A Bandwidth Enhanced U-Slot PIFA with Defected Ground Structure for Dual-Band Mobile Applications

T.Narasimha Murthy, N. Bala Subhramanyam, A.V.Narasimha Rao

Abstract: ***The Planar inverted-F antenna (PIFA) is compact antenna and it is widely used in hand-held communication terminals. Despite their favorable features of excellent performance characteristics, low-profile and flexibility of integration, the PIFA is inherently of small bandwidth. Since present day need for multi band communication by a single device, there is necessity for a multi band PIFA. The present work proposes a novel configuration of PIFA for dual band operation with bandwidth enhancement for hand-held wireless communication devices, which is achieved by modification of the physical structure of both radiating patch and of the ground plane. Simulated and measured results demonstrate that the new configuration covers two frequency bands with a considerable bandwidth improvement.***

Index Terms: Bandwidth, Cognitive Radio, Planner antennas, Resonance, Return-Loss, Ultra Wideband, HFSS.

I. INTRODUCTION

There has been an explosion of wireless communication technology in recent times in terms of bandwidth, multi-functionality and miniaturization. The imminent and considerably large commercial deployment of ultra-wideband (UWB) systems has spawned the need of ultra-wideband antennas. The fusion of different radio units into single radio unit has requires multi-band antennas [2].

In miniaturization of the handheld communication terminals, has put limitations on the size of the antenna (physically) and these aspects influence to choose the low profile, multi-band multi-functional and ultra wideband frequencies. The narrow impedance bandwidth is the main drawback of many low-profile antenna while designing it and in turn affects requirement of wideband functionality. The need for multi functionality in terms of multi band operation gives rise to the ability of band-switch-ability of the antenna.

PIFA is having the feasible solution due to its reduced space in the device, its omni-directional pattern and its integrability as a circuit element. The operation of this antenna can be understood easily with the help of other techniques or technologies like, quarter-wavelength monopole and rectangular micro-strip technic. Dual band operation is achieved by cutting a U-slot on the radiating patch of PIFA, and operational bandwidth is enhanced by implementing a Defected Ground Structure (DGS). The U-shaped Slot in the radiation patch the antenna is divided into two categories like radiating patch antennas, the outer patch is working in the low frequency band (900MHz) and the inner patch in the high frequency band (1800MHz) [3]. A method of introducing narrow apertures in the ground plane which alters the distribution of currents in it, is a popular way to improve the bandwidth performance [5]. These slots in the ground plane would resonance at same frequencies that cause in bandwidth increase. PIFA can be simply represented by a capacitor with shorted plates so anything that lowers the capacitance and Q factor, resulting in enhanced band width.

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In this process, the input impedance and the current flow of the antenna may be influenced.

In this paper, a novel technique is introduced to make the impedance bandwidth of PIFAs to be broadened and a modification in radiating patch is made to incorporate multiband communication.

II. METHODOLOGY OF DESIGN

PIFA consists of a planar patch kept parallelly with a ground plane which is the basic structural part of PIFA in which, a path of short circuit is established by connecting radiating patch of the chassis and the feeding system of the antenna. The fundamental mode resonant frequency for the antenna structure can be estimated and calculated the resonant frequency using the following equation.

$$f_o = \frac{c}{4(L+W-ws-h)\sqrt{\varepsilon r}} \qquad (1)$$

In which *c* is the free space velocity, L tends to length and W tends to the width of the radiating element. Shorting plate width is denoted by w_s and substrate height denoted by h. These dimensions are negligible compared the other dimensions.

$$f_o = \frac{c}{4(W+L)\sqrt{\varepsilon r}} \qquad (2)$$

From the equation 2, *C* implies light velocity, and the side dimensions of the radiation patch are W and. f_o is the resonant/operating frequency. The dimensions of the antenna can be calculated from the resonant frequency.

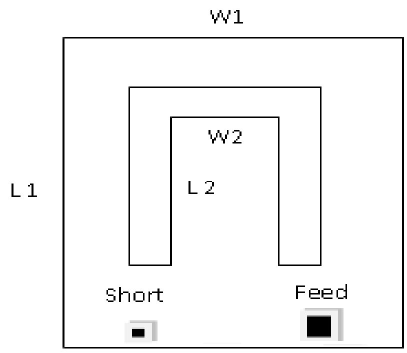

Figure 1.a. Schematic of proposed radiating patch

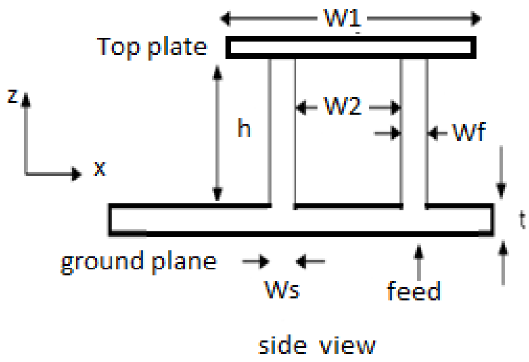

Figure 1.b. Side-view of the radiating patch.

