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DESIGN AND ANALYSIS OF A U-SLOT PLANAR INVERTED-F ANTENNA FOR GSM900 AND DCS1800 BAND

Savita Singh[1], Poonam Pathak[2]
Department of Electronics & Communication Engineering
BBD-NIIT, Lucknow, INDIA
Email Id: [1]savitasingh14@gmail.com; [2]pathakpoonam24@gmail.com

Abstract-In this paper, the new configuration for planar inverted-F antenna (PIFA) is proposed for dual band mobile phone application. To reduce the size of the antenna, folded and shorted structure is used. U-shaped slot is cut in the antenna radiation patch, which can obtain two operating frequencies. It has been shown that the proposed antenna can cover the operating frequencies of GSM 900 (890-960 MHz) and DCS 1800 (1710-1880 MHz) bands.
It is compact, low cost and having better antenna performance in terms of return loss, radiation patterns etc. The characteristics of the antenna are simulated using FEM based 3D EM software Ansoft HFSS.

Keywords*-Dual band; PIFA; Global system for mobile communication (GSM); Digital cellular system (DCS), HFSS*

1. INTRODUCTION

The latest development in wireless communication technologies has enhanced the capability of communication system. Cellular communication systems have a variety of different antenna sizes, ranging from small hand-held devices to wireless local-area networks operating at different frequency band. The incorporation of different radio units into the same piece of equipment has presented a need for multi-band antennas. Hence, miniaturized antennas for multiple bands applications has been a hot topic in antenna design.
First answers to cellular communications are the monopole λ/2 antennas but the inherent disadvantages like antenna's venerability to physical damage, uncontrolled radiation toward user and disability to resonance at multi-frequencies soon gave place to PIFAs. Inverted-F antennas (PIFA) are attractive for the wireless systems due to easy manufacturing, being low profile, desired cross polarization and low SAR, planar[1]-[3]. In short, PIFAs consist of radiating patches that are parallel to a ground and are connected to ground by a shorting plate making it able to resonance at λ/4.
In this paper, a compact dual band U-shaped PIFA for mobile phone applications has been presented. This antenna has a compact geometry, attractive electromagnetic performance characteristics, and operates with only a single coaxial feed. It is designed for GSM and DCS band by cutting a slot in the main radiating patch suitably making two sub radiating patches operating independently at the two specified band [4]-[6]. A U slot is selected because of minimum guided radiation towards the user end at the higher resonance frequency (DCS Band) compared to other geometries.

2. ANTENNA DESIGN

The schematic diagram of proposed antenna is shown in Figure-1.The antenna structure includes a radiation patch, a ground plate, a coaxial feed, and a shorting plate. Air is used as dielectric medium between the radiation patch and the ground. A foam material Rohacell($\in_r = 1.07$)can be used as filler to provide the structural rigidity. The radiation patch connects to ground plane through a wide shorting plate. The width of shorting plate and location of the coaxial feed point is regulated to achieve the impedance matching with the 50Ω coaxial line. A U-Slot is cut in the main radiating element to achieve dual band frequency operation and can greatly reduce the size of the antenna by increasing the electrical length of radiating patch [7]-[9]. The width and length of the slots help us to change the resonant frequencies independently. Due to the U-Slot in the radiation patch the antenna is divided into two radiation patches, the outer patch is mainly working in the lower frequency band (900MHz) and the inner patch in the higher frequency band (1800MHz). It is known that for monopole antenna, the desired length is quarter-wavelength since it is resonant in this case. Using same analogy, the size of a planar inverted–F antenna can be determined approximately from [1], [6]:

$$f_o = \frac{c}{4(W+L)} \quad (1)$$

Where c is the velocity of light, W and L are the width and length of the antenna radiation patch and f_o is the resonant/operating frequency. It may be observed that if the resonant frequency is known then several dimensions of the antenna can be calculated.

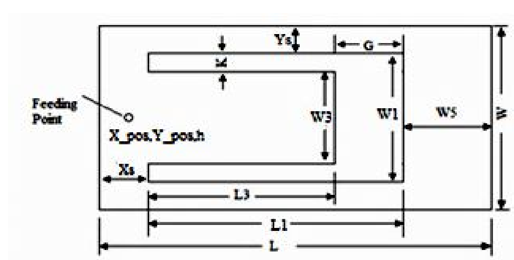

Figure 1:Configuration of proposed PIFA Antenna

Table-1 represents the optimized design parameters of the proposed antenna.

