Analysis of Meandered PIFA Antenna Along With DGS

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Abstract: To Obtaining a compact design by Integration of low frequency component with high frequency component is a challenge and it is achieved in this paper. A Planar inverted F- antenna (PIFA) in Meander structure that radiates at multiple frequencies is designed in this paper. The designed antenna structure is layered as per the pre-approved guidelines with copper (annealed) as ground, FR-4(lossy) as substrate with a loss tangent (0.02δ) and patch is made up of copper (lossy) fed with meander line feeding to reduce the size of antenna and the ground is defected using fractal structure of pattern. The designed antenna is radiated at 1.725GHz, 2.412GHz and 4.788GHz respectively and as a result to this compact size of the antenna, reflection coefficient is observed at -12.905dB, -40.958dB, -38.336dB respectively. The designed antenna works in multiple applications and covers different bands which include GSM 1800, WIMAX, Wi-Fi, 3G, 4G and future 5G applications. The proposed design has a compact dimension of 60X30X1.6mm (0.70x0.35x0.018 wavelengths at the center frequency of the lower band).

Keywords: Compact size, PIFA, Meander line, DGS, Wi-Fi and 5G

1. Introduction

Today there is a necessity to integrate all the wireless services in a single device with multiple functionalities such as Bluetooth, wi-fi and LTE technologies with high speed data transmission and high quality. To satisfy the required functionality, antennas that supports multi-band operation need to be designed which satisfies the standards [2] and due to the constrained space accessible in remote gadgets, the solicitation of the structure with minimal effort and reduction in size of the antenna is necessary. This regularly requires numerous antennas to cover each and it is beyond the realm of imagination to expect to fit them all in a little gadget [4].

An antenna as a front component required to have a proper communication with wideband, good radiation performance and proper gain. Since, strip antenna drawbacks are low gain, narrow bandwidth, and low power handling capacity. Efforts have been made to improve the performance of the antenna. Hence, a Planar Inverted F antenna (PIFA) antenna came into existence [6,7].

Due to compact volume of cellular phones, operating at multiple frequencies and should also cover different LTE bands, the antenna design became a big challenge. For this purpose, in order to reduce the size of antenna working at desired operation bands, Meander line configuration and folding technique is adopted. Such a design leads to thick antenna especially at multiple frequencies bands [5, 8] and improved gain [9].

The output admittance of antenna dependence on the provided input. Hence, Fractal DGS where irregular fragments or breaks are made to ground. Fractals are generally composed of multiple copies of same fractal shape which results in low side- lobe levels [11,12] and enables miniaturization of antenna and results in improvement of input impedance bandwidth.

Since, This Antenna is designed particularly for mobile applications, a PIFA antenna is particularly interesting due to their compactness, low bandwidth, low side lobes, Low profile and easy to integrate with good Specific Absorption Rate (SAR) and high efficiency. Today PIFA remains as one of the most popular antennas used in mobile phones. So, the idea is to design an antenna which would enhance the functionality and performance of wireless communication devices which also covers the existing wireless frequency bands.

Moreover, many design parameters have to be carefully tuned or optimized to achieve desired configuration. Defective Grounding Structure (DGS) is one of the methods used to enhance the bandwidth and return loss of patch antenna and controls Electro Magnetic Waves propagation through substrate layer. The antenna is designed and simulated using the CST Studio Suite 2018, high-frequency simulator based on the finite element method. The antenna is designed using FR-4 substrate with a dielectric constant of (εr=4.3), with a loss tangent of (δ=0.02) and a thickness of 1.6 mm including the copper thickness 0.035 mm at both sides of the substrate.

The purpose of this work is to propose a multi radiated smart antenna while maintaining a simple and straight forward design procedure to achieve a compact design with adequate performance [10].

2.Antenna Design

In this paper, a compact PIFA antenna with simple structure and easy integration is taken into consideration. The PIFA antenna radiating at 2.14 GHz with return loss of -25dB satisfies the requirement to cover Long Term Evolution (LTE) that has been used in mobile phones and tablet computers. The referred antenna covers GSM 1800, LTE band applications between 1.72 GHz to 2.37 GHz at -10 dB with a band width of 670 MHz The Reference PIFA antenna which is taken into consideration is shown in figure (1a).

