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Bandwidth Enhancement of Pentagonal & Circular Microstrip Patch Antenna with DGS for Radar & Satellite Applications

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P Arockia Michael Mercy* and KS Joseph Wilson

PG & Research Department of Physics Arul Anandar College, Madurai Kamaraj University, Madurai – 625514, Tamilnadu, India

***Corresponding Author:** P Arockia Michael Mercy, PG & Research Department of Physics Arul Anandar College, Madurai Kamaraj University, Madurai – 625514, Tamilnadu, India.

Abstract

The shape of the radiating patch exerts influence greatly on the performance of the microstrip patch. The vital target of this research article is to constitute the microstrip antennas of Circular and Pentagonal patches on FR4 substrate employing partial ground that notably lower the shape complication as a consequence of the antenna size reduction combined with a profitable radiation efficiency on the basis of the center frequency of 8.5 GHz. The specification of return loss, VSWR, gain, directivity, radiation pattern, and the radiation efficiency of the antenna are investigated using ANSYS HFSS 13.0 software which reveals beneficial outcomes of dual - band over the entire band frequency range of 5-15 GHz relating with the earlier analysis. The pentagonal patch antenna is detected far well compared to the circular patch which is achieved the best gain of 2.55 dB, 4.53 dB, return loss of -12.18 dB, -15.58 dB enhanced bandwidth of 0.45 GHz, 1.8 GHz and the higher radiation efficiency of 83%, 97% at 8.85 GHz, 12.90 GHz respectively. This is applicable for Marine Radar communication (SART), productive Satellite Communications, and also it is the best candidate for weather monitoring, defense and military purposes in Wireless Communication applications.

Keywords: Microstrip patch antenna; Circular & Pentagonal shape; FR4 Epoxy; S_{11} parameter; VSWR; bandwidth; gain; directivity; radiation pattern and radiation efficiency

Introduction

The apprehend of the content, scope, criterion, and breed of antennas are enclosed by the cosmos of antennas [1]. At present microstrip antennas is one of the rapidly developing antennas in telecommunication fabrication [2]. The claim for compact, low posture and broadband antennas are escalating outstandingly with the broad advanced extension of wireless communication technology a short time ago. To encounter the requirements, the micro-strip patch antenna could be configured on account of its small profile, lightweight, and low-priced [3]. MP antennas bring in plenty of improvements through quality, weightlessness, compact, economical, low portrait, trivial in proportion, ease of manufacture, and compatibility. It could be used in an extended implementations on account of its size and structure such as telemetry, radars, radio frequency identification (RFID), navigation, biomedical systems, missile systems, mobile and satellite communications, a global positioning system (GPS) for remote sensing [4]. It mainly incorporates three elements such as radiating patch a copper-made part that is kept on the substrate through the ground plane is fastened below the substrate which holds the entire structure of the antenna. MPAs are the optimal aspirants for the wireless communication field because of their conformity and its attainable any analytical profile and proportion [5]. It is greatly favored because it has the potential to integrate smoothly with other active and passive circuits of filters, amplifiers, oscillators, and mixers [6]. Normally, Microstrip Patch Antennas are more accessible with the square patch, rectangular patch, dipole patch, circular patch, elliptical patch, triangular patch, disc sector, circular ring, and ring sector [7]. A simple slot or small defect is created in the ground plane of the antenna is called defected ground structure which results in the diffusion of the current on the ground structure guiding a restrained propagation of Electromagnetic (EM) waves into and out of the substrate. It causes the betterment of bandwidth, minimization in structure in order that contraction, contributes better impedance matching, in consequence delivering good turnout outcomes. The antenna also enfolds the frequency range of Wi-MAX [8]. Ultra-Wideband Wireless Communication attained noteworthy attention in their twenties, particularly one time the Federal Communications Commission promoted an uncredited frequency band for mercantile utilization from 3.1 to 10.6 GHz frequency range [9]. The research paper is enticed to analyze the shapes of antenna like rectangular, elliptical, triangular, pentagonal, and circular at the frequency range of 5GHz -15 GHz. The partial ground is brought out to achieve dual-band assuring their competent activity for potentiating the impedance bandwidth and high radiation efficiency in the antenna design which is more applicable to the implementations of the weather forecasting, civil, military, monitoring, and police radars for vehicle speed detection.

