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Linearly Polarized Wideband Meandered Pifa Antenna For Mobile Applications

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Abstract

Generally, 6 to 7 patch antennas are used in a mobile for different applications. In this paper, a single antenna is proposed to address several applications in a mobile phone. For this purpose, a Meander line feed planar inverted F- antenna (PIFA) with DGS that radiates at multiple frequencies is deliberated in this work with VSWR < 2 at all the desired frequencies as it provides good isolation among the desired frequencies. Flame Retardant 4(FR - 4) is preferred as substrate(loss tangent,δ(0.02)) with thickness of 1.53mm.The ground defected structure resembles as slotted sections with fractal shape. The proposed antenna is radiated at three frequencies such as 1.7GHz (1.64 - 1.82 GHz), 2.4GHz (2.2 - 2.6 GHZ) and 4.8GHz (4.44 – 5.35 GHZ) with a reflection coefficient of -12.9dB, -39dB, - 39dB respectively. With the proposed structure the bandwidth is enhanced by 19% at the upper band with a peak gain of 5.32dBi along with the achievement of linear polarization at all the desired frequencies. The proposed design has a compact dimension of 60X30X1.6mm (0.70x0.35x0.018 wavelengths at lower band) and is well suited for 4G,WLAN, WI-FI and Wi-Max applications..

Keywords: Meander line, PIFA, DGS, Fractal, Wide band

1. Introduction

All wireless services must now be bundled into a single device with a variety of features, such as Bluetooth, Wifi, and LTE technologies for high-speed and high-quality data transmission. Antennas that handle several bands must be manufactured with a variety of specifications in order to provide the required functionality. As a result, the goal is to design an antenna that can operate in several bands to accommodate a wide range of applications [1,2]. An antenna must have a wideband, good radiation performance and enhanced gain as a front component. Patch antennas have a narrow bandwidth, poor gain, and low power handling capacity. Improvements to the antenna's performance have been attempted. Finally, the Planar Inverted F antenna (PIFA) was proposed, along with several approaches for multiband operations in mobile applications with improved performance [3,4]. Compactness, low side lobes, low profile, and ease of integration are among advantages of a PIFA antenna along with good Specific Absorption Rates (SAR) [22,25]. PIFA is still one of the most used antennas in today's mobile phones. Several methods were proposed and one of the methods to design PIFA is to print antenna directly on a substrate [5-7] without using any gap between the ground and antenna.

Furthermore, in order to attain the desired configuration, several design characteristics must be properly tweaked or optimized. Various strategies, such as changing the shape of the patch, have been proposed to obtain multi-band operations [8,11,23,24,25], meandering technique [9] and slotted structure in the ground [14]. Ground slots with open-circuited arms generate new resonances, whereas those with short-circuited arms serve as tuning stubs [14]. One of the strategies for improving the bandwidth and gain of a patch antenna, as well as controlling the propagation of Electro Magnetic Waves, is to utilize a Defective Grounding Structure (DGS) [10,20,21]. Different feeding approaches, such as meander line and micro strip line, have been proposed to improve performance characteristics [7,9,13]. Fractal structure is a geometrical technology that is utilized to lower side lobe levels and angles while also improving directional properties [12]. To generate a linearly polarized three-dimensional antenna, a single metal sheet is cut and suitably bent to reduce production processes necessary for soldering, assembling, and mounting the antenna on the PCB [15]. For many different applications, linearly polarized antennas have been proposed [15,19]. Broadband circular polarized PIFA was proposed by using a square patch at the ground corner with an arrow-shaped slot as defected ground structure (DGS) to provide diversified characteristics.

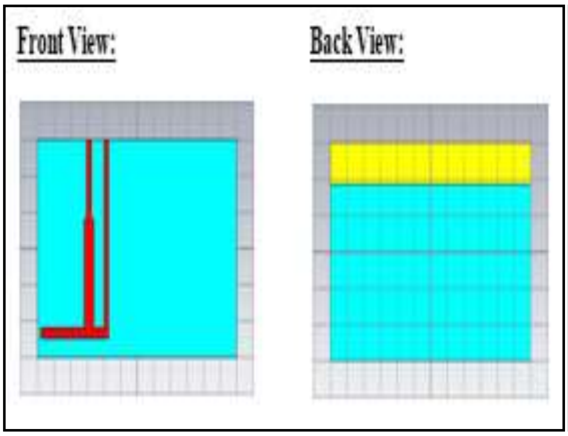
Antenna design has become a significant difficulty due to the tiny size of cellular phones, their ability to operate at many frequencies, and the necessity to cover multiple applications with adequate bandwidth. Meander line feed with fractal shaped DGS, where irregular fragments or breaks are made to the ground, is presented as a solution to this problem. Fractals, in their most basic form, are made up of many copies of the same fractal shape. In addition to all of these benefits, using the proposed approaches, linear polarization also obtained at all operating bands. The DGS ground plane turned the antenna into a multi-band resonating antenna with improved isolation and wide band characteristics.

