International Journal of Signal Processing, Image Processing and Pattern Recognition
Vol.9, No.8 (2016), pp.59-72
http://dx.doi.org/10.14257/ijsip.2016.9.8.05

Compact CMPA Design with Application of Air Gap

Rahul Dev Mishra

Department of Electronics Engineering, Madhav Institute of Technology and Science, Gwalior
rahuldevmishra08@yahoo.co.in

Abstract

Microstrip patch antennas are most widely used antennas because of its application in mobile phones, low cost, ease of fabrication etc. These antennas are planar, have applications in defense, aircraft and have so many shapes like rectangular, circular, triangle, square etc. Circular shape is one of the famous shapes among all. In CMPA as frequency increases the radius of circular patch decreases. In this paper circular patch designed at 900MHz & the important parameter like reflection coefficient, VSWR, polar plot, gain (IEEE) calculated. With application of air gap between dielectric there is variation in resonant frequency of the antenna. The frequency get shifted from 900 MHz to 2.712, 2.2298, 2.268 GHz. If the radius calculated for increased frequency the radius is small in comparison of 900MHz frequency that means antenna get compact. The comparison of all four designs has been done. Hence in this paper CMPA get compact in terms of frequency using air gap.

Keywords*: Air gap, Circular microstrip patch antenna (CMPA), Computer simulation technology (CST), Perfect electric conductor (PEC)*

1. Introduction

Circular patch [1-2] or disk is the next popular configuration after rectangular patch as shown in Figure 1.

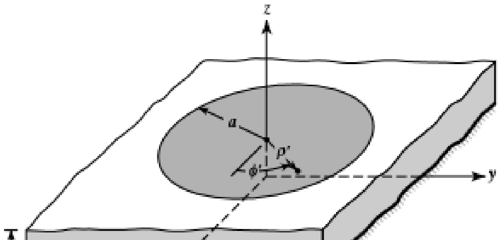

Figure 1. Geometry of CMPA

Circular microstrip [3] patch antennas find deep applications especially in the field of medical, satellite and military communications. Their utility is because of their light weight and small size. Satellite communications require more and more bandwidth; the demand for wideband antennas operating at higher frequencies becomes inevitable. The bandwidth can be increased with the application of air gap. The air gap is applied between the substrate as shown in Figure 2.

ISSN: 2005-4254 IJSIP

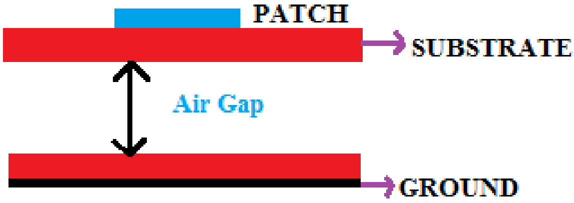

Figure 2. Antenna with Air Gap

By replacing FR4 substrate with air substrate the gain of the microstrip antennas [4-5] can be increased [6]. By providing air gap bandwidth can also be increases [7-8]. Now a day we need to make antenna compact because size is a major concern in growing world the techniques of making antenna compact are slot loading [9], using meta-material etc. In this paper the proposed technique is use of air gap to make antenna compact in terms of frequency.

2. Antenna Design

We have to design [10] circular patch as shown in Figure 1. This model is cavity model & to design this model the designer should know the parameters ϵ_r, f_r (Hz) and h in cm.

The design formula for this is given below in equation 1.

$$a= \frac{F}{\{1+\frac{2h}{\pi\epsilon_r F}\ln(\frac{\pi F}{2h})+1.7726]\}^{.5}} \quad (1)$$

Where $F= \frac{8.791*10^9}{f_r\sqrt{\epsilon_r}}$

3. Calculation

From equation 1 the actual radius (a) of patch for 900MHz antenna is obtained as.

Actual radius (a) = 46.494 mm

4. Antenna Design in CST

By calculated radius the circular patch is designed in CST [11]. The dimensions of circular patch are shown in Table 1.

Table 1. Dimensions of 900 MHz Antenna

S. No.	PLANE	LENGTH(mm)	WIDTH(mm)	HEIGHT(mm)	MATERIAL
1.	Ground	125	110	0.038	PEC
2.	Substrate	125	110	1.6	FR4
3.	Cut	32.494	7	0.038	vaccum
4.	feed	-57.666	3.01	0.038	PEC

The patch is designed with a radius of 46.494 & height of 0.038 mm. The design of circular patch antenna prepared in CST software is shown in Figure 3. After this a discrete port is connected at the end of the feed line and time domain analysis done using transient solver. Based on this analysis result is obtained these results is elaborated in next section.

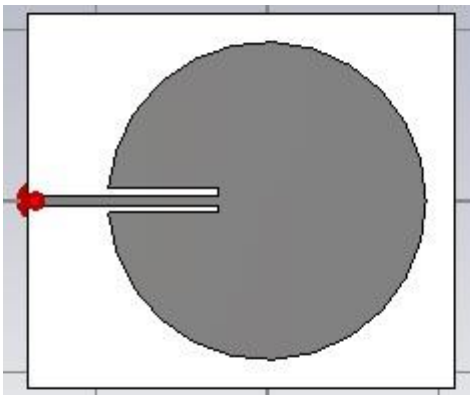

Figure 3. CMPA Layout in CST

5. Results of Simulation of Antenna in CST

The result obtained from time domain analysis is discussed here. The parameter reflection coefficient (S_{11}) is shown in Figure 4; it shows antenna is resonating at particular frequency. The value of S_{11} is -19.01 dB or we can say return loss of 19.01 dB.

