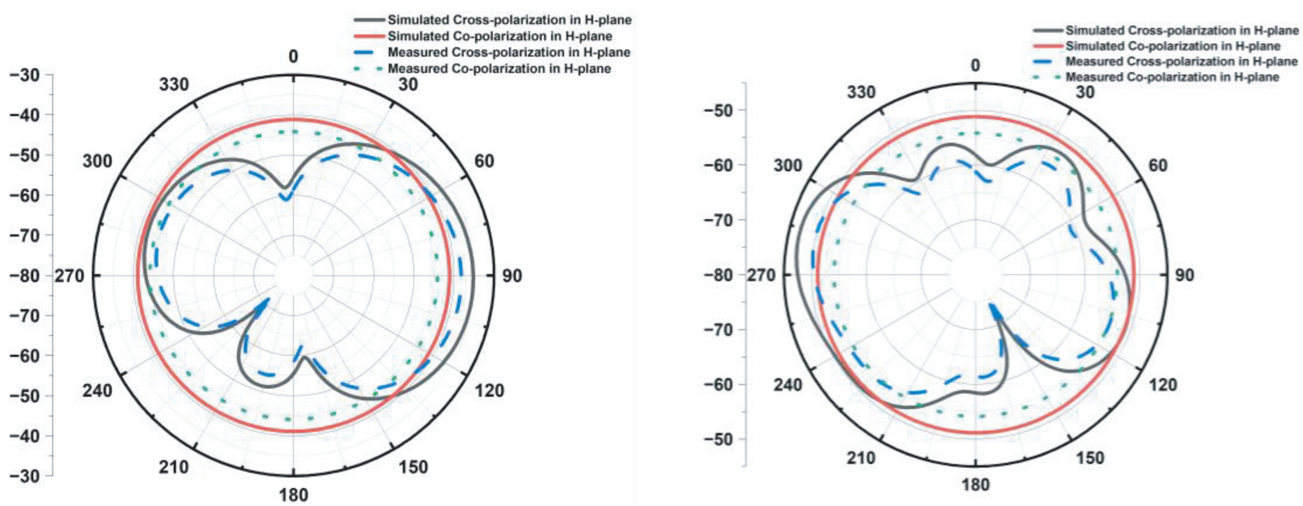


Figure 15. Planar model E & H plane patterns at 5.7 GHz.

Table 1. Simulated and measured outcomes of all the designed antenna models.

Antenna Model		Operating Frequencies (GHz)	Reflection Coefficient (dB)		Gain (dBi)	
			Measured	Simulated	Measured	Simulated
LPDA with circular patch top loading	Planar	3.5, 5.7, 7.5, 9.3	−12.2, −15.1, −14.7, −16.6	−14.68, −17.86, −14.6, −13.89	8.1, 7.8, 8.1, 9.1	8.4, 8, 8.2, 9.36
	conformal	3.5, 5.7, 7.5, 9.3	−11.32, −10.3, −17.7, −19.7	−12.88, −12.07, −18.6, −20.7	8.5, 8.3, 8.1, 10.7	8.6, 8.6, 8.2, 11.1
LPDA with hexagonal patch top loading	Planar	3.5, 5.7, 7.5, 9.3	−11.12, −10.8, −15.72, −14.7	−14.37, −12.3, −14.22, −13.2	8.4, 8.2, 9.1, 9.65	8.6, 8.4, 9.2, 9.95
	conformal	3.5, 5.7, 7.5, 9.3	−15.13, −14.27, −21.6, −23.71	−15.82, −14.81, −22.22, −24.21	9, 9.4, 8.9, 9.7	9.1, 9.6, 9, 9.7

