Design & Analysis of Compact Printed Monopole Antenna with Defected Ground Plane for Wideband Applications

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Abstract: In this paper, design and analysis of a compact printed monopole antenna with defected ground plane for wideband applications has been done. The proposed antenna has been designed on a FR4-epoxy substrate with dielectric constant 4.4 and height is 1.6mm. In this proposed antenna design, the complimentary split ring resonators (CSRRs) are etched from both patch as well as ground plane so as to work for wideband applications. The antenna has been fabricated with optimized dimensions and then tested. The proposed antenna is fed by microstrip line feed and has been designed and simulated by High Frequency Structure Simulator (HFSS version 13.0). The proposed antenna operates on S-band (2-4 GHz), C-band (4-8 GHz), X-band (8-12 GHz) and KU-band (12-18 GHz) applications. In the simulated results, the antenna design operates at four frequencies 2.7 GHz, 4.4 GHz, 6.6 GHz and 10.8 GHz with return losses of -18.39 dB, -13.79 dB, -17.10 dB and -22.82 dB. The gains at these four frequencies are 12.5 dB, 5.14 dB, 4.74 dB and 1.83 dB. In the measured results, the antenna design operates at four frequencies 2.6 GHz, 4.97 GHz, 6.13 GHz and 10.97 GHz with return losses of -18.10 dB, -25.80 dB, -23.10 dB and -17.30 dB.

Keywords: VSWR (Voltage standing wave ratio), VNA(Vector Network Analyzer), HFSS(High frequency Simulator Structure), CSRRs(complimentary split ring resonators), Compact Printed Monopole Antenna with Defected Ground Plane(CPMADGP).

Introduction

The wireless communication technology is developing very quickly, and this fact increases the popularity of compact printed antennas with high gain, less return loss and wide bandwidth [6]. Antenna can be defined as a transducer used for radiating and receiving electromagnetic waves. The substrate, patch and ground planes are the three basic layer of Microstrip Patch Antenna (MPA). Number of techniques made multi-band antenna. Slot technique is used to increase the number of operating frequency band. The concept of multi-band communication, multifunction application, and miniaturization has been proposed many years ago. The advantage of multi-band system is that, when there is interference in one band system, the other can still work normally. Another typical advantage is that it can form complementary function. Multi-band slot patch antenna is useful when one has to simultaneously deal with uplink and downlink data in satellite communication [1]. The defected ground plane structure is perceived by etched periodic and non-periodic structure defect in the ground plane [2] [3]. The main two limitations of wideband printed antenna are mutual coupling and the larger size of antenna. These two major limitations can be overcome by using the complementary split ring resonator. The Split Ring Resonators (SSR) mainly expressed by two metallic rings, either square or circular, carved or etched on substrates which made from a dielectric material and they have gaps on conflicting sides.

Antenna Design and Configuration

The geometry of the proposed compact printed monopole antenna with defected ground plane is displayed in Fig. 1. The substrate material choose for fabrication of proposed antenna is FR4-epoxy whose loss tangent 0.02, dielectric constant 4.4 and thickness is 1.6 mm. The patch is fed by microstrip line feed which have length of 13mm and width of 3 mm. The length and width of patch plane are 20.8 mm and 24 mm. The proposed antenna is simulated using HFSS software (version 13.0). The proposed shape of patch plane is made by introducing two bevels at lower side and at corner of patch, then three equal dimension notches of width 0.5 mm and length of 12.8 mm are etched from the patch along the length of the patch. Then three concentric CSRRs are etched from patch plane as shown in Figure 1.