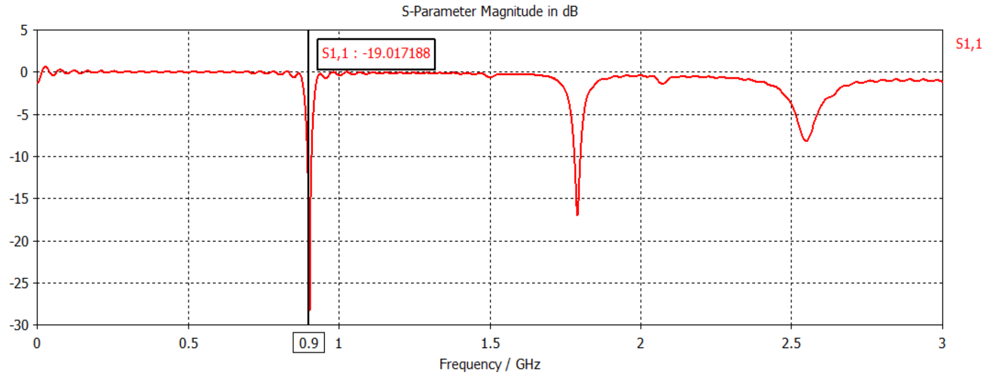

Figure 4. S_{11} of Designed Antenna

The polar plot of this antenna at 900MHz is plotted in Figure 5. It is plotted by applying farfield at broadband frequency.

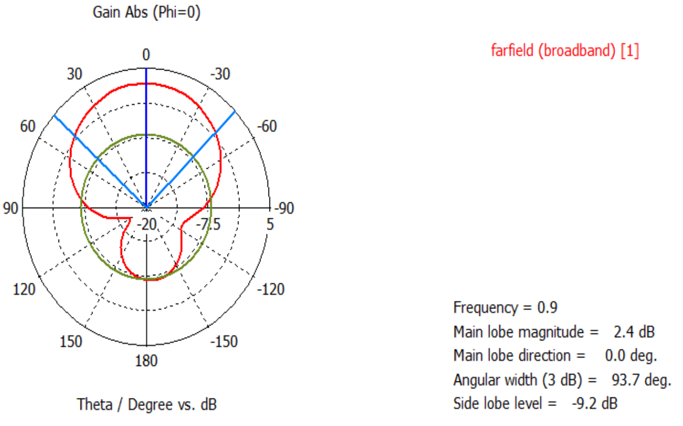

Figure 5. Polar Plot of Designed Antenna

The 3 D view of same plot is shown in Figure 6. In this plot red portion indicates radiations.

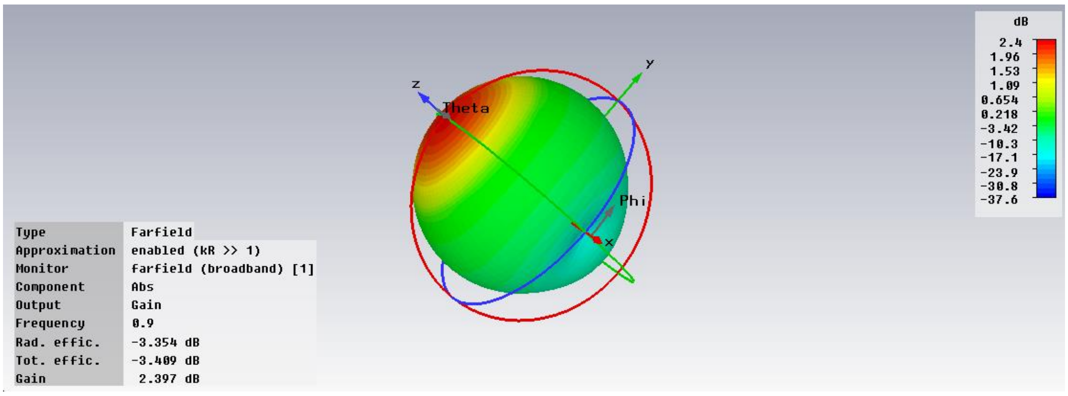

Figure 5. 3D Radiation Pattern of Designed Antenna

VSWR is a measure of matching between the feed and Circular patch. Its range is between 1 to ∞. For perfect matching its value should be nearer to 1. From Figure 7, its value is 1.25. It is dimensionless quantity.

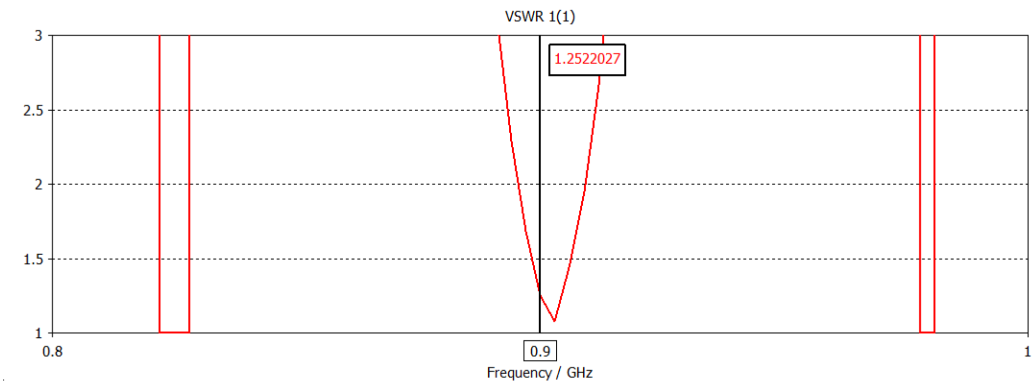

Figure 7. VSWR of Designed Antenna

The graph for gain is shown in Figure 8. Its value is 2.39 dB.