The proposed antenna is a Meandered feed Planar Inverted F Antenna (PIFA) with Defective Grounding Structure (DGS) provides compact size and attained multiple resonances with better isolation between different frequencies. The antenna is designed and simulated using the CST Studio Suite 2018, high-frequency simulator based on the finite element method. The antenna is created using FR-4 substrate with a dielectric constant of (εr=4.3), with a loss tangent o and a thickness of 1.6 mm including the thickness 0.035 mm at both sides of the substrate.

The integration of Meandered line with PIFA created a suitable LTE communication band line PIFA antenna with partial ground is shown in figure (1b). The antenna obtained a multiband response with good isolation between two frequencies and also leads to miniaturization of antenna with effective results but it wasn't able to provide enough reflection.

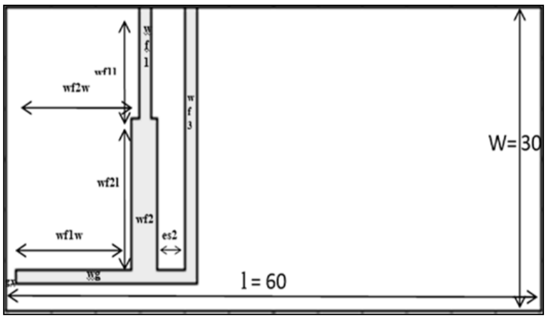

Figure 1a: Conventional PIFA Antenna

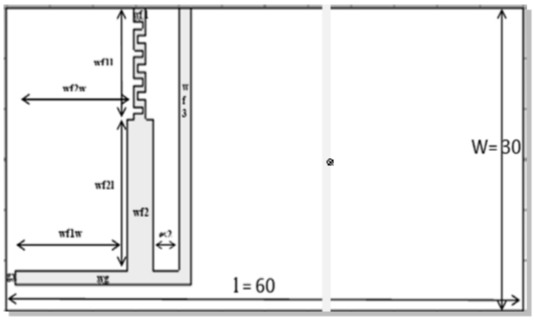

Figure 1b: Meandered PIFA Antenna

Here, the integration of Meandered line with PIFA created a suitable LTE band communication. The geometry of the proposed Meandered antenna with DGS is shown in figure (1c). The magnified view of the DGS shown in figure (1d). The antenna obtained a multiband response with good isolation between the frequencies and also leads to miniaturization of antenna with desired characteristics.

The ground plane with DGS made the antenna a multi band resonating antenna with desired characteristics. . The antenna parameters used for designing of this proposed antenna is given in table-1. The proposed antenna is a Meandered feed Planar Inverted F Antenna (PIFA) with Defective Grounding Structure (DGS) which provides compact size and attained multiple resonances with better isolation between individual frequencies and DGS is

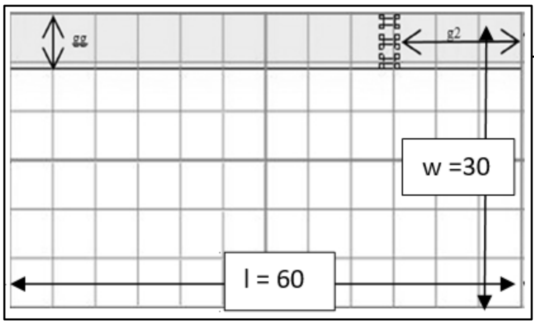

Figure 1 (c): Partial ground with DGS

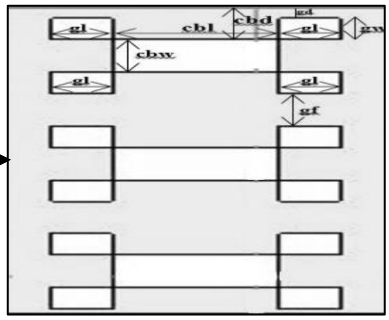

Figure 1 (d): Magnified View of DGS

designed by taking a Fractal shape into consideration as shown in figure 1d).

PARAMETER	VALUE	PARAMETER	VALUE

L	60	wf1	1.4
W	30	wf1l	11
hg=hp	0.035	wf1w	13.8
Hs	1.53	wf2	3
Gx	1	wf2l	15
es2	3	wf2w	13
Gg	5.7	wf3	1.4
Wg	1.4	wf3l	26
Gl	0.5	Cbl	1.4
Gw	0.4	Cbw	1.4
Gd	0.2	Cbd	0.6
g2	14.3	Gf	0.5

Table 1: Design Parameters

3. Design Equations:

The designing equations required for the designing of PIFA antenna is given below.

