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Design of Inverted F-Shape Antenna at 2.35 GHz for S-Band Applications

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Abstract

In this work, a simulation model of planar inverted F antenna (PIFA) will be presented with the radiating plate that has been connected to ground plane that has been accompanied by shortening plate and the FR4 substrate between ground plane and radiating plate. Where PIFA was built using computer simulation technology (CST) for the studio microwave (2019 release). The simulation model has been studied for return loss (S-parameter), bandwidth (BW), voltage standing wave ratio (VSWR), and input impedance (Zin) which are –21.875406dB, 301MHz, 1.1752855, and 50 Ω, respectively. The simulation results showed that the PIFA component covers a wide frequency band ranging between 2.202 and 2.504 GHz, which can be used in Bluetooth, Wi-Fi, and Long Term Evolution (LTE) applications that are used in the fourth generation cellulares communications.

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1. Introduction

As a result of limited space that is available in the wireless devices, a low-cost, compact antenna design is essential [1,2]. Integrations of Wi-Fi, Bluetooth, and LTE in some mobile devices with high-speed and accurate data transmission is becoming important today. The 4G is a scalable mobile technology that takes on new functions. It was created to meet the huge demands of communication and handling of new applications thanks to very high data flow (several GB), high interaction (short waiting time of a few milliseconds) and high reliability [3]. However, many antennas are usually required to cover all services, and not all of them can fit into a specific small device but are indispensable in wireless communication applications. Antennas operating in several bands must support multiple standards so as to meet this requirement. Which is why, the objective is to improve performance and functionality of the devices of wireless communication, as well as to cover existing radio communication frequency bands [4-6].

Because of the high compression and performance, patch inverted F-planar antennas (PIFAs) are particularly attractive. As a result of its low profile, light weight and desirable structure in many applications, the PIFA antenna was used in portable wireless systems. In today's world, the patch inverted F antenna (PIFA) is still one of the most widely utilized antennas in mobile phones [7]. Since the space for the wireless devices is limited, the size of such antenna type is kept so that it is suitable for portable wireless systems without sacrificing performance concerning the patterns of radiation and BW [8]. As a result, the pattern of the radiation must be close to omnidirectional and cover the operating frequency ranges for which desired antenna is designed. Figure 1 represents an inverted F-planar antenna. The efficiency of the antenna for the transmission is defined as dividing the electrical force issued in all directions by the electrical force absorbed at the ends of the antenna. In addition, the portion of the force feeding to the two ends of the antenna, which is not emitted, is converted into heat [8].

Therefore, with the development in communications systems, the use of the antenna has become more important, and there is a large category of antennas of different shapes and sizes, and the communication system may include one antenna at its end or a group of different entities in order to form one antenna unit, where in such a case A group of different antennas makes up an antenna group. Application and operating frequency also cause variation in the size of the antennas [9].

The latest designs offer a compact design for an antenna with a total size of 38.4 mm × 46.8 mm that has a square shape and inverted F-slits. The antenna resonance frequency for the single band is between 1.69 and 2.91 GHz with frequencies of 1.98 GHz and 2.56 GHz. The antenna design has three square corner slits and an inverted *F* slit. The slit loading within a radiator patch increases the effective current path. Due to the increase in the current path, the antenna radiation increases and a large bandwidth is obtained [11].

In this paper, the PIFA has been designed and improved, one of the most commonly utilized antennas in the cellphones, especially within the fourth generation (4G) applications for these phones. The most important parameters that play an active role in the quality of the antenna that is used were studied.

Figure 1. Inverted F-shaped antenna in a cellular phone system.

2. Antenna Design

The monopole antenna and a small ribbon patch antenna were combined to create a planar inverted *F* antenna in its simplest form. The PIFA consists of flat patch that is parallel to ground plane, a short circuit connecting the radiated patch to the ground plane, and an antenna feed mechanism. Equation (1) can be used to approximate the resonant frequency of the basic mode of PIFA [12].

$$F = {}^{c}/_{4\,(W+L)} \qquad (1)$$

where *F* represents the desired resonant frequency, *L* and *W* denote length and width of the radiated patch respectively, and *c* denotes speed of light as shown in Figure 2. The antenna was designed and tested using computer simulation technology (CST) microwave studio software. The figure depicts the design of the dual band PIFA software and its schematic diagram. The antenna is built on a 1.356 mm thick, FR-4 substrate with dielectric constant (ε_r) of 4.30.