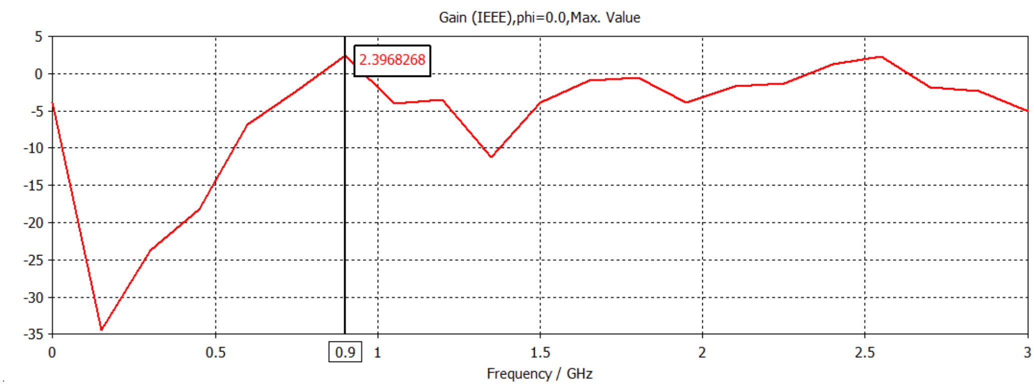

Figure 8. Gain (IEEE) of Designed Antenna

6. Antenna Designed with Application of Air Gap

The normal CMPA is discussed in above section. In this section air gap is applied between substrates and the variations in results are observed. The antenna with 3 mm air gap is designed with dimensions as mentioned in Table 2.

Table 2. Dimensions of Antenna with 3mm Gap

S.No.	PLANE	LENGTH(mm)	WIDTH(mm)	HEIGHT(mm)	MATERIAL
1.	Ground	125	110	0.038	PEC
2.	Substrate 1	125	110	1.6	FR4
3.	Air gap	125	110	3	Air
4.	Substrate 2	125	110	1.6	FR4
5.	Cut	32.494	7	0.038	vaccum
6.	feed	-57.666	3.01	0.038	PEC

Radius of patch a = 46.494 mm

Figure 9, showing perspective view of designed antenna in which air gap is shown. Bottom view is shown in Figure 10, which is clearly showing gap with discrete port.

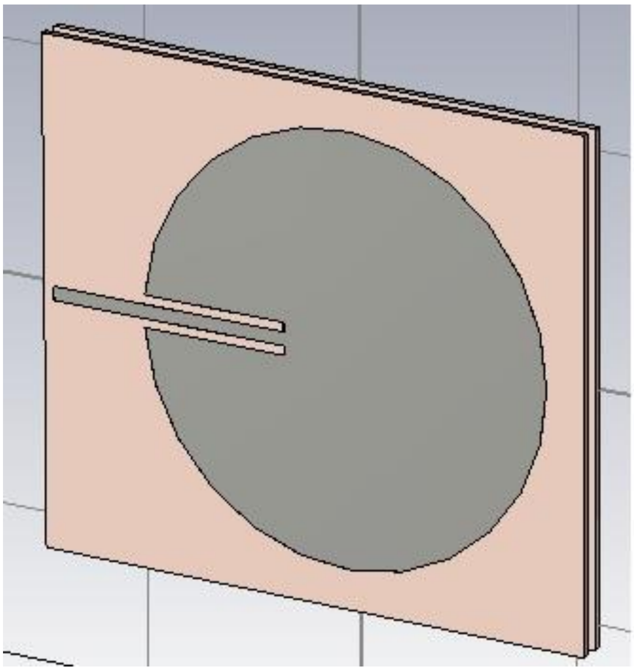

Figure 9. Perspective View of Antenna

Figure 10. Bottom View of Antenna

7. Results with Application of 3mm Air Gap

The results is obtained from transient analysis when gap is applied is discussed in this section. Here the dimensions are same only 3 mm gap is applied. So the S_{11} shifted from 900MHz to 2.172GHz as shown in Figure 11.

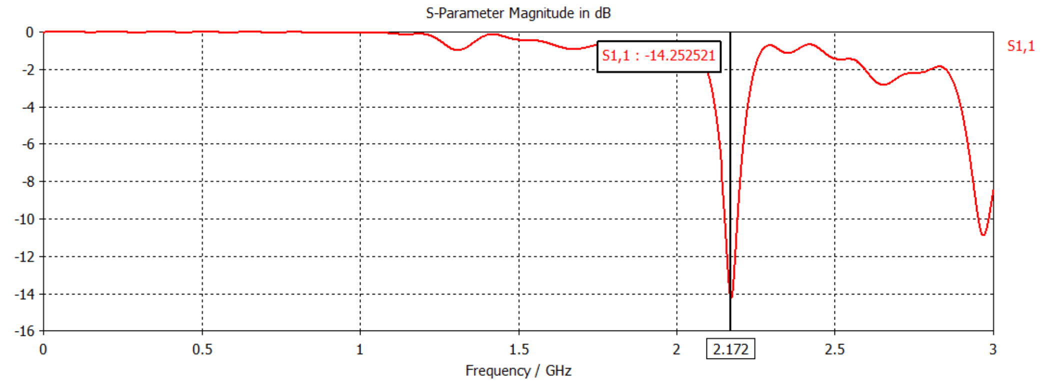

Figure 11. S_{11} of Antenna with 3mm Air Gap

Polar plot with gap is shown in Figure 12, which is different from 900MHz antenna pattern.