In this proposal, initially a basic PIFA structure is designed that results in resonance at three frequencies 1.75GHz, 2.48GHz and 5GHz with a return loss of -10dB, -23dB and -14dB respectively. Later, a meandered feed line structure and DGS is proposed to enhance the return loss as well as bandwidth. The proposed antenna is radiated at three frequencies such as 1.7GHz (1.64 - 1.82 GHz), 2.4GHz (2.2 - 2.6 GHZ) and 4.8GHz (4.44 – 5.35 GHZ) with a reflectioncoefficient of -12.9dB, -39dB, - 39dB respectively.

2. Antenna Design

CST Studio Suite 2018, a high-frequency simulator based on the finite element method, was used to design and simulate the antenna. The antenna is made from a FR-4 substrate with a dielectric constant of (ε_r =4.3), a loss tangent of (=0.02), and a thickness of 1.6 mm, including the copper thickness of 0.035 mm on both sides. The integration of Meandered line with PIFA created a suitable LTE communication band. The Figure 1 shows the PIFA antenna which is taken into consideration. The meandered line PIFA antenna with partial ground is shown in figure- 2. The suggested antenna to have Wide-Multi band characteristics is a Meandered Feed Planar Inverted F Antenna (PIFA) with Defective Ground Structure (DGS) that has various resonances and greater isolation between the frequencies is shown in figure 3. Hence, the designed antenna obtained a multiband response with good isolation between frequencies. Therefore, the methodology used in the designing process of proposed antenna is shown in figures 1, 2 and 3respectively and Table 1 lists the various design parameters of the suggested antenna after optimization.

i) Design Methodology



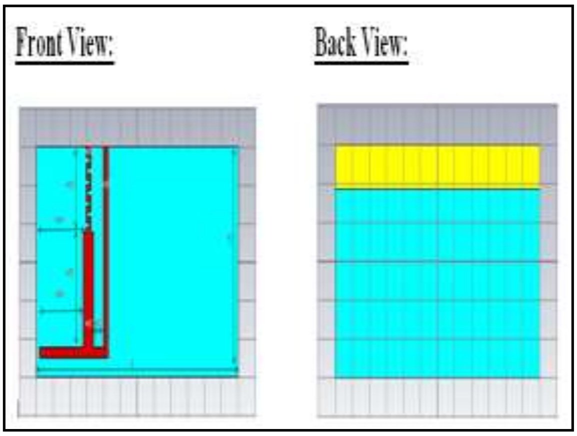


Fig 1: PIFA ANTENNA (Design 1)

Fig 2: MEANDERED PIFA (Design 1)

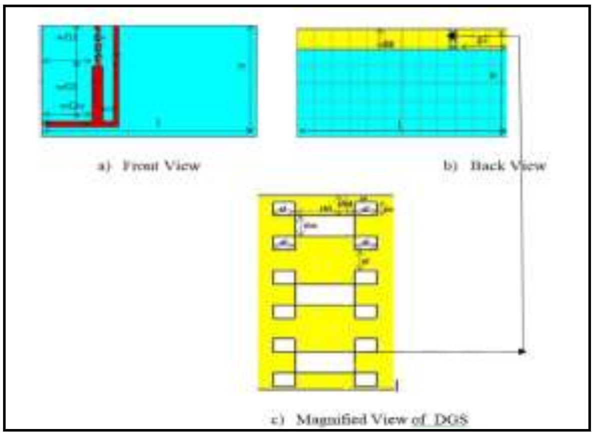


Fig 3: DGS MEANDERED PIFA (Design 3, Proposed)

Table 1: Parameters List

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	0.6
Gd	0.2	Cbd	0.6
g2	14.3	Gf	0.5

ii) DESIGN EQUATIONS

i) Designing equations for conventional micro strip patch antenna:

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:

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

d. Effective length (L_{eff}):

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}}$$

e. Calculation of length extension:

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

i. Designing equations for PIFA antenna:

a. Centre Frequency (fc) (Applicable for Vacuum as Dielectric Medium)

$$f_c = \frac{c}{4(W_p + L_p)}$$

b. Resonating Frequency(fr) (Applicable for other substrate as Dielectric Medium)

$$fr = \frac{c}{4(L_p + W_p)\sqrt{\varepsilon_r}}$$

3. Simulation S Results

The performance of the proposed design is analyzed using a variety of parameters, which are all detailed in this section.

a) Return loss (S parameters) :