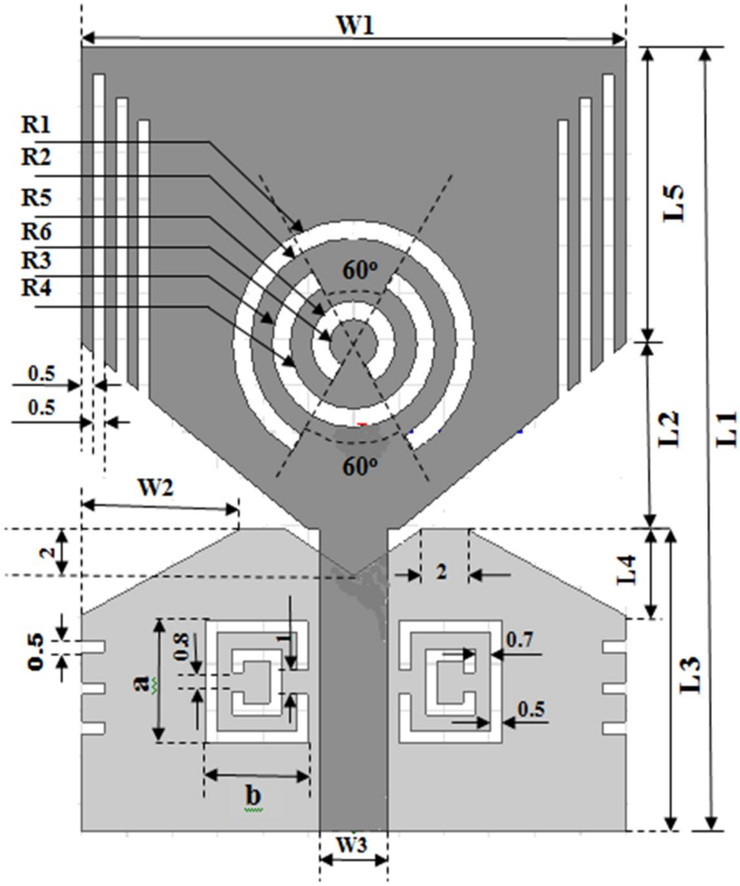
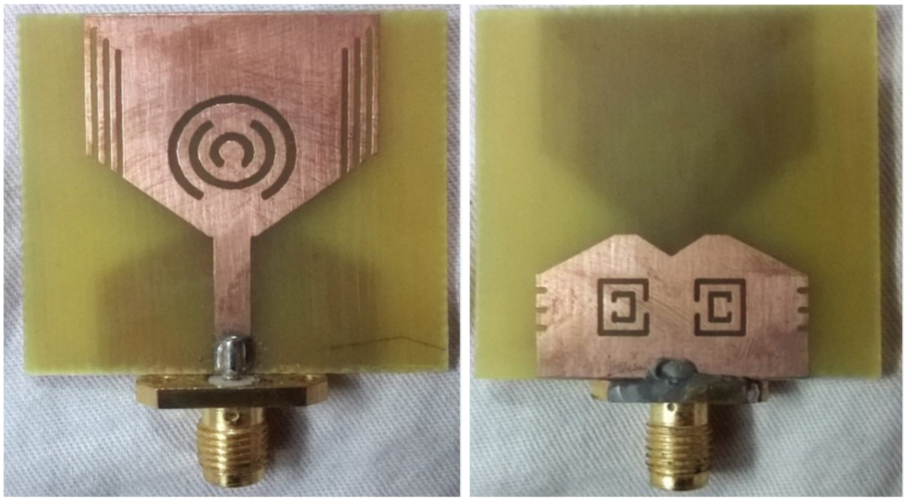


Figure 1: Geometry of the proposed CPMADGP with dimensions details, all dimensions are in mm (units)

The detail dimensions of proposed antenna shown in Table 1. The process of simulation ends, then the practical implementation achieved. The optimized parameters of designed antenna configurations are used for fabrication process. The fabricated projected antenna is shown in Figure 2.

Table 1. Dimensions of proposed CPMADGP

Parameters	Dimensions (mm)
L1	33.8
L2	8
L3	13
L4	3.7
L5	12.8
W1	24
W2	7
W3	3
R1	5.35
R2	4.55
R3	3.6
R4	2.8
R5	1.85
R6	1.05
a	5.24
b	4.55



(a) Top View (b) Bottom View

Figure 2: Fabricated geometry of proposed antenna

Results and Discussions

Simulated Results of Proposed CPMADGP

Return Loss

The return loss shows that how well the devices are matched. So, if the return loss is calculated low in value that means devices is matched well. Simulated results of return loss of proposed antenna represent in Figure 3.

