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Design of Triple-band Planar Inverted-F Antenna for 0.9/2.4/3.6 GHz Wireless Applications

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Abstract

This paper is proposed to design mobile handset antenna for make mobile handset more compact and thin. This antenna has an advantage of performing different frequency bands by one antenna design. Design and simulations are done using CST Microwave Studio program. A Reconfigurable Antenna is designed by using the FR-4 (lossy) substrate with the dielectric constant of er=4.3 and dielectric loss tangent 0.025. The substrate thickness of h=1.6[mm], length=L_sub, width=W_sub. The ground is designed by using the PEC material with h-0.035[mm]. The PIFA designed by using the copper with h=0.035[mm], length=1/L_sub. In a result, return loss was below (S|11|<-17.05dB at 0.9GHz, S|11|<-21.86dB at 2.4GHz and S|11|<-38.78dB at 3.6GHz band. VSWR=1.5 at 0.9GHz, VSWR=1.1 at 2.4GHz and VSWR=1.5 at 3.6GHz. In the future, this antenna design will be fabricated and used in a mobile handset systems.

***Keywords**:Wireless system, PIFA antenna, WiMax, GSM/PDC, Antenna theory*

1. Introduction

Recently, modern mobile handsets are miniature in size, and they are required to operate at multiple-frequency bands in order to provide the enhanced and multi-functional performances [1, 2]. Further, due the device convergence rends in the mobile handset, very limited space is available for the antenna structure [3, 4]. The conventional passive multiband antennas often require large size of antenna dimension [5, 6]. Moreover, passive multiband antennas might be less efficiency in term of minimize or eliminate unwanted radio frequency interference and/or reducing the adverse effects of co-site interference and jamming. In contrast active tunable antennas with frequency selectivity can overcome these disadvantages. This antenna known as a very attractive for handset applications due to its low profile, light weight, and conformal structure. Antennas are necessary and critical components of communication and radar systems. Arguably, nine different types of antennas have proliferated during the past 50 years in both wireless communication and radar systems [7, 8]. These nine varieties include dipoles/monopole, loop antennas, slot/horn antennas, reflector antennas, microstrip antennas, log periodic antennas, helical antennas, dielectric/lens antennas, and frequency-independent antennas. Each category possesses inherent benefits and detriments that make them more or

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less suitable for particular applications. Reconfigurability, when used in the context of antennas, is the capacity to change an individual radiator's fundamental operating characteristics through electrical, mechanical, or other means. Thus, under this definition, the traditional phasing of signals between elements in an array to achieve beam forming and beam steering does not make the antenna "reconfigurable" because the antenna's basic operating characteristics remain unchanged in this case [9]. Ideally, reconfigurable antennas should be able to alter their operating frequencies, impedance bandwidths, polarizations, and radiation patterns independently to accommodate changing operating requirements. These challenges lie not only in obtaining the desired levers of antenna functionality bt also in integrating this functionality into complete systems to arrive at efficient and cost-effective solutions. As in many cases of technology development, most of the system cost will come not from the antenna but the surrounding technologies that enable reconfigurability. In addition, Modern wireless systems employ multifunction broadband subsystems to support multiple frequency bands. This is connected with increases technical requirements for some parts of the system, *e.g.* filters and antennas with adaptable frequency behavior. Availability of multi-mode, multi-band, and multi-standard devices makes the simplification of RF front ends possible [10].

Multiband internal antennas have become a necessity for the state-of-the-art multifunction "smart-phone" and wireless sensor modules for the mobile devices. but this paper is proposed to design mobile handset antenna for make mobile handset more compact and thin. This antenna has an advantage of performing different frequency bands by one antenna design. For this purpose, a varactor diode is used in antenna design [11].

