International Journal of Engineering & Technology, 7 (4.5) (2018) 320-323

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper



A Novel Compact MIMO Planar Inverted-F Antenna (PIFA) for Future 5G Wireless Devices

Neha Loharia[1], Shashi B. Rana[2], Naveen Kumar[3*]

[1,2]Guru Nanak Dev University, Punjab, India
[3]Thapar Institute of Engineering & Technolgy (Deemed University), Punjab, India
**Corresponding author E-mail: n.kumar.1987@ieee.org*

Abstract

In the last decade, mobile communication has shown a tremendous growth in various categories of wireless communication. A novel miniature MIMO Planar inverted F Antenna (PIFA) for 5G future communication has been presented in this paper as a MIMO antenna working at 10 GHz band is not available in recent literature. The proposed PIFA has low profile structure with two radiating elements on its opposite edges. The proposed 5G frequency band of 10 GHz is covered by the MIMO antenna. Various antenna & MIMO performance parameters such as isolation, return loss, VSWR, diversity gain, ECC and radiation pattern are also presented and discussed. Simulated and measured results are in good match with each other.

Keywords: *PIFA, 5G, miniature, MIMO, wearable.*

1. Introduction

The antenna designs for 5G future application should be compact in size which is suitable for their use in various wireless devices. The wireless systems for future 5G communication will require number of antenna elements in the devices to support higher throughput and capacity enhancement [1]. Therefore conventional antennas are replaced by compact Planar Inverted F Antennas. Due to multiband properties and compact dimensions, PIFA is the best antenna structure to be used in mobile devices. The PIFA has been devised from Inverted-F Antenna (IFA) as IFA suffered from narrow bandwidth, due to which the wire radiator was replaced by a shorting plane in PIFA. The main advantage of PIFA is improved performance with a compact size [2,3].

This ever growing need for mobile data approaches the limits of 4G technologies. This requirement led to the efforts to work towards next future mobile communication generation i.e. fifth Generation (5G) and define, develop and standardize systems and services for this next generation communication system[1]. Recently studies are going on to design an antenna covering 5G wireless standards. Fifth-generation technology requires various techniques such as advanced MIMO structure, advance small cell technology, Internet of Things (IoT) etc. [4]-[6]. Using 5G technology in future will connect millions of devices and their simultaneous operation will be possible. The human race will become smarter with the rise of smart cities, smart power grids, telemedicine, smart transportation, machine to machine (M2M) communication and these future systems will become a reality due to 5G communication.

Various antenna designs for 5G wireless standards have been proposed in the recent past [7]. For serving the future demands of communication devices Massive MIMO is a promising technology. One of the major challenges in building Massive MIMO systems is the limited size of Base Station and Mobile devices which put a constraint on number of antennas[8]. In [9] a magneto-electric dipole antenna is proposed which use a novel H-shaped tapered ground technique. Due to this technique the antenna height gets reduced significantly. In one of the designs, authors proposed a 3 element single band PIFA antenna system resonating at 28 GHz mmWave band for future 5G wireless communications. The isolation among the PIFA elements is observed to be at -13 dB level [10]. For 5G communication, there are various single element and MIMO antenna designs which have been presented till now by using different antenna structures such as Microstrip patch antenna, Dielectric Resonator Antenna (DRA) or PIFA [7], [10]. In this paper, a novel MIMO antenna design for the 5G wireless standard is discussed that is developed by using PIFA structure with edge feeding mechanism. The design is an extension of single element PIFA from our previously published work [2].

Compared to other conventional antennas, PIFA has numerous benefits such as small & compact structure, multiband behavior, mechanically robust, low cost and reduced absorption rate [5]. PIFA has reduced Specific Absorption Rate (SAR) value; hence lesser radiations are incident towards user's body and head [6]. The proposed antenna covers a wide band of more than 1 GHz by using a shorting stub, edge feeding and truncated radiating patch.