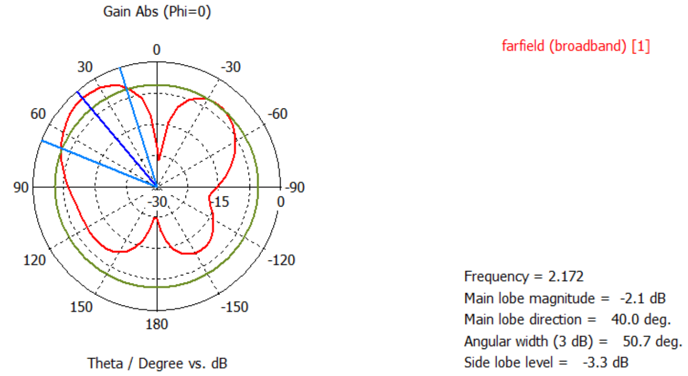

Figure 12. Polar Plot of Antenna with 3mm Air Gap

For Figure 12, the 3 D view is shown in Figure 13.

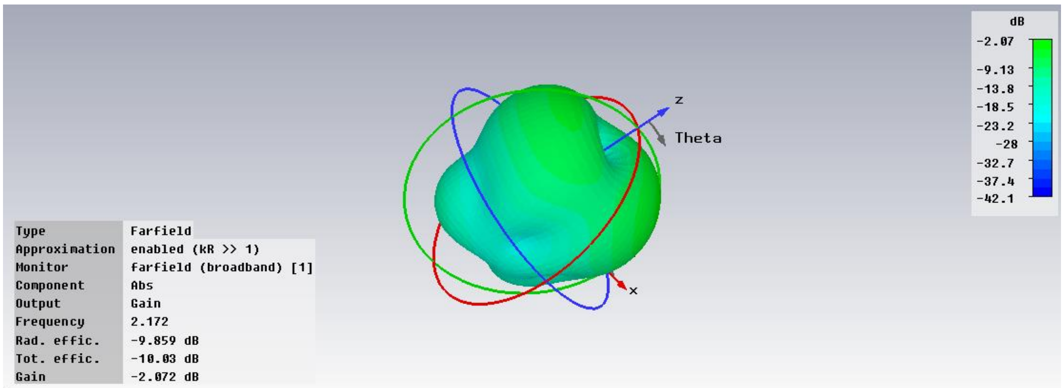

Figure 13. 3D Radiation Pattern of Antenna with 3 mm Air Gap

VSWR value is 1.48 and graph for this is plotted in Figure 14.

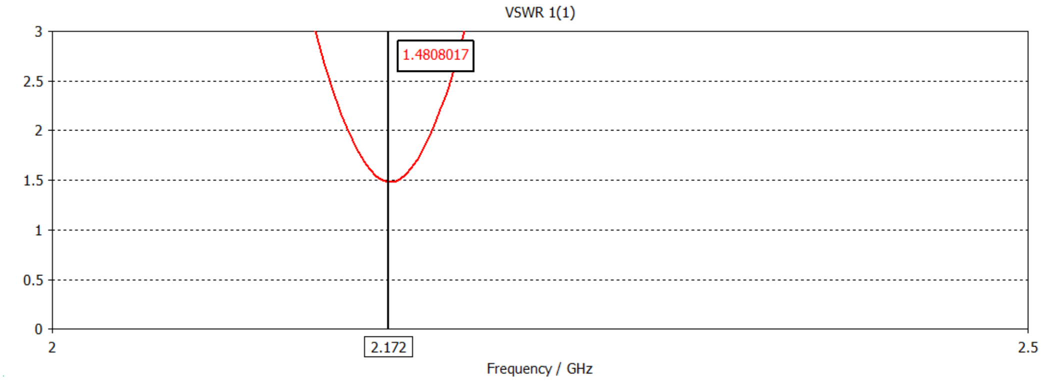

Figure 14. VSWR of Antenna with 3 mm Air Gap

Here the value of gain has increased at this frequency and is 5.80 dB. Graph for this is shown in Figure 15.

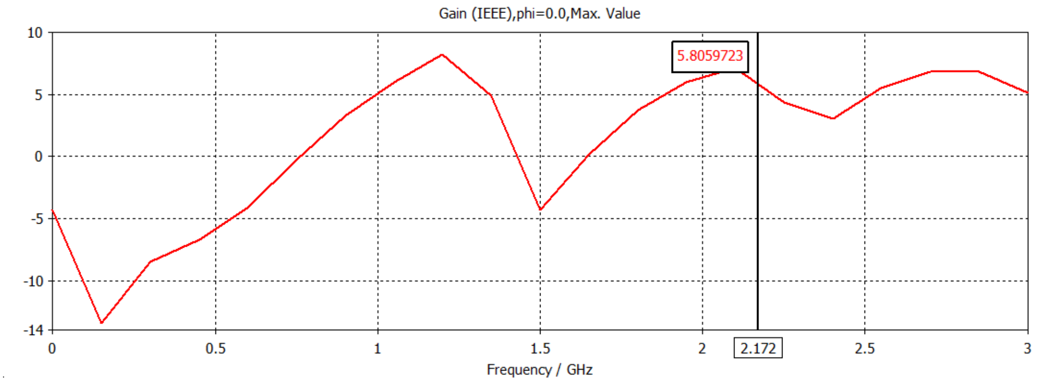

Figure 15. Gain of Antenna with 3mm Air Gap

8. Antenna Designed with 4mm Air Gap

In above section antenna is designed with 3 mm gap and results are discussed. But in this section the 1 mm gap is increased *i.e.*, total gap of 4 mm applied. The dimensions for this are written in Table 3.

Table 3. Dimensions of Antenna with 4mm Gap

S.No.	PLANE	LENGTH(mm)	WIDTH(mm)	HEIGHT(mm)	MATERIAL
1.	Ground	125	110	0.038	PEC
2.	Substrate	125	110	1.6	FR4
3.	Air gap	125	110	4	Air
4.	Substrate 2	125	110	1.6	FR4
5.	Cut	32.494	7	0.038	vaccum
6.	feed	-57.666	3.01	0.038	PEC

Radius of patch a = 46.494 mm

The perspective view is shown in Figure 16, and bottom view in Figure 17, respectively.

