Triple Band Planar Inverted F-Antenna For LTE, Wifi And Wimax Applications

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***Abstract*— A small triple band planar inverted-F antenna with independently controlling the resonant frequency is presented. In this paper, new configurations of slotted (PIFA) antennas simulated at different frequencies and which can be integrated in mobile handsets are proposed. The antenna occupies a compact size of 22.4 x 46 x 7.75 mm. The main radiating patch is etched/cut with slots (parallel and U-shaped slot) to generate and control the three resonant frequencies to cover 1.7GHz Long Term Evolution(LTE), 2.4GHz Wireless Local Area Network (WLAN/Bluetooth IEEE 802.11) and 3.7GHz Worldwide Interoperability for Microwave Access (WiMAX).**

Keywords- PIFA, tri-Band, LTE, WLAN(Bluetooth), WiMAX, U- shaped slot, RF antenna.

I. INTRODUCTION

With the rapid growth of the wireless mobile communication technology, the future technologies need a very small antenna and also the need of multiband antenna is increased to avoid using two antennas and to allow video, voice and data information to be transmitted. The advantage of planar inverted-F antenna (PIFA) makes them popular in many applications requiring a low profile antenna. PIFA antenna is promising to be a good candidate for the future technology due to the flexibility of the structure as it can be easily incorporate into the communication equipments [1] [2].

PIFA can be considered as a kind of linear Inverted F antenna (IFA) with the wire radiator element replaced by a plate to expand the bandwidth. The PIFA has many advantages, that is, easy fabrication, low manufacturing cost, and simple structure. PIFA can be hiding in the housing of the mobile phone when comparable to whip/ rod/ helix antennas. Besides, PIFA has reduced backward radiation towards the user’s head, minimizing the electromagnetic wave power absorption (SAR) and enhance antenna performance. It exhibits moderate to high gain in both vertical and horizontal states of polarization. This feature is very useful in certain wireless communications where the antenna orientation is not fixed and the reflections are present from the different corners of the environment. In those cases, the important parameter to be considered is the total field that is the vector sum of horizontal and vertical states of polarization [3].

Many researchers have studied different structure and different techniques to increase the bandwidth and to have multiband in single antenna by using U-shaped slots [4]. Also, by inserting two parallel slots close to the radiating edges of the patch antenna a wider impedance bandwidth and dual band resonance has been achieved [5]. In [2] rectangular slots are etched on the patch to achieve tri-band applications. Parametric study performed on PIFA was very useful in designing and optimizing the parameters to target the required communication bands [6]. In [7], a rectangular slot is inserted between a U-shaped slot to achieve dual band.

Based on the above analysis, we present a novel triple band planar inverted-F antenna. The main features of the antenna is to cut a U-slot in the radiation patch and two parallel slots on either sides of the radiating edges . Its biggest advantage is not only realizing the work of a triple-band PIFA, but also meeting the requirements of bandwidth and small antenna.

II. ANTENNA CONFIGURATIONS AND DESIGN PROCEDURE

The antenna has a simple structure fed by 0.5mm radius using probe fed technique. Fig. 1 demonstrates the 3D view of the proposed antenna used for simulated study. The dielectric material selected for the design is FR-4 which has dielectric constant of 4.4 and height of dielectric substrate (h) = 1.6 mm. Generally the overall dimension of the antenna is 22.4 x 46 x 7.75 mm. The parameters of the proposed antenna are shown in fig. 3. Zeland IE3D V.14.10 package is used to obtain the return loss, the gain, the radiation efficiency and the radiation patterns. Fig. 2 shows the simulated S11 of the proposed PIFA antenna. The simulated return loss shows three bands at 1.7, 2.4 and 3.7GHz. The proposed antenna satisfies the requirement to cover Long Term Evolution (LTE), Wireless Local Area Network (WLAN/Bluetooth IEEE 802.11) and Worldwide Interoperability for Microwave Access (WiMAX). Some parameters are affecting the characteristic of the response, the design started with the main radiated top patch which can be calculated by using equations (1 & 2), and then rectangular small parallel slots are inserted along the radiating edges on the main patch to add another resonant frequency. U-shaped slot is added then to generate and control the third resonant frequency as shown in fig.2. Further investigation is carried out in A, B and C to proof the concept of independently controlling the three resonant frequencies generated from the proposed antenna.

