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Compact wideband microstrip circular patch antenna for 6G application

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***Abstract*—In order to create an antenna with a wide band range, the work provided in this paper displays the parametric analysis for the circular patch antenna designs. Microstrip line in the 50 ohm range is used in the developed antenna. To achieve it, three proposed designs were put forth, out of which design2 achieves a broadband of below -10 dB return loss range from 20.33 to 47.11 GHz with a bandwidth of 26.78 GHz towards 6G. The HFSS (High Frequency Structure Simulator) is used on intel core i5, 8 GB RAM, Windows 11 to simulate the suggested antenna designs.**

***Index Terms*—Microstrip circular Patch antenna, return loss, gain, directivity, 6G**

I. Introduction

In the recent trend of telecommunication, the 6G standard is under consideration for wireless communication. As compared to 5G, 6G is known for more diverse applications mostly in Internet of Things [1], [2]. Reliability in communication with precise location estimation in centimeter range as well as coverage towards terrestrial area will be the crucial parameter for 6G.Miniaturization of antenna size most important factor for the compact application.

To achieve the goal of 6G communication, in this paper circular patch antenna design is considered. The circular shape patch consists of microstrip feeding lines. The ground plane is partial and it is optimized to obtain the required results. Designing the simple and compact antenna consists of a circular microstrip patch antenna.

The contribution to the paper is as follows:

- The proposed designed 2 has given better return loss below - 10 dB line.
- Better gain is achieved.
- Widerband and compact antenna design.

As 6G network is expected to handle the handheld mobile connections effectively as compared to fifth generation, directive antennas with increased bandwidth will be helpful for 6G equipped devices [3], [4]. In the current scenario, there exists a challange to design an antenna with wideband, better return loss, better gain and directivity as well as the antenna must be of compact size. Hence in this paper main focus was to achieve the combination of all these design characteristics. The detailed analysis is given in results section. The following details explains how the paper is organized :

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Section I represents the introduction of this paper. The literature survey is introduced in Section II. Section III depicts workflow of the work.aa The proposed antenna design is represented in Section IV. Comparison of simulated results is presented in Section V. This paper is concluded in Section VI.

II. Literature Survey

The author [5] used two hemispherical structure which was combined together as well as two feed points were added and have Right Handed Circular Polarization (RHCP) which is used for improving directing signal in a specific direction.

In the paper, [6] antenna designed is used in local area network, in medical and industry. In this paper, the author has concluded the design and measured results for a coupled dual linearly polarized circular microstrip patch antenna and got the microstrip patch antenna gain of 7.6 dBi. In the paper, [7] author developed a modern wireless system that helps for improving communication and the antenna has good performance in terms of frequency. Smaller in size as compared to other antenna. In this, a FR4 substrate comparison with two annular rings and a tiny top-mounted circular patch is used.A novel antenna geometry consists of a small circular patch and two annular rings that are concentric. Patch size can be effectively decreased with this arrangement. In this paper, [8] author shows the transition for the wide-band operation. It has two vertical patches that are helix-shaped to achieve broad-band CP performance and the size is reduced to 48 percent having a return loss of 10dB and a gain of 9.75dBi. Circular patch antenna with broad bandwidth and compact geometry receive more attention in wireless communication. To meet these requirements vertical patch antenna was proposed. To achieve wide-band circularly polarized helical antenna are commonly used and the ground plane is assumed to be finite and the thickness of the conductance plate is 0.5mm. The author concluded that compact wide-band integrated with broadband microstrip to slot line transition as feeding network and this proposed antenna. In this paper [9] The patch size is smaller than a typical square patch antenna and it employs a square ring antenna. It has a larger bandwidth and a lower resonance frequency. In order to reduce the experimental load author is using the cut and trial method with the help of the HFSS tool. A novel antenna having the micro-strip fed square ring and the prototype is designed. The paper [10] shows results-producing low profile spiral antenna with a sphere-shaped HIS reflector for frequency of 3 GHz, small axial ratio within 3 to 10 GHz as well fractional bandwidth of 108 %. author talked about the fabrication and application of the antenna such as it is easy to fabricate, low cost, and the gain is enhanced by replacing one patch above another with a distance of a quarter wavelength. The author used the shorting technique for enhancing the gain. The author concluded that to improve the gain we can use the shorting technique for the circular patch antenna.