1. Designing equations for conventional micro strip patch antenna [1]:

a. Patch width (w):

$$W = \frac{C}{2f_o}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

b. Effective Dielectric constant (ε_{reff}):

$$\varepsilon reff = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\,\frac{h}{W}\right)^{-\frac{1}{2}}$$

c. Calculation of actual patch length:

$$L = L_{eff} - 2\Delta L$$

Where,

i) Effective length (L_{eff}):

$$L_{eff} = \frac{C}{2f_o\sqrt{\epsilon_{reff}}}$$

ii) Calculation of length extension:

$$\Delta L = \frac{(\varepsilon reff + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon reff - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

2. Designing equations for conventional Micro strip PIFA antenna [3]:

a. Centre Frequency(fc) in vacuum:

$$f_c = \frac{C}{4\,(W + L_p)}$$

b. Resonating Frequency(f_r) in other medium:

$$f_r = \frac{c}{4(\ W + L_p)\sqrt{\varepsilon_r}}$$

4.Simulation Results

4.1.Return Loss, S11:

The amount of signal reflected towards source when it is radiated is determined by S-Parameters. The conventional PIFA antenna radiates at 1.725GHz, 2.412GHz, 4.788GHz and attains a return loss of - 10.308 dB, -17.327dB and - 9.8658dB respectively. Since very less return loss is obtained in this PIFA antenna, the antenna is modified using Meandered line structure to the feed as shown in Fig. 1 (b) to obtain a good return loss when compared with PIFA antenna with inset feed. The antenna radiated at 1.725GHz, 2.412GHz and 4.788GHz with a return loss of -12.609dB, -32.74dB and -25.871dB respectively.

For an enhancement of return loss to the Meandered PIFA antenna the ground is defected using DGS fractal structure as shown in fig. 1c). The antenna radiated at 1.725GHz, 2.412GHz and 4.788GHz with a return loss of -12.976dB, -39.665dB and -39.191dB respectively. The below figure (2) determines the Return loss of 3 designed antennas where the proposed Meandered with DGS antenna obtained efficient return loss. The proposed antenna achieved an efficient bandwidth of 180MHz radiates at 1.725GHz, 378.8MHz radiates at 2.412GHz and 912.9MHz radiates at 4.788GHz

4.2.VSWR:

The amount of signal reflected towards source due to mismatch while its radiated is also good which attained less than 2. In the designed antenna the obtained VSWR at 1.725GHz, 2.478 GHz, 5.1 GHz are 1.8785, 1.1369and