Table 1 shows the parameters that were used to design the desired antenna and test it using the computer simulation technology (CST) of the Microwave studio software 7.

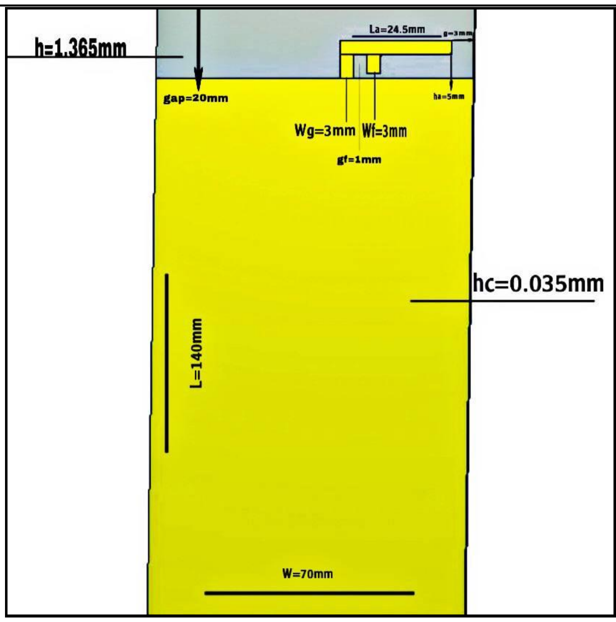

Figure 2. Design PIFA dimensions.

Table 1. Detailed dimensions of suggested PIFA.

Parameter	Symbols	Dimensions (mm)
Length of ground	L	140
Substrate Thickness	h	1.365
Width of ground	W	70
Width of cut	Gap	20
Length of antenna	La	24.5
Height of the antenna above the ground	h_a	5
Width of feed	w_f	3
Gap feed	g_f	1
Width antenna	w_a	3
Gap antenna	g_a	3
Copper thickness	h_c	0.035
Antenna distance from the edge of the substrate	g	5
Line width with ground	w_g	3

3. Simulation Results

The PIFA was designed using CST of a studio microwave (2019 release). Where Figures 3,4 and 5 show return loss of –21.875406 dB, a VSWR of 1.1752855, bandwidth of 301MHz, and an input impedance of 50 Ω at resonant frequency of 2.35 GHz. These results are important in wireless communication applications such as cellular services, Wi-Fi and Bluetooth, in addition to other important applications at the 56 kHz frequency. As a result, these values were considered good compared to these of others [13].

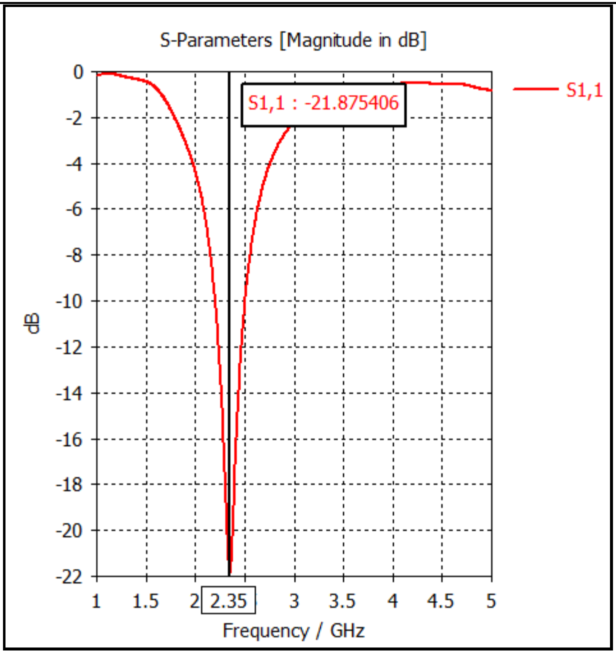

Figure 3. Return loss of the PIFA.