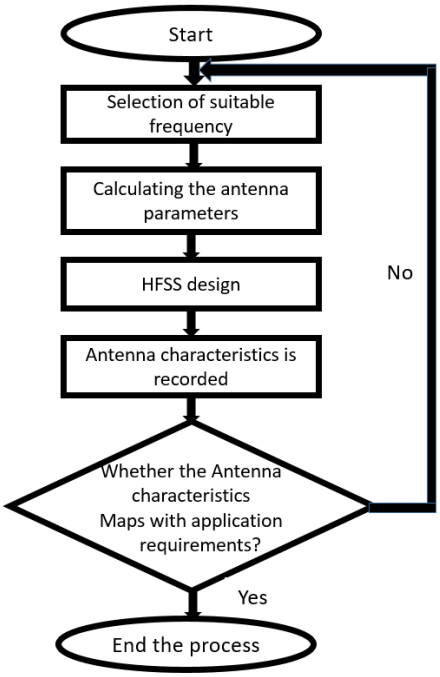


Fig. 1. Work Flow for proposed antenna

III. Work Flow

To design a circular patch antenna, different parameters had to be chosen carefully. Antenna performance gets changed due to changes in the parametric values. The frequency of operation, ϵ is known before the design starts. The proposed circular patch antenna is designed for 20.7900 GHz to 42.2200 GHz. The proposed design comprised of Ground (Gnd), substrate, and designed patch. The substrate considered for this patch is FR-4. Inset line feeding is considered for the design. The 3-dimensional model is designed using HFSS. The flow of the proposed work is presented in Fig. 1.

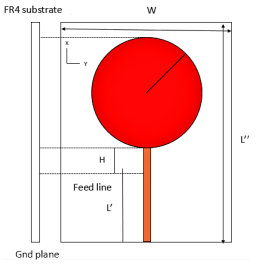


Fig. 2. Proposed prototype

IV. Proposed Antenna Design

Microstrip patch antennas possess complicated radiating structures to increase the generic performance. The resonant dimension is dependant on size of the patch. Here for the design, properties of the substrate (type of dielectric) and its height plays and important role to understand the design. As

antenna converts the electrical signal to corresponding electromagnetic wave for further communication of the message from transmitter to receiver, careful design is necessary.

The dimension of the antenna, substrate thickness, ground plane have been calculated prior to the proposed design starts. The corresponding simulated results for each design is presented in all the proposed desin section as well as in result section. The Fig. 2 represents schematic of proposed prototype and the Fig. 3 depicts the designed patch in HFSS.

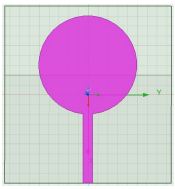


Fig. 3. Designed patch in HFSS

A. *Design1*

Return loss, Directivity, gain, Efield, Surface Current and Co and X pol for the proposed design1 is presented in Fig. 4 to Fig. 9. It can be observed from Fig. 4 that the proposed design1 has a return loss of -18.2542 to -14.4304 dB at resonating frequency from 14.4000 GHz to 40.6000 GHz.