The radiators are usually made of slits or notches to keep PIFAs compact and makes it suitable for multi-frequency band functioning,. The slits or notches change the distribution of the current on the radiating elements. This pull apart the radiator into multiple resonant regions also, for multi frequency band functioning [3,4].

The design equations for the proposed dual radiating structure are presented as [7].

$$f_{r1} = \frac{c}{4(L1+W1)\sqrt{\varepsilon r}} \qquad (3)$$

$$f_{r2} = \frac{c}{4(L2+W2)\sqrt{\varepsilon r}} \qquad (4)$$


Figure 2. The proposed PIFA prototype

The figures 1.a and 1.b show the diagram of an electrical or mechanical system of the top and side perspectives of the proposed antenna structure. The distance, (L_1-L_2) can affect the operating frequency of both operational bands. Consequently, both operational bands are moved in the completely different directions. The slit's length (W_1–W_2) determines only the higher band [11].

To improve the bandwidth of operation and Return loss, proposed antenna system design incorporates I-Shaped slotted Defected Ground Structure in chassis [8]. The

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slot width along Y-axis is 4.5 mm and the slot length along X-axis is 17.5 mm. Also this slot made on ground makes the size reduction and decrement of overall weight of the proposed antenna. The geometry of the proposed structure of PIFA and its prototype represented as in the Figure.2. A rectangular aperture is introduced into the ground plane of mobile device chassis. To enhance the band widths of PIFA is to be obtained by varying the placement and physical dimensions of the slot.

The optimal lengths of the high and low bands can be selected as the effective length of the ground plane that increases the bandwidths of PIFA antennas for both the bands [4]. The radiating patch is a very thin metal plate with a dielectric substrate of lossy FR-4 material, having loss tangent and relative permittivity are 0.025 and 4.9. The is plotted in Figure 3 shows the return loss of the reference antenna, which refers to single resonant structure which is a single-resonating-band PIFA antenna with operating frequency at 1.81 GHz. It is obvious from the Figure.3 that the resulting impedance bandwidth of the upper-band is bettered by the inclusion of the I-slot in the ground plane (chassis). Obviously, the antenna functionality and performance at the low band reaches its most suitable at the balanced dual-resonant operating frequency condition [9,10].

The effects of different aperture positions and dimensional values are analyzed and examined and these two studies are based on the operational bandwidths of the lower and upper operational frequency bands. The examined outs or results are composed with the internal dual-band (GSM900/ DCS1800/) PIFA structure. With the help of HFSS 10 by ANSOFT simulation tools, field patterns are obtained with the help reflection coefficient environment.

III. DESIGN ANALYSIS AND RESULTS

The Figure 1. describes the micro-strip antenna with a slot in chassis also resonates in the L-band but at resonant frequency fr = 1.765 GHz. The bandwidth of the micro-strip patch antenna with the proposed slot is 142.5 MHz at fr 1.765GHz. The value of return loss (S_{11}) received by the antenna -47.72 dB. Thus it has been corroborated that with I-Shape DGS, the bandwidth of the micro-strip patch antenna (MPA) can be increased by16.3 MHz (i.e. 142.5 MHz – 126.2 MHz = 16.3 MHz).

Figure 4 depicts the dual resonating nature of the antenna structure and the S_{11}at resonating frequencies of 874 MHz and 1.765 G Hz for both simulation and measurement. Figure 5 depicts the 3-D radiation pattern of the proposed antenna at 874 M Hz. Return loss of the proposed antenna structure, obtained by simulation is good and measured value of return loss is able to be agreed on the overall mentioned ranges of frequency.

It can be observed from the plot the proposed antenna is a good radiator whose radiation pattern as represented in the figure 6. The shown radiation pattern in azimuth plane is directional and for elevation is mostly omini directional. The overall gain of the antenna obtained after simulation is shown in Figure 5. A peak gain of 4.4412 dB is observed at resonance. The measured radiation pattern in Figure7shows an acceptable deviation from its simulation counterpart.

The overall performance analysis shows that the proposed antenna system is having a good radiation characteristics with desirable range of parameter metrics to meet the intent and purpose of the antenna for dual band enhanced bandwidth operation. The utilization of this antenna will be in any multiband wireless communication device or in the cognitive radio applications.