2. Microstrip Antenna Theory

2.1. Input Parameter

Resonant frequency:

The resonant frequency parameter has to be entered by the user to calculate almost every parameter of microstrip antenna. The width and length calculation is

directly related to this resonant frequency. The resonant frequency of microstrip antenna could be estimated by using this following formula:

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-1/2} \tag{1}$$

2.2. Output Parameter

Width:

The Width of the patch Antenna totally depends on the dielectric constant and thickness of the substrate and on the resonant frequency which is specified by the users. Here is the equation to calculate width of microstrip antenna:

$$W = \frac{c}{2f_r}\left(\frac{\varepsilon_r + 1}{2}\right)^{-1/2} \tag{2}$$

Effective Length:

Electrically the patch of microstrip antenna looks greater than in physical dimensions. For the principal E-plane (xy plane), this is demonstrated in the figure below where the dimensions of the patch along its length have been extended on each end by a distance ΔL , which is a function of the effective dielectric constant and width to height ratio:

$$\Delta l = 0.412 \frac{(\varepsilon_{re} + 0.3)(W/h + 0.264)}{(\varepsilon_{re} - 0.258)(W/h + 0.8)} \tag{3}$$

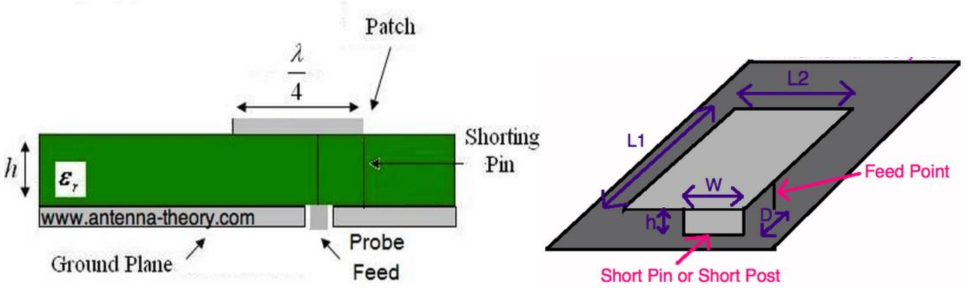
Length:

The length of microstrip filter depends on the effective permittivity of the substrate, the width and the desired resonant frequency:

$$L = \frac{c}{2 f_r \sqrt{\varepsilon_{re}}} - 2\Delta l \tag{4}$$

3. Planar Inverted-F Antenna Theory

Antenna designers are always looking for creative ways to improve performance. One method used in patch antenna design is to introduce shorting pins (from the patch to the ground plane) at various locations. To illustrate how this may help, two instances will be illustrated, the quarter-wavelength Patch Antenna, which leads into the Planar Inverted-F Antenna (PIFA). The Planar Inverted-F antenna (PIFA) is increasingly used in the mobile phone market. The antenna is resonant at a quarter-wavelength (thus reducing the required space needed on the phone), and also typically has good SAR properties. This antenna resembles an inverted F, which explains the PIFA name. The Planar Inverted-F Antenna is popular because it has a low profile and an omnidirectional pattern. The PIFA is shown from a side view in Figure 1 (a).



(a) (b)

Figure 1. Half-wavelength Patch with Shorting Pin at the Feed and PIFA Antenna

The PIFA is resonant at a quarter-wavelength due to the shorting pin at the end. We'll see how the resonant length is defined exactly in a minute. The feed is placed between the open and shorted end, and the position controls the input impedance. In PIFAs, the shorting pin can be a plate, as shown in Figure 1 (b):

In Figure 1 (b), we have a PIFA of length L1, of width L2. The shorting pin (or shorting post) is of width W, and begins at one edge of the PIFA as shown in Figure 1 (b). The feed point is along the same edge as shown. The feed is a distance D from the shorting pin. The PIFA is at a height h from the ground plane. The PIFA sits on top of a dielectric with perceptivity as with the patch antenna.