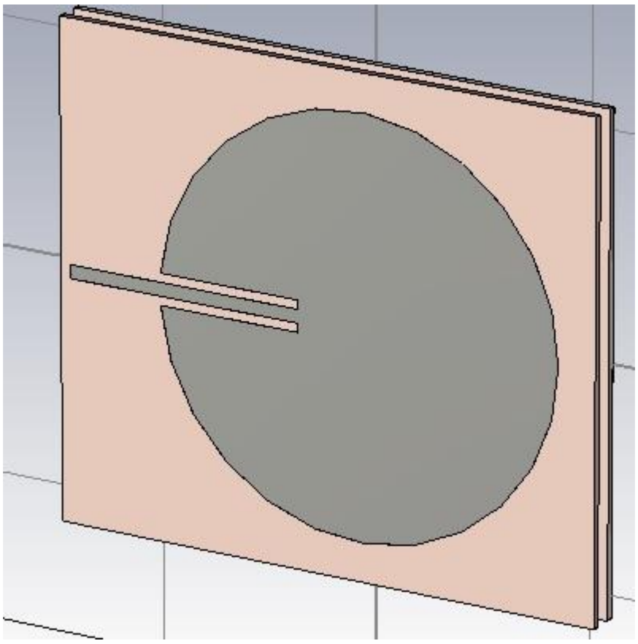

Figure 16. Perspective View of Antenna with 4 mm Gap

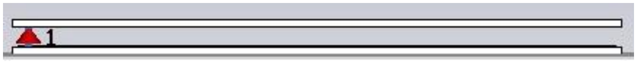

Figure 17. Bottom View of Antenna Perspective View of Antenna with 4 mm Gap

The value of S_{11} is -12.05 dB at 2.229 GHz in which frequency shifted from 900MHz to 2.229 GHz. The graph for this is plotted in Figure 18.

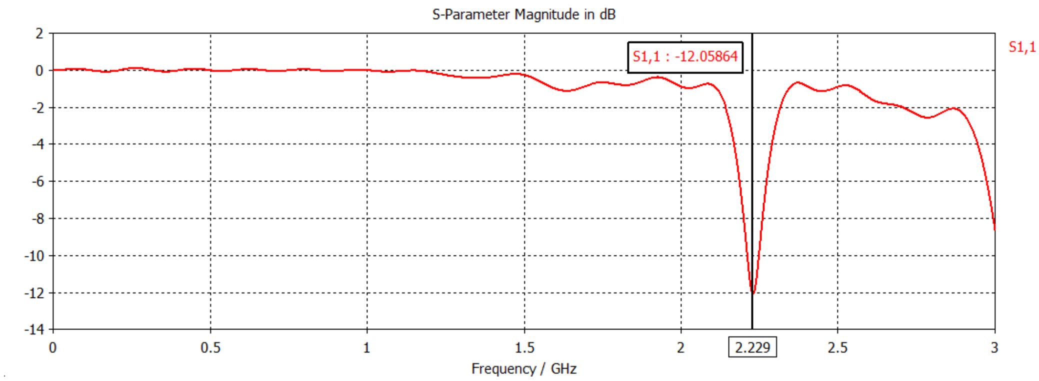

Figure 18. S_{11} of Antenna with 4 mm Gap

The value of VSWR is 1.66 as shown in Figure 19.

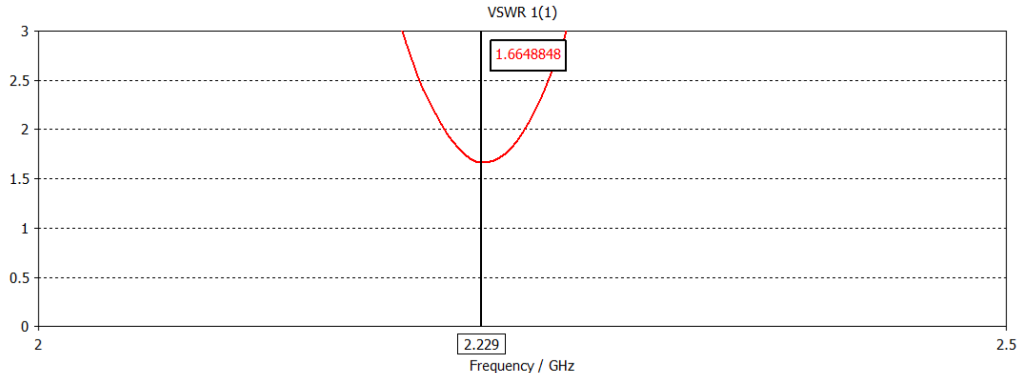

Figure 19. VSWR of Antenna with 4mm Gap

The graph for gain is plotted in Figure 20, and its value is 5.57 dB at 2.229 GHz.

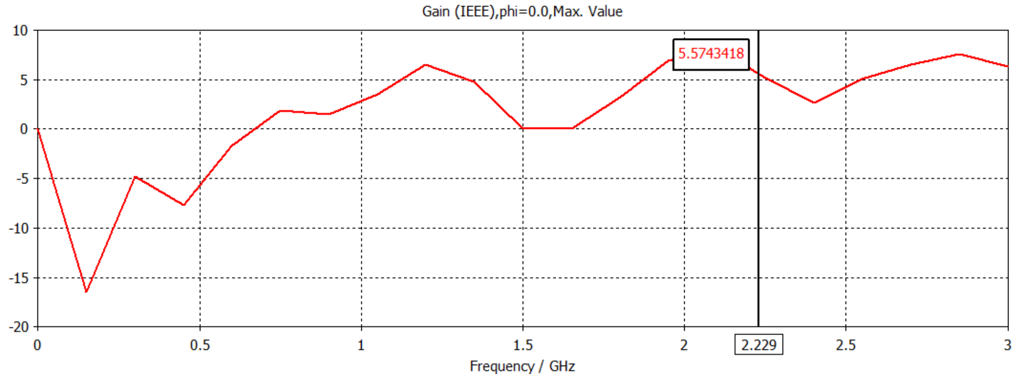

Figure 20. Gain (IEEE) of Antenna with 4 mm Gap

Polar plot is shown in Figure 21, and 3D view for this is shown in Figure 22.

