A Development and Analysis of Fractal Planar Inverted F Antenna (F-PIFA) for Mobile Phone Applications

[#]N.A. Saidatul, A.A.H. Azremi, R.B. Ahmad, P.J Soh
School of Computer and Communication Engineering, University Malaysia Perlis (UniMAP), Kangar, Perlis.
s0730810155@student.unimap.edu.my, azremi@unimap.edu.my, badli@unimap.edu.my, pjsoh@unimap.edu.my

***Abstract* - The development and simulation demonstrations of a novel Fractal Planar Inverted F Antenna (F-PIFA) are presented in this paper. The influence of various parameters on antenna characteristics has been investigated and the simulation results are obtained using CST software. Simple semi-empirical formulas of the operational frequency and numerical calculation on the antenna have been discussed. The proposed antenna operates effectively in the UMTS (3G)-(1885–2200 MHz) and HiperLAN (5100–5300 MHz) bands within 2:1 (voltage standing wave ratio (VSWR). The antenna shows wideband characteristics for mobile and wireless communication applications.**

1. Introduction

The Planar inverted-F antenna (PIFA) is currently being used as an embedded antenna in many radiotelephone handsets [1-2] because it is small and has a low profile, making it suitable for mounting on portable equipment. The antenna also has a high degree of sensitivity to both vertically and horizontally polarized radio waves, thus making the Planar Inverted-F Antenna ideally suited to mobile applications. In addition, PIFAs can reduce the possible electromagnetic energy absorption by the mobile handset user's head, because of relatively smaller backward radiation toward the user. This antenna also is reasonably efficient and free of excessive radiation illuminating the user's head (low SAR value) [3-5]. However, PIFA have some drawback s such as low efficiency, narrow bandwidth and not multiband. To enhance these drawbacks, especially narrow bandwidth, Fractal PIFA has been developed to achieve the design of internal compact and broadband antennas. Fractal antennas are comprised of elements patterned after self-similar designs to maximize the length, or increase the perimeter [6]. The beneficial give useful applications in cellular telephone and microwave communications. Furthermore, it is found a little adjustment of the shape can make it work in the demanded resonant frequencies [7]. It is known that fractal exhibit multiband antenna but at present time, there is no research on the combination of fractal to PIFA topology. Many possible fractal structures exist which may undoubtedly have attractive radiation properties. Thus, a possible avenue for future work is to investigate other types of fractals for antenna applications. The proposed designs are able to provide coverage at all desired frequency bands. In order to obtain a good fundamental antenna design, the initial studies were carried out theoretically, using CST Microwave Studio simulation software.

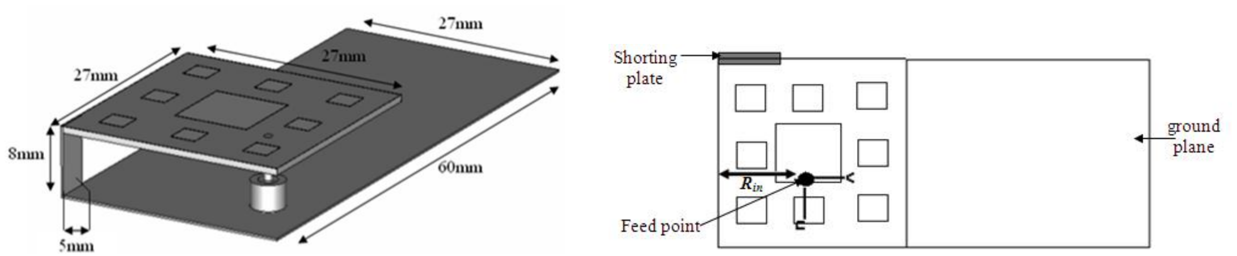
2. DESIGN SPECIFICATION

A Planar Inverted F Antenna is generally a quarter-wave (λ/4) resonant structure achieved by short-circuiting its radiating patch to the antenna's ground plane using a shorting plate. Its structure is similar to a shorted rectangular microstrip patch antenna with air as dielectric. The resonant frequency can be calculated by using the closed form equation as [9];

$$f\,(resonant) = c\,/\,4(L1 + L2) \qquad (1)$$

Where, c = velocity of light (3x10 m/sec), $L1$ and $L2$ = width and length of conducting element. The operating frequency of a microstrip patch antenna is inversely proportional to its physical dimensions. The width L1 and the length L2 can be subsequently fine tuned to obtain an improved frequency match by performing optimization procedure through experimental trials.