The impedance of the PIFA can be controlled via the distance of the feed to the short pin (D). The closer the feed is to the shorting pin, the impedance will decrease; the impedance can be increased by moving it farther from the short edge. The PIFA can have it's impedance tuned with this parameter.

The resonant frequency of the PIFA depends on W. If W=L2, then the shorting pin runs the entire width of the patch. In this case, the PIFA is resonant (has maximum radiation efficiency) when:

$$\text{If} \quad W = L2 \Rightarrow L1 = \frac{\lambda}{4} \tag{5}$$

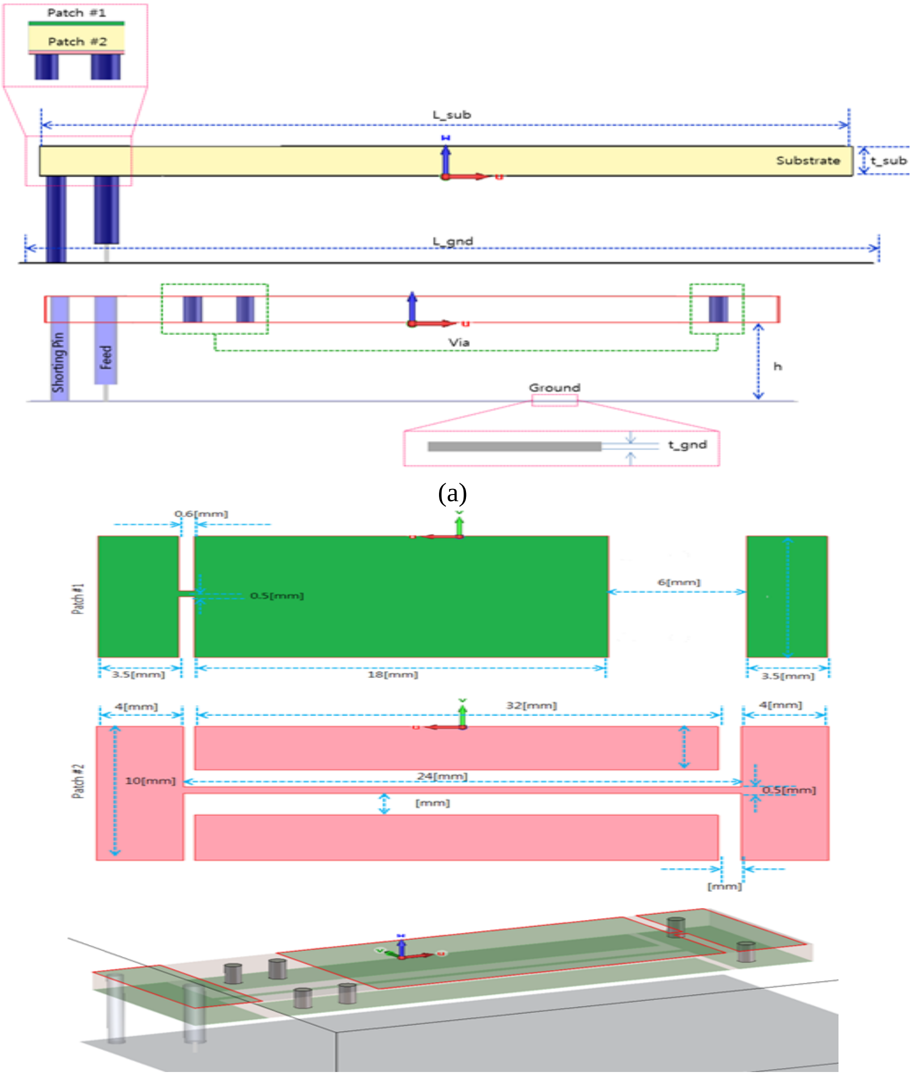
Suppose that W=0, so that the short is just a pin (or assume W << L2). Then the PIFA is resonant at:

$$\text{If} \quad W = 0 \Rightarrow L1 + L2 = \frac{\lambda}{4} \tag{6}$$

Why does the resonant length of the PIFA depend on the shorting pin length W? Intuitively, think about how a quarter-wavelength patch antenna radiates. It needs a quarter-wavelength of space between the edge and the shorting area. If W=L2, then the distance from one edge to the short is simply L1, which gives us Equation (5)[12].