Figures 5, 6, and 7 show the S-Parameters results of the PIFA antenna, the Meandered PIFA antenna, and the combined results of the three designs, respectively. The antenna radiates at three frequencies: 1.75GHz, 2.48GHz, and 5GHz, with return losses of -10dB, -23dB, and -14dB, respectively, in the basic PIFA construction. In the Meandered PIFA antenna, good return loss is observed at -12.609dB, -32.74dB and -25.817dB at 1.725GHz, 2.412GHz and 4.78GHz as shown in figure- 5. Later, a DGS structure is proposed in addition to meandered PIFA to enhance the return loss as well as bandwidth. The proposed antenna is radiated at three frequencies such as 1.7GHz (1.64 - 1.82 GHz), 2.4GHz (2.2 - 2.6 GHZ) and 4.8GHz (4.44 – 5.35 GHZ) with a reflectioncoefficient of -12.9dB, -39dB, - 39dB respectively.

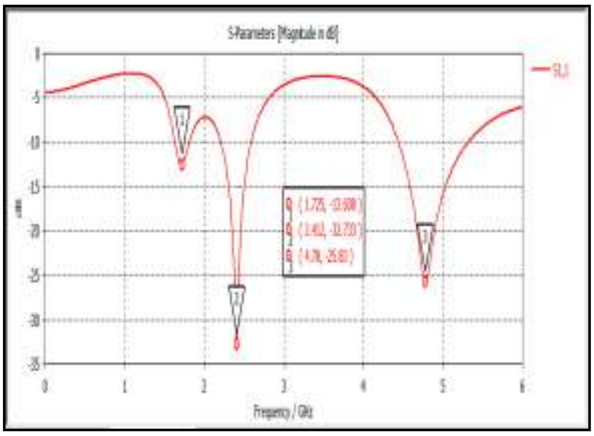


Fig 5: S-PARAMETERS of MEANDERED PIFA (MPIFA)

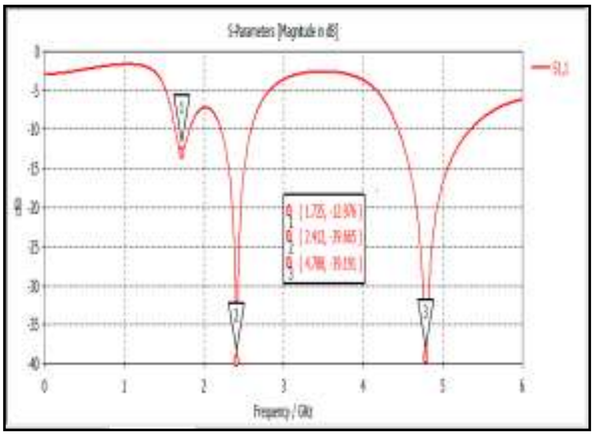


Fig 6: S-PARAMETERS of MPIFA with DGS

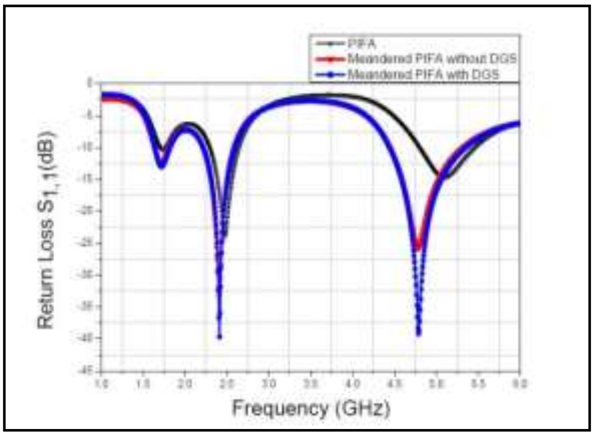


Fig 7: Return loss of three designs

b) VSWR:

The needed VSWR for mobile phone applications is 3 in order to achieve a return loss of -6dB [17]. Figure 3 shows the VSWR of the suggested antenna, which is less than 2 for all required frequencies, which is a sufficient result for proper frequency isolation.

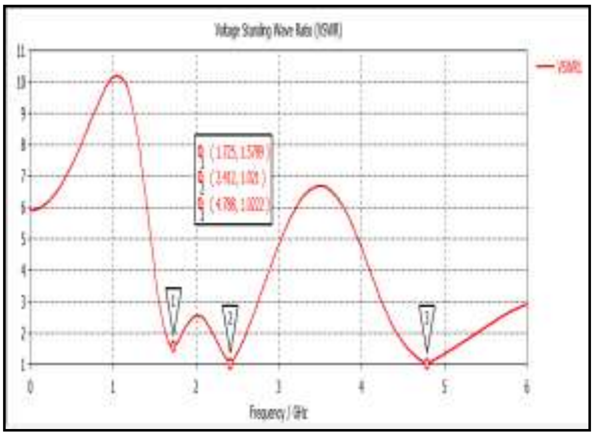


Fig 8: VSWR

c) Surface Current Distribution

Surface current distribution determines the flow of current at particular frequency on a metal patch. Figures 9,10,11 depicts the antenna current distributions at the relevant frequencies. At lower band of 1.725GHz, the current is distributed mainly over the two arms of PIFA and DGS, at 2.4 GHz, the current is distributed mainly on the PIFA structure and at the band of 4.78 GHz, the current is distributed mainly over the meandered feed structure of PIFA.

