Wide-Band Planar Inverted-F Antenna for Cognitive Radio

H. F. AbuTarboush[#1], D. Budimir[*2], R. Nilavalan[#1], *and* H. S. Al-Raweshidy [#1]

[1]*Wireless Network and Communication Centre, Brunel University, West London, UB8 3PH, UK*

Hattan.Abutarboush@brunel.ac.uk

[2] *Wireless Communications Research Group, University of Westminster, London, W1W 6UW, UK*

d.budimir@westminster.ac.uk

***Abstract*— A wide-band Planar Inverted-F Antenna (PIFA) is presented. The proposed antenna is simply structured consist of main patch supported by shorting wall and shorting pin, fed by 50 ohm microstrip transmission line. The antenna achieves an enhanced impedance bandwidth of 64.5 % covering from 2.1 to 4.1GHz with a stable radiation performance in terms of gain from 6 - 8 dBi. The radiated patch occupied a total volume of 53 x 55 mm. The antenna was studied by means of numerical simulation; the achieved -10 dB bandwidth of the antenna is confirmed and demonstrated by experimental measurements. The simulated and measured results are in good agreements.**

I. Introduction

Cognitive radio communication is envisaged to be a new/unconventional paradigm of methodologies for enhancing the performance of radio communication systems through the efficient utilization of radio spectrum. The driving force behind the idea of cognitive communication is the motivation of efficient and intelligent utilization of the radio spectrum. Owing to a number of possible methodologies for achieving the objectives associated with cognitive radio communication, it is very difficult to restrict its definition to a particular system specification. However, there are common traits of cognitive communication systems, for instance, according to [1-2], a cognitive communication system is an intelligent communication system, capable to learn from its radio environment and accordingly adapt its operational parameters for reliable communication and efficient utilization of radio spectrum. The next generation wireless communication technologies are deemed to come up to the demands of bandwidth hungry network applications, ubiquitous network connectivity and spectrum efficiency. Cognitive radio communication is a paradigm of methodologies to meet such demands. From the antenna design perspective, there is an increase in the demand for wide-band antennas which can be easily integrated with the communication system. Integrated wide band narrow band antenna for cognitive radio has been reported in [3-4].

In order for a communication system to be intelligent, capable to learn, adaptive, and reliable (thus cognitive) there is a need of joint cooperation between several protocols across the layers. Learning from the environment constitutes an important part of a cognitive radio communication system. The learning phase employs many (hard and soft) parameters; for instance, a cognitive radio should be capable to sense the spectrum over a wide range of frequencies, therefore the system need very wideband built in small antenna in order to sense the spectrum. Recently some designs have been reported to achieve wide band and multi-band antenna for Wireless LAN applications [5-7], and for WiMAX applications [8]. Many researchers have studied the deviation of multiple resonances and low-profile structure by using shorting walls, in [9] half U-slot antenna with shorting wall has reported with 28% impedance bandwidth. Bandwidth enhancement for conical radiation using shorting wall has been studied recently [10]. And a wideband stacked antenna using shorting wall has been introduced [11]. In all the above designs single and multi bands are achieved by either modifying the shape or by inserting single or double shorting wall to the antenna. The main goals from the previous research work and literatures related with the PIFA antenna are focusing on improving the impedance bandwidth performance and controlling the resonant frequencies to cover the needed band. The approached of using PIFA antenna to generate wide band has been used by [12] recently, in [12] Planer Inverted-F antenna (PIFA) was presented to achieve wide bands from 0.7 to 0.9 GHz and 1.7 – 2.6 GHz, however, the gain of this antenna was very low -1 to 2.26 dBi. Also in [13] wide impedance bandwidth 70 % achieved from 4 – 9 GHz by adding double shorting wall, however, the structure is very complicated also it is difficult to implement it, the gain for this antenna was very low 1.5 – 3.5 dBi. For these applications, planar inverted-F antenna is of major importance because of its simple structure. When a PIFA is fed using microstrip line it doesn't add weight and size to the system and it is a suitable design for the previous applications.

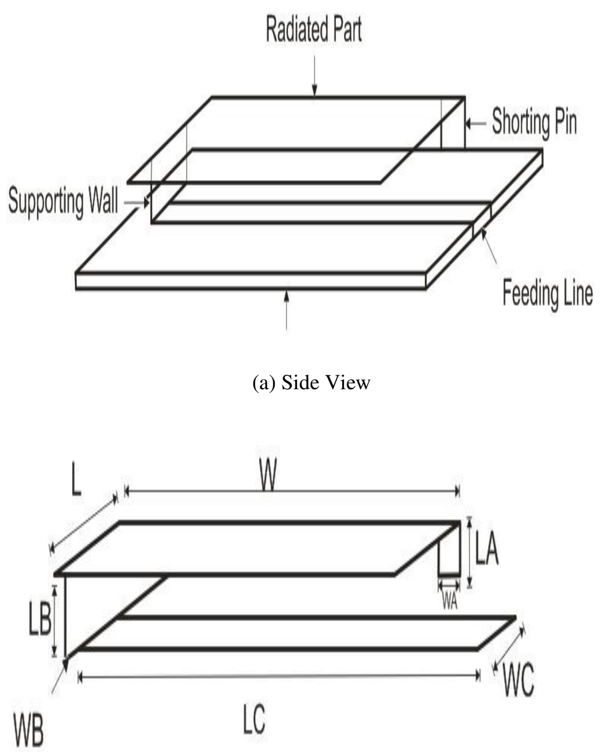
This paper introduces a novel wideband PIFA design, which is capable of operation in very wideband starting from 2.1 to 4.1GHz with stable gain from 6 dBi to 8 dBi. The antenna design as proposed herein, can be operate at either of the frequency bands used by DCS, UMTS, WLAN, DMB and WiMAX second and third band, reducing antenna redundancy.