In this paper, a MIMO PIFA is presented for wearable electronics & future 5G wireless devices. The proposed MIMO PIFA has a novel and compact structure with overall dimensions 18mm × 10mm × 3.5mm and covers wide frequency band suitable for future 5G communication. The antenna shows wideband property after introducing a shorting plate and truncated patch. High-Frequency Structure Simulator (HFSS) is utilized for antenna design & analysis.

2. Antenna Structure

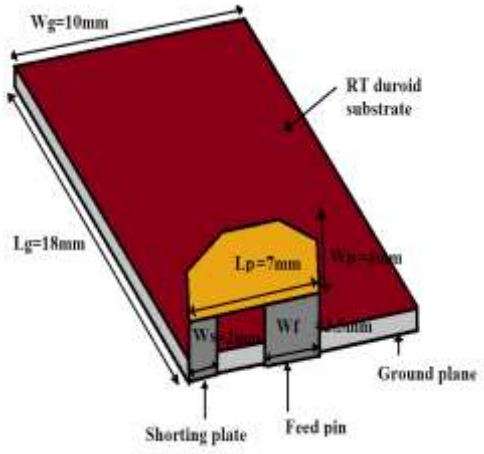
The proposed MIMO PIFA design is shown in Figure 1 which has truncated patch elements which uses edge feeding mechanism. Rogers RT Duroid 5880 substrate material is used for fabrication

Copyright © 2018 Authors. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

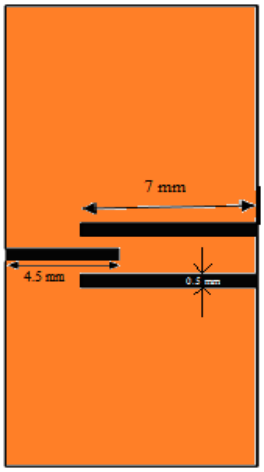
of the proposed MIMO PIFA having dielectric constant (ε_r = 2.2) and thickness (h= 0.8mm). The top radiating patch which has truncated edges to enhance antenna parameters and current distribution. The shorting plate shorts the ground plane and truncated radiating patch. Edge feeding mechanism is used to excite the antenna elements using lumped port with an overall height of 3.5mm.

As compared with the conventional PIFA designs, the top radiating patch is truncated at two adjacent edges while conventional PIFAs uses a rectangular patch. Moreover, the coaxial feed is replaced by a lumped feed, hence making it a different antenna from conventional PIFA design. The detailed dimensions of the proposed MIMO PIFA antenna system are shown in Figure 1 (a) and (b). The ground plane dimensions are Lg = 40 mm and Wg = 10 mm and thickness of the substrate is 0.8 mm. The dimensions of the top patch are Lp = 7 mm, Wp = 4 mm and height of patch is 3.5 mm from the ground plane. The width of shorting plate and feed pin is Ws = 2mm and Wf = 3.5mm respectively. The three slots on the ground plane out of which two are identical and on one side of the substrate while the other one is on opposite side of the substrate. Dimensions of two identical slots are 7 mm x 0.5 mm and the third slot is 4.5 mm x 0.5 mm as shown in Fig. 1 (b).

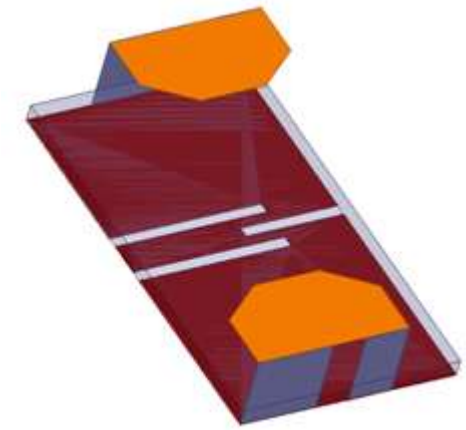
Fig. 1 (c) shows a 3D view of proposed MIMO PIFA showing two antenna elements placed above the ground plane and three open ended slots on the ground plane. To enhance antenna MIMO performance parameters mainly isolation, the ground plane of the antenna is modified by introducing three open ended slots. The rectangular slots in the ground plane consequently manipulate the current distribution. The slots are arranged in such a manner that the isolation between closely placed antenna elements will be below the acceptable level of -15 dB. The slots introduced in the ground plane are in the center of the plane so that they will not affect the resonance behaviour of any of the radiating patch.