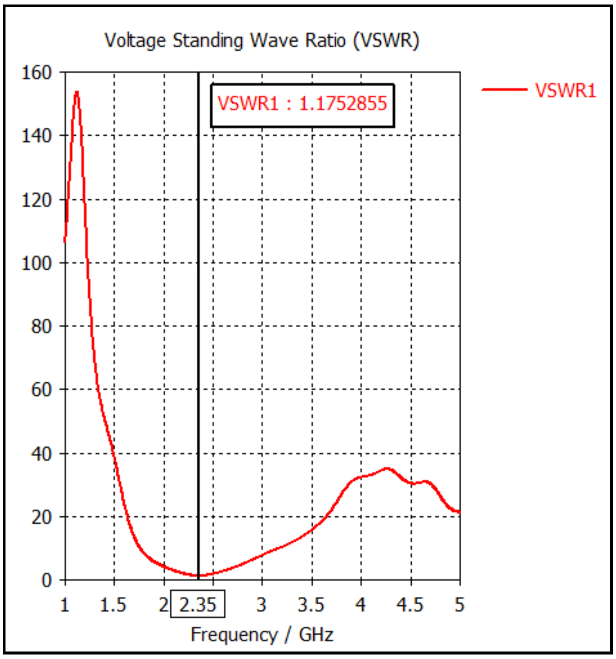

Figure 4. VSWR of the PIF.

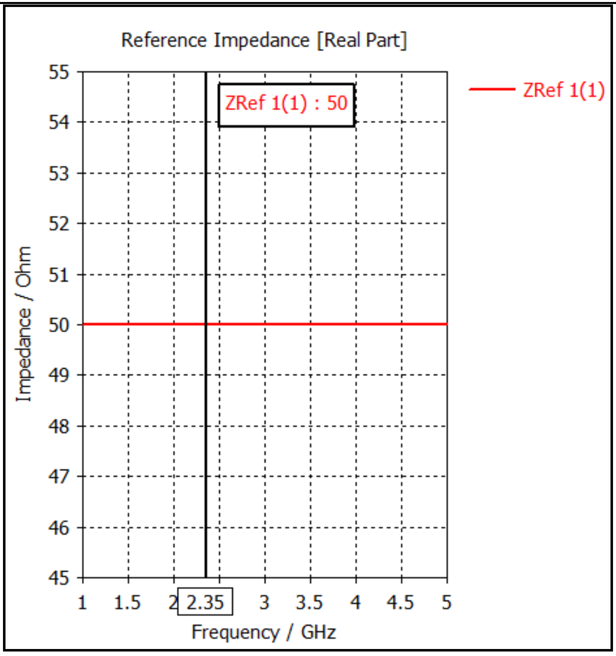

Figure 5. Input impedance of the PIFA.

Figure 6 shows the 3D radiation pattern of the gain. Therefore, we note that the suggested antenna is effective with radiation to absorb energy flow direction. As a result, the gain polar plots using Smith chart show that the gain is 5.25 dB when = 90°, as shown in Figure 7.

In Figure 7, the values of gain in polar form (as mentioned in Figure 6) are presented in Figure 7. The red loop is a cross-section of the gain lobe from top view. The blue line represents the highest gain value which has an angular displacement about 132 degrees from the center of radiation. The effective area of gain is determined by two light blue lines separated with 52 degrees. As a result, the main lobe magnitude was equal to 4.86 dB, this analysis of Smith's chart applies to Figure 9. This result was a highest value compare to Prasanna et. al. which is 1.01 dB [14].

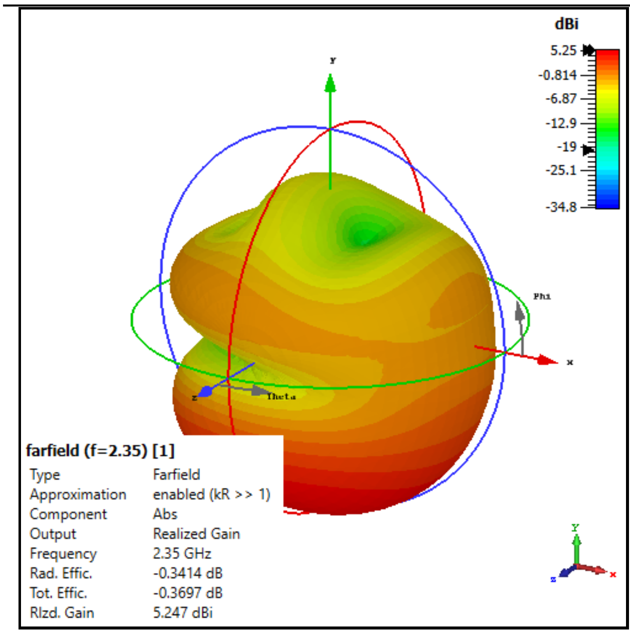

Figure 6. 3-D radiation pattern of gain.