The main contributions of this paper are as follows: A novel design for a PIFA capable of operating in very wideband for the sensing part in cognitive radio. The bandwidth achieved is 64.5 %; the radiation pattern shows an acceptable response for small terminals and a stable gain between 6 - 8 dBi.

The paper is divided as: section II, presents' dimensions, configurations and the design procedure, section III present the measurements process and finally section IV presents the conclusion.

II. Antenna Configuration and Design procedure

The proposed antenna has a very simple structure fed by 50 Ω microstrip line. Fig. 1 and Table I demonstrate the structure and the detailed dimensions of the proposed antenna. Generally the overall dimension of the ground plane is 70 x 70 x 10 mm^3; the selected substrate for this structure is Duroid 5880 with dielectric constant 2.2. The radiated patch is supported by shorting pin with height of 10 mm and width 10 mm, also shorting wall 25 x 8.5 mm width and length respectfully. HFSS package is used to obtain the return loss, gain and the radiation pattern.



(a) Side View

(b) Diminutions details

Fig. 1. (a-b) The structure and detailed diminutions of the proposed antenna

TABLE I

DETAILED DIMINUTIONS OF THE PROPOSED ANTENNA

Parameters	W	L	W_A	L_A	W_B	L_B	W_C	L_C
Value in (mm)	53	55	10	10	25	8.5	64	4.65

The characteristic impedance Zo of any line is function of its dielectric constant, the characteristic impedance of microstrip transmission line is the ratio of voltage and current of travelling wave, the following equation can be used to obtain the Zo:

$$\varepsilon_{eff} = \frac{\frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}}{\sqrt{\frac{1+12h}{W}}} + 0.04(1+\frac{h}{W})^2 \tag{1}$$

$$for \frac{W}{h} < 1$$

$$Z_0 = \frac{60}{\sqrt{\varepsilon_{eff}}} \ln(\frac{8\times h}{W} + \frac{W}{4\times h}) \tag{2}$$

$$for \frac{W}{h} < 1$$

$$\varepsilon_{eff} = \frac{\frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}}{\sqrt{\frac{1+12h}{W}}} \tag{3}$$

$$for \frac{W}{h} > 1$$

$$Z_0 = \frac{120\times \Pi}{\sqrt{\varepsilon_{eff}}(\frac{W}{h} + 1.393 + 0.677\ln(\frac{W}{h} + 1.444))} \tag{4}$$

$$for \frac{W}{h} > 1$$

III. Simulated and Experimental Results

The antenna was fabricated on RT Duriod 5880 material with dielectric constant 2.2 and height of 1.57 mm as shown in Fig. 3. The antenna was tested using Agilent VNA. The results for S_{11} are shown in Fig. 2.

Analysis of the results in Fig. 2 shows in general relatively good agreements between the simulated and experimental resonant frequencies. One factor that can be discounted is errors in the size of the antenna, a possible cause of not getting exact response is that the ground plane width is larger by 2 mm than indicated, that due to cutting the patch using 2 mm cutting tools. Also the soldering was not very accurate because the copper is very thin 0.2 mm, this might make the radiated patch not very flat, therefore, and using 0.5 mm might lead to a better matching between the measured and the simulated results.