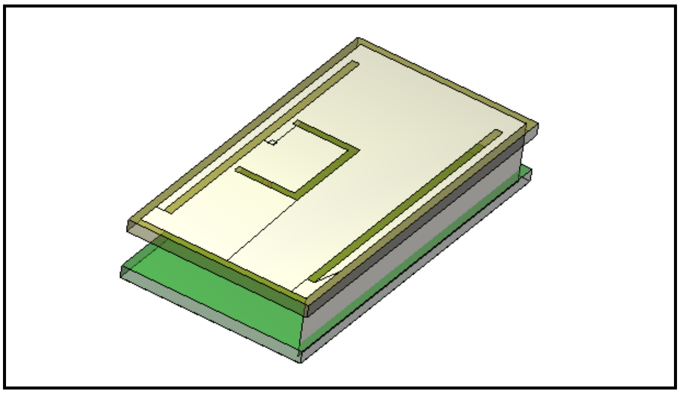

Figure 1: 3D View of the proposed antenna.

A. *EFFECT OF THE MAIN PATCH (SINGLE BAND):*

The proposed antenna consists of Main top patch, a shorting wall along one of the width, 0.5 mm radius probe to feed the patch and a ground plane. The patch is designed separately at first to operate at the WLAN 2.4 GHz band using equations (1 & 2), this equations are a very rough approximation which does not cover all the parameters which significantly affect the operational frequency of PIFA. The total size of the main top patch is 22.4 x 38 mm supported by a shorting wall is attached to the ground plane with height of 7.75 mm.

$$f = c/4(w + L)\sqrt{\varepsilon_r} \text{ - - - - - - - - - - - - - (1)}$$

From [6] empirical equation is given as,

$$f = c/(3W + 5.6L + 3.7h - 3W_f - 3.7W_s - 4.3L_b - 2.5L_s) \text{ - - (2)}$$

Where *L* and *W* are the length and width of the top plate and ε_r is the dielectric constant. h is the hieight between the patch and the ground plane. W_f and W_s are the width of the feed and shorting wall respectively. Whereas L_b is the horizontal distance between these plates and L_s is the distance of shorting plate from side edge of the top plate. The antenna is fed using a probe of radius 0.5 mm. The main top patch generates a single band at 2.4 GHz with S11= -33.81 dB and bandwidth of 300 MHz as shown in fig. 2a. It has been found that, different locations of the shorting wall along the X-direction will provide shift of the centre operating frequency. Also it has been found that the operated frequency can be tuned by increasing or decreasing the width, height and the length of the radiated patch.

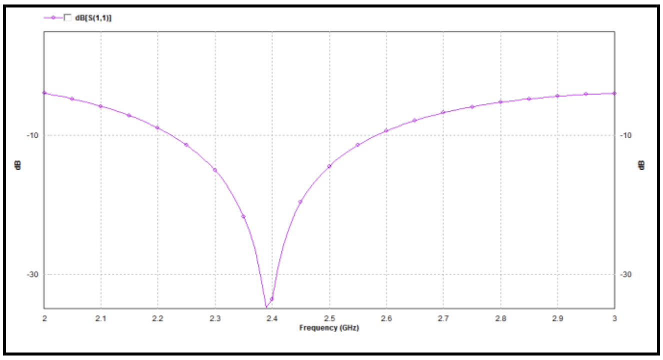

Figure 2.a: Return loss response with only main patch and no slots.

B. *EFFECT OF SLOTS ALONG RADIATING EDGES (DUAL BAND):*

As a second step to obtain multi-band, parallel rectangular slots are applied to the main top patch to generate the second band; the total area of the rectangular slot is 1 x 39.4 mm each. The slot has been assigned close to the radiating edges of the main patch, it give the shape a look like thin rectangle which will be called in this paper as parallel slots. After adding the slots to the main patch another band has been generated at 1.7 GHz with bandwidth of 170 MHz as shown in fig. 2b. The 2.4 GHz band is still resonating with bandwidth of 80 MHz. By increasing or decreasing the size of the slot, the resonant frequency can be shifted either to a lower or higher band. Our target is 1.7GHz LTE band.

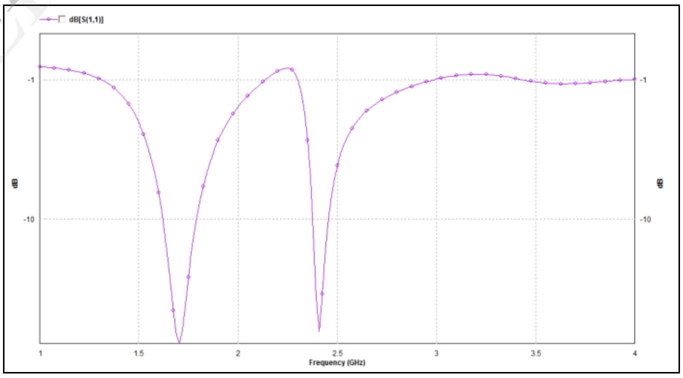

Figure 2.b: Return loss response with main patch and parallel slots.