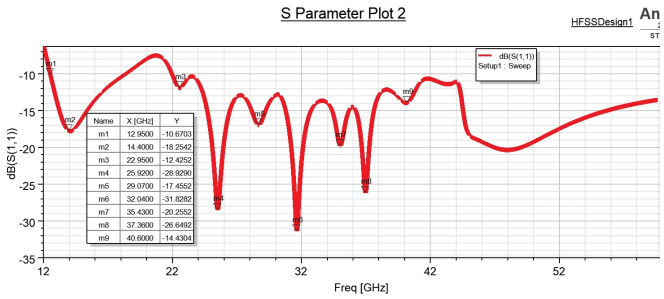


Fig. 4. Return Loss1

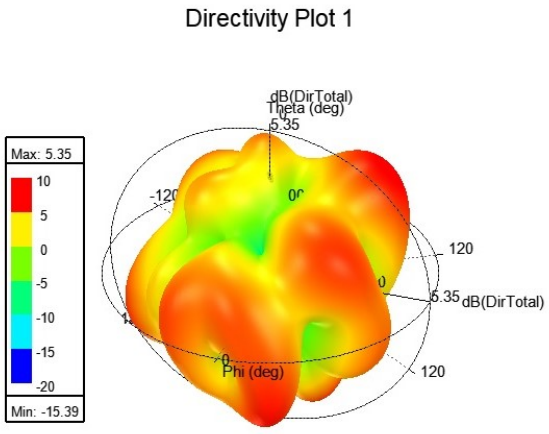


Fig. 5. Directivity (design1)

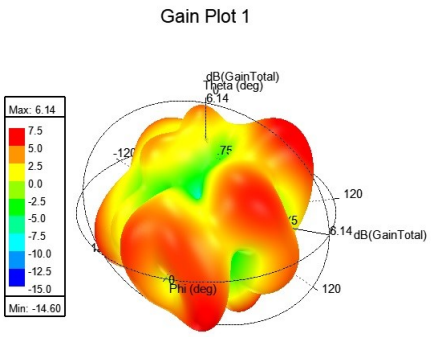


Fig. 6. Gain (design1)

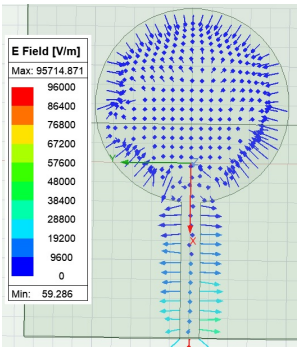


Fig. 7. Efield1

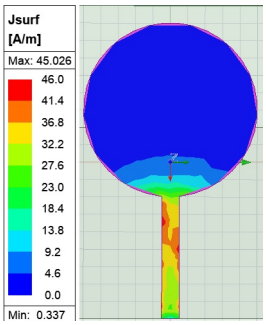


Fig. 8. Surface current1

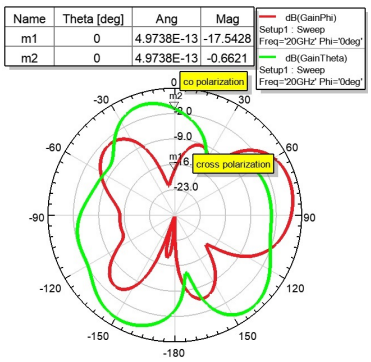
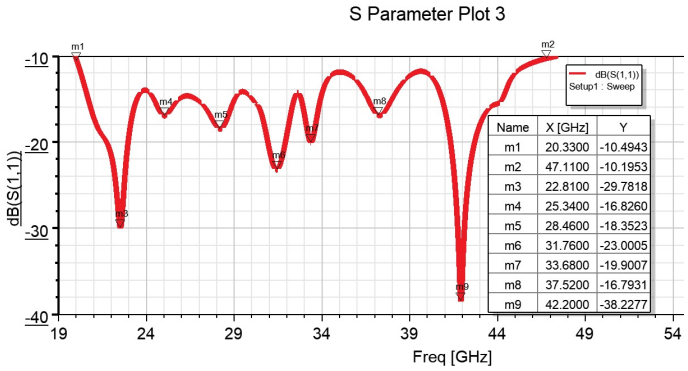


Fig. 9. Co and X pol of the design1

B. Design2

Fig. 10 to Fig. 15 represents return loss, Directivity, gain, Efield, Surface Current and Co and X pol for the proposed design2. It can be observed from Fig. 10 that the proposed design2 has a return loss of -29.7818 to -38.2277 dB at resonating frequency from 22.8100 GHz to 42.2000 GHz.



