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TRI-BAND PLANAR INVERTED F-ANTENNA (PIFA) FOR GSM BANDS AND BLUETOOTH APPLICATIONS

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ABSTRACT

Recently, the demand for wireless devices that support multi-band frequency has increased. In fact, employing single-band antennas leads to large space requirement in handheld devices. Therefore, due to the space constraints in mobile devices, an antenna which will cover multiple bands of frequencies will be the best solution in order to allow more space in the mobile devices. The integration of such technology in mobile communication system has led to a great demand in developing small size antenna with multi-band operation that is able to operate in the required system. In this paper, a triple band planar inverted-F antenna (PIFA) is proposed. The antenna has been measured and found to operate at three operating frequencies of GSM bands (900 MHz and 1800 MHz), and Bluetooth band (2400 MHz). A dual L-shaped slot was used on the patch to obtain the triple-band resonant frequencies. Performance of the antenna has examined and results have shown that the proposed antenna can successfully cover frequencies 900 MHz, 1800 MHz and 2400 MHz.

Keywords: Tri-band, PIFA, GSM, bluetooth.

INTRODUCTION

Planar antennas are the newest generations of antennas boasting the attractive features required, such as broad operating bandwidth, low profile, light weight and ease of integrations into arrays of radio frequency circuits, to make them ideal components of modern communications systems. Planar antennas have variety of types and one of them is planar inverted F antenna (PIFA). Planar Inverted-F Antennas (PIFAs) are resonant at a quarter-wavelength and are widely used for mobile phone applications and other communication devices due to its merits of small size, light weight, low specific absorption rate (SAR) values, good gain and multiband operation [1-7].

The PIFA antenna is popular because it has a low profile and an omni-directional pattern. The antenna should be miniaturized since there is a limited space in the printed circuit, without causing degradation to the performance of the antenna parameters such as the bandwidth and radiation patterns [1].

To broaden the bandwidth of PIFA structure, various techniques have been employed and the most widely used method is to increase the height of the shorting plate which finally results in increase of volume [8].

The design of triple-band planar inverted F-antenna has taken many forms. In [3], a tri-band planar antenna was made from slotted radiating patch and a parasitic patch with overall size of 22×22×5.2 mm^3. The author in [9] has proposed PIFA with two shorting strips and slits while the main patch consists of meander-typed slit and two L-shaped slant slits at the right edge is added. In [10], a dual-frequency planar inverted F-L (PIFL) antenna of size of 30mm x 10mm x 8mm, mounted on a 30mm x15mm finite ground plane was proposed. The antenna operates at 2.5 GHz and 5.2 GHz WLAN bands.

A tri-band planar inverted-F antenna (PIFA) is discussed in this paper. The results have shown that the antenna is capable to cover cellular frequencies of GSM900 and DCS1800 and non-cellular frequency such as Bluetooth/WLAN 2400 MHz. The antenna has been modeled and simulated with CST MWS simulation software.

ANTENNA DESIGN

The proposed antenna consists of a ground plane, a shorting plate, a feeding pin, and top patch that has two slots of L-shaped in order to obtain a triple frequency. An FR4 dielectric substrate was used on the ground plane and the radiating patch (top patch) which have thickness of 1.6mm. An air gap is separating between the ground plane and the radiating patch. A coaxial feeding probe is used through the feeding pin. The proposed antenna is shown in Figure-1.

The size of the top plate of the antenna can be approximately determined using the following formula:

$$f = \frac{c}{4(L+W)} \qquad (1)$$

where c is the speed of light = 3×10^8 m/s, f is the frequency in (Hz), L is the length of the radiating patch (mm) and W is the width of the radiating patch (mm).

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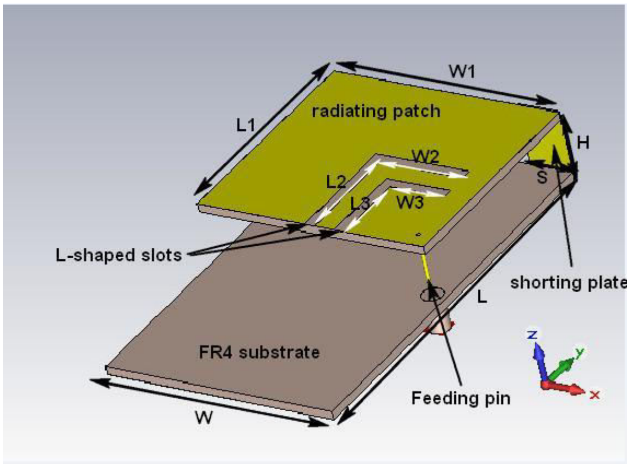

Figure-1. Geometry of the proposed antenna.