Table 1: Parameters of Proposed Antenna

Parameter	Value(mm)
Lg	100
Wg	52
L	50
W	40
L1	36
W1	34
L3	29.5
W3	30
Ys	3
W5	10
Xs	5
h	9
Ws	12
G	6.5
Feed Position (x_pos,y_pos,0)	(3,18,0) RCS1

3. RESULTS AND DISCUSSIONS

The design and simulation of the proposed antenna is carried out using Finite Element Method (FEM) based 3D EM software Ansoft HFSS. The CAD model of proposed antenna is shown in Figure-2. The reflection coefficient is simulated with antenna parameters listed in Table1.The simulated return loss (S11) is shown in Figure-3. The impedance bandwidth ($|S_{11}| < -10dB$) covers GSM900 (890-960 MHz) and DCS1800 (1710-1880 MHz) bands which is better than [6] as shown in Figure-3.

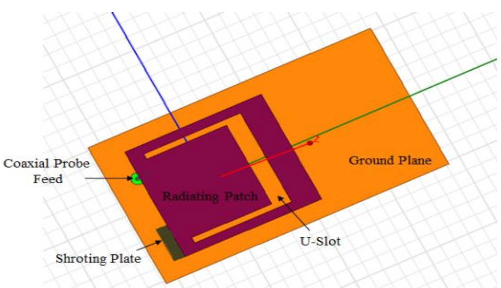

Figure 2: CAD Model of proposed U-Slot PIFA Antenna

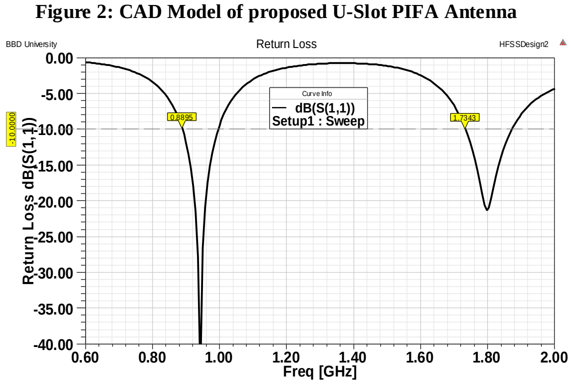

Figure 3: Simulated Return Loss of the proposed antenna

The 2D radiation pattern is shown in Figure-4.As the pattern shape is concerned almost Omni-directional characteristics can be seen in E & H plane. The antenna has no privileged in terms of gain in the lower band (GSM).Gain is slightly higher in DCS band. To provide physical insight of the PIFA electric field intensity distribution on antenna surface for both the frequencies band is shown in Figure-5. It can be seen from Figure-5(a), the radiation happens from far-edge of the outer radiating patch where field intensity is maximum which resonates at GSM (900 MHz) band and almost zero at inner patch. Similarly from figure-5(b), field intensity is maximum at inner patch and almost zero at outer patch which clearly signifies that inner patch is radiating at DCS (1800 MHz) band.