Name	X [GHz]	Y
m1	20.3300	-10.4943
m2	47.1100	-10.1953
m3	22.8100	-29.7818
m4	25.3400	-16.8260
m5	28.4600	-18.3523
m6	31.7600	-23.0005
m7	33.6800	-19.9007
m8	37.5200	-16.7931
m9	42.2000	-38.2277

Fig. 10. Return Loss2

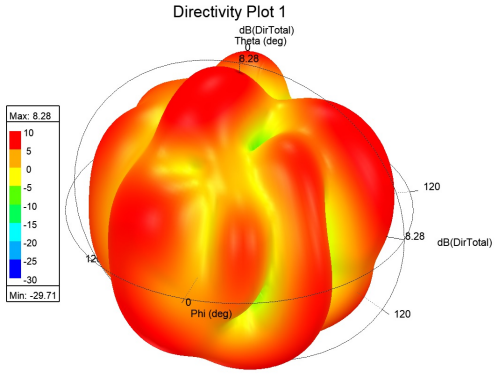


Fig. 11. Directivity (design2)

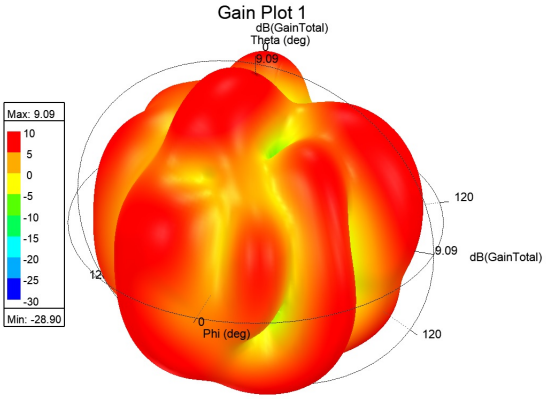


Fig. 12. Gain (design2)

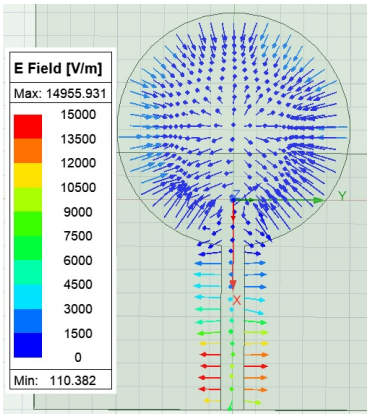


Fig. 13. efield2

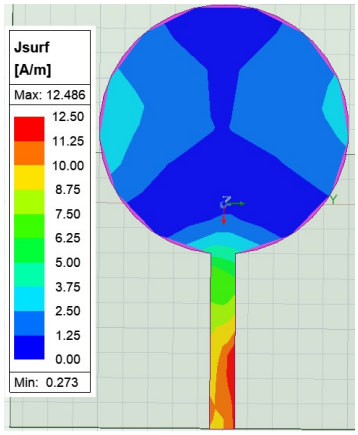


Fig. 14. surface current2

Name	Theta [deg]	Ang	Mag
m1	0	4.9738E-13	-10.3815
m2	0	4.9738E-13	6.6028

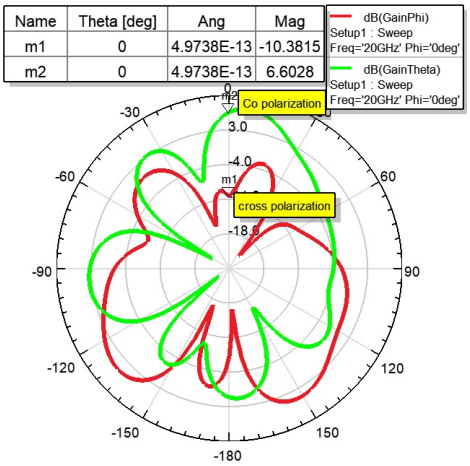


Fig. 15. Co and X pol of the design2

C. Design3

Fig. 16 to Fig. 21 represents return loss, Directivity, gain, Efield, Surface Current and Co and X pol for the proposed design3. It can be observed from Fig. 16 that the proposed design3 has a return loss of -11.4779 to -19.8700 dB at resonating frequency from 14.4400 GHz to 34.1800 GHz.