Antenna Design Consideration

Microstrip patch antenna can have either shape. The shape variations are helpful for the compactness of the patch antenna in its applications [10]. In this paper, there are two shapes are taken for the MSPA design such as pentagonal-shape, and circular-shape which are reviewed beneath. A better performance antenna could be computed by the low dielectric constant substrate materials which provide the higher radiation efficiency, liberally hold together fields for radiation, and enhanced bandwidth [11]. The various microstrip patches, implanted over the low-cost FR4-epoxy substrate material holds a dielectric constant value of 4.4 with a loss tangent value of 0.02. The incombustible (FR4) is a favored substrate with better strength to weight ratio and acquires appreciable mechanical strength with zero water absorption. The considered thickness of the substrate is 1.53 mm. The presented antenna of size 20 × 40 mm is a compact structure and is endowed with a 50 Ωmicrostrip feed line of measurements Lf 19.2 mm height and Wf = 3 mm width. To achieve the best outcomes of dual-band characteristics, the ground structure of the antenna is modified which is called the partial ground of length Lg = 16.2 mm and Wg = 12.12 mm. The location and measurements of the substrate and partial ground plane are conserved constants throughout the analysis. Subsequently, the configuring of the microstrip antennas with the shapes of circular, pentagonal patches are analyzed and carried out by HFSS 13.0 software. The endmost upgraded antenna framework proportions are engraved in Table 1.

Pentagonal shape Patch

Both linear and circular polarizations are reinforced by the pentagonal microstrip patch antenna. Better performance is attained by the pentagonal patch compared to the rectangular patch antenna. The rectangular patch antenna needs multiple feeds to acquire circular polarization whereas the pentagonal patch antenna gives circular polarization with only one feed [15]. Our proposed pentagonal is configured with the measurements of 44.36 mm, 35 mm, and 60 mm side respectively.

S. No	Parameter name	Designed Values (mm)
1	Substrate length, (Ls)	40
2	Substrate width, (Ws)	20
3	Ground length, (Lg)	16.2
4	Ground width, (Wg)	12.12
5	Substrate thick-ness, (h)	1.53
6	Feed line Length	19.2
7	Feedline Width	3

Table 1: Proportions of sketched antenna.

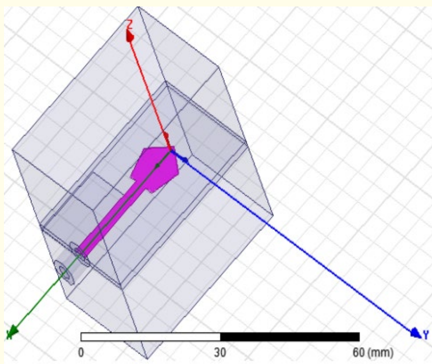


Figure 1: Configuration of pentagonal patch.

Center position: 4.859539, 0, 0.
Start: -1, 0, 0.
Number of segments: 5.

Circular patch microstrip antenna

This kind of antenna with an effective radius bestows better radiation characteristics [16]. It is designed as an excellent wireless passive strain sensors for SHM implementation with regard to the radiation efficiency, VSWR gain, radiation pattern, bandwidth, and return loss. In spite of the selected material pre-owned in the configuration of the antenna sensor, the direct relationship was held in-between strain and the resonant frequency of the CMPA [17]. In our designed circular patch antenna analysis, the substrate, partial ground plane parameters used the same as for other shapes of the antenna.

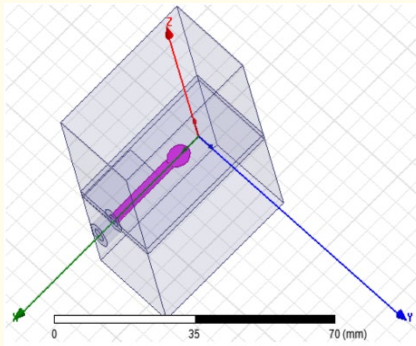


Figure 2: Configuration of a circular patch.

The dimensions of the proposed circular patch are as follows.
Center Position: 6.69, 0, 0.
The proposed circular patch radius is 3 mm.

The proposed various patches of antenna framework parameters such as return loss, gain, and bandwidth is found, analyzed, and simulated by HFSS 13.0 software. To find out the best outcomes of the above analysis, the obtained results are compared instantaneously.

Results and Discussion

S11 Parameter

The antenna parameter of the S_{11} parameter of the above-discussed antenna is analyzed at the frequency range of 5-15 GHz and is specified further down. The S_{11} graph for pentagonal, and circular patch antennas is manifested from Fig. 3. (a) to Fig. 3. (b).

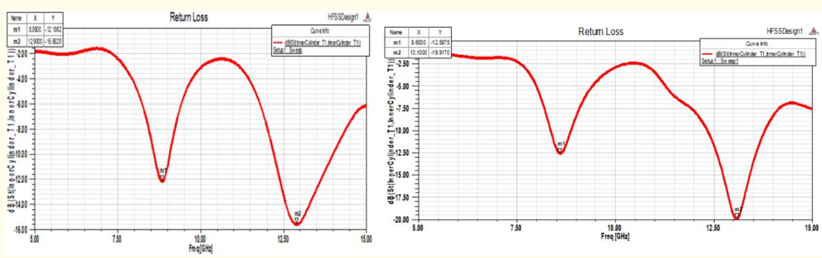


Figure 3(a): Retrn loss of Pentagonal Patch. ***Figure 3 (b):*** Bandwidth of Circular Patch.