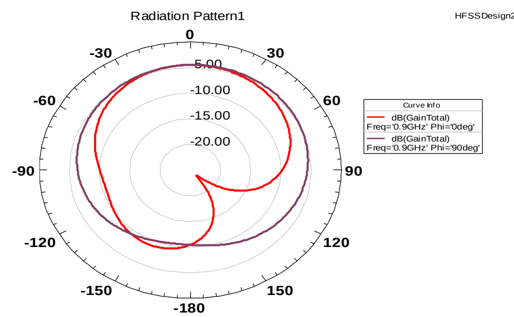

Figure 4(a): 2D Radiation pattern of U-slot PIFA at 900MHz

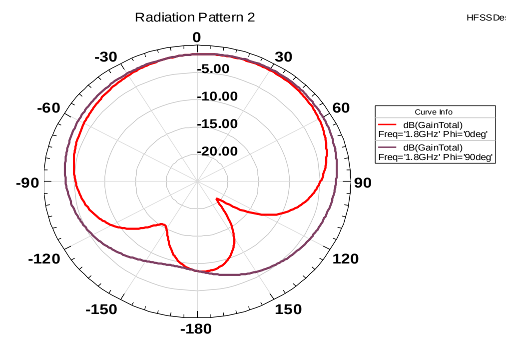

Figure 4(b):2D Radiation pattern of U-slot PIFA at 1800MHz

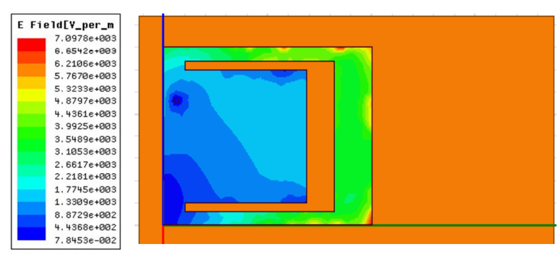

Figure 5(a): Electric Field Intensity over patch at 900 MHz

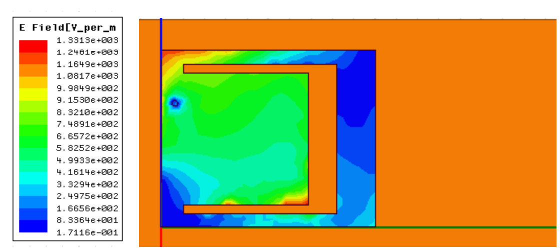

Figure 5(b): Electric Field Intensity over patch at 1800 MHz

4. PARAMETRIC ANALYSIS

Parametric analysis of the proposed antenna is carried out to observe the effect on the result over the variation of different parameters in antenna design for better radiation performance. Study is carried out by changing one parameter at a time to observe its effects on the characteristics of the PIFA while all other parameters are held constant [10]-[12]

Both length (Lg) and width (Wg) of ground plate size slightly influenced the bandwidth [13] but the resonant frequency is not sensitive to the dimensions of the ground plane size (Lg, Wg) because the antenna dimension is the dominant factor for radiation. It is seen that change in resonance frequency is small compare to change in length or width of ground plane [14]. The proposed antenna performance is optimized with ground plane size of 100mm X50mm which is appropriate for most cellular phone.

A. *Change in position of probe feed:*

Feed point position is varied from 6 mm to 14 mm for impedance matching. Figure-6 shows the simulated return loss with variation of probe position (y_pos) by keeping other dimension of antenna as nominal as given in Table 1. It is observed that as the position of the probe is increased from the center to the edge, the resonant frequency is shifted to the higher frequency side. Minimum reflection is observed at feed position of 18 mm where antenna is matched with 50Ω feed.

B. *Change in height of radiating plate*

The height (h) of radiating plate is varied from 6mm to 12 mm to observe the effect on bandwidth and resonance frequency while all other parameter are again nominal as in Table I. It is observed from Return Loss plot shown in Figure-7, that as the height increases the impedance bandwidth increases and resonant frequency decreases.

C. *Change in width of shorting plate*

The next investigation is to change the width of shorting plate from 6mm to 14mm while keeping the other parameters unchanged. The simulated return loss is shown in Figure-8. It can be observed that as the shorting plate width increases there is increase in the resonant frequency.

D. *Change in length and width of radiating plate*

The length and width of radiating plate is varied from 40mm to 52mm and 30mm to 42mm respectively. Fig.ure-9 & Figure-10 shows return loss plot with the variation in the length and width of the radiating patch. As expected increase in the length and width of the main radiating patch, decreases the lower resonant frequency.

E. *Change in slot width of radiating plate*

The addition of a U-shaped slot had no effect on the lower resonant frequency because it determines the upper resonant frequency. With the variation in gap (G) along with slot width (W5), upper resonance frequency can be controlled independently.

Figure-11 shows the return loss plot with variation of the slot width W5 keeping all other parameters constant. Significant change in resonance frequency at higher frequency band is observed while there is no change in lower resonance frequency.