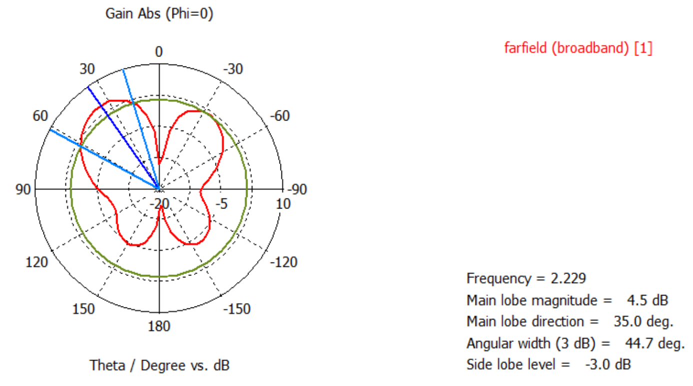

Figure 21. Polar Plot of Antenna with 4mm Air Gap

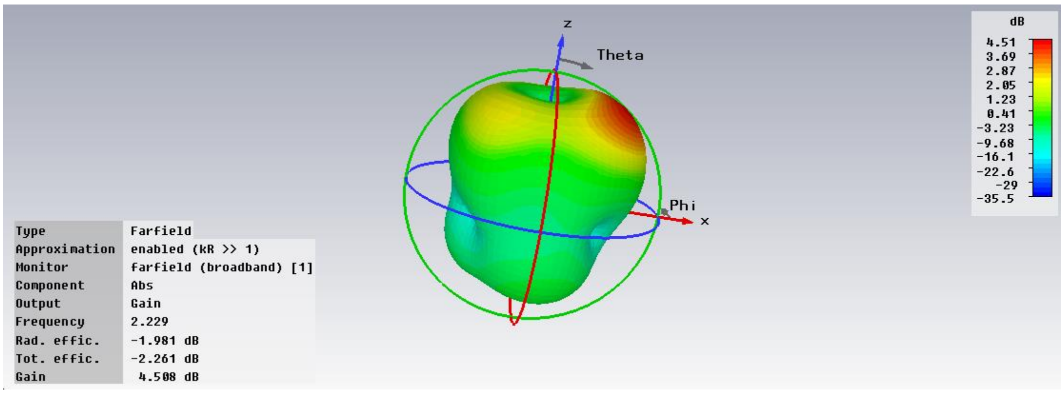

Figure 22. 3D View of Polar Plot of Antenna with 4 mm Gap

9. Antenna Designed with Application of 5mm Air Gap

In this section 5 mm air gap is applied between the substrate. The dimensions are shown in Table 4.

Table 4. Dimensions of Antenna with 5 mm Gap

S.No.	PLANE	LENGTH(mm)	WIDTH(mm)	HEIGHT(mm)	MATERIAL
1.	Ground	125	110	0.038	PEC
2.	Substrate	125	110	1.6	FR4
3.	Air gap	125	110	5	Air
4.	Substrate 2	125	110	1.6	FR4
5.	Cut	32.494	7	0.038	vaccum
6.	feed	-57.666	3.01	0.038	PEC

Radius of patch a = 46.494 mm

With the help of these dimensions a layout of antenna has prepared in CST as shown in Figure 23.

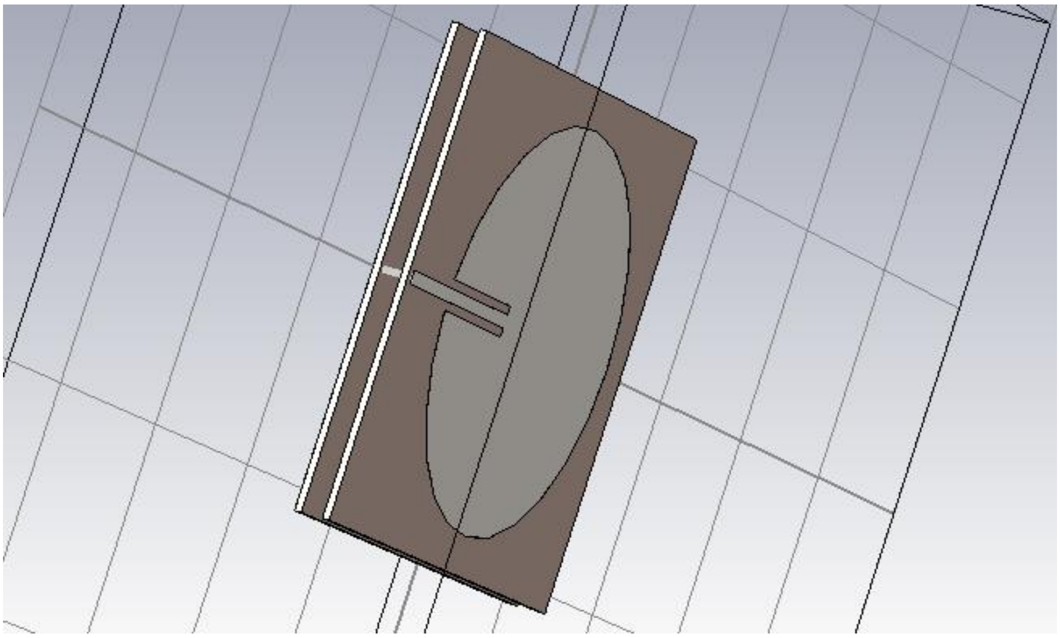

Figure 23. Perspective View of Antenna with 5 mm Gap

In the Figure 24, the bottom view of the antenna had shown which is showing the gap clearly.

