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Antenna Design For Fifth Generation (5G) Applications

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Abstract

In this proposed paper, a compact triple band Planer Inverted F-Antenna (PIFA) for 5G applications is presented. Proposed antenna resonate at 17.0GHz (16.74GHz - 17.34GHz), 28.60GHz (28.40GHz-28.88GHz) and 32.5GHz (32.06GHz - 32.92GHz) frequency. And its corresponding 10dB impedance bandwidth are 0.605GHz, 0.48GHz and 0.86GHz. The footprint of antenna is 0.25λg. Gain of the proposed antenna at resonating frequency is -0.22dBi, 1.1dBi and 2.96dBi. The overall size of the antenna is 4.4mm X 4.2mm X 0.8mm.

1. Introduction

With the incessant evolution of technology and exponential escalation in demand make system complex day-to-day. And size of portable wireless communication system play a major role and due to that designing requirement and limitation increases. To handle such problem for current technology and also suitable for upcoming technology, there is need of compact multiband antenna, which is able to work in such complex situations. In order to come across the ever escalating user necessities, there is need to design low profile antenna that can deliver the multi-standard performance in terms of multi-band frequency range. PIFA comes out as a promising candidate in this field. PIFA's are compact antenna that are compatible with printed circuit technology and are now widely used in a range of applications, including hand-held terminals, such as cellular mobile phones and laptops.

The Specific Absorption Rate (SAR) in PIFA is very low as compared to other conventional planar antennas thereby reducing undesirable effects of electromagnetic radiation. PIFA provides good radiation pattern and moderate gain.

For the 5G application, number of papers are available in literature [1-2], covering high frequency 28GHz single band PIFA. For dual band resonance at 28GHz and 38GHz for 5G application, papers are also available in literature [3-4]. Using the PIFA antenna, work is also done for GSM band frequency [5-7]. For designing multiple frequency band for GSM application, different type of slots are used in rectangular patch such as meander slot, L-type slot and multiple U-shape for getting multiple resonance and even air spacing is also used for enhancing the antenna performance. For triple band in GSM band [8-9] and for quad band [10] is presented but for triple band and quad band antenna is presented for low frequency but for high frequency triple band antenna is hard to find in literature.

In this paper, a small form factor tri-band PIFA antenna has been proposed. Antenna resonate at 17.0GHz (16.74GHz - 17.34GHz), 28.60GHz (28.40GHz-28.88GHz) and 32.5GHz (32.06GHz - 32.92GHz) frequency. And its corresponding 10dB impedance bandwidth are 0.605GHz, 0.48GHz and 0.86GHz. The proposed antenna designed and simulated using FEM based 3D simulator Ansys HFSS.

2. Antenna Design

Proposed antenna designed on the cost effective FR-4 substrate. Thickness of the substrate is 0.8mm, dielectric constant is 4.4 and tangent loss of the substrate is 0.02. Proposed antenna length and width for step-1 is calculated with the help of equation 1. The operating frequency of PIFA antenna is inversely proportional to the patch length and can be determined approximately by [2]:

$$f_o = \frac{c}{4\,(L_1 + L_2)} \qquad \text{............ (1)}$$

where, c is the speed of light and $c = \frac{c_0}{\sqrt{\varepsilon_r}}$

$c_0 = 3 \times 10^8\ \mathrm{m/s}$

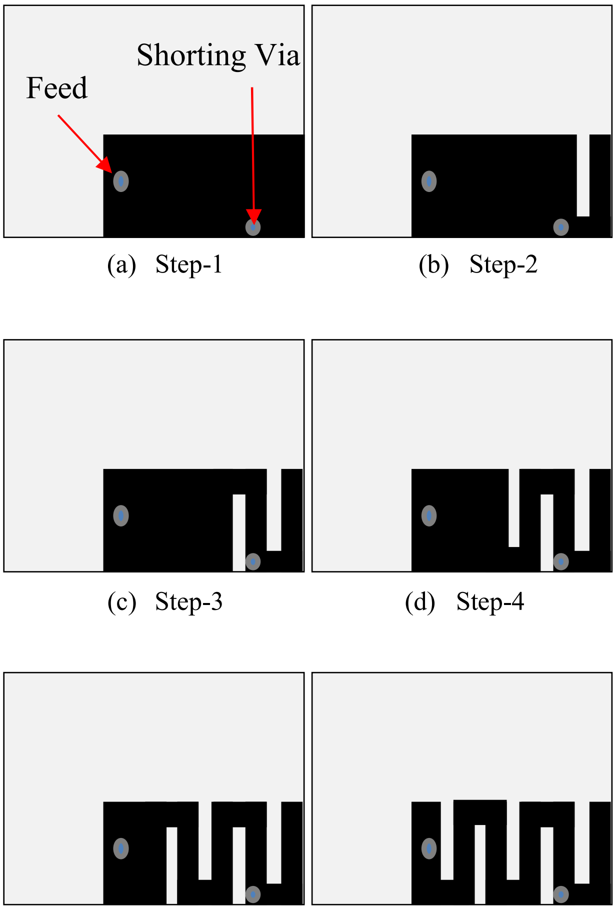
$\varepsilon_r =$ relative permittivity

L_1 and L_2 are the length and width of the radiating element.

f_o is the operating frequency or resonant frequency.

The above equation gives rough approximation of the dimensions required for a PIFA to operate at a desired resonant frequency. After optimization length and width of the patch is 0.8mm and 0.6mm. Overall size of the proposed antenna is 4.4 X 4.2 X 0.8mm^3. Antenna designing steps are shown in figure 1 and 3D view of proposed antenna with dimension is shown in figure 2.

Base design of the structure is rectangular shape and size of the patch is 2.5mm X 1.6mm. With this size antenna resonate at 20.7GHz (20.04GHz - 21.53GHz) and its impedance and fractional percentage bandwidth are 1.49GHz and 7.19%. To shift resonating frequency towards higher frequency side, one way is to reduce the patch size but this way fabrication become more complex and scope for achieving multiband due to change in patch design become more complex.