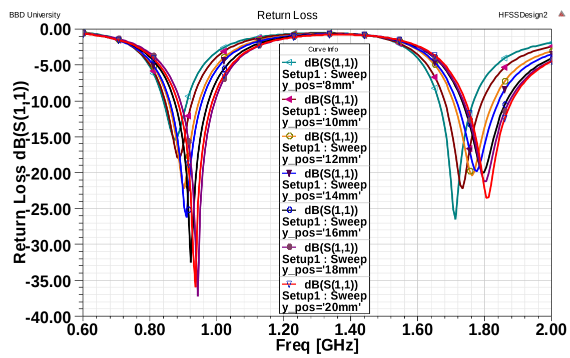

Figure 6:Simulated return loss of the antenna with different probe position (y_pos)

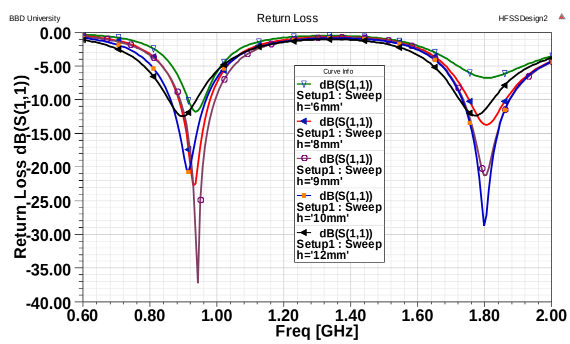

Figure 7:.Simulated return loss of the antenna with different patch height (h)

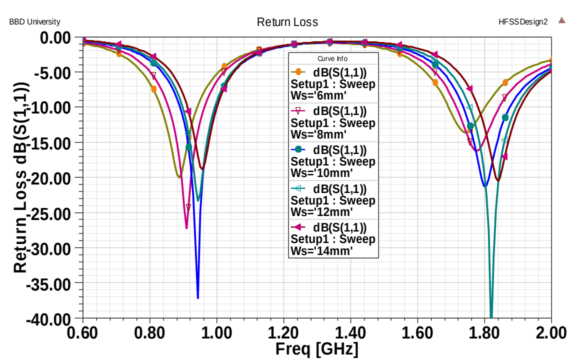

Figure 8:Simulated return loss of the antenna with different shorting length (Ws)

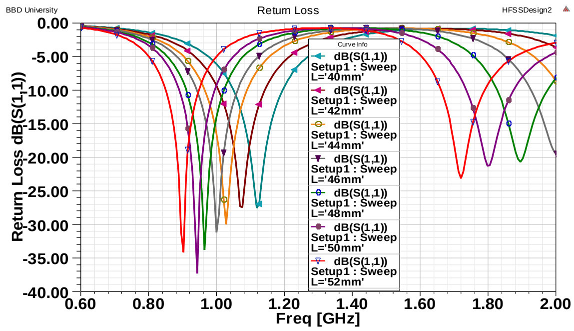

Figure 9:Simulated return loss of the antenna with different length of outer patch (L)

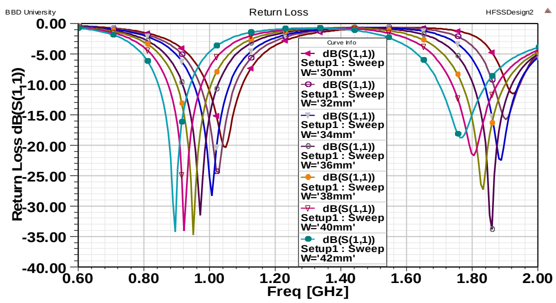

Figure 10:Simulated return loss of the antenna with different width of outer patch (W)

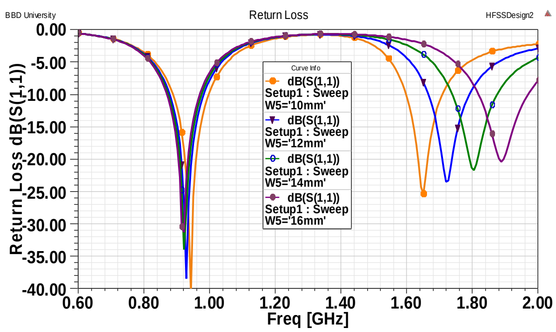

Figure11:.Simulated return loss of the antenna with different width of W5

5. CONCLUSION

This paper has focused on the development of a dual-band PIFA for mobile phone applications. By cutting the U-slot in the antenna radiation patch, the dual band operation is realized which covers the frequency bands of GSM900 (890-960 MHz) and DCS1800 (1720-1880 MHz). The simulation results has been carried out which clearly shows that antenna return loss is better than -10dB in both the frequencies band. Since the lower and higher resonant frequency can be determined independently it makes the design procedure easier making it more flexible in wireless applications. Radiation pattern and E-Field distribution on the patch surface is investigated. In addition, the detailed parametric analysis of designed antenna is also carried out to study the effects of various antenna parameters.

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