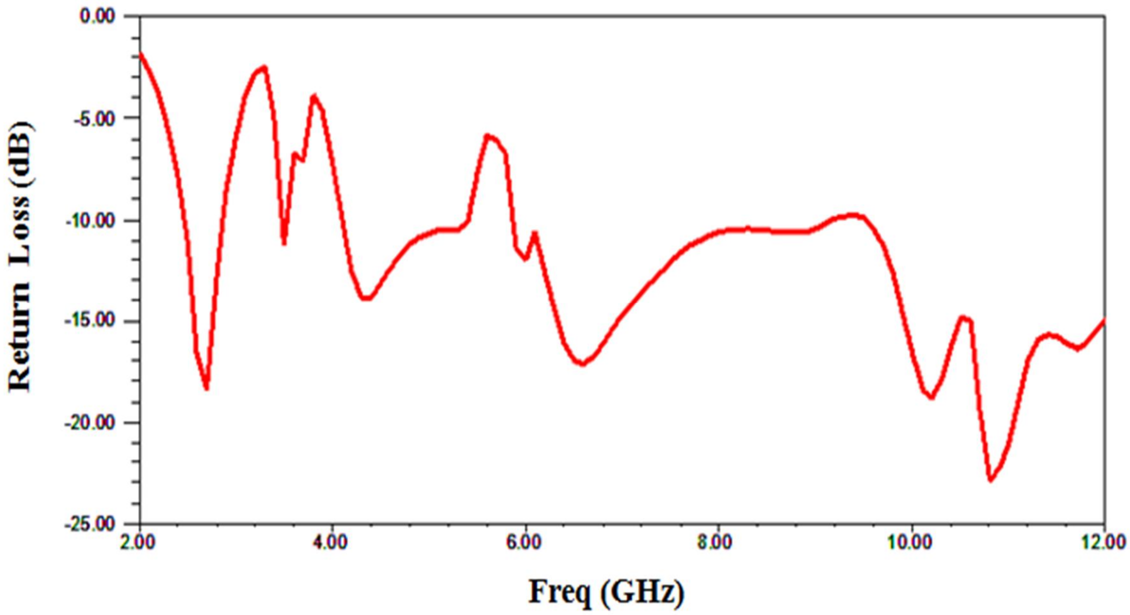


Figure 3: Simulated return loss against frequency plot of proposed CPMADGP

VSWR

VSWR is the abbreviation of Voltage Standing Wave Ratio. If the value of VSWR is high that shows increase in the mismatch between transmission line and the device (antenna).The simulated results of VSWR are shown below in Figure 4.

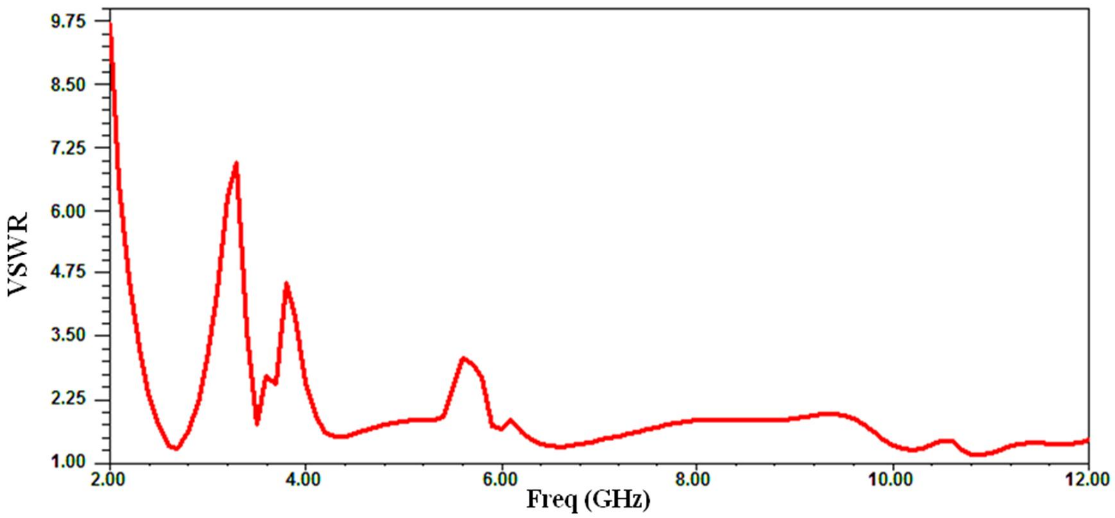


Figure 4: Simulated VSWR against frequency plot of proposed CPMADGP

Gain

It is an essential parameter. It is measured in dB (unit). The 100% efficient antenna has a gain which is equal to its directivity. The gain of the proposed antenna is shown below in the Figure 5.