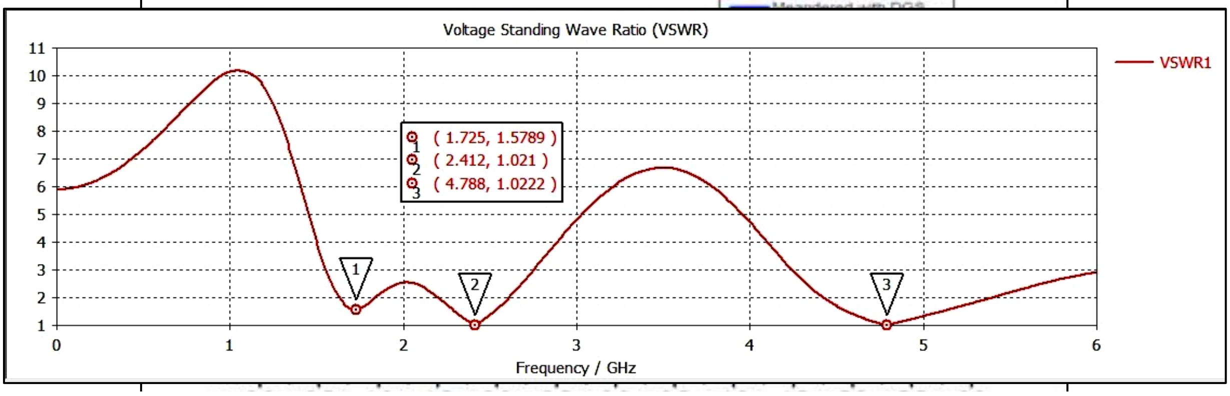

Figure 3: Voltage Standing Wave Ratio

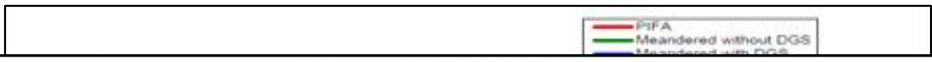

Figure 2: Return Loss

1.4536 respectively. The figure-3 below displays VSWR of the meandered feed PIFA with DGS.

4.2.Gain:

The gain is related as the ratio of amount of Maximum intensity radiated from antenna to the maximum radiation intensity from test antenna. The designed MEANDERED PIFA with DGS obtained better gain when compared with previous design. The gain obtained by the antenna is 1.74dB at 1.725GHz, 1.53dB at 2.412GHz and 3.49dB at 4.788GHz.

The analysis of Gain vs Frequency at different frequencies were conducted where the antenna obtained an efficient gain with Defective Grounded Meandered PIFA Antenna as shown in below figure 4.

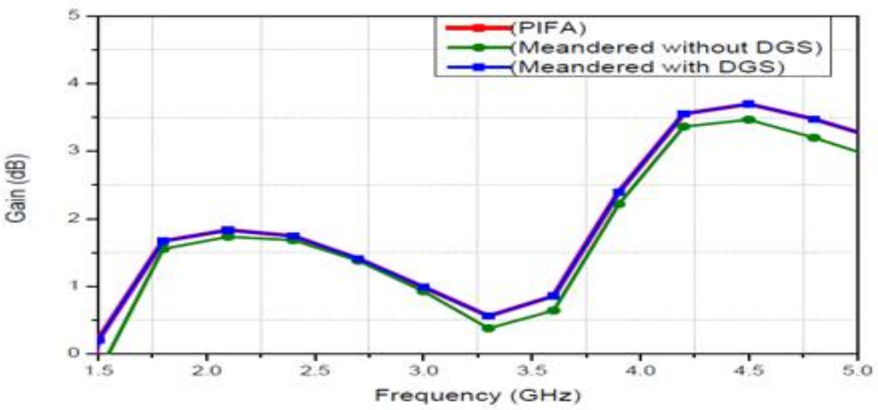

Figure 4: Gain vs Frequency

4.4.Directivity:

Directivity determines the Ratio of radiated intensity in particular direction to that of average radiated in all directions. The designed antenna obtained efficient directivity when compared with reference model at three frequencies. The directivity of the antenna is more than gain which should be the main criteria while designing the antenna. The antenna obtained a directivity of 2.07dBi at 1.725GHz, 2dBi at 2.412GHz, 5.32dBi at 4.788GHz respectively.The below figures 5 (a), 5 (b) and 5 (c) determines the Directivity at individual frequencies.