Fig. 16. Return Loss3

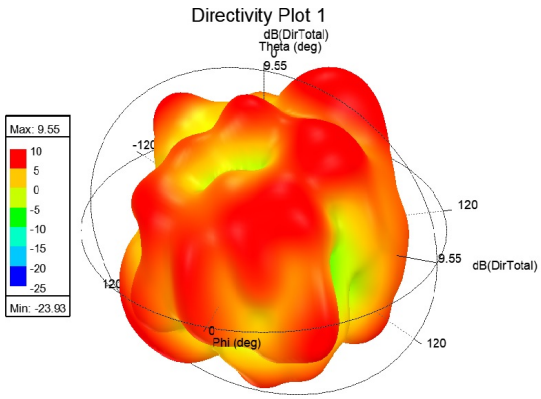


Fig. 17. Directivity (design3)

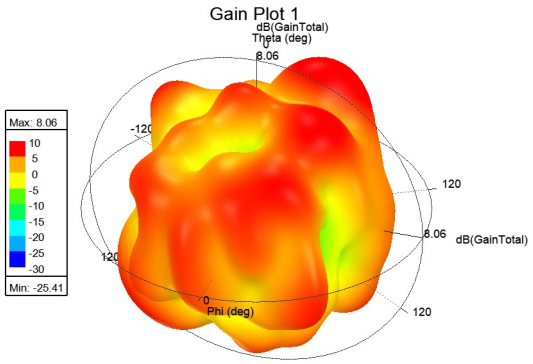


Fig. 18. Gain (design3)

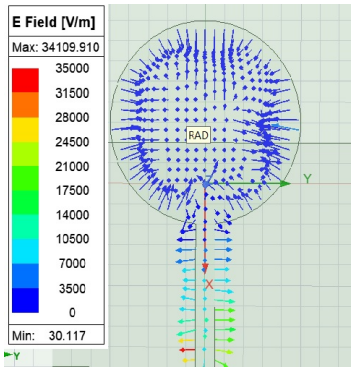


Fig. 19. efield3

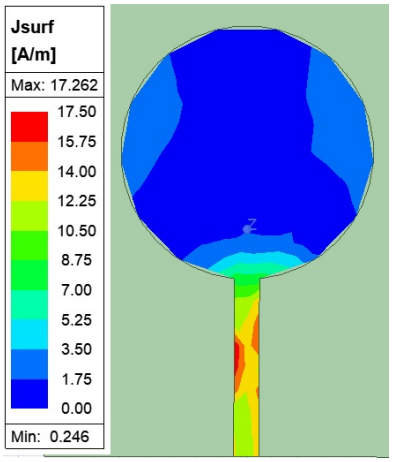


Fig. 20. surface current3

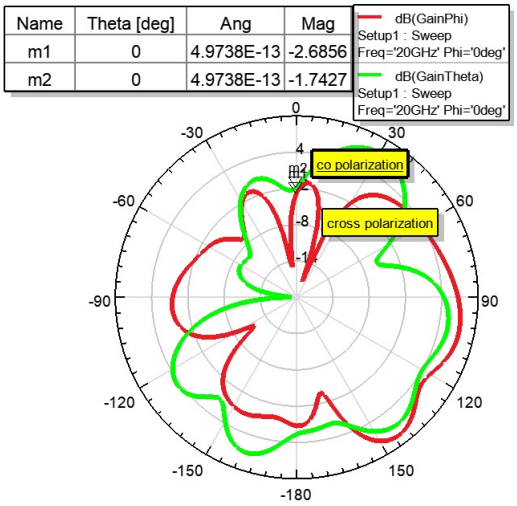


Fig. 21. Co and X pol of the design3

V. Comparison of Simulated Results

The Figure. 22 represents return losses for all the proposed designs. Table. I and Table. II represents a comparison of the designed results. Table. III represents the Comparison of several authors' papers.