The mathematical formulation that led to the dimensions for tri-band frequency is treated separately as summarized in Table-1.

Table-1. Calculations of the dimensions of the proposed antenna.

GSM 900 MHz	DCS 1800 MHz	Bluetooth 2400 MHz
$f1 = \frac{c}{4(L1+W1)}$	$f2 = \frac{c}{4(L2+W2)}$	$f3 = \frac{c}{4(L3+W3)}$
$L1+W1 = \frac{c}{4(f1)}$	$L2+W2 = \frac{c}{4(f2)}$	$L3+W3 = \frac{c}{4(f3)}$
$L1+W1 = \frac{300}{4(900)}$	$L2+W2 = \frac{300}{4(1800)}$	$L3+W3 = \frac{300}{4(2400)}$
$L1+W1 = 83.33mm$	$L2+W2 = 41.67mm$	$L3+W3 = 31.25mm$

RESULTS AND DISCUSSIONS

It is found that PIFA characteristics are affected by a number of parameters such as the ground plane size (L and W), shorting plate width (S), height of antenna (H) and gap slot size (G). The importance of parametric study is that it will allow the design to be optimized, since the formula that was used for the design will only produce a rough approximation.

Four different sizes of ground plane that was simulated and compared. The results show that when the size of the ground plane is increased, the third frequency, 2.4 GHz shifted to the higher frequency range and its return loss has reduced. So, the most optimum size chosen for the design was 84×46 mm (L×W), since its return loss and resonant frequency produced good acceptable result (Figure-2).

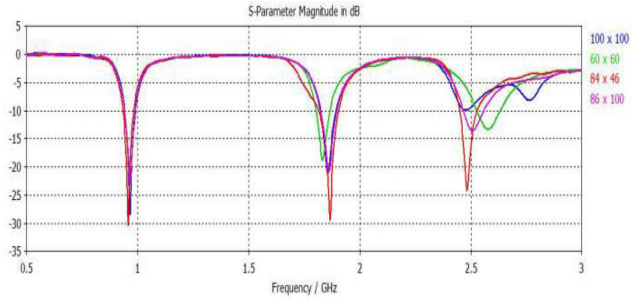

Figure-2. Comparison of different ground plane sizes (L and W).

The width of shorting plate (S), the copper plate with thickness of 0.35 mm, has been changed while the other parameters were kept constant in order to find out the effects of the variation of return loss of the PIFA antenna. There were four different shorting widths to compare as shown in Figure-3. The highest is 10 mm and the lowest is 6 mm. As observed, changing the shorting width had only affected the lower frequency. As the shorting width was increased, the 0.9 GHz resonant frequency increased or shifted to the right. Therefore the most optimized width that was chosen for the design was 8.5 mm, since it produced good performance in terms of return loss and resonant frequencies.

The gap slot (G) of the L-shape was changed while keeping the other parameters fixed. Three different sizes were compared in order to find out the effect on the antenna performance. It has been observed that as the gap slot size increased, the resonant frequency shifted to the left while the return loss reduced (Figure-3). Therefore, the optimized size that produced good return loss and the desired resonant frequency was when the gap slot = 2 mm.

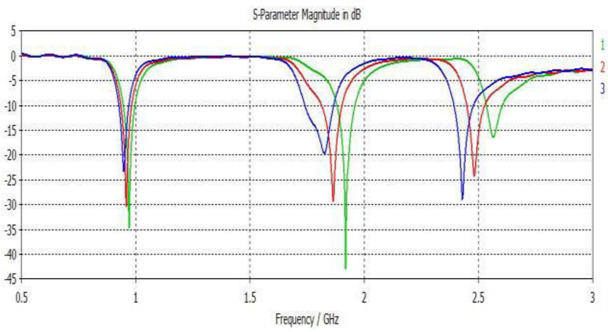

Figure-3. Comparison of different gap slots size (G) on patch.

The height of the antenna (H) is also an important parameter in terms of bandwidth and resonant frequency of the PIFA antenna. Therefore the parametric study should be made for different heights of antenna so that the best optimized height that produces good result should be selected. Four different heights were simulated. When the

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height is reduced, the bandwidth increased but the return loss of the antenna decreased and vice versa when the height increased. Therefore, the optimum height was 6.8 mm.