4. Design of the PIFA Antenna

Figure 2 shows the geometry of our proposed antenna model. The proposed novel antenna is designed by using the FR-4 (lossy) substrate with the dielectric constant of er=4.3 and dielectric loss tangent 0.025. The substrate thickness of h=1.6[mm], length=L_sub, width=W_sub. The ground is designed by using the PEC material with h-0.035[mm] and length=3/L_sub. The patch designed by using the copper with h=0.035[mm], length=1/L_sub.



(a)

(b)

Figure 2. The Planar Inverted-F Antenna Design with Short Pin

5. Result

Figure 3 shows the simulated return loss of the proposed antenna. From the obtained results, it is clearly seen the return losses of the proposed antenna can cover the required bandwidth of the (S|11|<-17dB at 0.9GHz, S|11|<-21dB at 2.4GHz and S|11|<-38dB at 3.6GHz band.

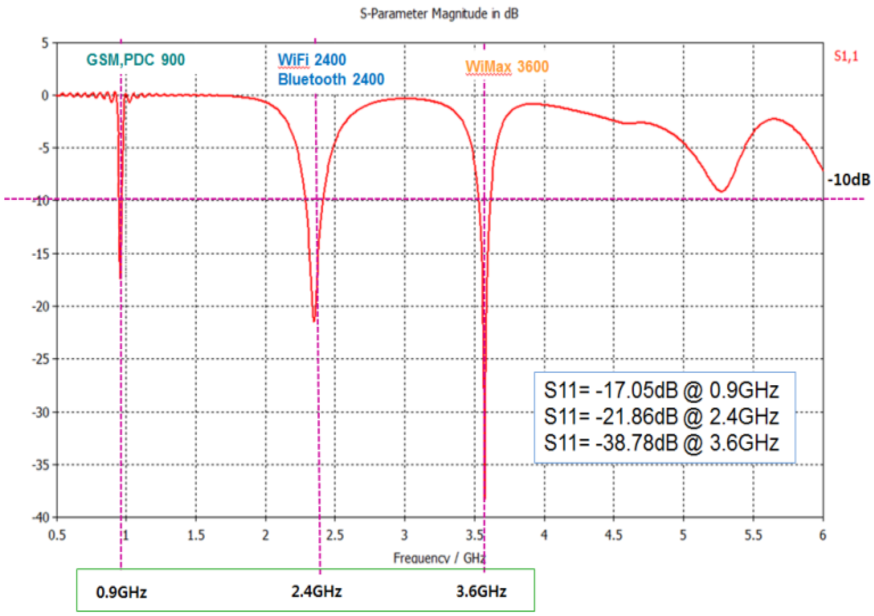


Figure 3. S-Paremeter Magnitude in dB (Return loss)