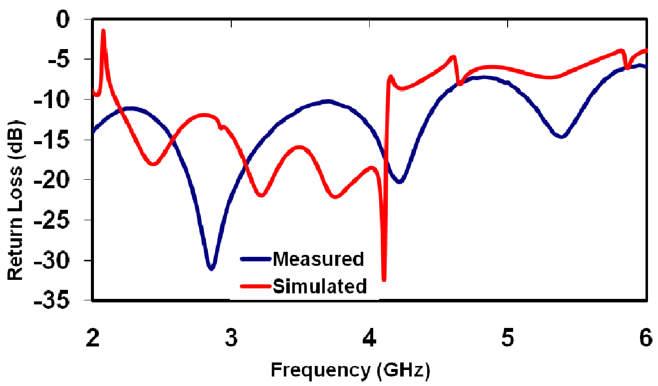


Fig. 2. Simulated (red) and experimental (blue) results for the return loss

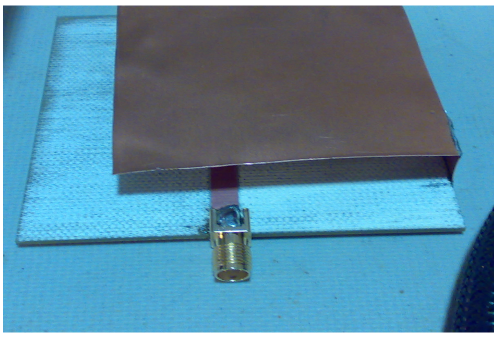
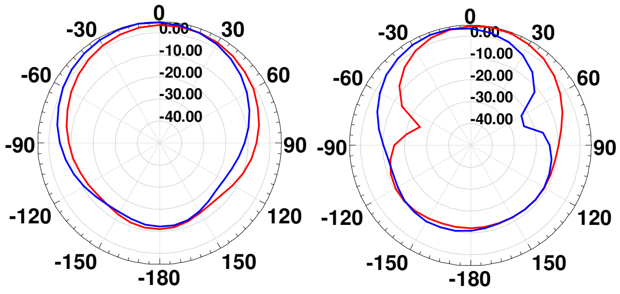


Fig. 3. Prototype of the proposed wideband Antenna

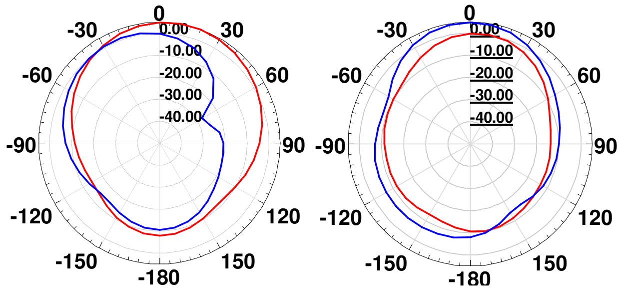
The proposed antenna can be used in many different application as it fulfill the requirements of -10 dB bandwidth to cover the applications shown in table II. In addition the radiation patterns E and H plane for the centre frequencies of 2.1, 2.6 and 3.7 GHz are shown in Fig. 4. The gain for the antenna is shown in Fig.5.

TABLE II
APPLICATIONS FOR THE PROPOSED ANTENNA

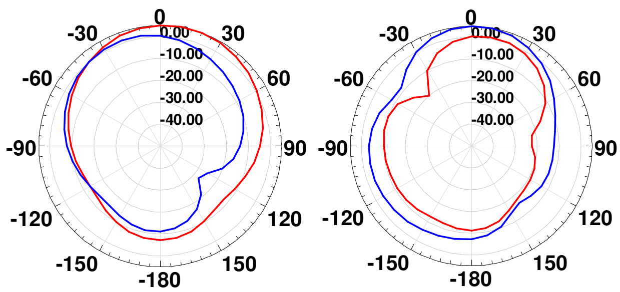
Frequency Band In (MHz)	Applications
1995 – 2200	DCS
2110 – 2170	UMTS
2400 – 2483	WLAN
2605 – 2655	DMB
2500 – 2800	WiMAX (Lower Band)
5200 – 5800	WiMAX (Middle Band)



(a)



(b)



(c)

Fig 4. The radiation patterns co-pol (red) and x-pol (blue) for E and H Plane of the proposed antenna: (a) at 2.1 GHz. (b) at 2.6GHz. (c) at 3.7 GHz.

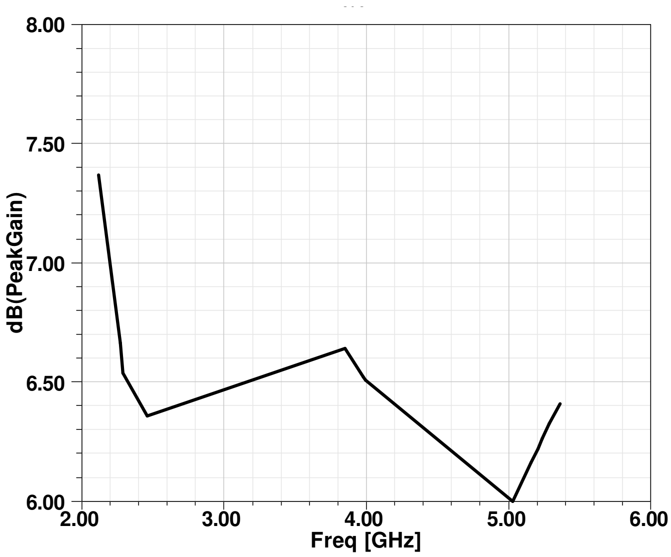


Fig. 5. The Gain for the proposed wideband Antenna

IV. CONCLUSION

A wide impedance bandwidth and high gain for PIFA has been proposed. The designed antenna can be used in cognitive radio for sensing the environment from 2.1 to 4.1 GHz the impedance bandwidth generated from this antenna is 64.5% and gain between 6 to 8 dBi. The simulated and measured results are in good agreements.

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