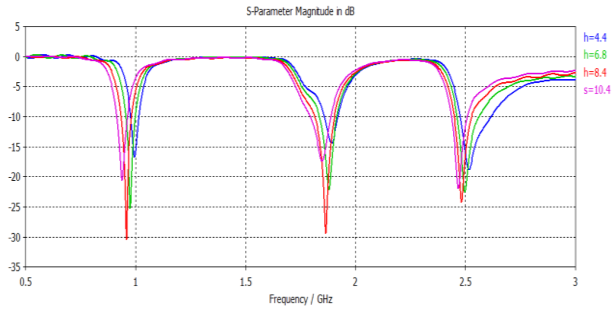

Figure-4. Comparison of different heights of antenna (H).

The radiation pattern of the three frequencies was simulated in polar view as shown in Figure-5. It can be seen from that the three operating frequencies have an omni-directional characteristic. Table-2 summarizes the important parameters obtained from the far-field study.

Table-2. Simulated directivity, gain and radiation efficiency of the proposed PIFA antenna.

Center frequency (GHz)	**Directivity** (dBi)	**Gain** (dB)	**Radiation efficiency**	
			(dB)	(%)
0.9	4.54	5.100	-0.5621	87.9
1.8	4.1	6.632	-0.003244	98.6
2.4	3.8	5.482	-0.1724	96.1

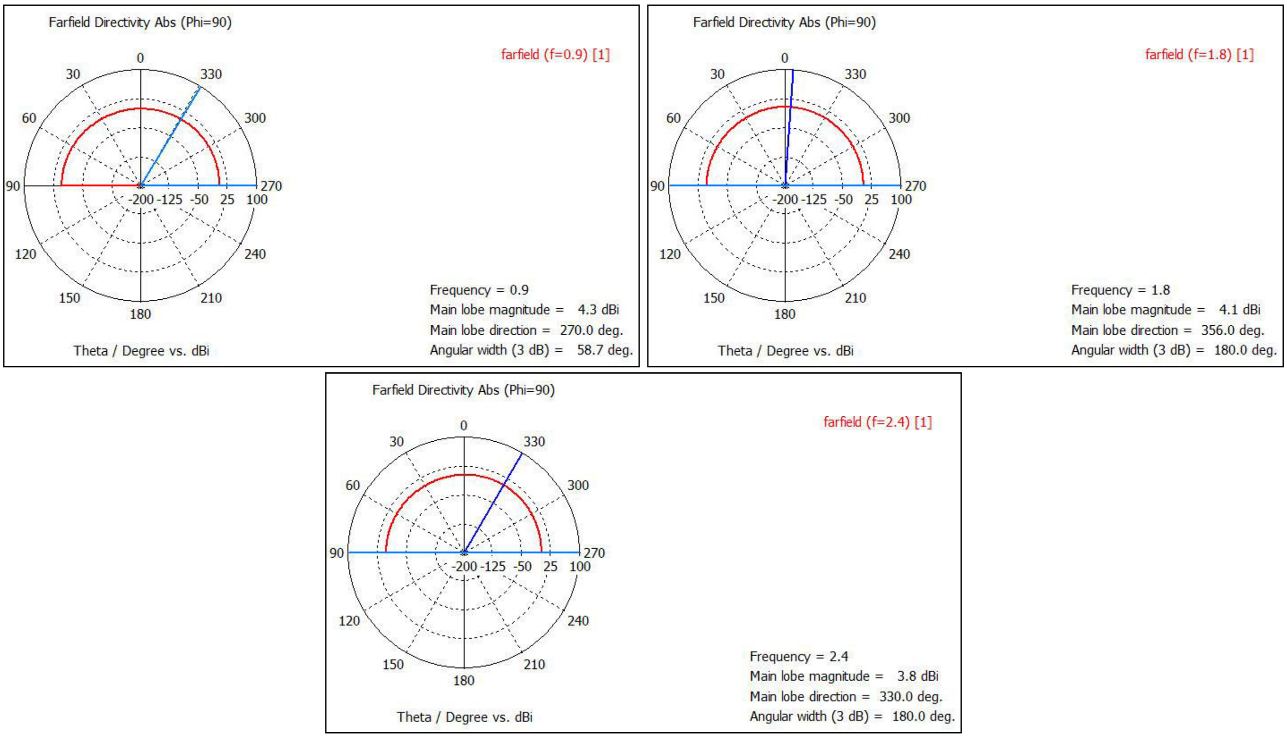

Figure-5. Radiation pattern for 0.9 GHz, 1.8 GHz and 2.4 GHz respectively.

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Figures 6(a) and 6(b) show the design of the proposed PIFA in CST MW studio and the fabricated prototype.