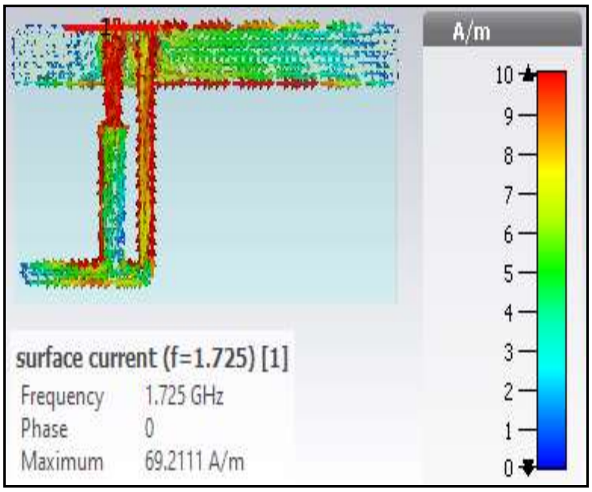


Fig 9: Surface current at 1.725GHz

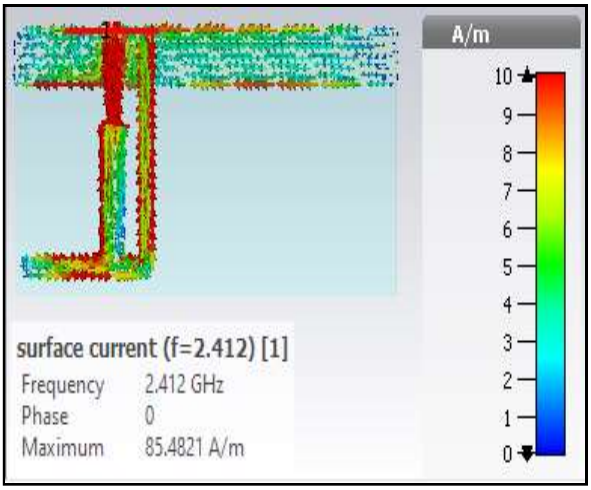


Fig 10: Surface current at 2.412GHz

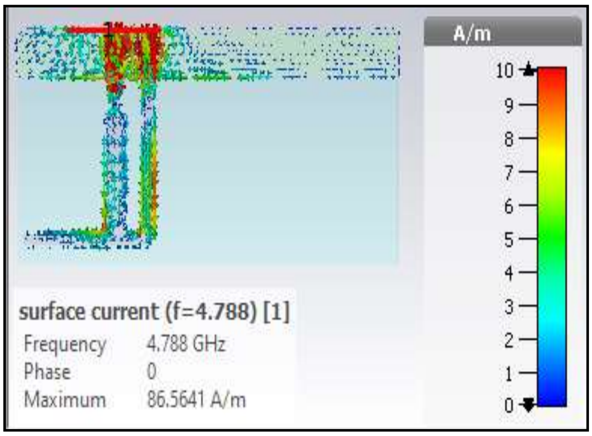


Fig 11: Surface current at 4.788GHz

d) GAIN:

Antenna gain refers to the amount of signal a given antenna can emit or receive in a given direction. Gain is estimated by comparing the antenna's observed power sent or received in a certain direction to the power transmitted or received by a hypothetical ideal antenna in the same situation. The Plots for gain at different frequencies is shown in figures 12,13 and 14.From the simulations, it is observed that the gain at three required frequencies are 1.41 dB, 1.73 dB and 3.31 dB at 1.725GHz, 2.412GHz and 4.78GHz respectively and gain verses frequency in a normal scale at all the desired frequencies is shown in figure 15.