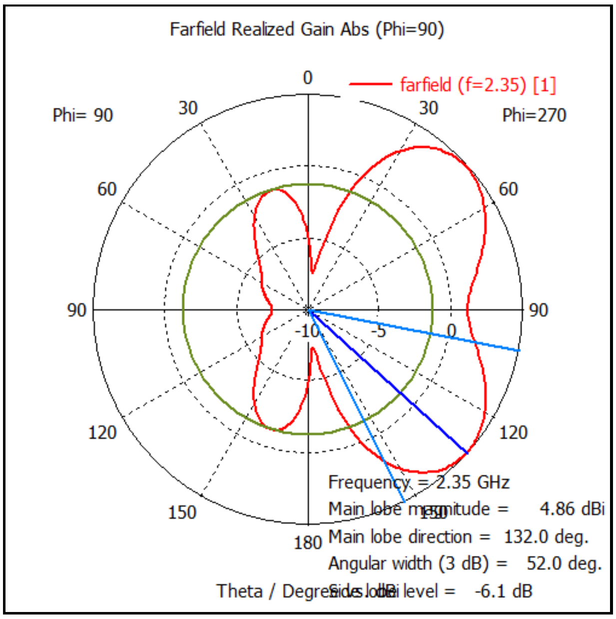

Figure 7. Polar plots of gain at $\Phi = 90^o$.

Figures 9 and 10 show the 3D radiation pattern and the polar plots of the trend using Smith's chart where it is noticed that the radiative directivity is 5.62 dB when the value of Φ is equal to 90^o. These results are close to the results of the last one [15].

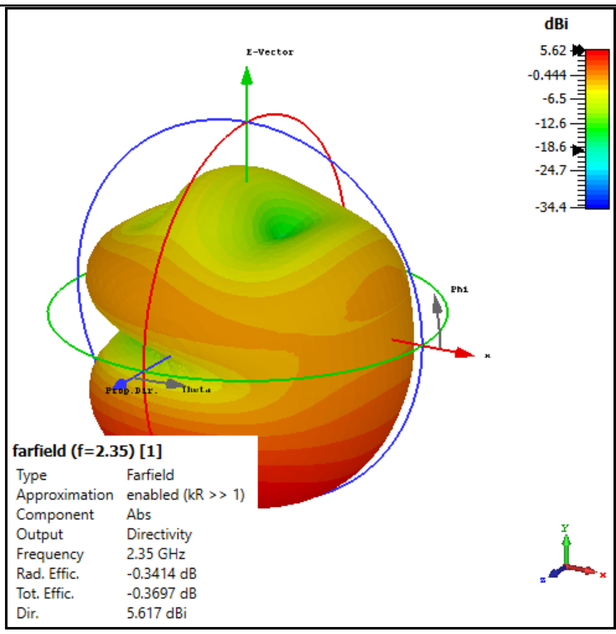

Figure 8. 3D radiation pattern of directivity.

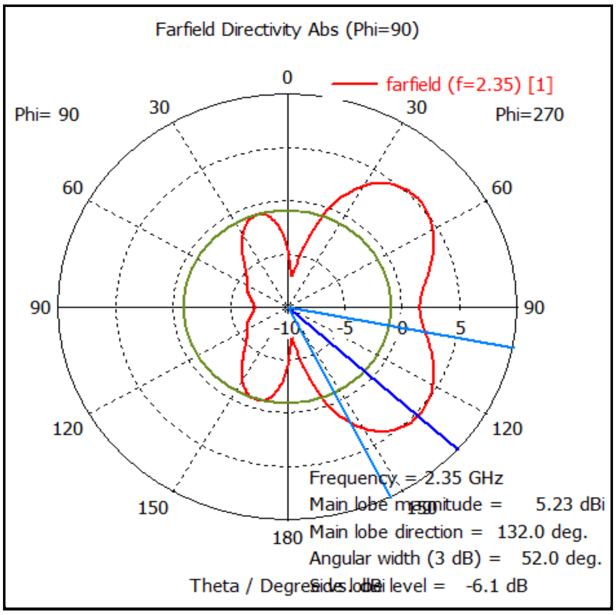

Figure 9. Polar plots of directivity at $\Phi = 90^o$.

4. Conclusions

In this study the results of the analysis showed that the values of return loss, bandwidth, VSWR and input impedance of the designed antenna are –21.875406 dB, 301 MHz, 1.1752855 and 50 Ω, respectively. It is considered good and desirable results to operate at the resonant frequency used. Therefore, this antenna can be used within the work area of wireless communication systems, Bluetooth, Wi-Fi and mobile phones applications for the fourth-generation services.

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