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A Novel Low profile Planar Inverted-F Antenna (PIFA) for Mobile Handsets

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Abstract- A low profile planar inverted-F antenna (PIFA) is proposed for mobile handset applications. The proposed antenna covers DCS-1800 & PCS-1900 bands. The antenna consists of a square planar element suspended above the FR4 dielectric substrate. The ground plane is on the bottom side of the substrate. Overall size of the antenna is 22*22*5.2 mm3 and is well suited for mobile handsets due to its low profile, small size, wide bandwidth and good gain. The antenna geometry, simulations of return loss, input impedance, VSWR & gain are also discussed.

Index Terms- PIFA, internal antenna, FR4 dielectric, planar element, return loss, VSWR.

I. Introduction

In last three decades PIFA antenna structure has emerged as one of the most promising candidate in the category of low profile antennas used in handheld devices. Broad range of applications employs PIFA as their basic antenna. For a system to perform optimally, the antennas must have simple construction, high radiation efficiency, small volume, low-loss impedance matching.

PIFA is extended form of Inverted F antenna (IFA) which have a plate in place of wire radiator element to expand the bandwidth. There are many advantages of PIFA making its widespread use in devices that is, easy fabrication, simple structure, small volume, low manufacturing cost. PIFA structure is easy to hide in the casing of the mobile handset as compared to monopole, rod & helix antennas. Also, PIFA has reduced backward radiation towards user's head and body which further minimizes SAR and improves performance[1]. They can resonate at much smaller antenna size and by cutting slots in radiating patch, resonance can be modified. Proper shape of the patch and positions of feeding and shorting pins results in multiband operation.

The major drawback of PIFA is its narrow bandwidth; therefore it is important and necessary to widen the bandwidth for using it in mobile phones and other devices. The evolution of the handset antenna structures from a monopole to the PIFA shows that the essential component of a mobile handset antenna is the "wire". The patches, slots, and stubs are only used to compensate for the mismatch and improve the radiation characteristics.

Next section explains the basic structure of simple PIFA and discusses the relationship between various parameters. Section III discusses the design of the proposed antenna with square patch radiator and its properties using HFSS simulation software. Section IV provides conclusion and section V discusses future scope of the design.

II. PIFA Theory

The Inverted-F antenna has transformed the horizontal element from a wire to a plate resulting in the so called planar inverted-F antenna (PIFA). It has a self-resonating structure with purely resistive load impedance at the frequency of operation. Variation of length, distance and location of the feed and shorting point, height of the radiator etc. affects the electrical performance of these antenna structures [2]. Typical configuration of PIFA is shown in Fig. 1. The antenna is fed through feeding pin which connects to the ground plane. The shorting pin and shorting plate allows good impedance matching achieved with the patch above ground plane of size less than λ/4. Resulting PIFA structure is of compact size than conventional λ/2 patch antennas.

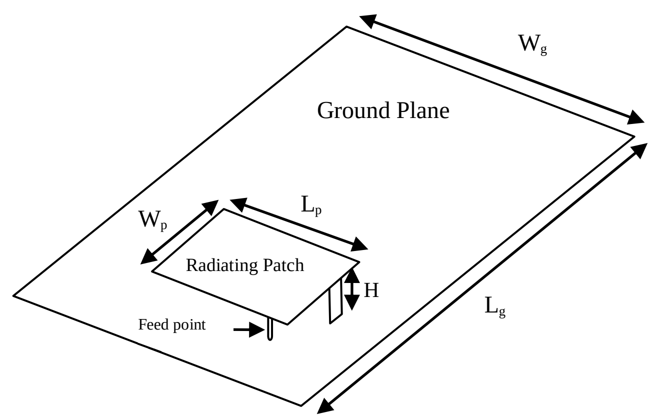

Fig.1. Basic PIFA Structure

The frequency at which PIFA resonates can be calculated by using a basic formula as given below

$$fo = \frac{c}{4(Wp + Lp)} \quad \ldots\ldots (1)$$

Where c is the speed of light,

W_p and L_p are the width and length of the top plate of PIFA,

f_0 is the resonant frequency.