In fig. 3(a), the return loss for the Pentagonal patch is studied for the frequency range is 5 -15 GHz where return loss is obtained in less than -10 dB. The resonance frequencies of this patch antenna are 8.85 GHz, 12.9GHz where maximum return loss -12.1862 dB, -15.5828 dB respectively.

In fig. 3(b), the return loss for the circular patch is tested for the frequency range is 5 -15 GHz where return loss is reached in less than -10 dB. The resonance frequencies of this patch antenna are 8.6 GHz, 13.10 GHz where maximum return loss -12.5875 dB, -19.9170dB respectively.

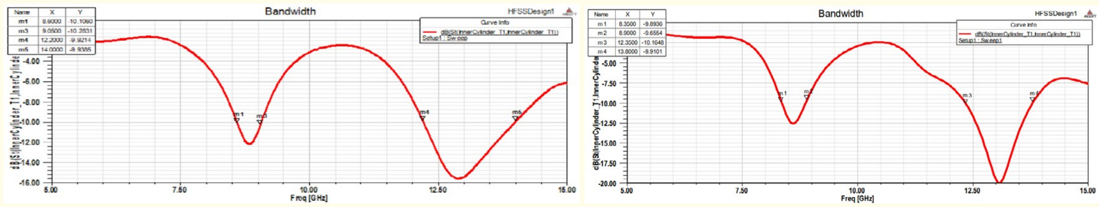


Figure 4(a): Bandwidth of Pentagonal Patch. ***Figure 4(b):*** Bandwidth of Circular Patch.

The pentagonal patch microstrip antenna obtained bandwidth of about 0.45 GHz and 1.8 GHz for dual bands respectively. The circular patch antenna attained bandwidth of about 0.55 GHz and 1.44 GHz for dual bands respectively.

VSWR of Pentagonal & Circular Patches

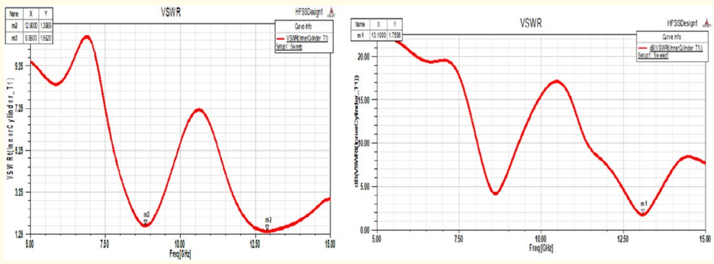


Figure 5(a): VSWR of Pentagonal Patch. ***Figure 5(b):*** VSWR of Circular Patch.

In general, the acceptable value of Voltage Standing Wave Ratio must lie between 1 to 2. The below figures represent the VSWR plot for various patches of the antenna over the frequency range of 5 to 15 GHz. The VSWR plot for the pentagonal, and circular patches of microstrip antenna is shown in above figure.

Gain, Directivity and 3D Polar Plot for pentagonal Patch)

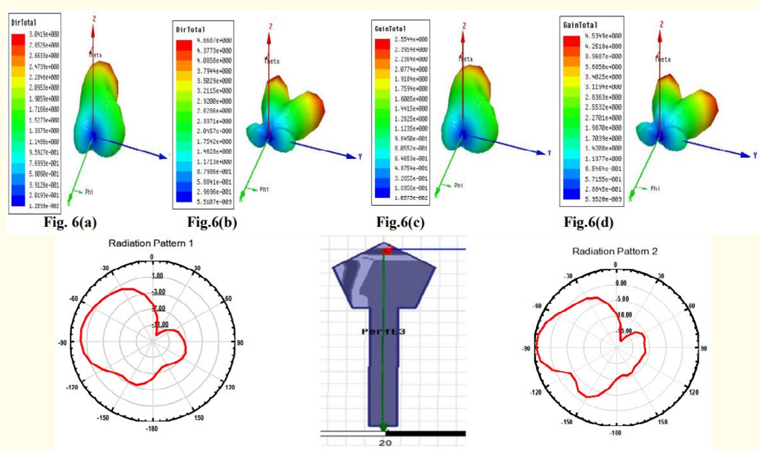
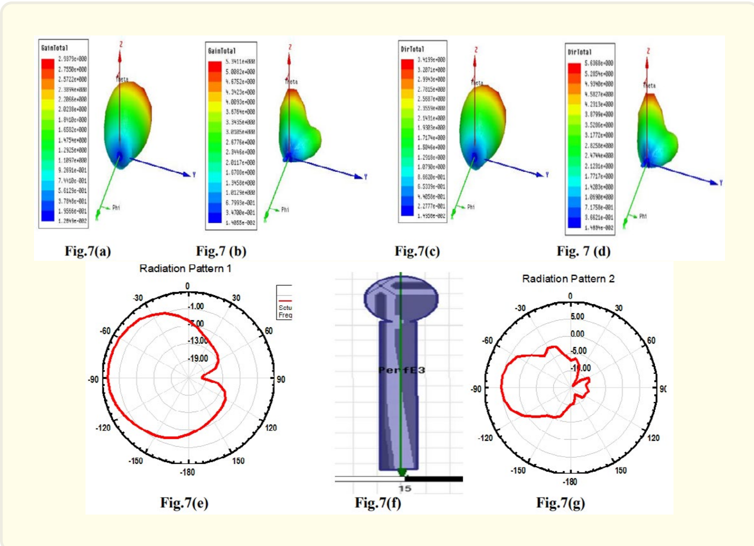