Figure 24. Bottom View of Antenna with 5 mm Air Gap

The reflection coefficient of antenna is shown in Figure 25. The value of S_{11} is -10.3926 dB.

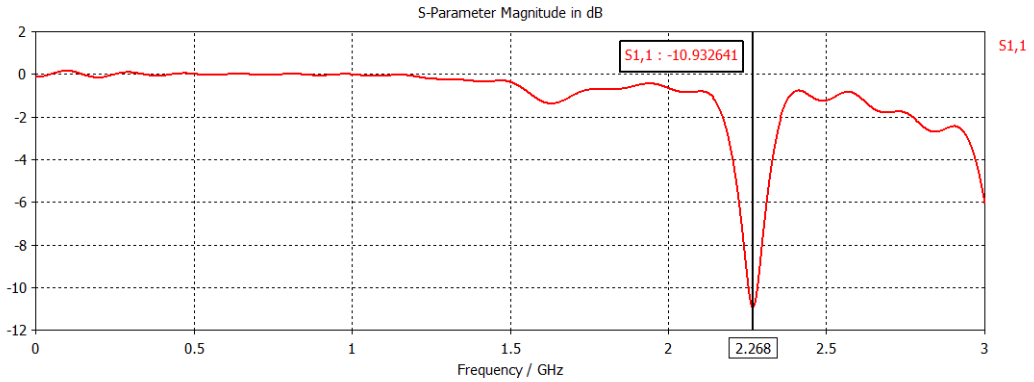

Figure 25. S_{11} of Antenna with 5 mm Gap

The VSWR with 5 mm air gap is shown in Figure 26, & the value of VSWR is 1.79.

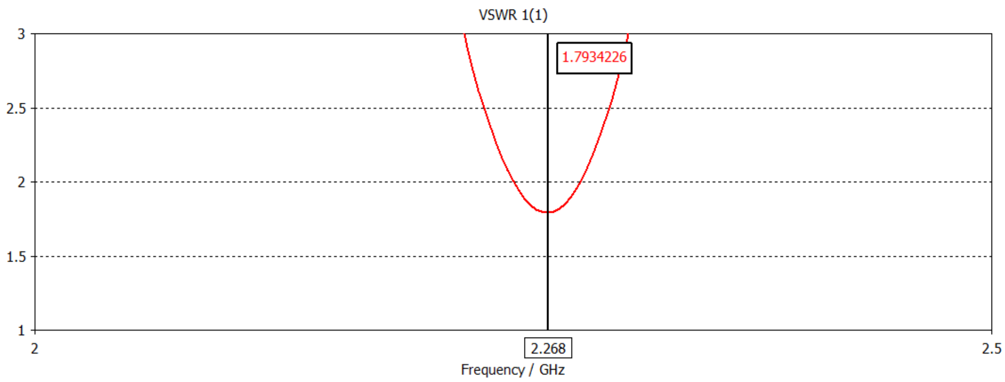

Figure 26. VSWR of Antenna with 5 mm Gap

The gain (IEEE) plotted for antenna with 5mm air gap is shown in Figure 27, & the value of gain is 5.6503 dB.

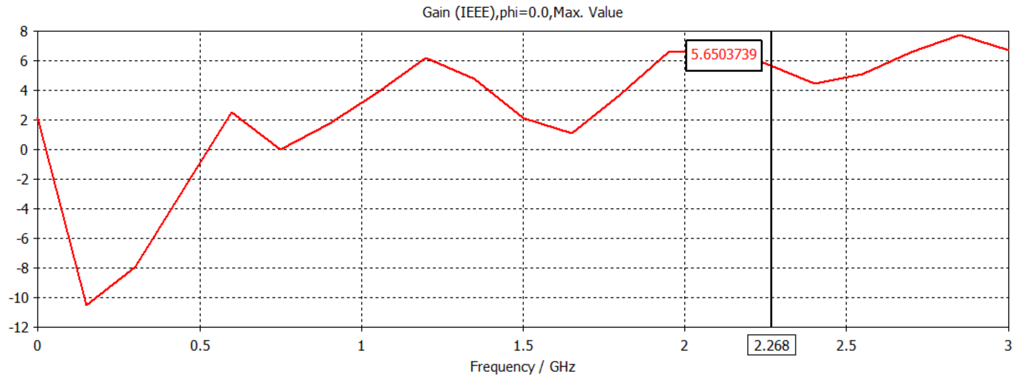

Figure 27. Gain(IEEE) of Antenna with 5 mm Gap

The polar plot for this antenna is shown in Figure 28.

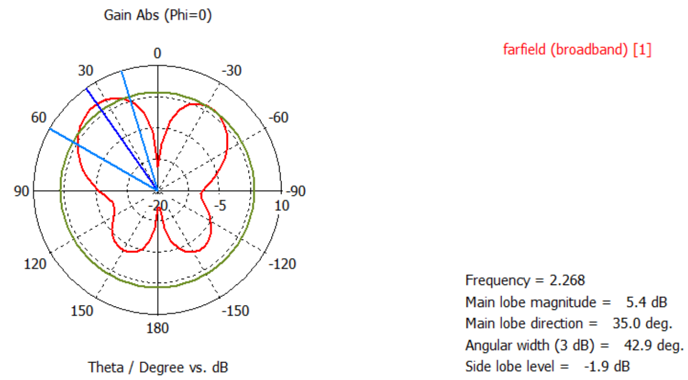

Figure 28. Polar Plot of Antenna with 5 mm Air Gap

The 3D view of Figure 28, is shown in Figure 29.