TABLE I
COMPARISON OF THE DESIGN RESULTS1

Antenna	Resonant Frequency (GHz)	Return loss (dB)	Gain (dBi)	Directivity (dBi)
Design1	14.4000 to 40.6000	-18.2542 to -14.4304	6.14	5.35
Design2	**22.8100 to 42.2000**	**-29.7818 to -38.2277**	**9.09**	**8.28**
Design3	14.4400 to 34.1800	-11.4779 to -19.8700	8.06	9.55

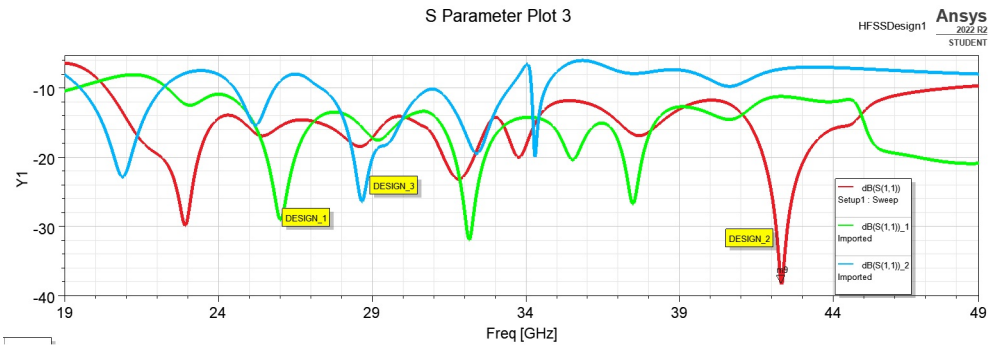


Fig. 22. Comparison of return losses for all the designs

TABLE II
COMPARISON OF THE DESIGN RESULTS2

Antenna	CO and X	E field(V/m)	current(A/m)
Design1	-17.5428 to -0.6621	95714.871	45.026
Design2	-10.3815 to 6.6028	14955	12.486
Design3	-2.6856 to -1.7427	34109.910	17.262

TABLE III
COMPARISON OF SEVERAL AUTHOR'S CONTRIBUTIONS AND THEIR RESULTS

Sl No	Year	Title of the paper	Tool Used	Return Loss in dB	Gain in dB	Conclusion
1	2003	[6]	Ansoft Ensemble 6.1.	10	7.6	Bw of 14.3 %
2	2004	[11]	CST	10	5.0-6.5	Bw of 30 %
3	2007	[7]	CST	10	1.35 TO 3.5	Cross Polarization is better
4	2008	[8]	HFSS	10	9.75	BW of 30 %
5	2009	[9]	HFSS	10	5.2 TO 6.0	Bw of 1.1 %
6	2009	[12]	HFSS	10	5.7	Bw of 1.5 to 3 %
7	2011	[13]	HFSS	—	1 TO 1.5	Tripple Modes were investigated
8	2017	[5]	HFSS		1.35 TO 3.5	Centre patch operates in TM_{11} mode

VI. CONCLUSION

Circular microstrip patch antenna with a bandwidth of 26.78 GHz and a return loss of below -10 dB range from 20.33 to 47.11 GHz for 6G is presented. In terms of return loss, directivity, and gain, this work shows better results. The optimization of the antenna dimension to achieve better return loss characterstic and validate by fabrication is the future scope of this paper.

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