Fig 14: GAIN AT 4.788 GHz

Fig 15: GAIN verses FREQUENCY

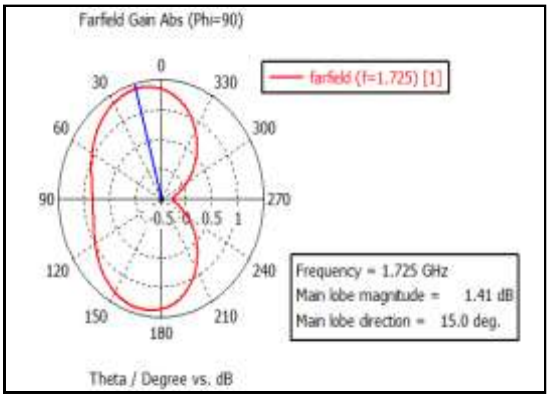


Fig 12: GAIN AT 1.725GHz

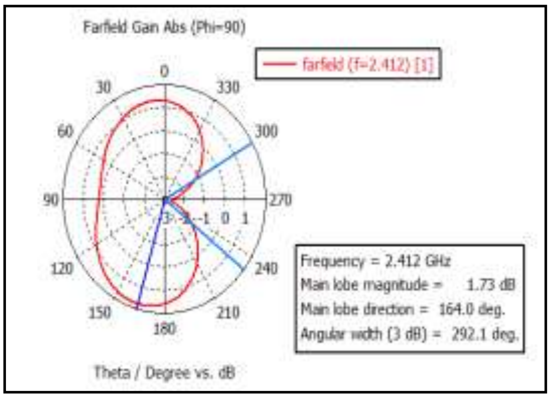


Fig 13: GAIN AT 2.412GHz

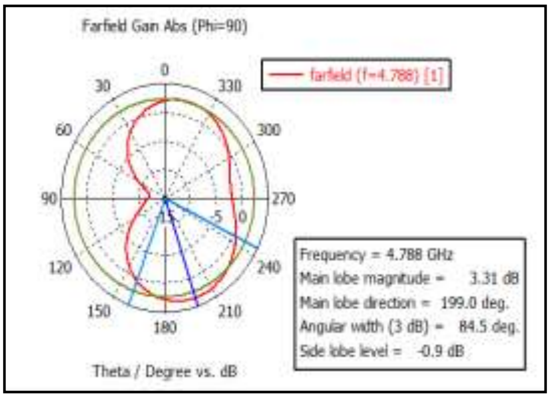


Fig 14: Gain at 4.78GHz

e) Directivity

The directivity of an antenna is a measure of its radiation pattern's concentration in a particular direction. It is measured in decibels (dB). As an antenna's directivity improves, the beam it emits becomes more focused. As a result of a higher directivity, the beam travels further. The directivities of the proposed configuration is shown in figures 15, 16 and 17. From the simulation results, its valve is observed to be at 2.07dBi at 1.725GHz, 2dBi at 2.412GHz, 5.32dBi at 4.788GHz. The maximum directivity occurs at 4.788 GHz.

f) Axial Ratio (AR)

The type of polarization from the antenna basics is determined by this parameter. For the proposed antenna, from the simulation results these values are found to be 40 dB at 1.725GHz, 26.25 dB at 2.412GHz, 3.96dB at 4.788 GHz. This value is observed to be positive at all the desired frequencies which makes it to be a linearly polarized antenna. Moreover, the value of this AR maximum is 40 dB and reduced to 3.96 dB at 4.788 GHz which is due to the presence of meander arm in the design. This can be observed clearly from current distributions of proposed structure. According to simulation results, the suggested antenna has axial ratios of 40 dB at 1.725GHz, 26.25 dB at 2.412GHz, and 3.96 dB at 4.788 GHz. This result is positive at all target frequencies, indicating that it is a linearly polarized antenna. Furthermore, the maximum of AR, 40 dB at 1.725 GHz is reduced to 3.96 dB at 4.788 GHz which is due to the inclusion of a meander arm in the design. The current distributions of proposed structure are clearly demonstrated from figures 18, 19 and 20.