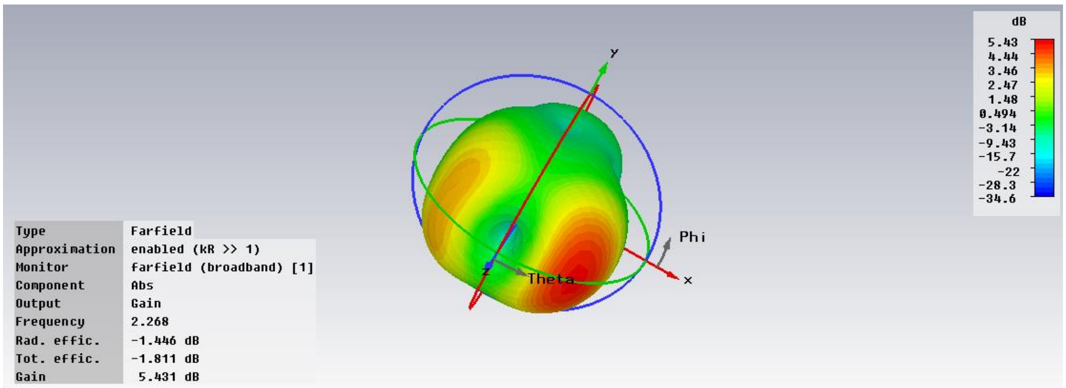

Figure 29. 3D View of Polar Plot of Antenna with 5 mm Gap

10. Comparison

In this section the comparison of normal design and design with air gaps is discussed here. The important parameter observed and listed in Table 5. From Table 5, it can be observed with the application of air gap-

1. The S_{11} getting worst.
2. The value of VSWR also increasing which means matching deteriorating.

3. Gain has increased in all three designs.
4. Frequency shifted *i.e.*, increased which means design gets compact.

Table 4. Comparison of Parameters of Designs

S.No.	PARAMETERS	900MHz	3MM GAP	4MM GAP	5MM GAP
1.	S_{11} (dB)	-19.01	-14.25	-12.05	-10.93
2.	VSWR	1.25	1.48	1.66	1.79
3.	Gain	2.39	5.80	5.57	5.65
4.	Frequency(GHz)	.9	2.172	2.229	2.268

11. Conclusion

In this paper CMPA designed at 900 MHz. For making antenna compact air gap technique is used here. As air gap is applied the resonant frequency of the antenna shifting to the higher frequencies. With the application of gain of the antenna has increased. Hence the conclusion of the paper is that as air gap is increasing antenna getting compact in terms of frequency and gain of the antenna increasing.

References

[1] L. Soufian and A. Hassan, "Dssign of Ultra Wideband Small Circular Patch Antenna for Wireless Communication" ARPN Journal of Engineering and Applied Sciences, vol. 10, no. 4, March **(2015)**.
[2] K. V. L. Bhavani, B. T. P. Madhav, P. P. Poorna, V. V. S Murty, K. Ravikumar and A. Srujana, "Design of Compact U-Slot Circular Patch Antenna on RT DUROID 5880 Substrate", International Journal of Modern Engineering Research (IJMER), vol. 1, no. 1, pp. 140-145.
[3] R. Youssef, B. Seddik and T. Raja, "The Effect of the Radius of the Circular Patch Antenna in the Ku-Band" International Journal of Microwaves Applications, vol. 3, no. 6, **(2014)** November -December, pp. 35-37.
[4] A. G. Derneryd "A Theoretical Investigation of the Rectangular Microstrip Antenna Element," IEEE Trans. Antennas Propagat, vol. AP-26, no. 4, **(1978)** July, pp. 532–535.
[5] I. J. Bahl and P. Bhartia "Microstrip Antennas", Artech House, Dedham, MA, **(1980)**.
[6] O. Ijarotimi, "Gain Enhancement in Microstrip Patch Antennas by Replacing Conventional (FR-4 and Rogers) Substrate with Air Substrate", International Journal of Innovative Research in Electronics and Communications (IJIREC), vol. 1, no. 1, April **(2014)**, pp. 39-44.
[7] M. T. A. Jones, I. Yesubabu, D. Sugumar and A. Dhanaraju, "Gain and Bandwidth Enhancement of a Circular Microstrip Patch Antenna Using an air Layer between two Substrates" International Journal of Computer Science, Systems Engineering and Information Technology, vol. 4, no. 1, **(2011)**, pp. 73-76.
[8] G. Pankaj and O. P. Sharma "Parasitic Gap Coupled Microstrip Patches with Slot for Broadband Performance", International Journal of Advanced Research in Computer and Communication Engineering, vol. 2, no. 3, March **(2013)**, pp. 1485-1489.
[9] S. L. Kumar, G. Bhaskar and P. S. Partha, "A Review on the Design of Compact Microstrip Antennas" IJECT, ol. 2, no. 4, **(2011)** October- December..
[10] C. A. Balanis, "Antenna theory analysis and design", 3rd edition, chapter 14, pp. 843-848.
[11] www.cst.com.

Author

Rahul Dev Mishra was born in 1990, received his Bachelor Degree in 2011 from Scope College of Engineering Bhopal Madhya Pradesh India. Currently he is pursuing masters in Electronics and communication (Microwave Engineering) at Madhav Institute of Technology and Science in Gwalior, India. His research work is microstrip antenna designing to observe the effects of radiations on animals.