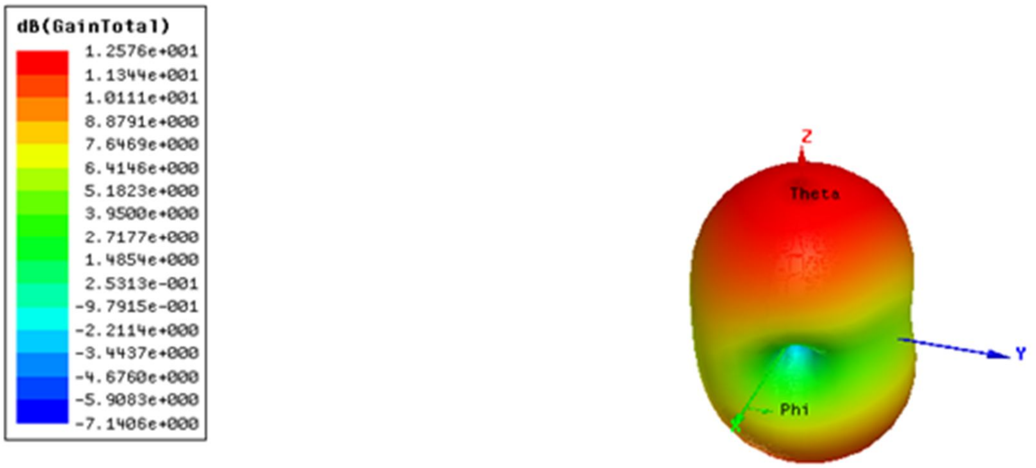


Figure 5: (a) 3D plot of gain at 2.7 GHz

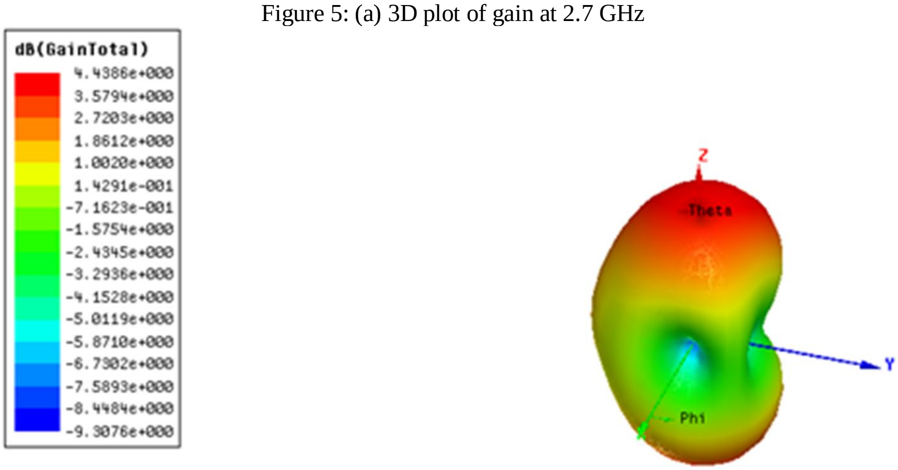


Figure 5: (b) 3D plot of gain at 3.5 GHz

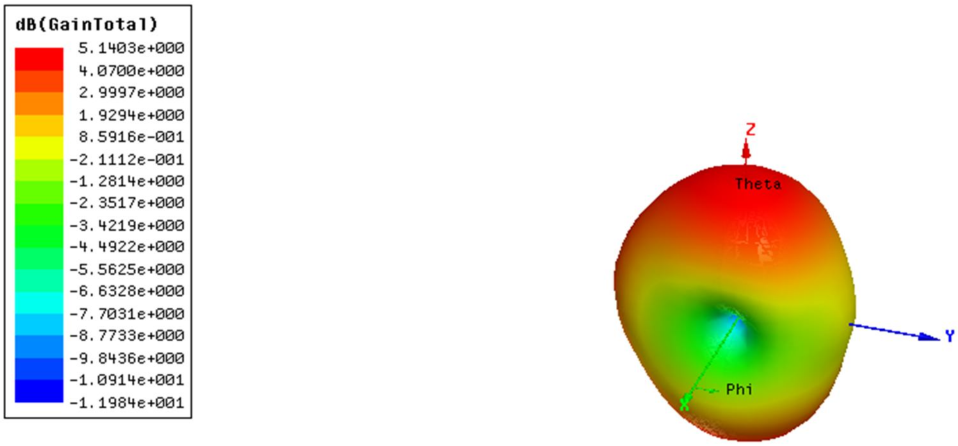


Figure 5: (c) 3D plot of gain at 4.4 GHz

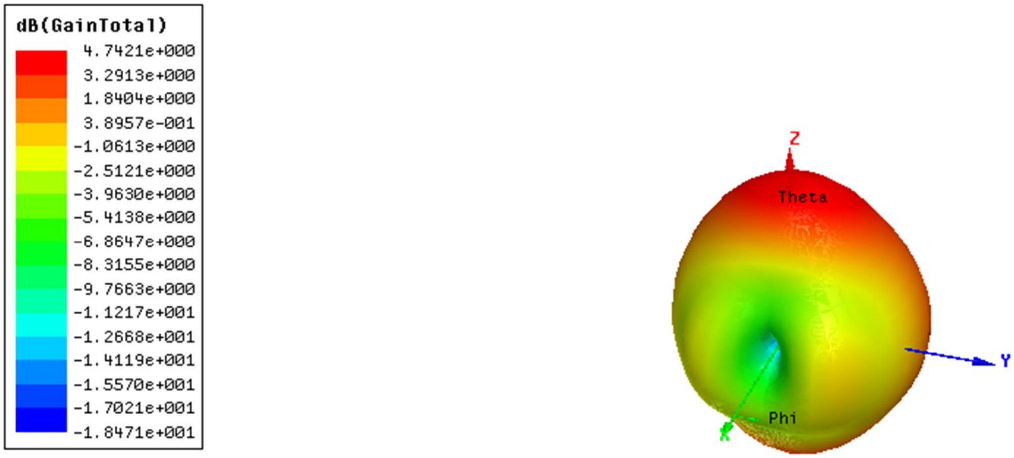


Figure 5: (d) 3D plot of gain at 6.6 GHz

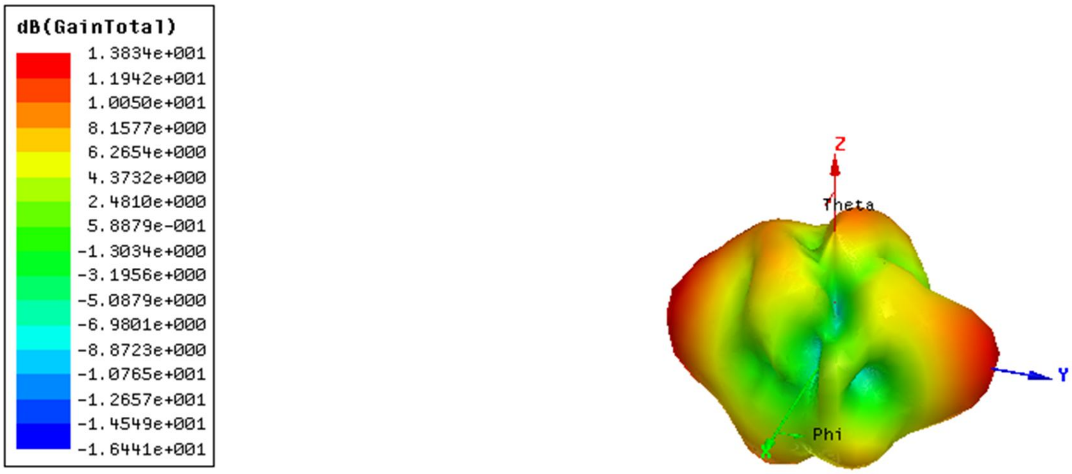


Figure 5: (e) 3D plot of gain at 10.8 GHz

Table 2. Simulated results of proposed CPMADGP

Resonant Frequency (GHz)	Return Losses (dB)	VSWR	Gain (dB)
2.7	-18.39	1.27	12.57
3.5	-11.24	1.75	4.43
4.4	-13.79	1.51	5.14
6.6	-17.10	1.32	4.74
10.8	-22.82	1.15	13.83

Radiation Pattern

The power radiated or received by an antenna is a function of the radial space and angular location from the patch antenna. The radiation pattern of proposed antenna shown below in Figure 6.