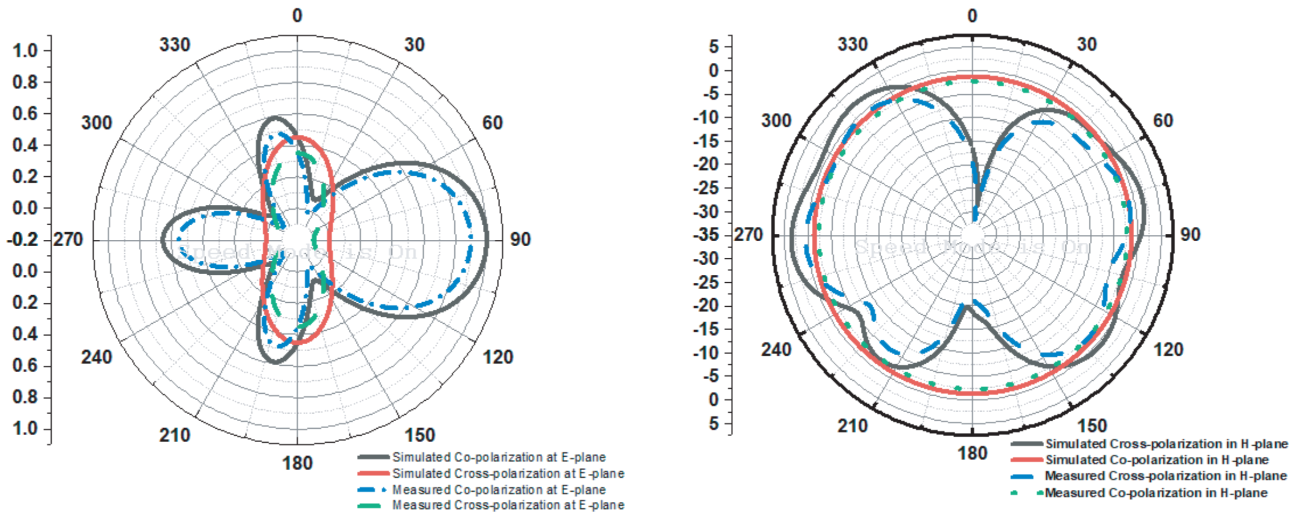


Figure 16. Planar model E & H plane patterns at 7.5 GHz.

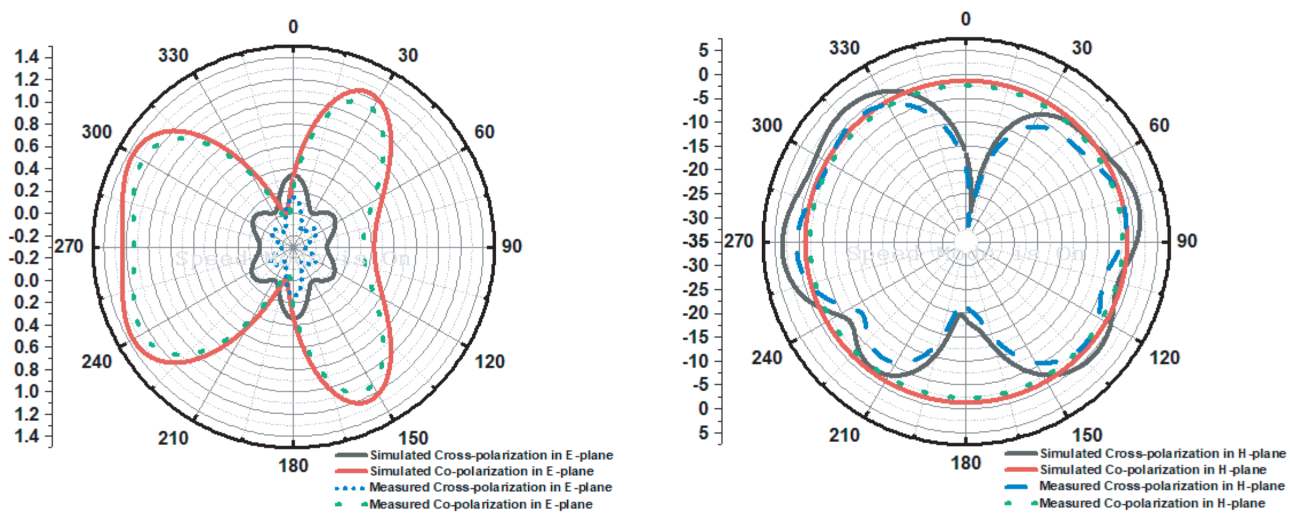
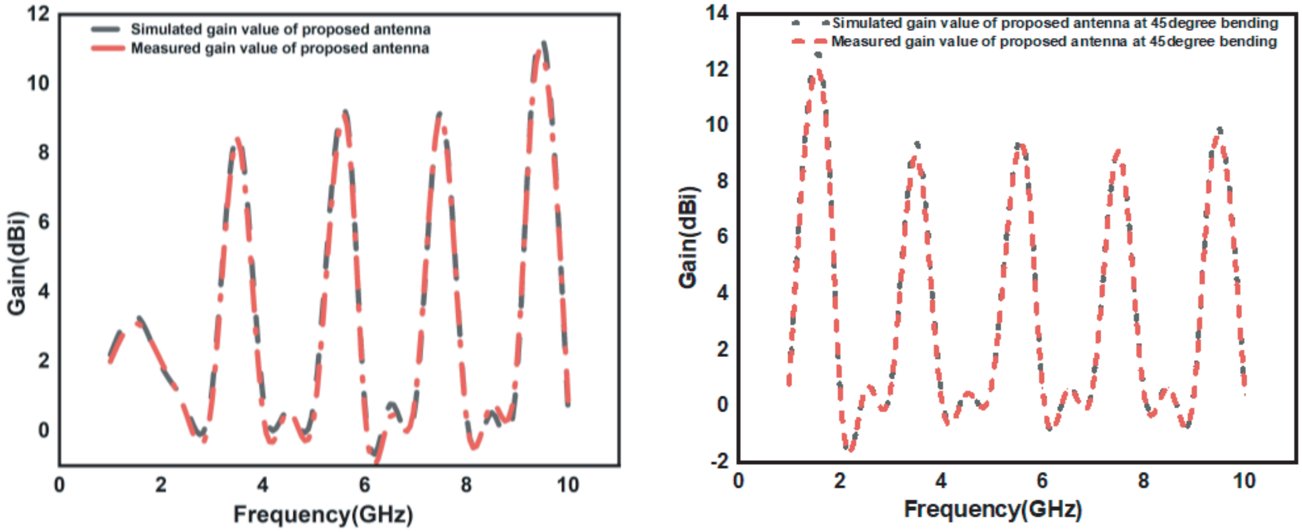