(a)



(b)



(c)

Fig.1:. Dimensions of Proposed MIMO PIFA (a) Top view with single element [2] (b) Back View (c) 3D View with Two elements

The final proposed antenna shows a wideband frequency range of 9-11 GHz covering candidate 5G communication standards. Proposed PIFA is fabricated using Rogers RT Duroid 5880 having thickness 0.8mm. For the top radiating patch, a copper sheet of thickness 0.2 mm is used. SMA connector is used to excite the antenna elements. Fabricated antenna prototype is as shown in Figure 2. Figure 2 (a) shows a 3D view of fabricated prototype of proposed MIMO PIFA in which we can observe that the radiating patches are fed by SMA connectors. Before testing the prototype on Vector Network Analyzer (VNA) the calibration needs to be done of both the ports of VNA for desired frequency sweep. After calibrating the VNA, one end of testing cables are connected to the ports of VNA and the other end to the SMA connectors of the antenna. Then S-parameter plots can be observed on VNA display from where we can plot S11, S12 or S21, S22 which will be discussed in the next section.



(a)



(b)

Fig. 2:. (a) Fabricated Proposed MIMO PIFA Antenna (b) Testing Arrangement on VNA

3. Results and Validation

3.1. Return Loss Plot

As shown in Fig. 3, S parameters are obtained after simulation, -10dB return loss level is considered excellent in case of mobile communication. For isolation between the elements, S21 or S12 is observed for which the acceptable value is less than -15 dB.

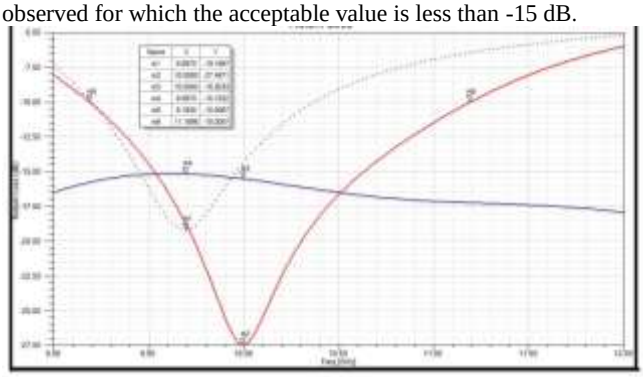


Fig. 3:. Simulated Return Loss Plot of Proposed MIMO PIFA

After the simulation, the two elements of proposed MIMO PIFA shows minimum return loss at 9.69 GHz & 10 GHz with values -19.19 dB & -27.48 dB respectively. After testing the prototype on VNA, the resonance is achieved at 9.80 GHz & 10 GHz showing the return loss of -18.80 dB & -31.50 dB respectively.

As it can be seen from Fig. 4, the measured return loss of one element is minimum at 10 GHz and the second element is at 9.80 GHz. The isolation (S12 or S21) is well below -25 dB at the operating band.

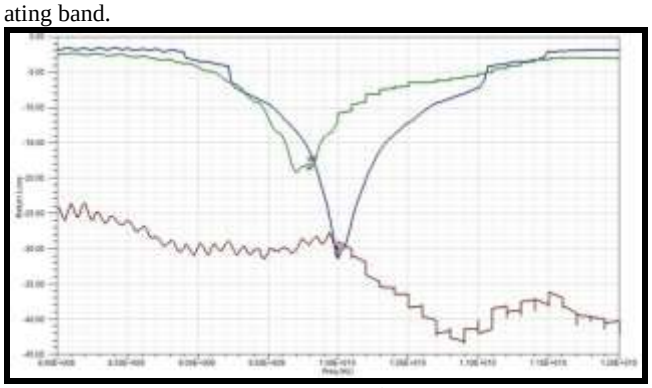


Fig. 4: Measured Return Loss Plot of Proposed MIMO PIFA

3.2. Voltage Standing Wave Ratio (VSWR) Plot

Fig. 5 shows VSWR plot for the proposed MIMO PIFA. The value of VSWR should not exceed 3 dB and ideally, it should be 1 dB. We can observe in the plot that the value of VSWR is well below 3 dB and is considered good for mobile communication devices. VSWR obtained at resonances are 1.91 dB & 0.73 dB.