C. *EFFECT OF U - SHAPED SLOT (TRIPLE BAND):*

It is clear from the previous designs the main patch has generated single band at 2.4GHz, adding parallel slots to the main patch another band can be generated at 1.7GHz. Since this paper is to investigate the possibility of generating multi-band from small antenna and controlling the generated band, another slot (U-shaped) is added to the structure resulting in generating another band at 3.7GHz with bandwidth of 210MHz. 1.7GHz and 2.4GHz bands are still resonating but with bandwidth to 150MHz and 70MHz respectively.

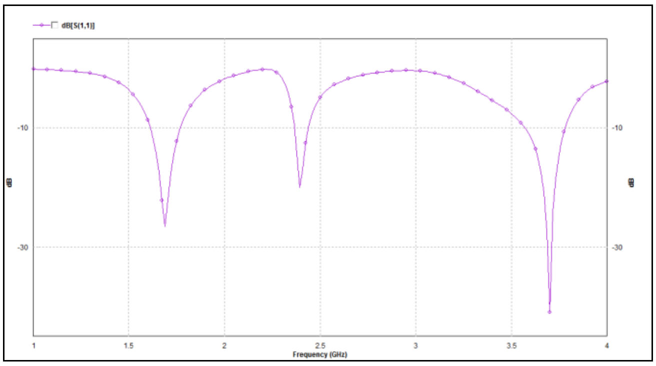

Figure 2.c: Return loss response with main patch, parallel slots and U-shaped slot.

III. SIMULATION RESULTS

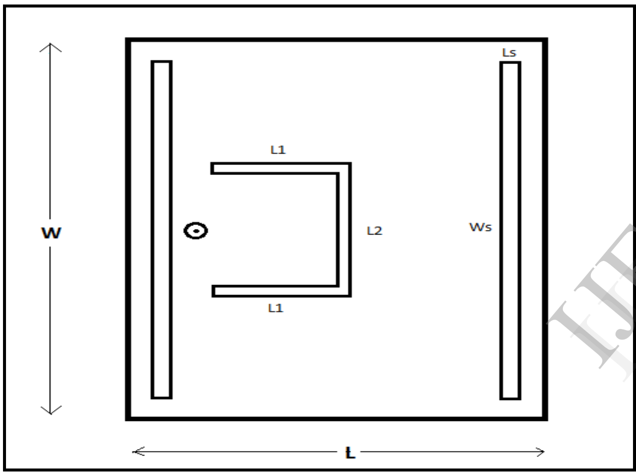

Figure 3: Top view of the patch showing the parallel and U-shaped slots for triband Applications.

For an antenna working at 1.7GHz, 2.4GHz and 3.7GHz, patch dimensions are:

Type of feed – Coaxial feed at (-8.19, 0) from center.

L = 22.4 mm

W = 46 mm

h = 7.75 mm

t = 1.6 mm

ε_r = 4.4

Ls = 1 mm

Ws = 39.4 mm

L1= 9.5 mm

L2 = 13 mm

A. RETURN LOSS:

The practical circuit realization suffers with the mismatch between the available source power and the power delivered. This mismatch is known as return loss.

Return loss = -20log (Ţin)

where 'Ţin' is input reflection coefficient. The return loss of the antenna is obtained as -23.37 dB at 1.7GHz, -18.62 dB at 2.4GHz and -38.87 dB at 3.7GHz. So the designed antenna offers good gain and minimum losses at the specified frequency. It has a bandwidth of 150MHz, 70MHz and 210MHz respectively. The return loss of the antenna is shown in Fig 2.c.

B. RADIATION PATTERN:

A microstrip patch antenna (PIFA) radiates normal to its patch surface. The elevation pattern for Φ=0 and Φ=90 degrees would be important. Figure below (see 4.a, 4.b, 4.c) show the 2D radiation pattern of the antenna at the desired frequency of 1.7GHz, 2.4GHz and 3.7GHz for Φ=0 and Φ=90 degrees in polar plot.

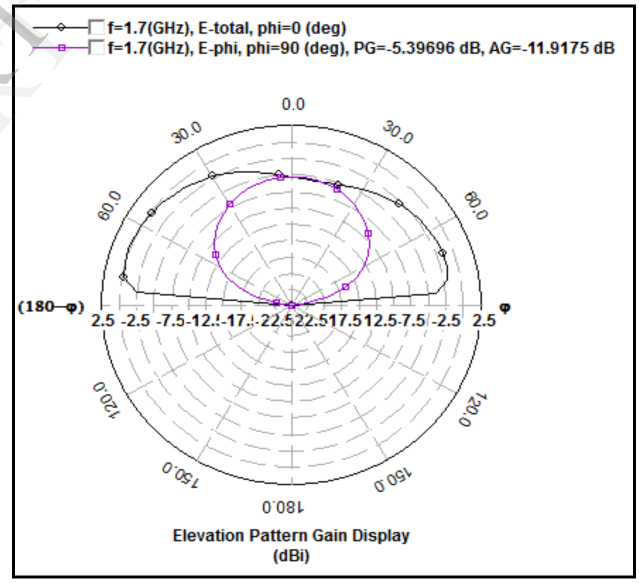

Figure 4.a: Elevation pattern gain display (dBi) at 1.7GHz.