Figure 17. Planar model E & H plane patterns at 9.3 GHz.

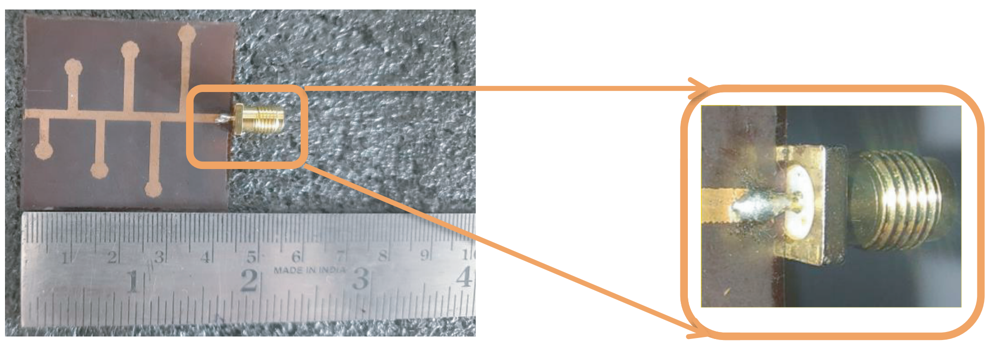
Table 2. Comparison of proposed antenna models with existing reference antenna array models.

Antenna Model	**Substrate**	**Flexibility**	**Size (mm)**	**Operating Frequencies (GHz)**	**Gain**
[5]	PET	Non flexible	111.98×55	2.4–2.484, 5.2–5.8	6–7 (dB)
[6]	FR4	Non flexible	82×48	2.54, 2.9, 3.7, 4.28, 4.98, 5.52, 6.42, 7.48, 8.12, 8.82, 9.4	0.05–4.1 (dB)
[9]	Kapton	Flexible	90×52	2.75–3.53, 4–6.2	8 (dBi)
LPDA with circular patch top loading	Polyimide	Flexible	44×40	3.5, 5.7, 7.5, 9.3	8.5, 8.3, 8.1, 10.7 (dBi)
LPDA with hexagonal patch top loading	Polyimide	Flexible	44×40	3.5, 5.7, 7.5, 9.3	9, 9.4, 8.9, 9.7 (dBi)

