Al-Nahrain Journal of Science
ANJS, Vol.26 (1), March, 2023, pp. 27-30

Design and Optimization of Planar Inverted F Antenna (PIFA) for Wireless Applications

Iman N. Taban[1,*], Ali H. Khidhir[1] and Ahmed A. Naser[2]

[1]Department of Physics, College of Science, University of Baghdad, Jadriya, Baghdad, Iraq
[2]Department of Software, College of Information Technology, University of Ninevah, Mosul, Iraq

Article's Information

Received: 12.07.2022
Accepted: 06.03.2023
Published: 31.03.2023

Keywords:
PIFA
5G
CST
3.5 GHz

Abstract

For 5G communication networks, including Long-Term Evolution Advanced mobile communication services, PIFA antenna is proposed. The proposed antenna structure is consisting of substrate, ground plane, shorting plate and feeding post connected to the ground plane. This antenna has been design based on a FR-4 has relative permittivity of 4.3 it has a volume of (120×60×1.5) mm^3. The experimental results of the Planar Inverted F Antenna (PIFA) that have been measured at the range from (3-4) GHz of frequency experimentally using the Site Master (Anritsu S362E), it has been demonstrated that the return loss, bandwidth, VSWR, and impedance are –41.15dB, 510 MHz, 1.04 and 48.414 Ω respectively at resonant frequency 3.5 GHz. The theoretical and practical values are so close to each other which justifies the antenna's excellent fit.

DOI: 10.22401/ANJS.26.1.05

*Corresponding author: imanaann99@gmail.com

1. Introduction

Future antenna designs for 5G applications should be small enough to fit inside different wireless devices. In order to support higher throughput and capacity enhancement. There will be a need for several antenna elements in the devices for the wireless systems for the upcoming 5G connectivity [1]. The development of 5G technology will allow for increased connectivity, exceptional speed, and data throughput, all of which will have very low latency [2]. The LTE base station construction requires two key components. First, the cellular networks of LTE are divided into small cells, such as picocells and femtocells, to increase the number of cell sites since the improvement of spectrum efficiency necessitates a bigger frequency reuse factor [3]. One of the lowest profile antennas commonly used in handheld wireless devices is the planar inverted-F antenna (PIFA), which has various benefits including a straightforward design, a compact footprint, ease of fabrication, and low production costs [4,5]. In user terminals, a variety of printed antennas, including microstrip antennas and planar/printed inverted-F antennas (PIFA), are frequently utilized as radiating elements [6]. For antenna design and modeling, Computer Simulation Technology (CST) microwave studioTM was utilized [7].

One of the most popular array antennas for millimeter wave frequency bands that can be used for 5G-based smartphone applications is the Planar Inverted-F Antenna (PIFA) [8]. This work gives a detailed numerical and experimental research covering all the parameters which may affect the characteristics of PIFA. It is a full parametric study of PIFA.

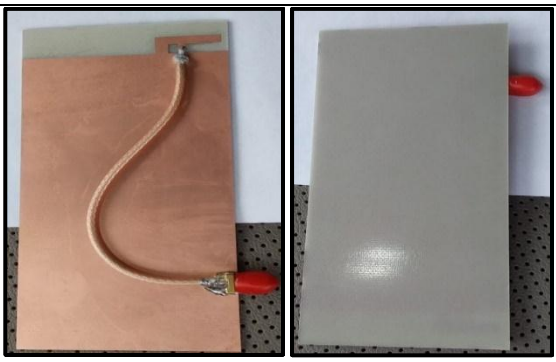
2. Planar Inverted F Antenna (PIFA) Construct

The proposed antenna constructed using the reasonably priced FR-4 substrate. The substrate is 1.5 mm thick, and its dielectric constant is 4.3. Equation (1), which was coded using Matlab software and is described in the paper titled "Design and Simulation of Planar Inverted F Antenna (PIFA) For Long Term Evolution Systems", is used to compute the proposed antenna's length and width. The length of a PIFA antenna has an inverse relationship with its operating frequency, which can be roughly calculated by [9]:

$$f = \frac{C}{4(L_1+L_2)} \qquad \ldots(1)$$

where C is the light-speed, $C = \frac{C_o}{\sqrt{\varepsilon r}}$ and $C_o = 3 \times 10^8$ m/s, εr = relative permittivity, L_1 and L_2 are the radiating element's width and length, f_o is either the resonance frequency or operational frequency.