In order to start designing F-PIFA antenna, a large square structure is created in the plane and divided into nine smaller congruent squares where the open central square is dropped out. Similarly the remaining eight square are divided into nine smaller congruent squares with each central being omitted. Fig. 1(a) shows the dimension and geometry of F-PIFA antenna. The combining PIFA elements with Fractal theory method result in a novel wideband Fractal PIFA. The second iteration of F-PIFA is printed over a thin Rogers RO4003 substrate of dielectric constant ε_r = 3.38, and thickness, h = 0.813mm. The size of the radiating patch is selected to be 27 x 27mm while the ground plane dimension is 27 x 60mm. The dimensions of the Planar Inverted F antenna (PIFA) are summarized as follows; PIFA height (h) = 8.0 mm, ii. Feed distance from the edge, (R_{in})= 12.8 mm, iii. Shorting Plate Width (Ws) = 5.0 mm.



(a) (b)

Fig. 1: Geometry of F-PIFA (a) Dimension of F-PIFA, (b) F-PIFA from front side view

3. Antenna Result and Discussion

Fig. 2 shows the measured and simulated results for the matched resonance of the F-PIFA operate at UMTS (3G) applications, and corresponding to good input impedance. In order to validate the antenna, a PNA Network Analyzer E83628 was used to measure the input return losses of the fabricated antennas. The measured S11 result shows the first bandwidth reaches 590MHz (1630–2220 MHz), and satisfies UMTS (3G) specifications. The second band has a bandwidth 520MHz (4780–5300 MHz), and does satisfy for hiperLAN requirement (5150–5300 MHz). The examined results showed a reasonably bandwidth and can be applied for cellular applications. As shown in Fig 3 is the antenna gain result. At the first resonant the gain value is 2dB and it keep increasing proportional to the frequency. As for the second resonant, the gain value starts at 2.78dB and rise up until 3.57dB at 5.32GHz but slightly decrease to 1.45dB at 5.3GHz. This is due to the S_{11} result, the last maximum frequency is at 5.3GHz. From the radiation pattern result (Fig. 4), the pattern become more directive as compare to the other radiation pattern produced at 2 GHz is nearly omni-directional, thus the gain is higher compare to other frequencies. The gap between simulated and measurement for gain is only 1.2db. This loses might created at the stage the antenna been manufactured.