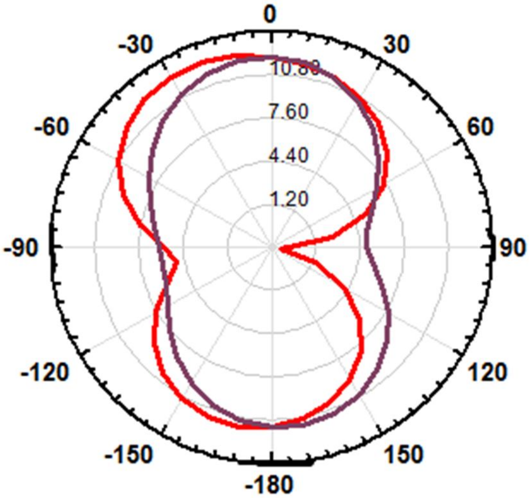


Figure 6: (a) Simulated 2D radiation pattern at 2.7 GHz

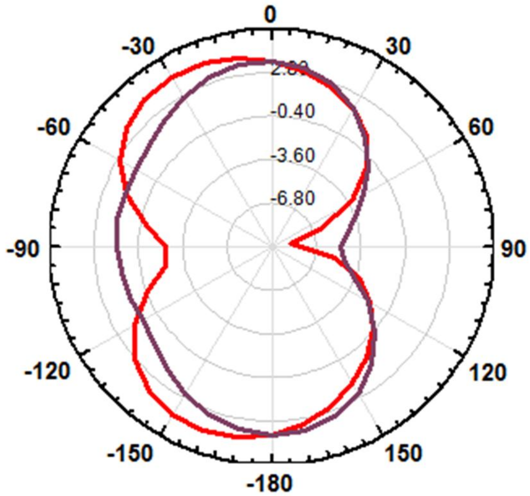


Figure 6: (b) Simulated 2D radiation pattern at 3.5 GHz

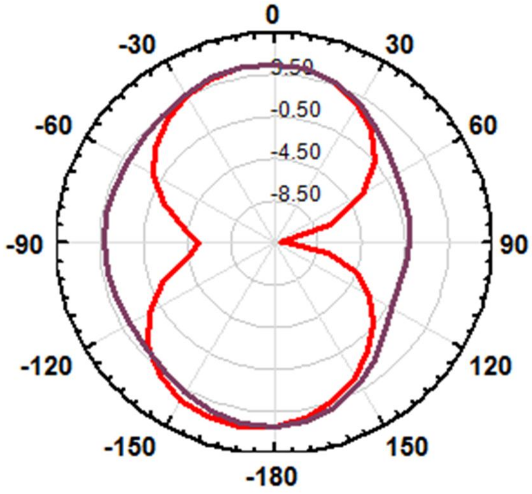


Figure 6: (c) Simulated 2D radiation pattern at 4.4 GHz

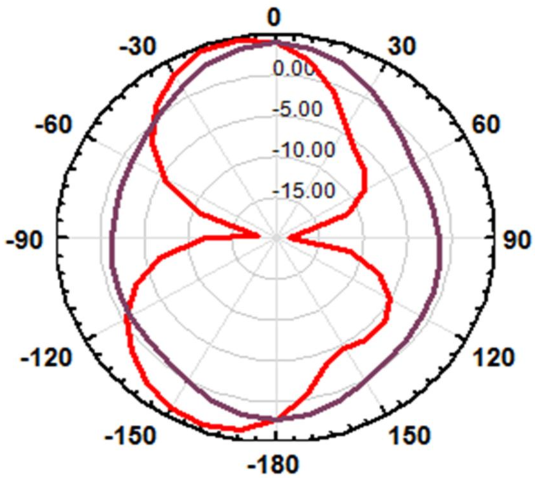


Figure 6: (d) Simulated 2D radiation pattern at 6.6 GHz

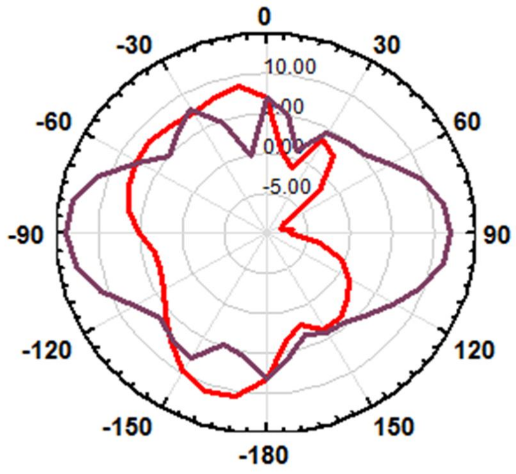
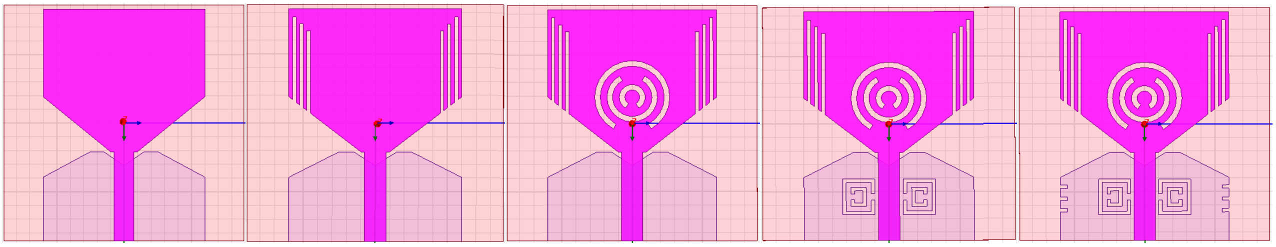


Figure 6: (e) Simulated 2D radiation pattern at 10.8 GHz

The parametric study



(a) Design 1 (b) Design 2 (c) Design 3 (d) Design 4 (e) Design 5

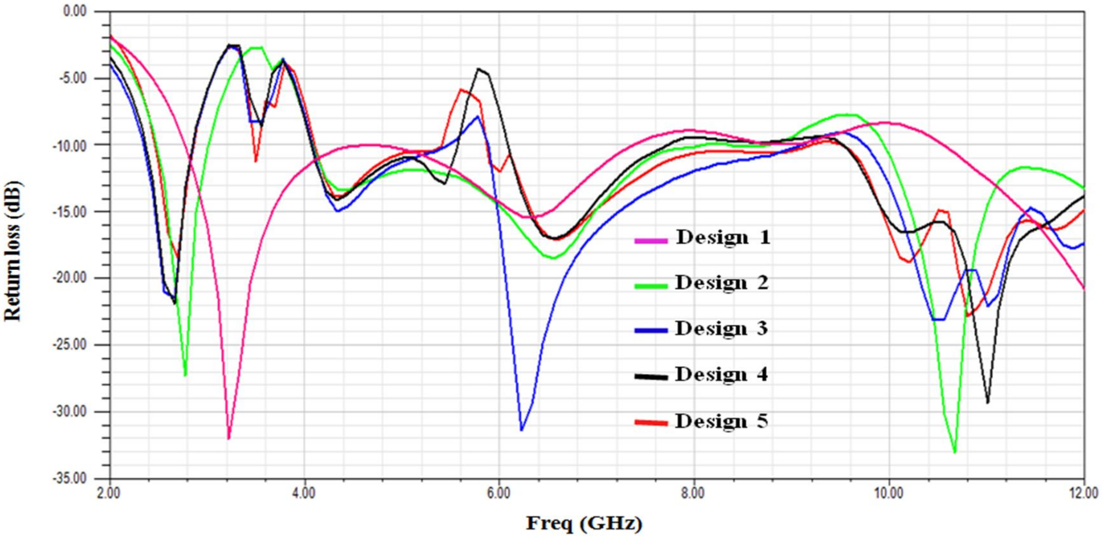


Figure 7: Comparison of return loss Vs frequency graph of different designs

The effect of addition of slots and notches both on patch and ground plane are shown in Figure 7. At initial stage of antenna design, the simulated results show that there are only three bands of narrow bandwidth. So, as the slots are cut along the length of patch then the bandwidth increased somewhat in the simulated results. Hence, when complimentary split ring resonator (CSRR) slot in the patch then it seems that there are more bands introduced in the simulated results. So on, when two double complimentary split ring resonator slots are cut in ground then the bandwidth of that multiband increases. At last as the design completed the best possible results are obtained that means wide bandwidth, low return loss, multiband and so on.