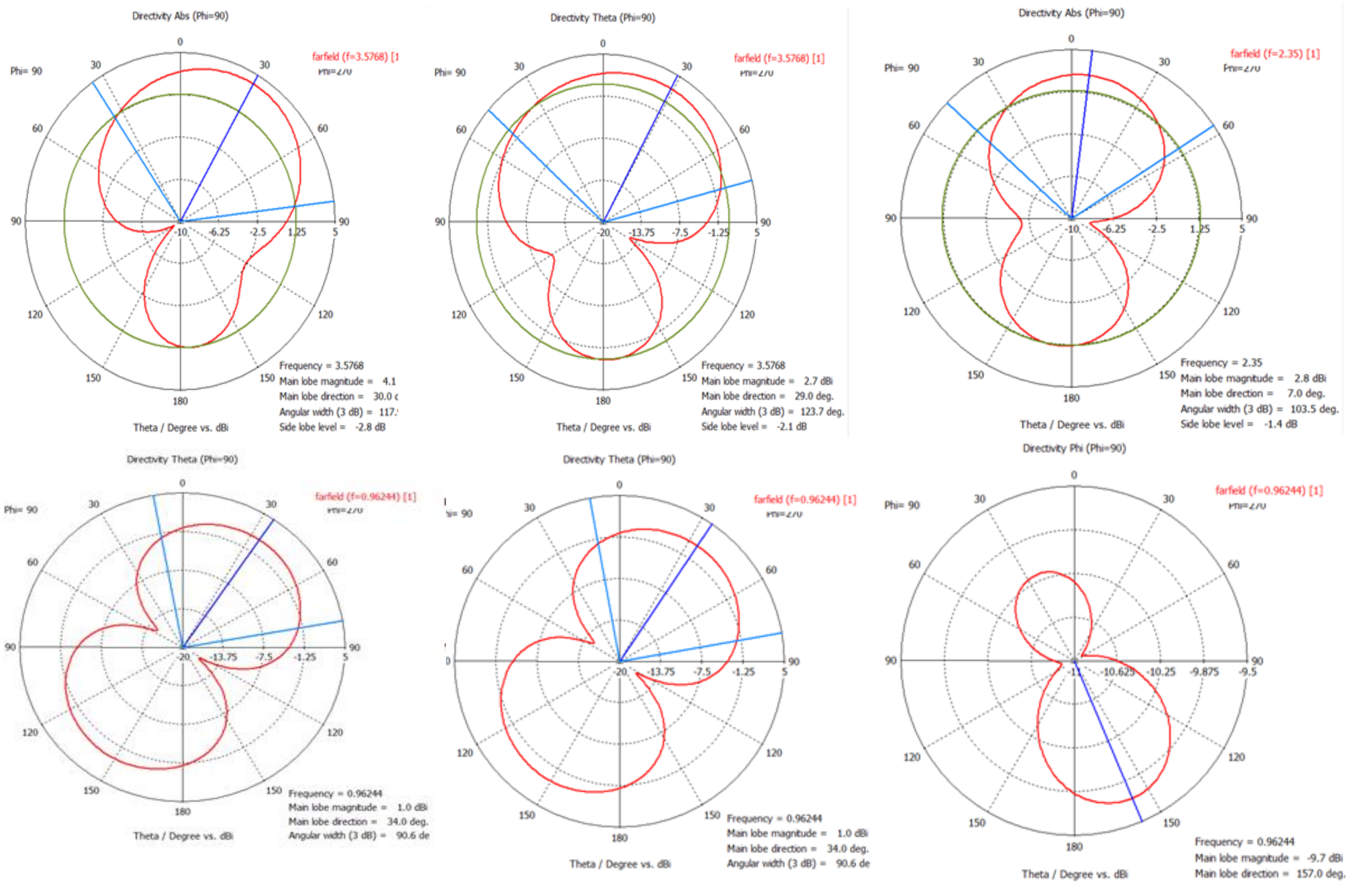


Figure 4. E-Plane and H-Plane Radiation pattern at 0.9GHz, 2.4GHz and 3.6GHz

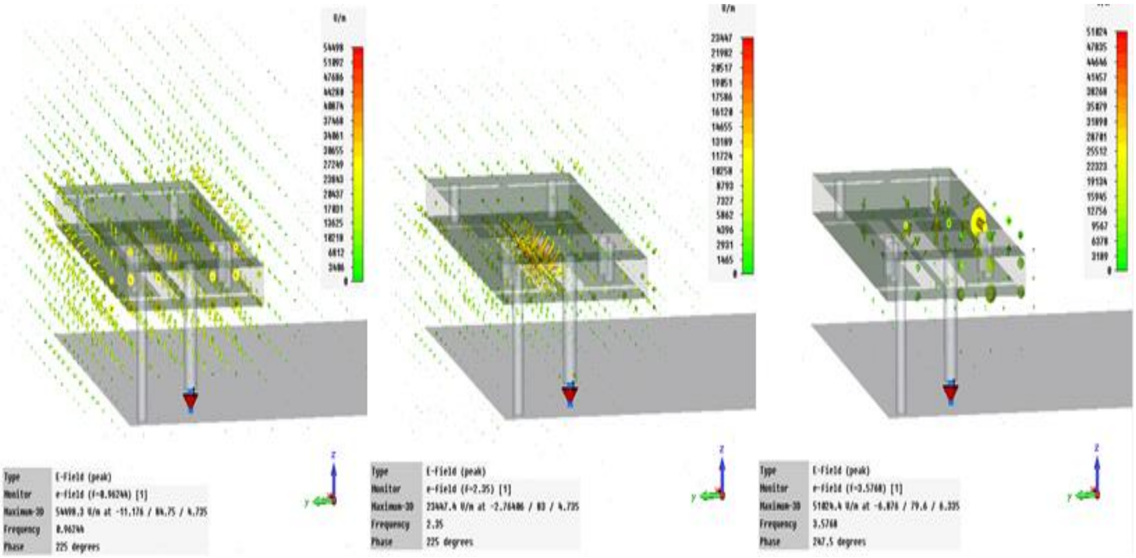


Figure 5. The Result of E-Field at 0.9GHz, 2.4GHz and 3.6GHz

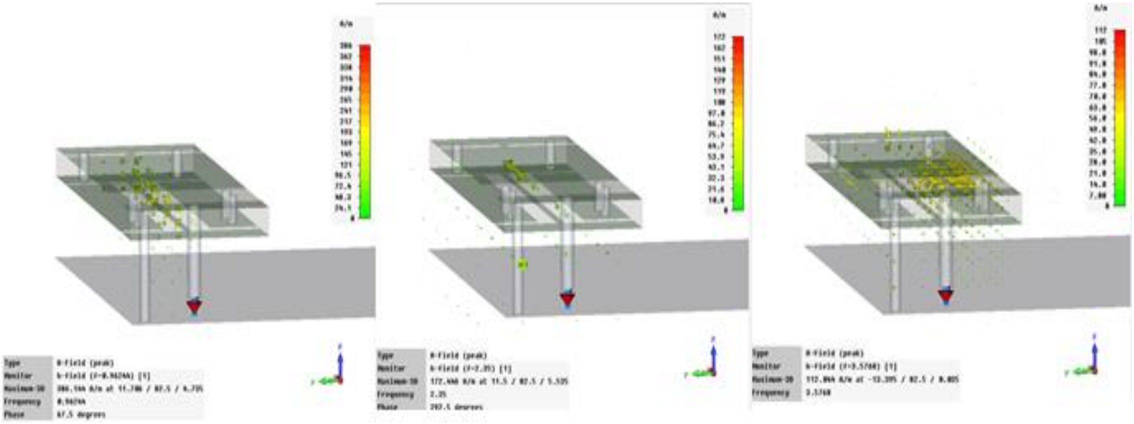


Figure 6. The Result of H-Field at 0.9GHz, 2.4GHz and 3.6GHz

6. Conclusion

Design and simulations are done using CST Microwave Studio program. Antenna is designed by using the FR-4 substrate with the dielectric constant of er=4.3 and dielectric loss tangent 0.025. The substrate thickness of h=1.6[mm], length=L_sub, width=W_sub. The ground is designed by using the PEC material with h-0.035[mm] and length=3/L_sub. The patch designed by using the copper with h=0.035[mm], length=1/L_sub. In a result, return loss was below -17.05dB at 0.9GHz, -21.86dB at 2.4GHz and -38.78dB at 3.6GHz band.

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