Above equation represents that the sum of the width and length of the top plate should be λ/4. This approximation is very rough and does not cover all the parameters that significantly affects the resonant frequency of the antenna [3]. As width of the shorting plate also affects resonant frequency of the antenna. So, reduction in the width of shorting plate results in lowering the resonant frequency and vice versa. By analyzing the resonant frequency and bandwidth characteristics we can determine the optimum location of the feed point, at which minimum return loss is to be obtained. By optimizing the spacing between feed point and shorting point impedance matching of the PIFA can be obtained.

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[4]. Also by optimizing the dimensions of the ground plane, the bandwidth of PIFA can be adjusted such as reduction in dimensions of ground plane can effectively widen the bandwidth of the antenna. Several other techniques can also be used to enhance the bandwidth of a PIFA namely using dielectric material of high permittivity [5], using capacitive loading, using additional shorting plate etc.

III. PROPOSED PIFA DESIGN

In this section a novel and simple PIFA design with broad bandwidth is discussed. The bandwidth here can be specified as impedance bandwidth for which return loss S11 is -6 dB as this value is good enough for mobile handset applications. Also frequency bandwidth can be specified for voltage standing wave ratio (VSWR) less than 2:1 which is equivalent to 10 dB level [6]. At this level 10% of the incident power is reflected back at the source. The geometry of the proposed antenna design is as shown in Fig. 2. The antenna comprises a square shaped top plate also referred as radiating patch, ground plane, feed wire and shorting pin or plate.

As compared with conventional PIFA design, the difference is the structure of top plate. As in conventional PIFA structure the top plate is of rectangular shape while in this paper the square top plate is proposed. Effect of using square shaped top plate results in reduction in volume of antenna. The antenna is using an FR4 PCB with relative permittivity, ε_r = 4.4 and dielectric loss tangent, δ = 0.02.

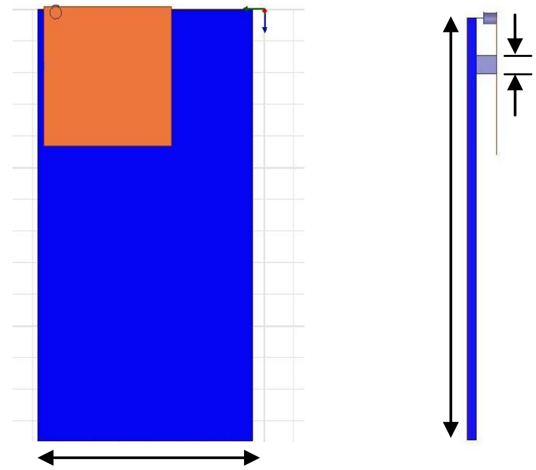

Fig. 2 Proposed antenna design (a) Top view, (b) Side view

The proposed design was simulated using HFSS simulator and design configuration is as follows : L_p= 22 mm, W_p= 22 mm, H= 5.2 mm, L_s = 5.2 mm, W_s = 3 mm. The ground plane was selected with size of L_g = 68 mm and W_g = 37 mm. The space between ground plane and top plate is air filled; here air is used as dielectric material [7]. Using a dielectric material between ground plane and top plate has effect on gain and bandwidth of PIFA antenna**.** To get good return loss and gain, the height of top plate selected is 5.2 mm. The ground plane, shorting plate and top plate are made perfect electrical conductor (pec) [8].