The dimensions needed for a PIFA to operate at a desired resonant frequency can be roughly estimated using the equation above. The proposed antenna's size in its entirety is (120×60×1.5 mm^3), as shown in Figure 1. The printed circuit board is created using the CNC machine (Acctek AKM6090) method (PCB). Results after testing the antenna were fairly similar to those predicted by simulation.



(a) (b)

Figure 1. (a) Front view of the PIFA, (b) Back view of the PIFA.

3. Results and Discussion

As indicated in Figure 2, the antenna has undergone experimental testing utilizing Site Master (Anritsu S362E). The Site Master device's results data are exported using Tools for Anritsu Master Software 2013 (version: 2.24.0).

The measured results for the PIFA which have been obtained through measurement process. Shows the results of RL, VSWR, and smith chart are measured and stored in the Vector Network Analyzer (VNA) file form on the laptop. The VNA file has been converted to Comma-Separated Values (CSV) files by line sweep tools software. Finally, ORIGINAL PRO2021b software is used to read CSV file and printed in the form of charts with more options through the laptop device.

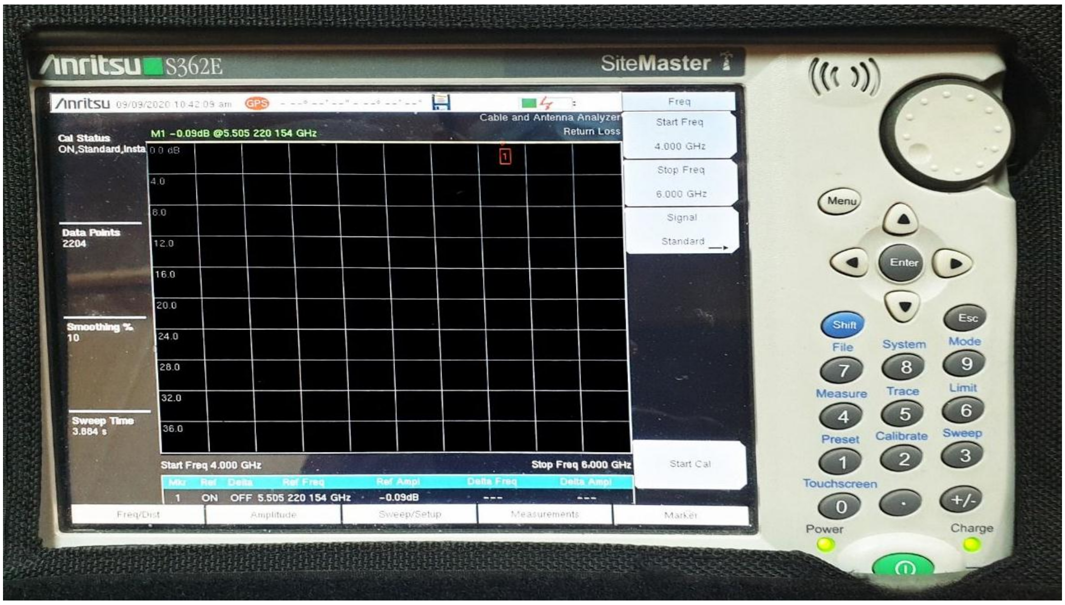


Figure 2. Testing process for PIFA.

The experimental results of the PIFA that have been measured at the range from 1 to 5 GHz of frequency are illustrated in Figure 3. The results of the return loss, bandwidth, voltage standing wave ratio, and finally input impedance are –41.15 dB, 510 MHz (from 3.21 GHz to 3.72 GHz), 1.04, and 48.414 Ω, respectively.