In design 1, the antenna design operates at three frequencies 3.22 GHz, 6.33 GHz and 12 GHz with return losses of -31.95 dB, -15.41 dB and -20.91 dB, having the value of VSWR of 1.05, 1.41 and 1.19. The bandwidths are 1.78 GHz, 2.45 GHz and > 1.45 GHz. In design 2, the antenna design operates at three frequencies 2.77 GHz, 6.55 GHz and 10.66 GHz with return losses of -27.22 dB, -18.47 dB and -33.05 dB, having the value of VSWR of 1.09, 1.27 and 1.04. The bandwidths are 0.56 GHz, 3.78 GHz and 2 GHz. In design 3, the antenna design operates at four frequencies 2.66 GHz, 4.33 GHz, 6.22 GHz and 10.55 GHz with return losses of -21.39 dB, -14.92 dB, -31.36 dB and -23.13 dB, having the value of VSWR of 1.18, 1.43, 1.05 and 1.14. The bandwidths for these four frequencies are 0.44 GHz, 1.44 GHz, 3.34GHz and > 2.23 GHz. In design 4, the antenna design operates at four frequencies 2.66 GHz, 4.33 GHz, 6.55 GHz and 11 GHz with return losses of -21.92 dB, -14.09 dB, -17.01 dB and -29.26 dB, having the value of VSWR of 1.17, 1.49, 1.32 and 1.07. The bandwidths are 0.44 GHz, 1.44 GHz, 1.66 GHz and > 2.45 GHz. In design 5, the antenna design operates at five frequencies 2.7 GHz, 3.5 GHz, 4.4 GHz, 6.6 GHz and 10.8 GHz with return losses of -18.39 dB, -11.24 dB, -13.79 dB, -17.10 dB and -22.82 dB, having the value of VSWR of 1.27, 1.75, 1.51, 1.32 and 1.15. The bandwidths are 0.4 GHz, 0.1 GHz, 1.3 GHz, 3.3 GHz and > 2.5 GHz.

Measured Results of Proposed CPMADGP

Return Loss

The measured return loss variation represents in Figure 8.

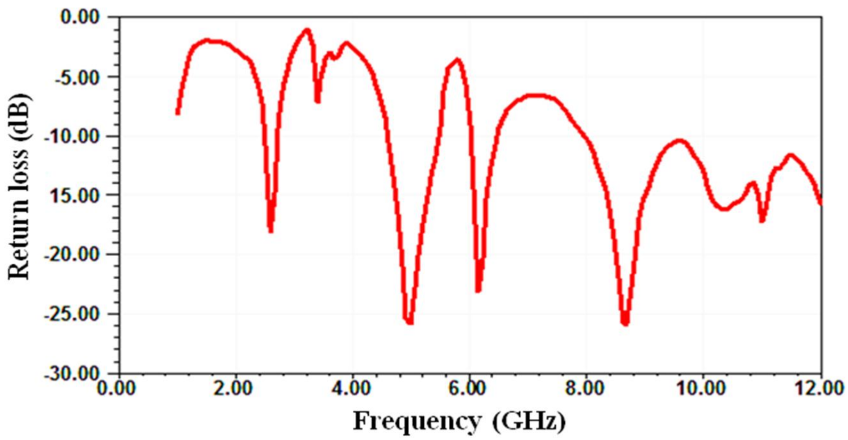


Figure 8: Measured return loss against frequency plot of proposed CPMADGP

VSWR

The measured VSWR against frequency graph shown below in Figure 9.

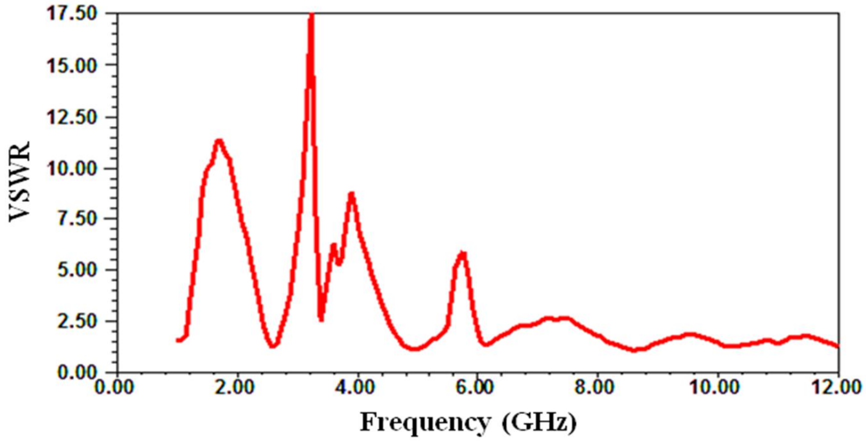


Figure 9: Measured VSWR against frequency plot of proposed CPMADGP

Comparison of simulated and measured results of proposed CPMADGP

Return Loss

The comparison of simulated and measured return loss variation is shown in Figure 10.