Fig. 6(a) Fig.6(b) Fig.6(c) Fig.6(d)

Fig.6(e) Fig.6 (f) Fig.6(g)

Talking an account of the gain, directivity, and 3D Polar plot characteristics, Fig. 6(a) to Fig.6 (g) shows the average peak gain of the proposed pentagonal patch antenna for the first band is almost 2.55 dB, for the second band is 4.53 dB and the directivity is about 3.04 dB and 4.66 dB also the antenna yields high radiation efficiency around 83% and 97% at 8.85 GHz, 12.9 GHz respectively. It is marked from the directivity, the gain curve, and the 3D Polar plot that the proposed pentagonal shape antenna is utterly capable of transmitting and receiving in the desired X and Ku band frequency ranges.

Gain, Directivity and 3D Polar Plot for circular Patch



Talking about the gain, directivity, and 3D Polar plot characteristics, Fig. 7(a) to 7(g) exhibit an average peak gain of the proposed circular patch antenna for the first band is almost 2.93 dB, for the second band is 5.34 dB and the directivity is about 3.41 dB and 5.63 dB also the antenna yields high radiation efficiency around 85% and 94% at 8.6 GHz, 13.10 GHz respectively. From that analysis, we come to know the directivity, the gain curve, and the 3D Polar plot of the proposed rectangular shape antenna is utterly capable of transmitting and receiving in the desired X and Ku band frequency ranges.

Patch shapes	***Resonant Frequency (GHz)***	***Return loss (dB)***	***VSWR (dB)***	***Band width (GHz)***	***Gain (dB)***	***Directivity (dB)***	***Radiation Efficiency (%)***
Pentagonal	8.85 12.90	-12.18 -15.58	1.65 1.39	0.45 1.8	2.55 4.53	3.04 4.66	83 97
Circular	8.6 13.10	-12.58 -19.91	1.75	0.55 1.44	2.93 5.34	3.41 5.63	85 94

Table 2: Comparative Study of Various Patch Shapes.

The feed line patch antenna with the pentagonal patch, and the circular patch is discussed and analyzed in this research article. Both shape took an account in this design yields distinctive benefits over all the antenna aspects for X and Ku band applications. The comparative analysis brings out that the pentagonal shape antenna comes up with the preferable results as weighed up as for circular patch antenna. Peak directivity, higher gain, improved radiation efficiency, wider bandwidth, and lesser return loss are the crucial factors of antenna design which are achieved by the both shapes of the antenna except the pentagonal shape microstrip patch antenna is much better than others. The over and above considered variables are analyzed and simulated in a detailed manner under Table 2.

Conclusion

The proposed microstrip patch antenna was designed using two different patches as pentagonal, and circular and the performance parameters such as radiation efficiency, 3D polar plot, gain, directivity, bandwidth, VSWR, and return loss were noted simultaneously. Hence, both the analyzed patch antennas are more suitable for X-band and Ku-band applications at the frequency range from 8 GHz to 15 GHz. The two shape of antenna which we have considered for our analysis give better results in dual-band frequency. But the pentagonal antenna delivered the most favorable and record level outcomes in all the framework analysis compared to that of the circular patch antenna. It provides better bandwidth, peak gain, high directivity, and enhanced radiation efficiency. From the above investigation, we confirm that the above-considered shapes of antenna for the implementation of radar engineering, police radars for measuring the speed of the vehicles, for military applications, for navigation intentions, and in finding out the weather forecast and Satellite broadcast communication, space-crafts, wireless computer networks.

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