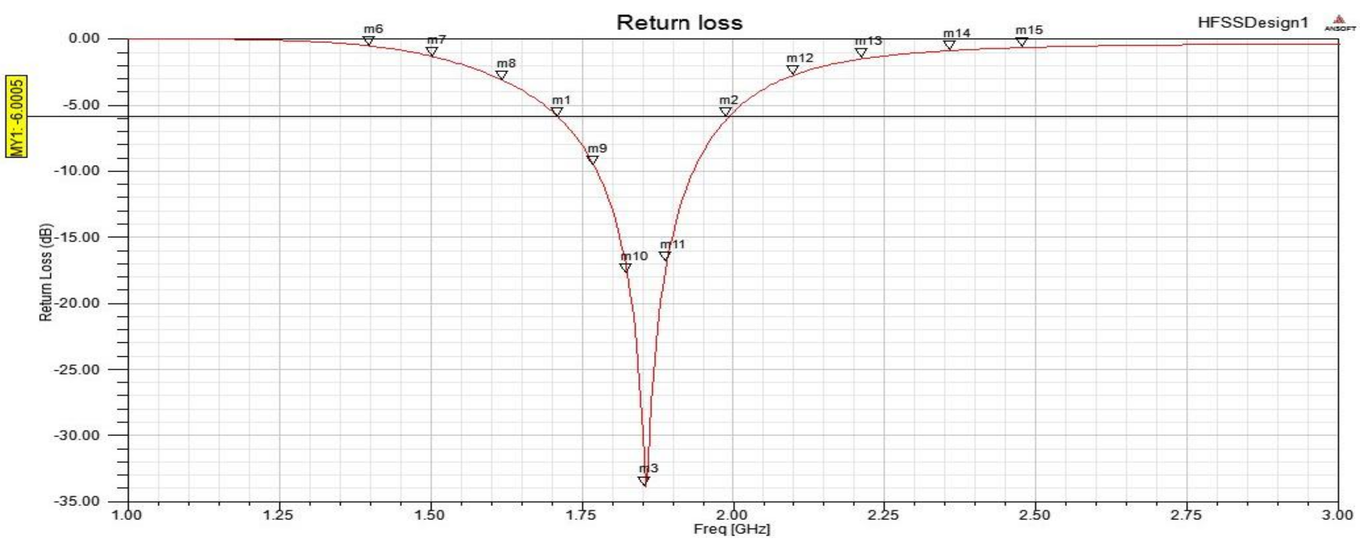

Fig. 3 Simulated Results: Return Loss of PIFA

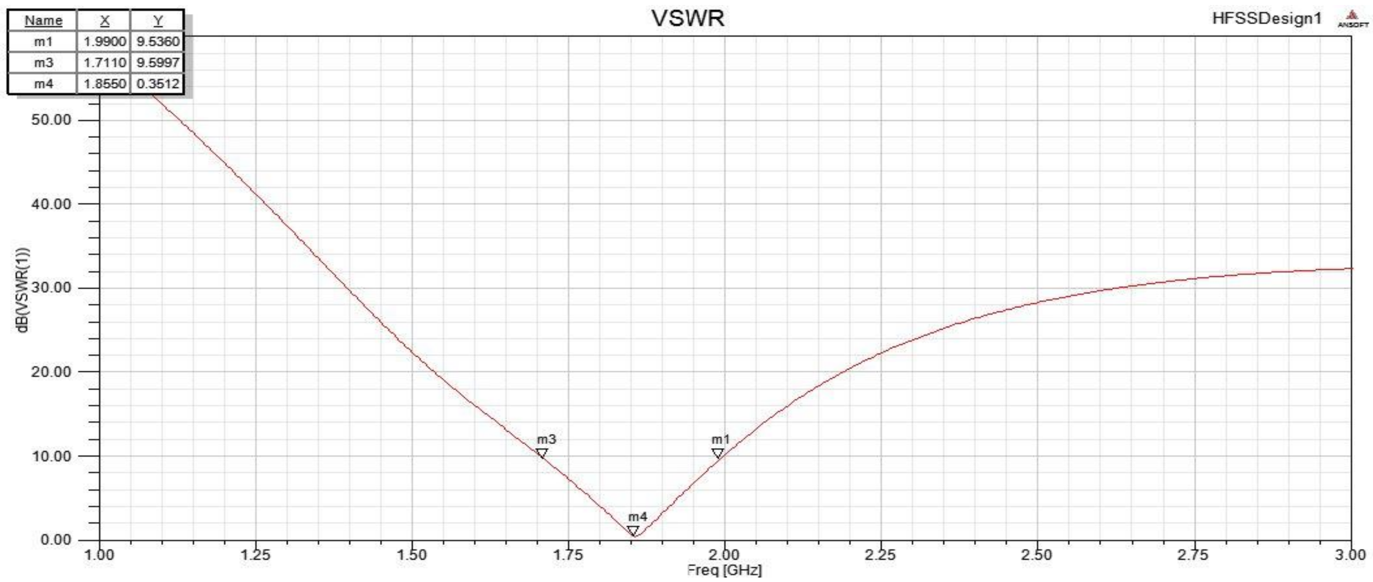

Fig. 4 Simulated Results : 3D Gain Plot of PIFA

loss is -33.88 dB obtained at resonant frequency of 1.855 GHz. At resonant frequency the impedance obtained is 1.0183 + 0.0365 j. Also, it is observed from results that at resonant frequency the Voltage Standing Wave Ratio (VSWR) is well below 2dB [7] i.e. at 1.8550 GHz value of VSWR is 0.3512 dB. The upper and lower frequency at which return loss of -6 dB is obtained is 1.990 GHz and 1.711 GHz, respectively. Therefore, the impedance bandwidth of the proposed PIFA design is the difference between upper and lower frequency [9] which is 0.28 GHz. Hence, the impedance bandwidth of PIFA is 15.1 %.

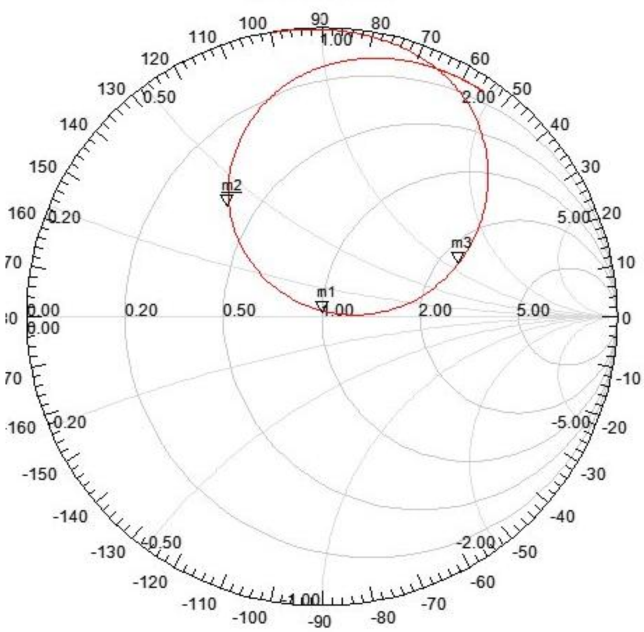

Fig. 5 Simulated Results : Input Impedance of PIFA

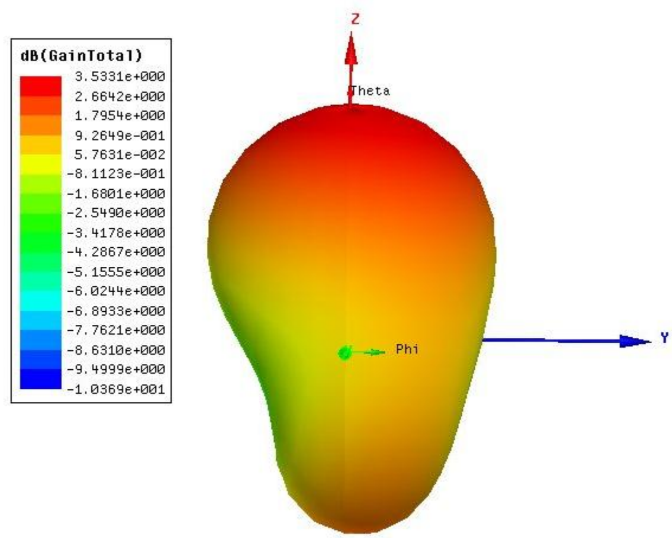

Fig. 6 Simulated Results : 3D Gain Plot of PIFA

IV. CONCLUSION

The design of a modified low profile PIFA with square shaped top plate have been presented and proposed. PIFA antennas are having a narrow bandwidth characteristic which is overcome by using several techniques. The main aim of the design is to widen the bandwidth with limited volume. Simulation results have shown good performance characteristics in terms of return loss, gain, VSWR. The design details of the antenna can be used as base for increasing the number of bands covering several communication standards.

V. FUTURE SCOPE

Proposed antenna design can be modified by introducing slots, shorting plates, slots on ground plane and several other techniques to get multiple bands supported by the structure (3G, 4G LTE, WLAN etc.). More and more frequencies in a structure are well suited for mobile applications as there is space constraint in handsets.

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