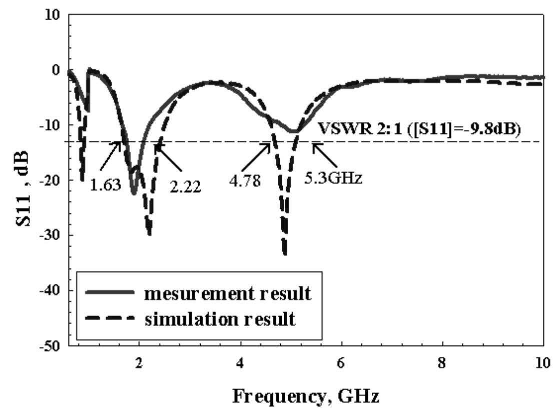


Fig. 2: S11 simulated and measured result for F-PIFA

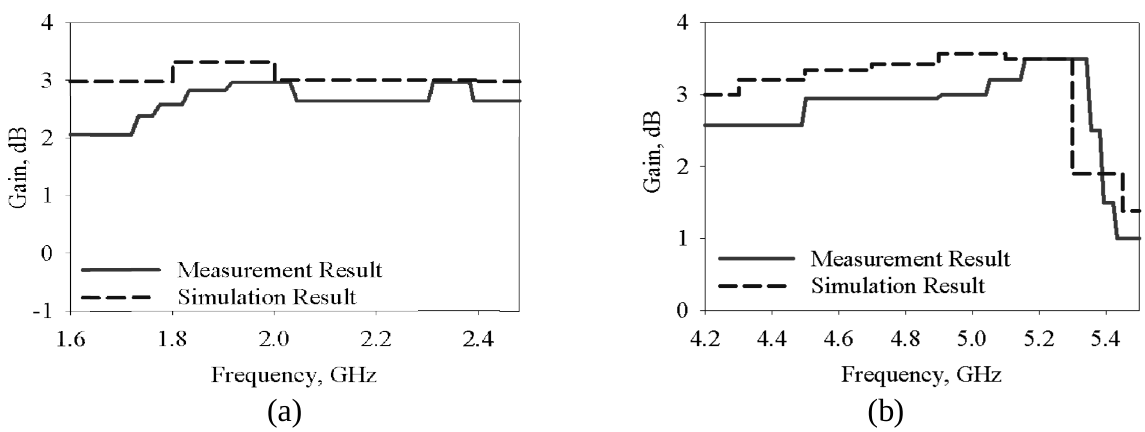
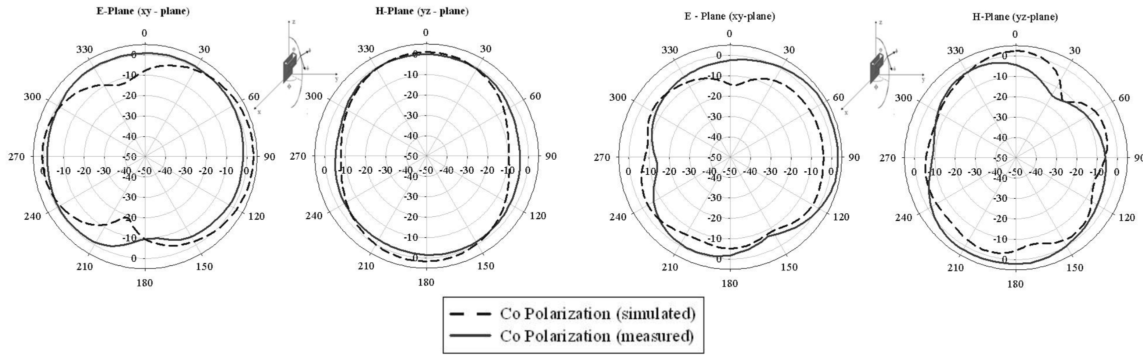


Fig. 3: Gain simulated and measured results for F-PIFA a) UMTS band frequency, b) HiperLAN band Frequency

The radiation performance of the antenna is examined on two principal planes, E(y-z) and H(x-z). Fig. 4 illustrates the co and cross polarization radiation pattern for the E and H planes. The radiation patterns are measured using anechoic chamber SATIMO SG-64. It is observed that the radiation pattern in the two planes is omni-directional, thus, extremely suitable for applications in mobile communication devices. Its sensitivity to both the vertical and horizontal polarization is of immense practical importance in mobile cellular communication application because the antenna orientation is not fixed.



(a) (b)

Fig. 4: Radiation Pattern for F-PIFA at a) 2.0GHz, b) 5.0 GHz

4. Conclusion

In this paper, we have proposed a compact Fractal PIFA which has wide bandwidth for mobile phones operating in 2GHz for UMTS (3G) frequency band and 5GHz for HiperLAN. The accomplishment of acceptable bandwidth is definitely an important consideration for antenna design in mobile communications systems. The S11 bandwidth covers the required operating frequency range for mobile phone application. The radiation pattern results show an omni directional radiation, radiating equally in all direction. This satisfies the requirements in wireless communication.

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