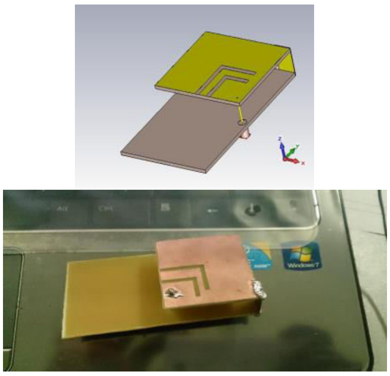

Figure-6. (a) PIFA design in CST (b) Fabricated PIFA.

The return loss obtained in measurement and the one obtained in simulation were compared shown in Figure-7. It can be observed that there is slight mismatch between the two graphs. This difference is due to the misalignment of the antenna when assembled together since the PIFA antenna contained different parts such as shorting plate made up of copper, radiating patch, feeding pin and ground plane. The other effect that contributed to the measurement result could be related to the interference from the surrounding environment such as electronics, human body or other sources of electromagnetic radiation.

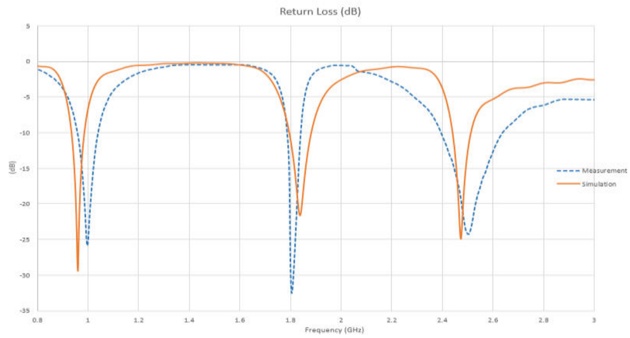

Figure-7. Comparison of measured and simulated result of return loss.

The standing wave ratio of the simulation and measurement was also compared as shown in Figure-8. It shows that both the simulating and measurement VSWR have very close agreement. Both of them have their VSWR with less than 2, and that means that the antenna has an acceptable impedance matching.

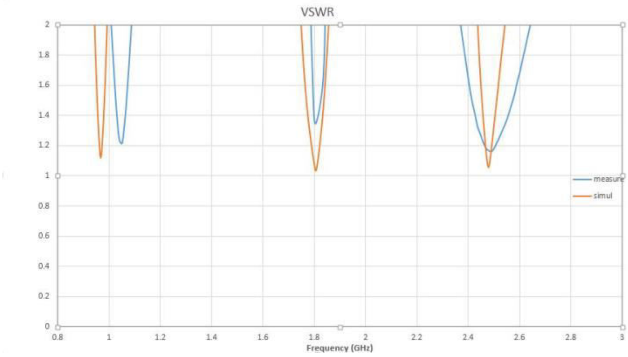

Figure-8. Comparison of measured and simulated VSWR of the antenna.

Table-3. Bandwidth, return loss and center frequency difference between measurement and simulation.

	Measurement	Simulation	Difference
Center frequencies (GHz)	0.996	0.96	0.036(3.6%)
	1.804	1.84	0.036(3.6%)
	2.503	2.47	0.033(3.3%)
Return loss (dB)	-25.36	-29.37	4.01
	-30.28	-21.63	8.65
	-24.22	-24.93	0.71
Bandwidth (MHz)	77(7.7%)	46(4.8%)	31(2.9%)
	55(3.1%)	103(5.6%)	48 (8.7%)
	242(9.7%)	99(4%)	143(5.7%)

The two results obtained from measurement and simulation has differences in bandwidth. Table-3 shows the difference in terms of return loss, operating frequency and bandwidth. As observed, the difference between center frequencies and return loss of measurement and simulation result is very small, whereas there is a noticeable difference between the bandwidth of the simulation and the measurement. Again, this is caused by the misalignments of the antenna during the fabrications, which would alter the overall design of the antenna. Hence, these factors can contribute to the antenna performance. However, the bandwidth obtained is still within the acceptable range.

CONCLUSIONS

In this paper, a tri-band planar inverted-F antenna (PIFA) has been proposed, designed and analyzed. The results have shown that the antenna can operate at three operating frequencies of GSM bands 900 MHz and 1800 MHz, and Bluetooth band of 2400 MHz. The main idea of realizing these frequencies was achieved using a dual L-shaped slot on the patch.

The S_{11} parameter obtained in simulation showed all the three frequencies of 0.96 GHz, 1.804 GHz and 2.4 GHz have good return loss of less than -10 dB. The standing wave ratio showed good impedance matching of less than 2. The radiation pattern that was obtained in the simulation showed omni-directional for the three bands. The agreement between the simulated and measured results is very close.

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