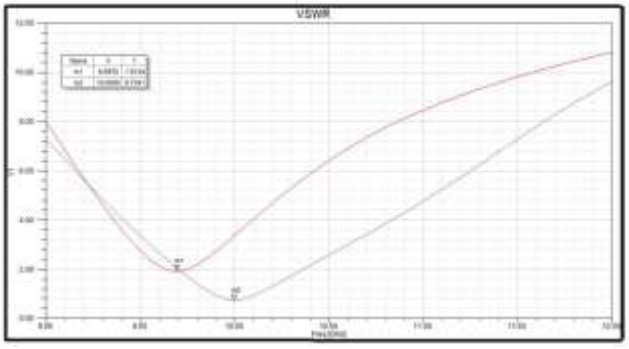


Fig. 5:. Simulated VSWR plot of Proposed MIMO PIFA

3.3. Diversity Gain

For MIMO antenna structures, the diversity gain is an important figure of merit. The diversity gain of the antenna can be calculated from S-parameters and is shown in Figure 6. The value is very much near to 10 dB which is excellent characteristics for MIMO antenna system.

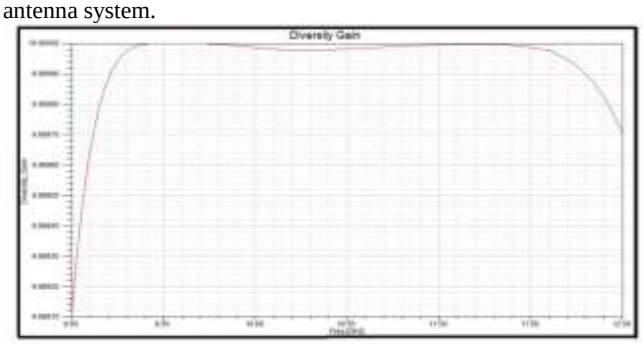


Fig. 6: Simulated 2-D Diversity Gain Plot

3.4. Radiation Pattern

As shown in Figure 7, the radiation pattern of the antenna is omnidirectional with good coverage on the front side of the antenna. The radiation pattern is plotted for phi = 0^0 and 90^0.

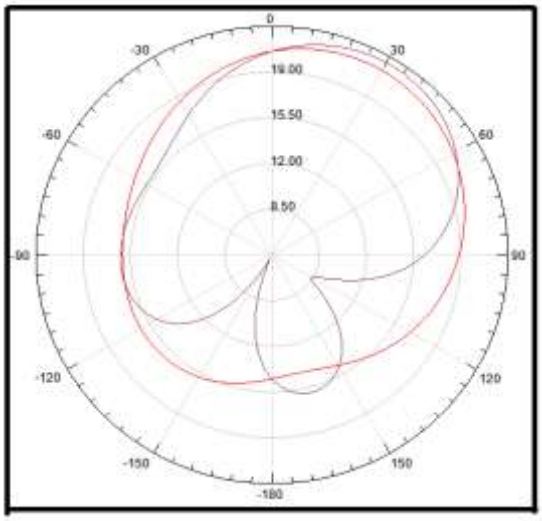


Fig. 7:. Simulated Radiation Pattern of Proposed MIMO PIFA

3.5. Effective Correlation Coefficient (ECC)

As it can be seen in Figure 8 the ECC plot is obtained from S-parameters and it should be less than 0.5. The obtained value for ECC is around 0.002 for the whole band of operation which refers to the fact that proposed MIMO antenna has excellent MIMO performance characteristics.