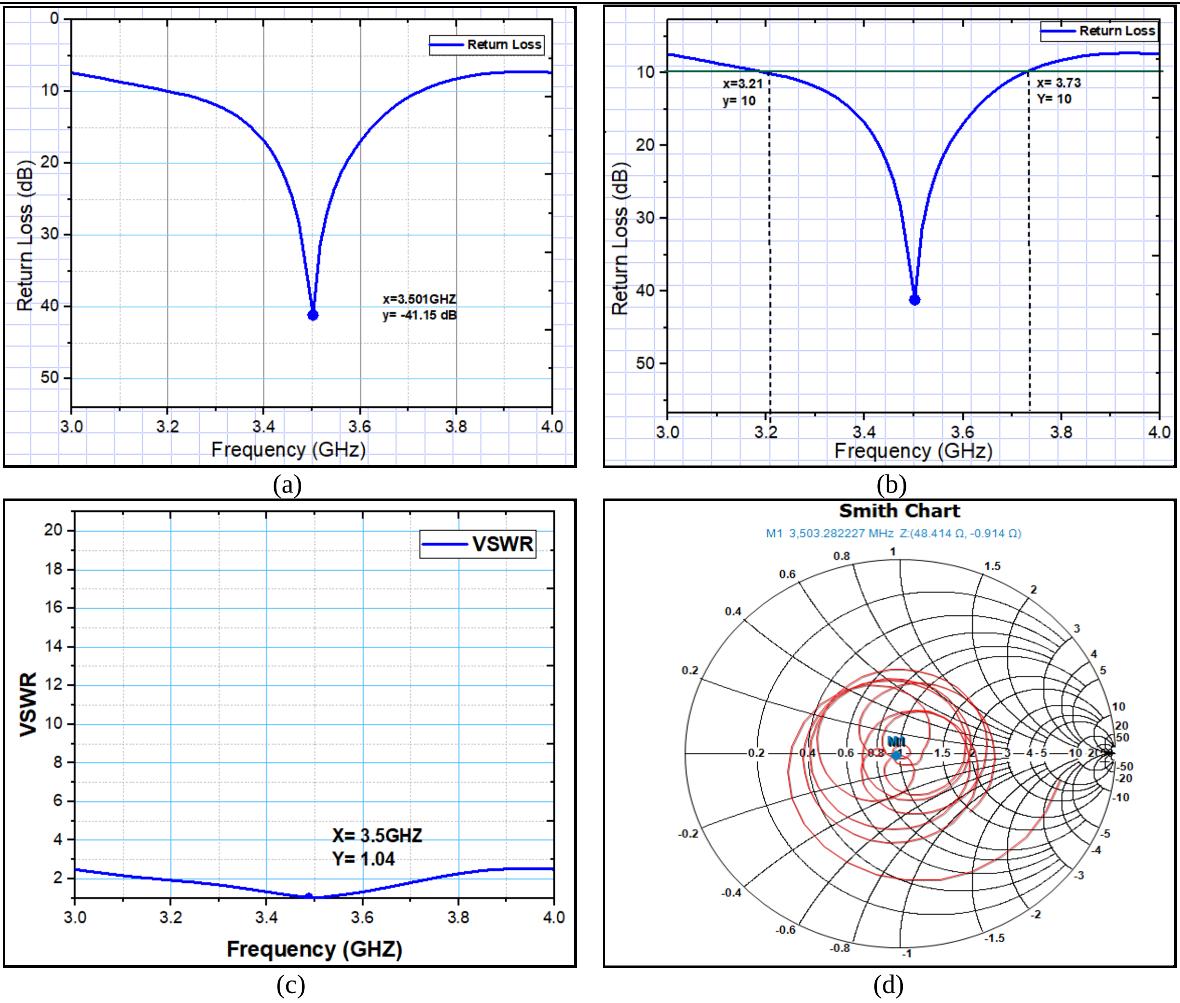


Figure 3. The measured results of the PIFA; (a) return loss, (b) bandwidth, (c) VSWR, (d) smith chart.

4. Comparison of the Results

Table 1 presents the resonant frequency, return loss, bandwidth, and VSWR values for the PIFA antenna in both theoretical and practical values.

Table 1. The simulated and experimental results for the PIFA.

Parameters	Simulated	Measured
Frequency GHz	3.5	3.52
Return loss dB	–52.100	–41.15
Bandwidth MHz	686	510
VSWR	1.0002	1.04
Impedance Ω	49.99	48.414

The experimental value of the return loss was very close to the simulation value, which means that the reflected power in the manufactured antenna is minimal. The comparison between RL as a function of frequency graph for the simulation and experimental results are viewed in Figure 4 and the measured results show a reduction in return loss of roughly 11 dB. The primary cause was due to limitations in the CNC production technology, and some results were also affected by the incorrect setting of the dielectric constant.

The standing wave has no distortion, and there is practically any reflection from the transformed wave, according to the VSWR value. The antenna has a perfect match, as indicated by the smith chart's reading of 48.414 Ω for the input impedance.