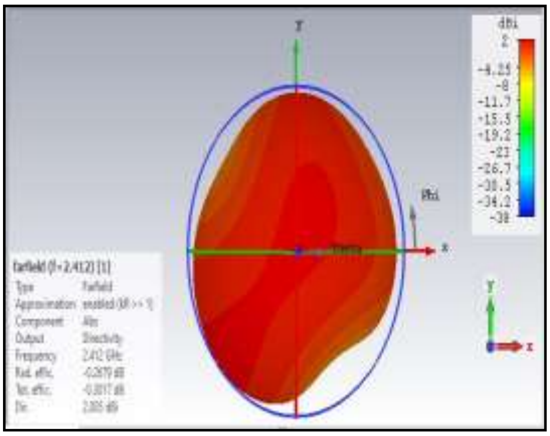


Fig 15: DIRETIVITY AT 1.725 GHz

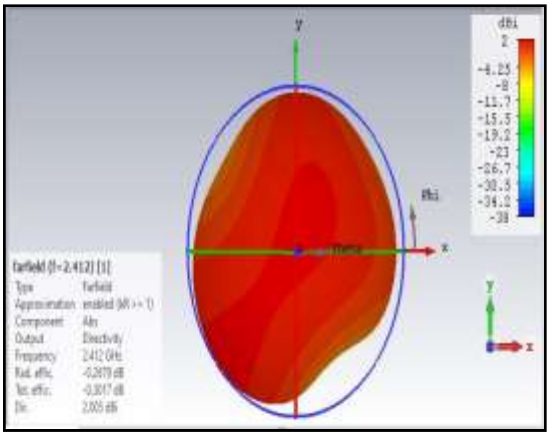


Fig 16: DIRETIVITY AT 2.412 GHz

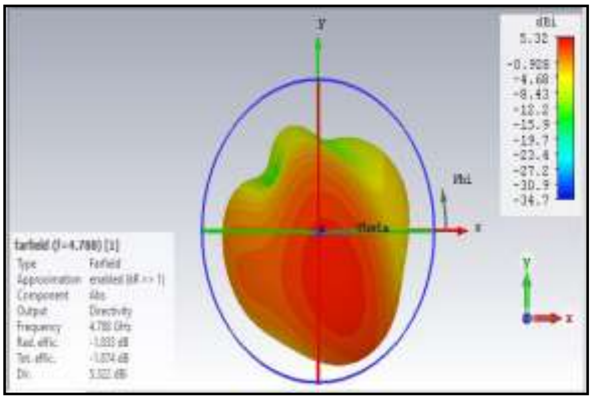


Fig 17: DIRETIVITY AT 4.788 GHz

This antenna provides a 19 percent increase in bandwidth at 4.788 GHz, with a bandwidth of 912MHz, which is adequate for WLAN. Because the bandwidth available at this frequency is higher, it is a key criterion for 5G applications. At 2.412 GHz, the bandwidth available is approximately 378 MHz, which is suitable for Bluetooth, LTE-U (2.4 to 2.4835 GHz), WCS – 2300, and IMT – E 2600 (FDD) applications and it has a bandwidth of 180 MHz in the lower band of resonant frequency at 1.725 GHz, which is ideal for DCS – 1800 applications. Hence, multi bands are provided by this proposed antenna with wideband characteristics applicable for mobile phone applications with linear polarization. Table 2 shows the performance of the three different configurations where as the table 3 depicts the different parameter characteristics of the proposed structure.