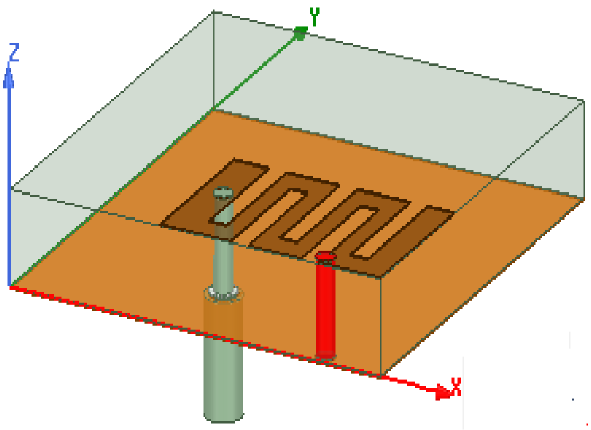


(a) Step-1 (b) Step-2

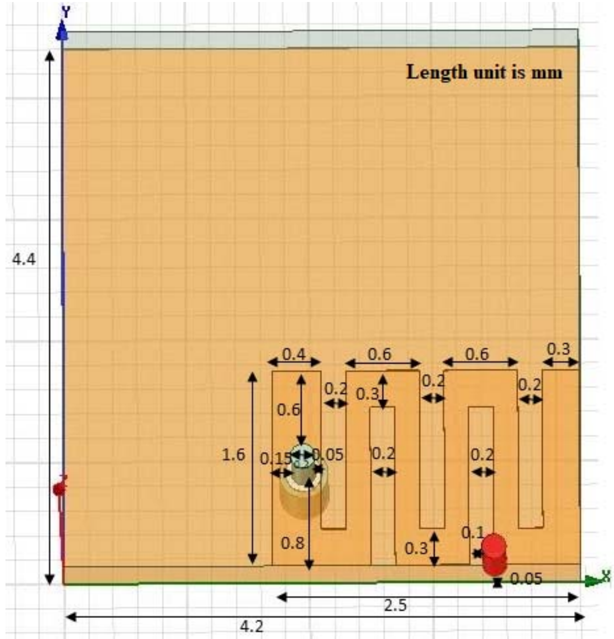
(c) Step-3 (d) Step-4

(e) Step-5 (f) Step-6

Fig.1 Proposed antenna designing steps



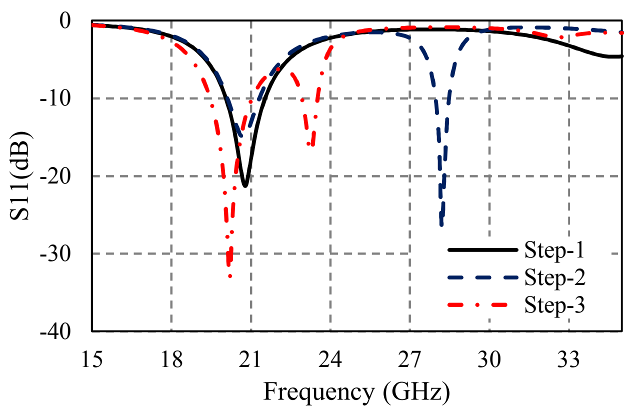
(a)



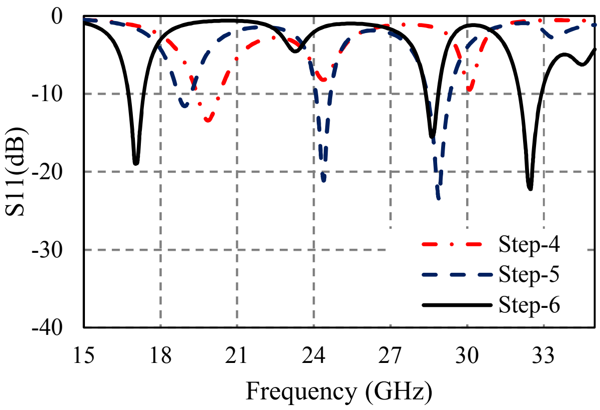
(b)

Fig.2 Proposed antenna design (a) 3D design (b) proposed antenna top view with dimensions

In the next step, one rectangular slot of size 0.2mm X 1.3mm is removed from the patch. Due to that current path on the patch is affected and for lower frequency it show single path because the wave length is much larger than slot width so it do not affect considerably but at higher frequency, slot width come in picture and show significant effect in resonance frequency and due to that antenna show dual resonance at 20.67GHz (20.06GHz - 21.30GHz) and 28.15GHz (27.91GHz - 28.48GHz). Both band impedance bandwidth and fractional percentage bandwidth is 1.24GHz, 5.99% and 0.57GHz, 2.02%. In step-1 and in step-2 lower frequency does not affected significantly and resonate at approximately same frequency. Impedance bandwidth of step-1 to step-3 is shown in figure 3(a) and step-4 to step-6 is shown in figure 3(b).



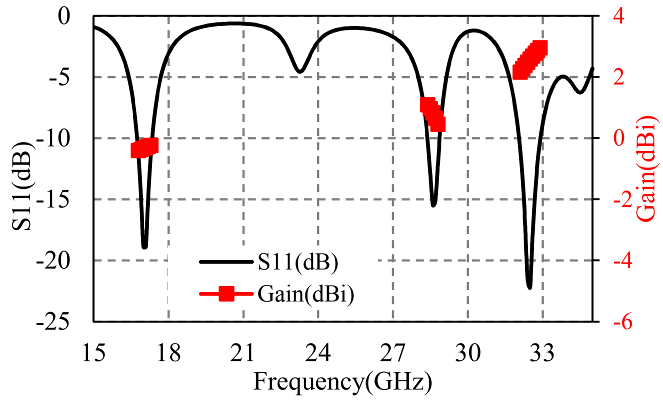
(a)



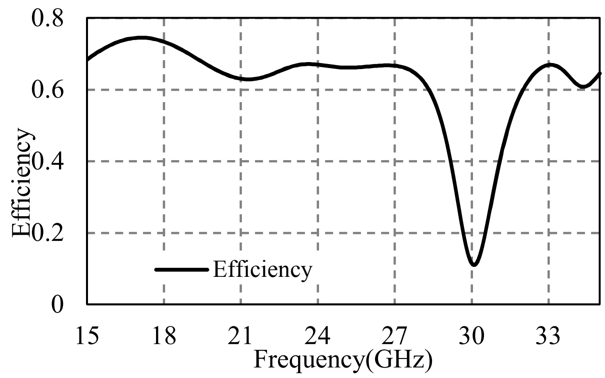
(b)