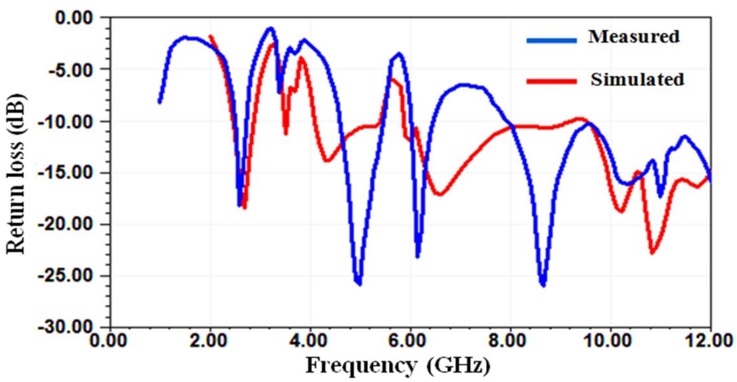


Figure 10: Comparison of simulated and measured return loss against frequency plot of proposed CPMADGP

VSWR

The comparison of simulated and measured results of VSWR against frequency plot is shown in Figure 11 below:

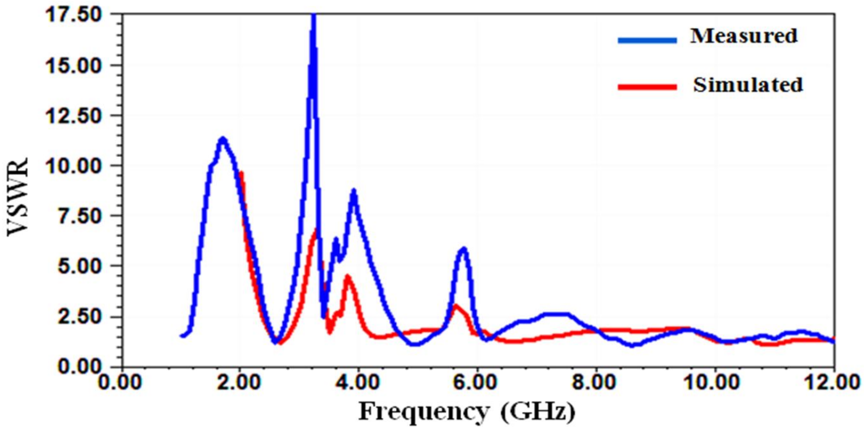


Figure 11: Comparison of simulated and measured VSWR against frequency plot of proposed CPMADGP

Table 3: Comparison of simulated and measured results of proposed CPMADGP

Simulated Results			Measured Results		
Resonant Frequency (GHz)	Return Loss (dB)	VSWR	Resonant Frequency (GHz)	Return Loss (dB)	VSWR
2.7	-18.39	1.27	2.6	-18.10	1.26
4.4	-13.79	1.51	4.9	-25.80	1.18
6.6	-17.10	1.32	6.13	-23.10	1.36
10.8	-22.82	1.15	10.9	-17.30	1.44

Conclusion

The design and analysis of a compact printed monopole antenna with defected ground plane which supports wideband applications. The proposed antenna has been designed on a FR4-epoxy substrate with dielectric constant 4.4 and height 1.6mm. The proposed antenna is fed by microstrip line feed. The performance parameters of antenna such as VSWR, return loss, gain, bandwidth and radiation pattern has been obtained. First of all, the designing analysis of the compact printed monopole antenna with defected ground plane was accomplished. After that all the simulated results was obtained. The proposed antenna was designed, fabricated and then tested with the help of vector network analyzer (VNA). In the simulated results, the antenna design operates at four frequencies 2.7 GHz, 4.4 GHz, 6.6 GHz and 10.8 GHz with return losses of -18.39 dB, -13.79 dB, -17.10 dB and -22.82 dB.The gains at these four frequencies are 12.5 dB, 5.14 dB, 4.74 dB and 1.83 dB. The bandwidths are 0.4 GHz, 1.3 GHz, 3.3 GHz and > 2.5 GHz. In the measured results, the antenna design operates at four frequencies 2.6 GHz, 4.97 GHz, 6.13 GHz and 10.97 GHz with return losses of -18.10 dB, -25.80 dB, -23.10 dB and -17.30 dB. This proposed antenna is designed for S-band, C-band, X-band and Ku-band applications. The performance parameter of proposed antenna can be further improved. Soft computing techniques will also be applied to proposed antenna. In this area, there are many options available for future work.

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