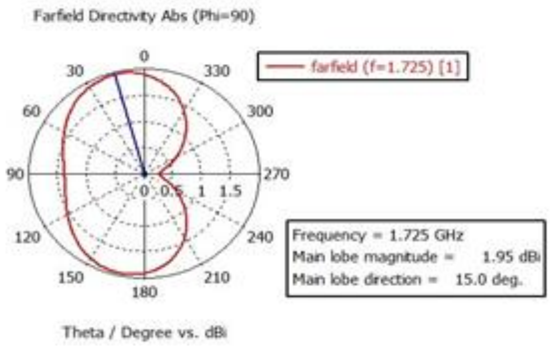

Figure 5(a): Directivity at 1.725GHz

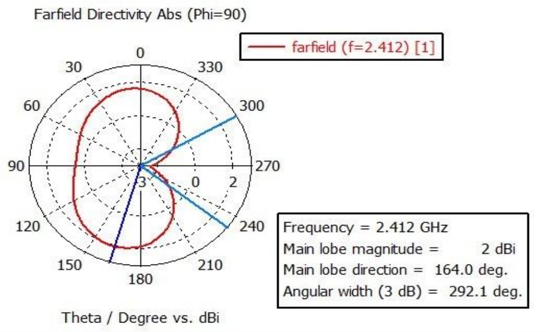

Figure 5(b): Directivity at 2.412 GHz

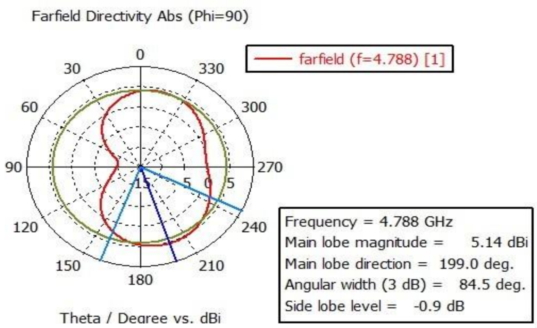

Figure 5 (c): Directivity at 4.788GHz

4.5.Surface Current Distribution:

Surface current determines the flow of current at particular frequency on a metal surface. The designed antenna obtained efficient current distribution over the antenna at desired frequencies. The figure 6 a), b) and c determines the current distributed at particular frequencies as shown in below figures. At frequency 1.725 GHz, current is distributed more at shorted arm, meandered structure and along the surface of the ground plane. Similarly, at 2.412 GHz, current distribution is more at short arm, meandered arm and also on the surface of the other arm of PIFA Antenna in addition to current distribution over the surface of the ground plane. But the current distribution over the surface of the ground plane is less at a frequency of 2.412 GHz when compared to the frequency at 1.725 GHZ. It can be observed clearly from figure 6(a) and 6(b). The current distribution at a frequency of 4.788 GHz, the current is mostly distributed over the feeding arm and shorting arm as shown I figure 6 (c).