Fig.3 Impedance bandwidth S11|dB| (a) Step-1 to Step-3 (b) Step-4 to Step-6

In step-3, one more rectangular slot of size 0.2mm X 1.3mm is removed from the patch next to the previous slot in such a way that the electrical path of the current increases and it look like a meander line. Due to increase in the electrical path the higher frequency that resonates at 28.15GHz in step-2 shifted toward the lower frequency side and the path length is considerable small compare to lower frequency wavelength it does not affect lower frequency significantly. Due to second slot in step-3 antenna resonate at 20.19GHz (19.42GHz - 21.06GHz) and 23.24GHz (22.90GHz - 23.50GHz). From step-1 to step-3 we can also observe that by introducing slot in patch we can also increase the number of resonating band and also control the resonating frequency by the size of the slot. In step-4 one more slot of same size is cut down from the patch. Now the number of resonance frequency is increased from two to three but only 19.81GHz resonant frequency show good impedance matching and rest two higher frequency need further optimization for impedance matching. Due to step-4 antenna resonate at 19.81GHz (19.37GHz - 20.30GHz), 24.33GHz and 30.08GHz. Antenna resonating band impedance bandwidth and percentage impedance bandwidth is 0.93GHz and 4.69%. Now from the step-4 slot also show effect on the lower resonant frequency. But this effect is cumulative effect of all three slots that we introduced in the patch in previous steps. In step-5 one more same size slot is introduced in the patch due to that antenna performance is improved and antenna show better impedance matching at all three frequencies. Now after this slot, antenna resonate at 18.88GHz (18.62GHz - 19.18GHz), 24.39GHz (24.04GHz - 24.67GHz) and 28.89GHz (28.39GHz - 29.30GHz). Impedance bandwidth and corresponding percentage fractional bandwidth are 0.56GHz, 2.96%, 0.63GHz, 2.58% and 0.91GHz, 3.14%. Now in final step one more slot of same size is introduced and optimization of feed location and shorting via position is carried out. After number of optimizations, final impedance matching feed location is (1.95, 0.9) and via radius is 0.1mm at location (3.5, 0.15) and is found best suitable for proposed antenna. After step-6 optimization, final proposed antenna resonate at 17.0GHz (16.74GHz - 17.34GHz), 28.60GHz (28.40GHz - 28.88GHz) and 32.5GHz (32.06GHz - 32.92GHz) frequencies. And its corresponding 10dB impedance bandwidth are 0.605GHz, 0.48GHz and 0.86GHz. And percentage fractional bandwidth are 3.55%, 1.67% and 2.64%. For 5G application these band and bandwidth are suitable and can be used in different types of wireless devices. Final proposed antenna impedance bandwidth, gain and efficiency response are shown in figure 4.



(a)

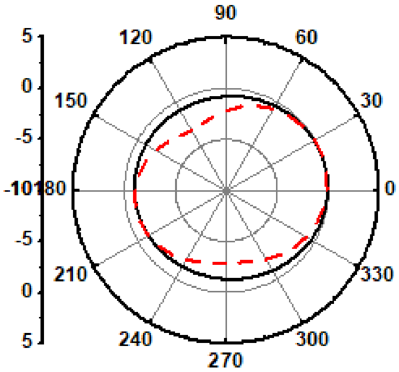


(b)

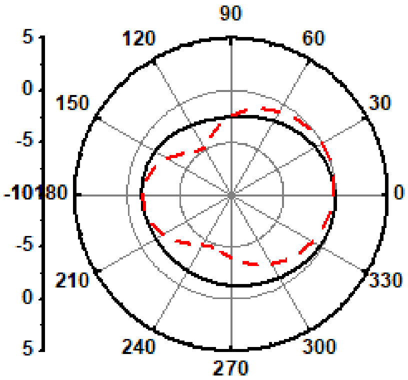
Fig.4 Proposed antenna (a) Impedance bandwidth S11|dB| & Gain (dBi) (b) Efficiency

By increase in number of slot in patch the effective copper is reduced and the size of the patch itself is very small that directly affect the gain of the antenna due to that proposed antenna gain is -0.22dBi, 1.1dBi and 2.96dBi for the corresponding frequency. With increase in frequency, wavelength is decreased and because the wavelength is small the effective copper area in patch is increased and due to that with increase in resonant frequency antenna gain is increased. Efficiency of the antenna for all three resonant frequencies is good and can be observed from the figure 4(b).