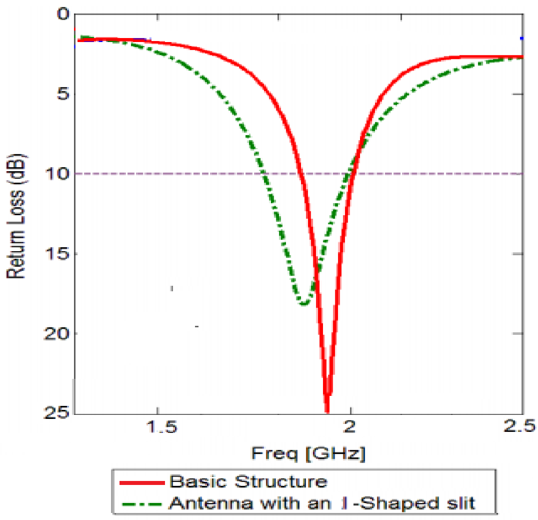

Figure 3. Enhanced band width of PIFA

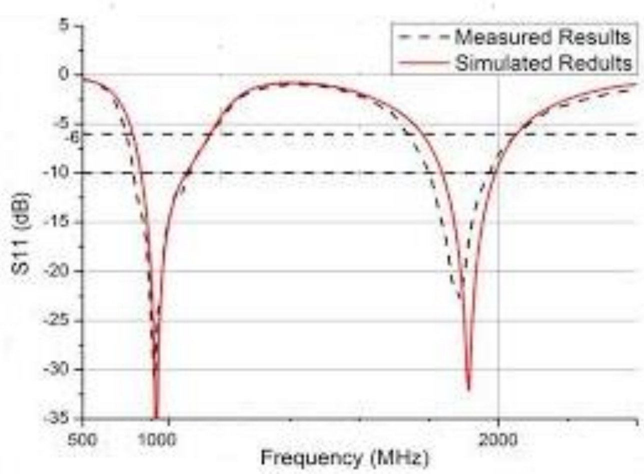

Figure 4. S11 of the over-all Antenna Structure

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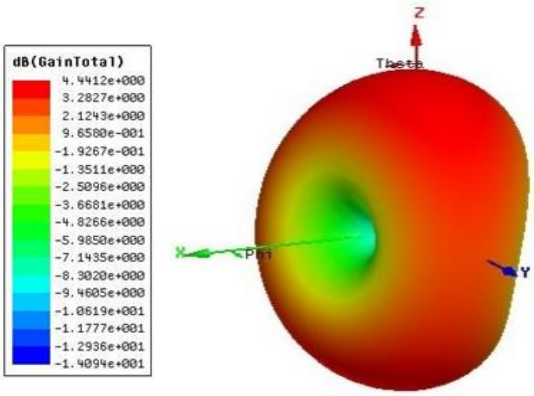

Figure 5. Radio-emission pattern of the presented Antenna

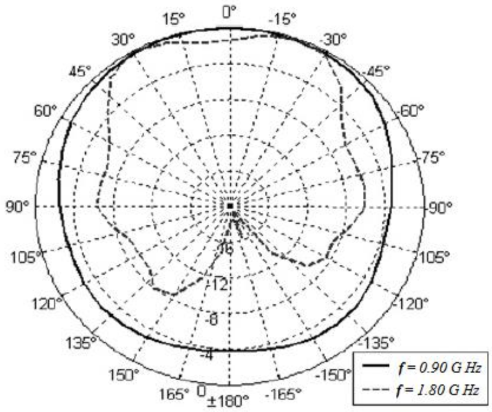

Figure.6.a. Radio emission pattern in dB related to the θ for elevation
X-Z plane (φ =0) for the design frequencies

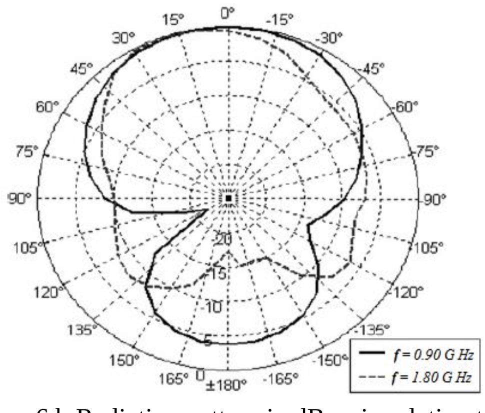

Figure. 6.b.Radiation pattern in dB as in relation to φ for azimuth X-Y plane (φ = 90^0) for distinct frequencies.

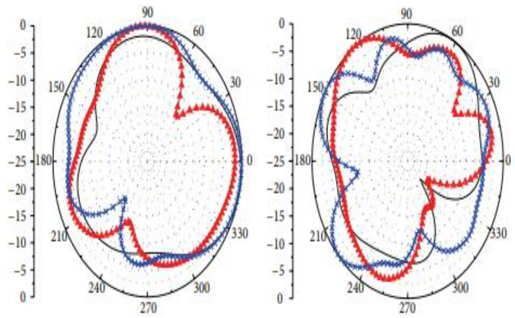

Figure 7. Measured 2D radiation patterns a) 900 M Hz b) 1800 M Hz

IV CONCLUSION

A dual band enhanced Bandwidth PIFA has been designed, analyzed and been simulated by computer simulation software HFSS and prototype is fabricated. The results reveal the dual band operation and enhanced impedance band width of the proposed antenna structure. Its usefulness can be in mobile wireless communication devices operating at 900 M Hz and 1800 MHz. A further improvement in band width performance can be obtained by the reconfiguring the slot in the defected ground structure or by providing another slot in the radiating patch, which facilitates another frequency band of operation for the antenna.

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