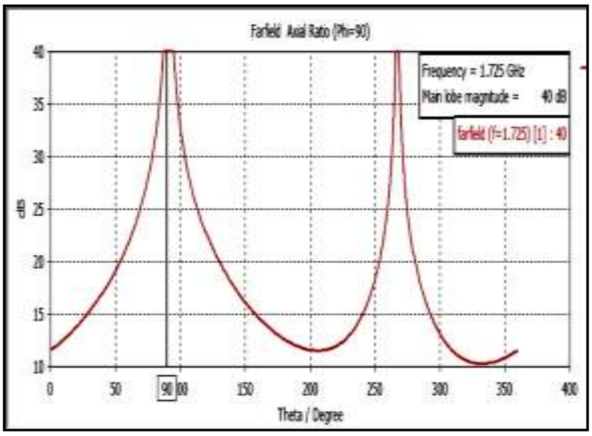


Fig 18: Axial Ratio at 1.725 GHz

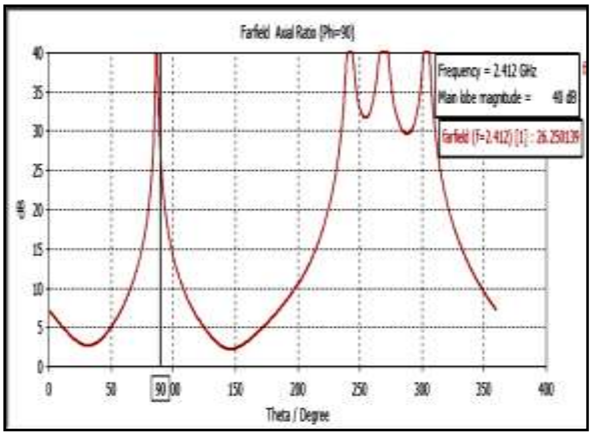


Fig 19: Axial Ratio at 2.412 GHz

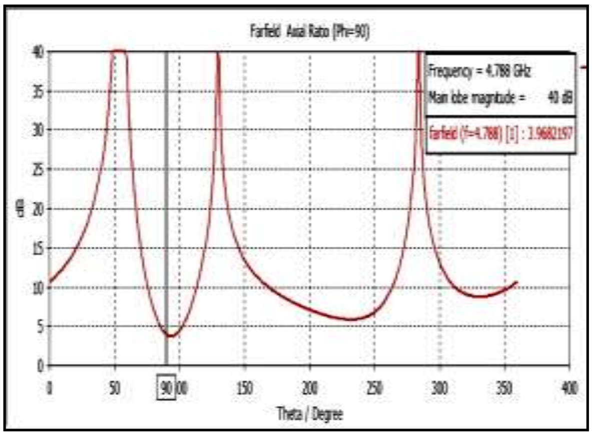


Fig 20: Axial Ratio at 4.788GHz

Table 2: Performance analysis of three configurations

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	10.3	1.88	1.4	67.9	12.61	1.611	1.37	177	12.97	1.58	1.53	180
2	2.412	17.3	1.31	1.65	357.1	32.74	1.0473	1.68	377	39.66	1.02	1.74	378
3	4.788	9.86	1.95	3.29	681	25.81	1.1084	3.21	875	39.19	1.02	3.49	912

Table 3: Performance of proposed configuration

S. No	Resonant Frequency (GHz)	VSWR	Gain (dB)	Directivity (dBi)	Higher frequency (GHz)	Lower frequency (GHz)	Band Width (MHz) at -10 dB	Axial Ratio(dB)
1.	1.725	1.578	1.41	2.07	1.8205	1.6399	180	40
2.	2.412	1.021	1.73	2	2.5944	2.2156	378	26.25
3.	4.788	1.022	3.31	5.32	5.3529	4.44	912	3.96

4 Conclusion

Instead of employing 6 to 7 antennas in a mobile phone, each addressing one band for a distinct application, it is possible to cover all of these bands with a single antenna in a mobile phone where space is limited and it is a challenge. This work overcomes this challenge by suggesting a PIFA antenna with the help of Meandering and DGS. The proposed configuration resonates at three bands at 1.7GHz (1.64 - 1.82 GHz), 2.4GHz (2.2 - 2.6 GHZ) and 4.8GHz (4.44 – 5.35 GHZ) with a reflection coefficient of -12.9dB, -39dB, - 39dB, VSWR < 2 at all the desired frequencies, 1.41 dB, 1.73 dB and 3.31 dB at 1.725GHz, 2.412GHz and 4.78GHz respectively as Gain, 2.07dBi at 1.725GHz, 2dBi at 2.412GHz, 5.32dBi at 4.788GHz as directional characteristics, 40 dB at 1.725GHz, 26.25 dB at 2.412GHz as axial ratio. The bandwidth is enhanced by 19% at the upper band and this can be used to cover different applications like WLAN, Bluetooth, LTE-U (2.4 to 2.4835 GHz), WCS – 2300, and IMT – E 2600 (FDD), DCS – 1800 and supports for 5G applications.

References

[1] Guo, Yong-Xin, Irene Ang, and M. Y. W. Chia. "Compact internal multiband antennas for mobile handsets." IEEE Antennas and Wireless Propagation Letters 2 (2003): 143-146.

[2] Deng, Sheng-Ming, Ching-Long Tsai, Jiun-Peng Gu, Kwong-Kau Tiong, and Kuo-Wei Liu. "A novel design of LTE smart mobile antenna with multiband operation." Progress In Electromagnetics Research C 42 (2013): 109-124.

[3] Razali, Ahmad R., and Marek E. Bialkowski. "Dual-band slim inverted-F antenna with enhanced operational bandwidth." Microwave and Optical Technology Letters 54, no. 3 (2012): 684-689.

[4] Zhao, Guo-Huang, An-Guo Wang, Wen Leng, Bin Chen, and Hua Chen. "Wideband internal antenna with coupled feeding for 4G mobile phone." Microwave and Optical Technology Letters 55, no. 3 (2013): 513-516.

[5] Naser-Moghadasi, Mohammad, Zahra Mansouri, Sachin Sharma, Ferdows B. Zarrabi, and Bal S. Virdee. "Low SAR PIFA antenna for wideband applications." IETE Journal of Research 62, no. 5 (2016): 564-570.

[6] Naser, Ahmed A., Khalil H. Sayidmarie, and Jabir S. Aziz. "Design and implementation of a PIFA antenna for multi-band LTE handset applications." In 2016 Loughborough Antennas & Propagation Conference (LAPC), pp. 1-5. IEEE, 2016.

[7] Naser, Ahmed A., Khalil H. Sayidmarie, and Jabir S. Aziz. "A meandered line-PIFA antenna for LTE (Band-Class-13) handset applications." In 2015 Loughborough Antennas & Propagation Conference (LAPC), pp. 1-5. IEEE, 2015.

[8] El Halaoui, Mustapha, Hassan Asselman, Abdelmoumen Kaabal, and Saida Ahyoud. "Design and simulation of a planar inverted-F antenna (PIFA) for Wi-Fi and LTE Applications." International Journal of Innovation and Applied Studies 9, no. 3 (2014): 1048.