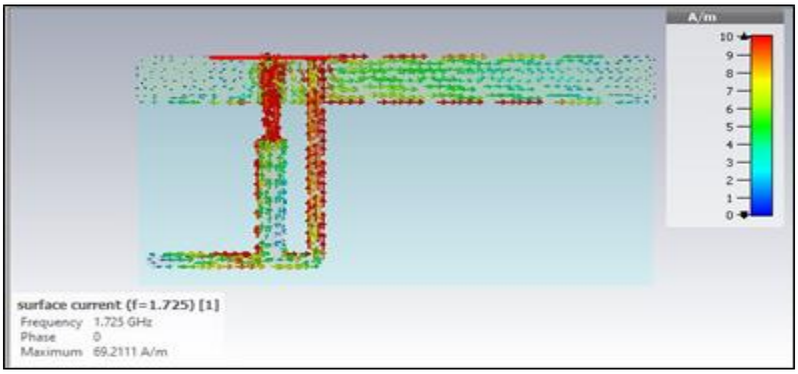

Figure 6 (a): Current distribution at 1.725GHz

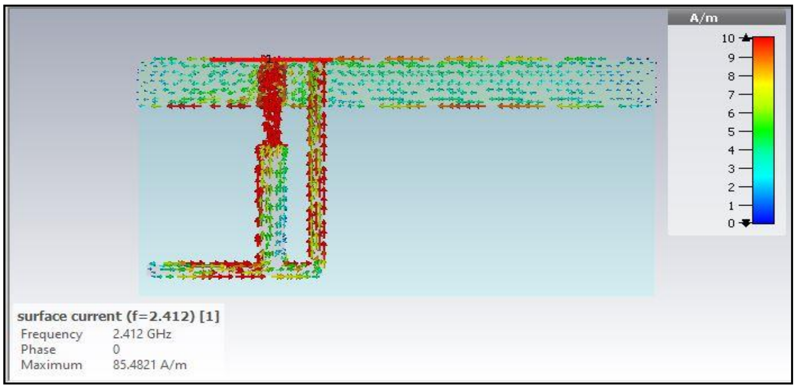

Figure 6 (b): Current distribution at 2.412GHz

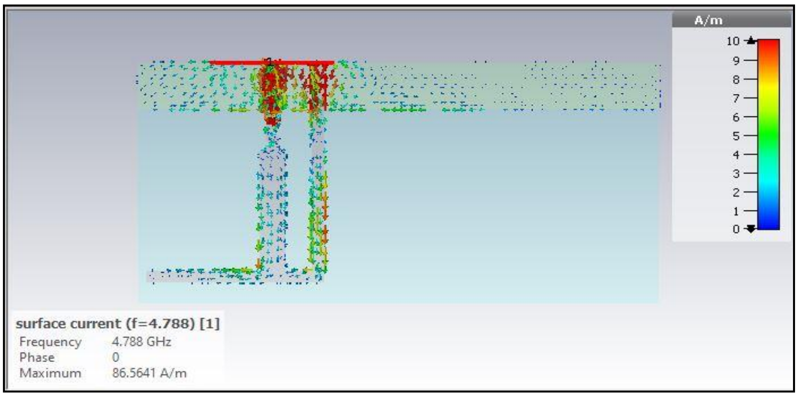

Figure 6 (c): Current distribution at 4.788GHz

The below table-2 determines the performance of Meandered PIFA along with DGS in terms of radiation parameters with respective to return loss, VSWR, Gain and Directivity at multiple frequencies of proposed design. The proposed design is resonating at three different frequencies at 1.725 GHz, 2.412 GHz and 4.788 GHz. The proposed antenna is having Voltage standing wave ratio of 1.578, 1.021 and 1.022 at frequencies of 1.725 GHz, 2.412 GHz and 4.788 GHz respectively. This antenna is having a maximum gain of 5.32 dBi at 4.788 GHz when compared to other frequencies. The bandwidth offered by this antenna is about 18% improvement at 4.788 GHz with a bandwidth of 912MHz, suitable for WLAN. As the bandwidth offered at this frequency is more which the main criterion for 5G applications is. The bandwidth offered at 2.412 GHz is about 378 MHz which suits for Bluetooth, LTE -U (2.4 to 2.4835 GHz), WCS - 2300, IMT – E 2600 (FDD) applications. At lower band of resonant frequency at 1.725 GHz, it is providing a bandwidth of 180 MHz, suitable for DCS – 1800 applications.

S. No	Resonant Frequency (GHz)	VSWR	Gain (dB)	Directivity (dBi)	Higher frequency (GHz)	Lower frequency (GHz)	Band Width (MHz)
1.	1.725	1.578	1.53	2.07	1.8205	1.6399	180
2.	2.412	1.021	1.74	2	2.5944	2.2156	378
3.	4.788	1.022	3.49	5.32	5.3529	4.44	912

Table No. 2: Performance of Meandered PIFA along with DGS

The below table-3 determines the comparison between the conventional PIFA antenna, PIFA antenna with meandered line feed and PIFA antenna with meandered feed and DGS in terms of radiation parameters. From the table, it is found that the proposed antenna provides 18% of enhancement in bandwidth at 4.788GHz frequency which is suitable for 5G applications. The bandwidth is calculated at -10dB return loss which covers multiple application frequency bands. The proposed design is providing more gain and bandwidth when compared to other two designs. Therefore, the proposed design is more suitable for many applications related to wireless applications.

S. No	Frequency (GHz)	Conventional PIFA Antenna				MEANDERED PIFA Antenna				MEANDERED PIFA WITH DGS			
		PARAMETERS				PARAMETERS				PARAMETERS			
		S11 (dB)	VSWR	Gain (dB)	Band width at -10dB (MHz)	S11 (dB)	VSWR	Gain (dB)	Band width at -10dB (MHz)	S11 (dB)	VSWR	Gain (dB)	Band width at -10dB (MHz)
1	1.725	10.31	1.878	1.4	67.9	12.61	1.611	1.37	177	12.976	1.5789	1.53	180
2	2.412	17.327	1.3149	1.65	357.1	32.74	1.0473	1.68	377	39.665	1.021	1.74	378
3	4.788	9.8658	1.9462	3.29	681	25.817	1.1084	3.21	875	39.191	1.0222	3.49	912

5.Conclusion

The designed Meander feed PIFA antenna with DGS obtained efficient results to work at multiple frequencies for GSM 1800, WLAN, WCS - 2300, IMT – E 2600, LTE -U, DCS and also for 5G applications in addition to L, S and C band applications. The proposed antenna has 18% of improvement in bandwidth at 4.788 GHZ, is the main consideration for 5G applications with a compact size. Gain provided by the proposed antenna at all the desired frequencies is also more compared to all other considered designs. Hence the proposed design is more suitable for many applications related to wireless applications.

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