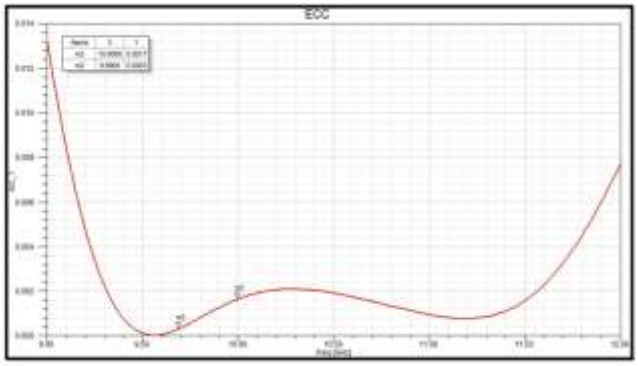


Fig. 8:. Simulated ECC plot of Proposed MIMO PIFA

As presented in the Table 1 below, simulated and measured results are compared, there is a good match between both the results. There is a mismatch in overall bandwidth and resonant frequency of antenna elements in simulated and measured results due to material losses, handmade fabrication, soldering defects etc. But isolation is significantly lower during measurement, there is 10 dB decrease in isolation between the elements.

Table 1:. Comparison between Simulated & Measured Results

Parameters	Simulated Results	Measured Results
Resonance	S11: 9.69 GHz S22:10.00 GHz	S11: 9.80 GHz S22: 10.00 GHz
Return Loss	S11 : -19.19 dB S22 : -27.48 dB	S11 : -18.80 dB S22 : -31.50 dB
Overall Bandwidth	Ant 1: 1.99 GHz Ant 2: 1.17 GHz	Ant 1: 1.10 GHz Ant 2: 0.66 GHz
Diversity Gain	> 9.9999	--
Isolation (S21 or S12)	-15 dB	-25 dB
ECC	<0.002	--

4. Conclusion

In this work, a novel edge fed MIMO Planar Inverted F Antenna has been proposed for future 5G communication devices. The designed antenna can be integrated with any wireless device because of its compact size and low height. The designed antenna shows good radiation pattern and excellent MIMO performance characteristics. The antenna structure is very compact i.e. 18mm × 10mm × 3.5mm and can be easily placed in the housing of the wireless devices.

References

[1] Chen, S., & Zhao, J. (2014), The requirements, challenges, and technologies for 5G of terrestrial mobile telecommunication. *IEEE Communications Magazine 52*, 36-43.

[2] Lahoria, N., Rana, Shashi B., & Kumar, N. (2016), A Novel Miniature Edge Fed Planar Inverted-F Antenna (PIFA) for Future 5G Wireless Devices. *International Journal of Research in Electronics and Communication Technology 3*, 7-9.

[3] Saini, S. et al. (2015), A compact T-slot multiband Planar Inverted-F Antenna for handheld devices. *2nd International Conference on Recent Advances in Engineering & Computational Sciences (RAECS)*, pp. 1-4.

[4] Samsung White Paper, Available on: http://www.samsung.com/global/business-images/insights/2015/Samsung-5G-Vision-0.pdf

[5] Wong, K. L. (2003), Planar antennas for wireless communications. *Microwave Journal 46*, 144-145.

[6] Rappaport, Theodore S., et al. (2013), Millimeter wave mobile communications for 5G cellular: It will work!. *IEEE Access* 1, 335-349.

[7] Wong, H., et al. (2012), Small antennas in wireless communications. *Proceedings of the IEEE 100*, 2109-2121.

[8] Mak, K. M., et al. (2014), Circularly polarized patch antenna for future 5G mobile phones. *IEEE Access 2*, 1521-1529.

[9] Lai, H. W., & Hang W. (2015), Substrate integrated magneto-electric dipole antenna for 5G Wi-Fi. *IEEE Transactions on Antennas and Propagation 63*, 870-874.

[10] Haraz, Osama M., Ashraf, M., & Alshebeili, S. (2015), Single-band PIFA MIMO antenna system design for future 5G wireless communication applications. *Proceeding of 11th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob)*, pp. 608-612.