[9] Verma, Akhilesh, Deepak Punetha, and Diwaker Pant. "A novel quad band compact meandered PIFA antenna for GPS, UMTS, WiMAX, HiperLAN/2 applications." In 2015 Second International Conference on Advances in Computing and Communication Engineering, pp. 404-408. IEEE, 2015.

[10] Guha, Debatosh, Sujoy Biswas, and Chandrakanta Kumar. "Printed antenna designs using defected ground structures: a review of fundamentals and state-of-the-art developments." In Forum for Electromagnetic Research Methods and Application Technologies (FERMAT), vol. 2, pp. 1-13. 2014.

[11] Zhang, Yunjing, Dan Wang, Li Zhang, and Mei Song Tong. "A Modified Planar Inverted-F Antenna with Triple-Band for Wi-Fi and LTE Applications." Progress In Electromagnetics Research 73 (2018): 173-181.

[12] Ponnapalli, VA Sankar, and P. V. Y. Jayasree. "Heptagonal fractal antenna array for wireless communications." In Microelectronics, Electromagnetics and Telecommunications, pp. 387- 394. Springer, New Delhi, 2016.

[13] Khola, R. K., and Naveen Kumar Gupta. "Design of multiband microstrip patch antenna for wireless 1 GHz TO 5 GHz band applications with microstrip line feeding technique." Int J Comput Sci Mob Comput 4, no. 6 (2015): 64-69.

[14] Razali, Ahmad R., and Marek E. Bialkowski. "Coplanar inverted-F antenna with open-end ground slots for multiband operation." IEEE Antennas and Wireless Propagation Letters 8 (2009): 1029-1032.

[15] Serra, Andrea Antonio, Paolo Nepa, Giuliano Manara, and Riccardo Massini. "A low-profile linearly polarized 3D PIFA for handheld GPS terminals." IEEE Transactions on Antennas and Propagation 58, no. 4 (2010): 1060-1066.

[16] Agarwal, Mayank, Rajesh Singh, and Manoj Kumar Meshram. "Dual-band linearly polarized planar inverted-f antenna (PIFA) for GPS/WiMAX applications." In 2013 Students Conference on Engineering and Systems (SCES), pp. 1-6. IEEE, 2013.

[17] Su, Saou-Wen. "Linearly-polarized patch PIFA for GPS/GLONASS operation inside a metal back cover tablet." In 2014 International Symposium on Antennas and Propagation Conference Proceedings, pp. 271-272. IEEE, 2014.

[18] Lai, Xiao-Zheng, Ze-Ming Xie, Xuan-Liang Cen, and Zhiyong Zheng. "A novel technique for broadband circular polarized PIFA and diversity PIFA systems." Progress In Electromagnetics Research 142 (2013): 41-55.

[19] Liu, Lingfeng, Xiaonan Wang, and Peng Zhang. "Performance Analysis of Linear Polarization Antenna in 2.45 GHz on Body Communications." International Journal of Applied Engineering Research 12, no. 17 (2017): 6405-6413.

[20] Lin, Ding-Bing, I. Tang, and Ming-Zhang Hong. "A compact quad-band PIFA by tuning the defected ground structure for mobile phones." Progress In Electromagnetics Research 24 (2010): 173-189.

[21] Cabedo, Arnau, Jaume Anguera, Cristina Picher, Miquel Ribó, and Carles Puente. "Multiband handset antenna combining a PIFA, slots, and ground plane modes." IEEE Transactions on Antennas and Propagation 57, no. 9 (2009): 2526-2533.

[22] Sultan, K. S., H. H. Abdullah, E. A. Abdallah, and E. A. Hashish. "Low-SAR, miniaturized printed antenna for mobile, ISM, and WLAN services." IEEE antennas and wireless propagation letters 12 (2013): 1106-1109.

[23] Chang, Chih-Hua, and Kin-Lu Wong. "Printed lambda/8 PIFA for Penta-Band WWAN Operation in the Mobile Phone." IEEE Transactions on Antennas and Propagation 57, no. 5 (2009): 1373-1381.

[24] Kang, Ting-Wei, and Kin-Lu Wong. "Simple small-size coupled-fed uniplanar PIFA for multiband clamshell mobile phone application." Microwave and Optical Technology Letters 51, no. 12 (2009): 2805-2810.

[25] Kusuma, Andi Hakim, Abdel-Fattah Sheta, Ibrahim M. Elshafiey, Zeeshan Siddiqui, Majeed AS Alkanhal, Saeed Aldosari, Saleh A. Alshebeili, and Samir F. Mahmoud. "A new low SAR antenna structure for wireless handset applications." Progress In Electromagnetics Research 112 (2011): 23-40.