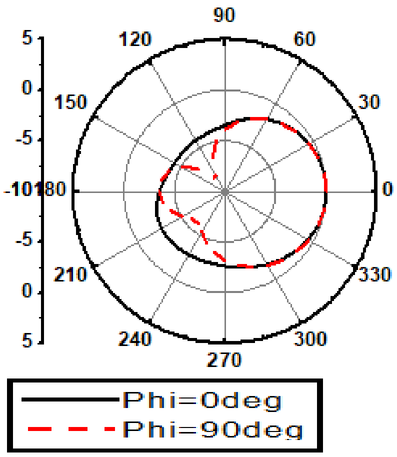
To justify the performance of antenna, radiation pattern in both E-plane and H-plane must show good behavior over the theta angle variation from 0deg to 360deg. Proposed antenna polar plot 2D radiation pattern for all the three resonating frequency is shown in figure 5. In figure 5(a) antenna radiation pattern for E-plane and H-plane at 17.0GHz is shown. Antenna show omni-direction radiation pattern in both the plane. And further, radiation pattern at 28.6GHz and 32.5GHz is shown in figure 5(b) & (c). As the frequency increases small variation and distortion in radiation pattern come in picture and it can be easily observed from the pattern that losses its omni-directional properties and moving towards directional properties.



(a) 17.0GHz



(b) 28.60GHz



(c) 32.5GHz

Fig.5 Proposed antenna radiation pattern at (a) 17.0GHz (b) 28.60GHz (c) 32.5GHz

Pattern of the antenna after small distortion is still in very good shape in term of performance.

3. Acknowledgements

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4. References

1. W. Ahmad, A. Ali, and W. T. Khan, “Small form factor PIFA Antenna Design at 28 GHz for 5G Applications,” presented at 2016 IEEE International Symposium on Antennas and Propagation (APSURSI), Fajardo, PR, 26 June-1 July 2016.

2. H. M. R. Nurul, Z.Mansor and M. K. A. Rahim, “Planar Inverted-F Antenna (PIFA) Design for Millimeter Wave Application,” International Conference on Engineering Technology and Technopreneurship, September 2017.

3. Waleed Ahmad and Wasif Tanveer Khan, “Small Form Factor Dual Band (28/38 GHz) PIFA Antenna for 5G Applications,” presented at 2017 IEEE MTT-S International Conference on Microwaves for Intelligent Mobility (ICMIM), Nagoya, JP, 19-21 March, 2017.

4. Y. A. M. K. Hashem, O. M. Haraz and E. D. M. El-Sayed, “6-Element 28/38 GHz Dual-Band MIMO PIFA for Future 5G Cellular Systems,” presented at 2016 IEEE International Symposium on Antennas and Propagation (APSURSI), Fajardo, PR, 26 June-1 July 2016.

5. Z. D. Liu, P. S. Hall and D. Wake, “Dual frequency planar inverted F antenna,” IEEE Transactions on Antennas and Propagation, vol. 45, no. 10, pp. 1451-1458, October 1997.

6. F. L. Lin and C. W. Chiu, “Compact dual-band PIFA with multi-resonators,” IEE Electronics letters, vol. 38, no. 12, pp. 538-539, June 2002.

7. S. H. Yeh, K. L. Wong, T. W. Chiou and S. T. Fang, “Dual-band planar inverted F antenna for GSM/DCS mobile phones,” IEEE Transactions on Antennas and Propagation, vol. 51, no. 5, pp. 1124-1126, May 2003.

8. C. T. P. Song, P. S. Hall, H. Ghafouri-Shiraz and D. Wake, “Triple band planar inverted F antennas for handheld devices,” Electronics Letters, vol. 36, no. 2, pp. 112-114, January 2000.

9. Y. S. Shin, B. N. Kim, W. I. Kwak and S. O. Park, “GSM/DCS/IMT-2000 triple band built in antenna for wireless terminals,” IEEE Antennas and Wireless Propagation Letters, vol. 3, pp. 104-107, 2004.

10. P. Ciais, R. Staraj, G. Kossiavas and C. Luxey, “Design of an internal quad band antenna for mobile phones,” IEEE Microwave and Wireless Components Letters, vol. 14, no. 4, pp. 148-150, April 2004.