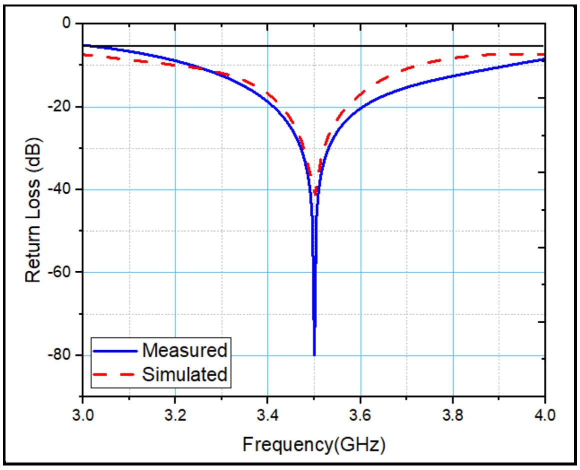


Figure 4. The comparison of return loss graph between simulation and measured results.

The measured value of the input impedance is closer than the simulation value to the reference impedance (50 Ω). This means that the matching between the transmission line is perfect in the manufactured antenna.

The values of the VSWR are so close to each other and almost equal to one. Practical value of VSWR means not generating voltage standing waves that lead to significant loss of the received or transmitted signal.

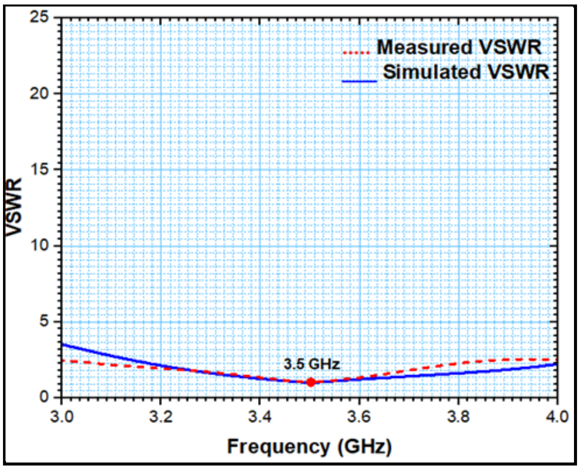


Figure 5. VSWR of the PIFA.

5. Conclusions

This research proposed a novel Planar Inverted F Antenna design for upcoming 5 G communication devices. functions at 3.5 GHz. The antenna is made to have excellent radiation patterns, great performance, and efficiency in satellite and terrestrial communications.

References

[1] Loharia, N.; Rana, S. B; Kumar, N.; "A Novel Compact MIMO Planar Inverted-F Antenna (PIFA) for Future 5G Wireless Devices". International Journal of Engineering & Technology, 7(4.5): 320-323, 2018.

[2] Pant, A.; Singh, M; Parihar, M. S.; "A frequency reconfigurable/switchable MIMO antenna for LTE and early 5G applications". AEU-international Journal of Electronics and Communications, 131, 153638, 2021.

[3] Yen-Sheng Chen, C.-P. C.; "IET Microw". Antennas Propagation,10 (4): 385-392, 2016.

[4] Nurul Inshirah Mohd Razali, N. S. N. I. A. I.; Indonesian Journal of Electrical Engineering and Computer Science, 10 (2): 741-747, 2018.

[5] Kumar, A. T. A. J. S. N.; "Study of planar inverted-F antenna (PIFA) for mobile devices". Int. J. Electron. Commun. Technol, 7109: 83-85, 2013.

[6] Biswal, S. P; Das, S.; "Two-element printed PIFA-MIMO antenna system for WiMAX and WLAN applications". IET Microwaves, Antennas & Propagation, 12(14): 2262-2270, 2018.

[7] Khan, M. M; Hossain, T.; "Compact Planar Inverted F Antenna (PIFA) for Smart Wireless Body Sensors Networks". International Electronic Conference on Sensors and Applications, 2 (63): 4-6, 2020.

[8] Nurul, H. M. R.; Mansor, Z; Rahim, M. K. A.; "Dual element MIMO planar inverted-F antenna for 5G millimeter wave application". TELKOMNIKA (Telecommunication Computing Electronics and Control), 17(4): 1648-1655, 2019.

[9] Meena, R. K.; Dabhade, M. K.; Srivastava, K; Kanaujia, B. K.; "Antenna Design for Fifth Generation (5G) Applications". In 2019 URSI Asia-Pacific Radio Science Conference (AP-RASC): 1-4, IEEE, March, 2019.