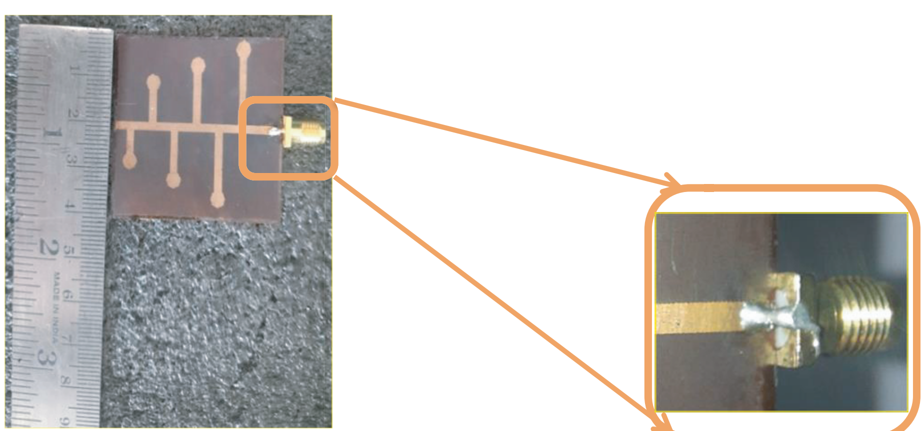


(a) (b)

Figure 18. Measured and simulated gain for planar and conformal models. (a) Planar model. (b) Conformal model.



(a)



(b)

Figure 19. Fabricated model. (a) Front view. (b) Back view.

Figure 18, from which it is shown that planar antenna produces 8.4 dBi, 8.2 dBi, 9.1 dBi ,and 9.65 dBi gain values, whereas its conformal model produces gain values of 9 dBi, 9.4 dBi, 8.9 dBi, and 9.7 dBi at 3.5 GHz, 5.7 GHz, 7.5 GHz, and 9.3 GHz frequencies, respectively.

Figure 19 shows the fabricated model of the PLPDA with hexagonal patch top loading. It consists of two parallel microstrip lines fed at the edge with the inner conductor of the SMA connector connected at upper conducting microstrip, while the outer conductor connected at the lower conducting microstrip as ground. Figure 20 shows its measurement setup in an anechoic chamber with combinational analyzer.

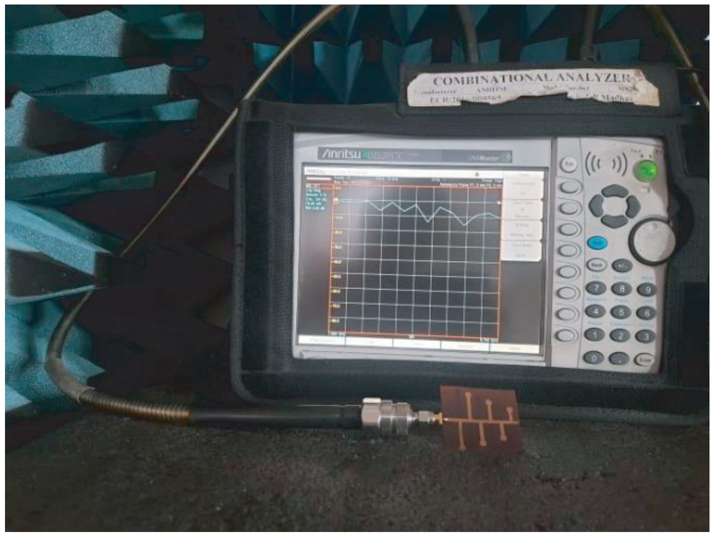


Figure 20. Measurement set up in anechoic chamber with proposed antenna model.

2.3. Comparative Analysis

Table 1 shows the operating frequencies, reflection coefficient, and gain values of the designed antenna models. Table 2 compares the proposed models with the existing antenna models in terms of substrate material, size, operating frequencies, flexibility, and gain.

3. CONCLUSIONS

In this work, planar and conformal log periodic structured antennas with different shapes of top loadings, such as circular patch and hexagonal patch for multi-band applications are designed and fabricated on a polyimide substrate. Both planar and conformal models of two antennas resonate at 3.5 GHz, 5.7 GHz, 7.5 GHz, and 9.3 GHz frequencies with better gain values ranging from 8 to 11 dBi. Compared to antenna 1, antenna 2 produces more gain over all resonated frequencies. The proposed models have a reflection coefficient of below -10 dB over the specified resonant frequencies and maintain VSWR ≤ 2. Therefore, these proposed antennas can be used in WLAN, WiMAX, Wi-Fi, ISM, fixed satellite, and radio navigation and location applications. Also from the results, it is concluded that the measured and simulated results are in good agreement.

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