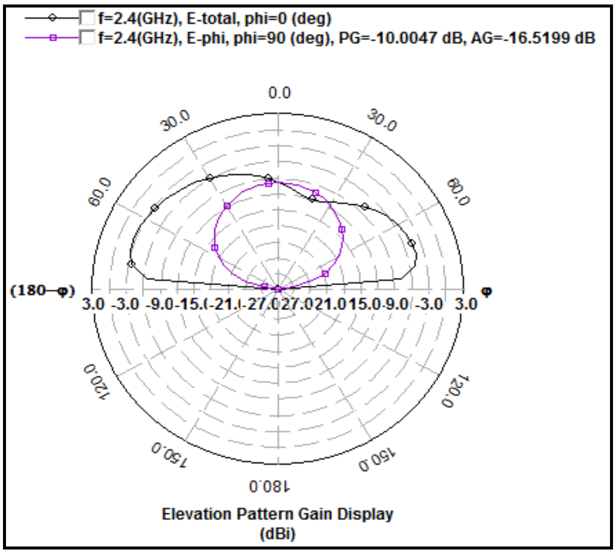

Figure 4.b: Elevation pattern gain display (dBi) at 2.4GHz.

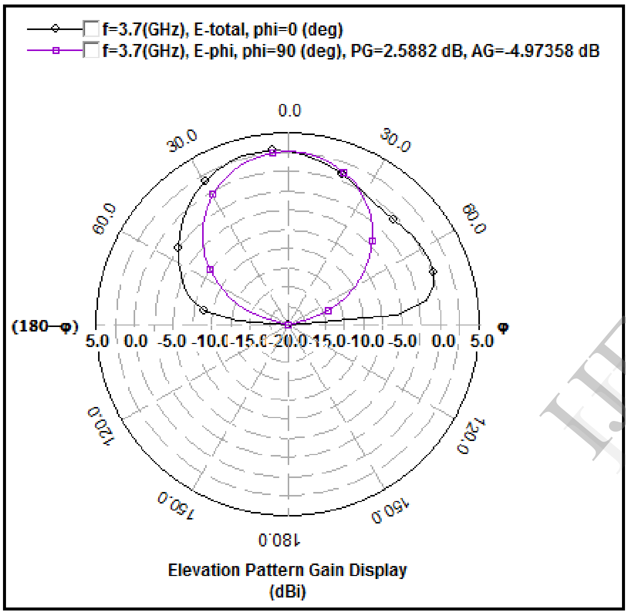

Figure 4.c: Elevation pattern gain display (dBi) at 3.7GHz.

C. *VOLTAGE STANDING WAVE RATIO:*

VSWR is a function of reflection coefficient, which describes the power reflected from the antenna. If the reflection coefficient is given by Ʈ, then the VSWR is defined as

VSWR = (1 + Ʈ) / (1 - Ʈ)

As shown in fig 5, the VSWR of 1.16, 1.29 and 1.05 was achieved for 1.7GHz, 2.4GHz and 3.7GHz respectively from simulation results.

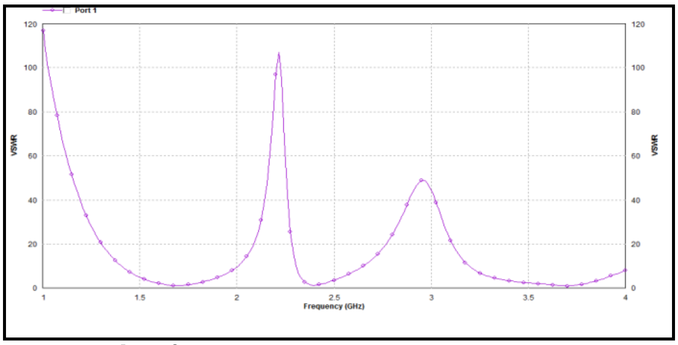

Figure 5: Plot of VSWR v/s Frequency.

IV. CONCLUSION

A Novel compact multi-band Printed Inverted-F Antenna has been designed and simulated to independently control LTE, WiFi and WiMAX bands. The antenna can be used as single-band or as multiband. Although the antenna has been design to operate in LTE, WiFi and WiMAX, it would also be possible to design the bands to any other system by changing the parameters of the top patch and by varying the length and width of the slots. This design also has a provision for tuning only the frequencies in WiMAX bands by varying the dimensions of the U-shaped slot.

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