International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:9, No:1, 2015

Compact Ultra-Wideband Printed Monopole Antenna with Inverted L-Shaped Slots for Data Communication and RF Energy Harvesting

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Abstract**—**A compact UWB planar antenna fed with a microstrip-line is proposed. The new design consist of a rectangular patch with symmetric l-shaped slots and fed by 50 Ω microstrip transmission line and a reduced ground-plane which have a periodic slots with an overall size of 47 mm x 20 mm. It is intended to be used in wireless applications that cover the ultra-wideband (UWB) frequency band. A wider impedance bandwidth of around 116.5% (1.875 – 7.115 GHz) with stable radiation pattern is achieved. The proposed antenna has excellent characteristics, low profile and cost-effective compared to existing UWB antennas. The UWB antenna is designed and analyzed using CST Microwave Studio in transient mode to verify antenna parameters improvements.

Keywords**—**UWB Planar Antenna, L-shaped Slots, Wireless Applications, impedance band-width, radiation pattern, CST Microwave Studio.

I. Introduction

THE term Ultra Wideband or UWB signal has come to signify a number of synonymous terms such as: impulse, carrier-free, baseband, time domain, nonsinusoidal, orthogonal function and large-relative-bandwidth radio/radar signals. Here, we use the term "UWB" to include all of these. The term "UltraWideband", which is somewhat of a misnomer, was not applied to these systems until about 1989, apparently by the US department of defense. Contributions to the development of a field addressing UWB RF signals started in the late of 1960's with the pioneering contributions of Harmuth at Catholic university of America, Ross and Robbins at Sperry Rand corporation, Paul van Etten at the USAF's Rome air Development Center in Russia [1].

In February 14, 2002, the Federal Communications Commission (FCC) amended the Part 15 rules which govern unlicensed radio devices to include the operation of UWB devices. The FCC also allocated a bandwidth of 7.5GHz, from 3.1GHz to 10.6GHz to UWB applications [2].

Ultra-Wideband (UWB), a radio transmission technology which occupies an extremely wide bandwidth exceeding the minimum of 500MHz or at least 20% of the center frequency [2], is a revolutionary approach for short-range high-bandwidth wireless communication.

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UWB technology is widely employed in many applications such as indoor positioning, radar/medical imaging and target sensor data collection. One of the challenges for the implementation of UWB systems is the development of a suitable or optimal antenna. The first important requirement for designing an UWB antenna is the extremely wide impedance bandwidth. In 2002, the US FCC allocated an unlicensed band from 3.1GHz to 10.6GHz on the frequency spectrum for UWB applications [2]. Hence, up to 7.5GHz of bandwidth is required for a UWB antenna. And commonly, the return loss for the entire ultra-wide band should be in the criterion of less than -10dB. Next, for indoor wireless communication, omnidirectional property and radiation pattern is demanded for UWB antenna to enable convenience in communication between transmitters and receivers. Therefore, low directivity is desired and the gain should be as uniform as possible for different directions.

Printed microstrip slot antennas were extensively investigated [3]-[4] in the past three decades due to their numerous advantages such as low profile, lightweight, and easy fabrication. Microstrip line fed slot antennas with various shapes of microstrip feed line and wide slot have been introduced for large impedance bandwidths. With different shapes such as circular slot [5], U slot [6], [7], Z slot [8], square-ring slot [9], PI slot [10] etc.

Another technique to increase significantly the slot antenna's bandwidth is to use different shapes of tuning stubs such as T-shaped [11], H-shaped [12], G shaped [13], W shaped [14], square-shaped [15], cross-shaped [16]. Further the dielectric resonator antenna (DRA) is one of the attractive antennas for UWB application due to several characteristics such as high radiation efficiency, low dissipation loss, light weight, and small size [17]-[20].

Based on the above references, we propose a very simple planar UWB antenna with inverted L slots in the radiator and a reduced ground-plane which introduces three periodic slots at the center to improve moreover the impedance bandwidth of the proposed antenna and featuring a compact size 20mmX47mm. As described in subsequent sections, the initial antenna and optimization were carried out by simulations with CST Microwave Studio [21], a commercial electromagnetic simulator. It is observed that by adjusting the slot size, the proposed design can achieve a wider impedance bandwidth and stable radiation patterns that can operate over the whole frequency band have been obtained.

II. General Description of UWB Antenna

The proposed antenna is a planar microstrip antenna with ultra-wideband radiation properties. This antenna has a new structure with a rectangular radiation patch (Fig. 1). The rectangular monopole antenna is fed by a microstrip line on an FR4 substrate with a thickness of 1.58 mm, relative permittivity of 4.4, and a loss tangent of 0.019, it's having the length (LF) of 15.5 mm and width (WF) of 3mm, which ensures that the antenna is matched to a 50 impedance source.

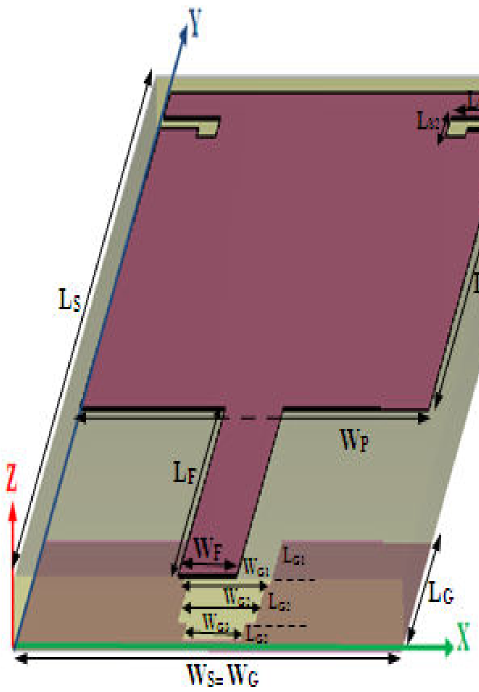

Fig. 1 Perspective view of the proposed antenna

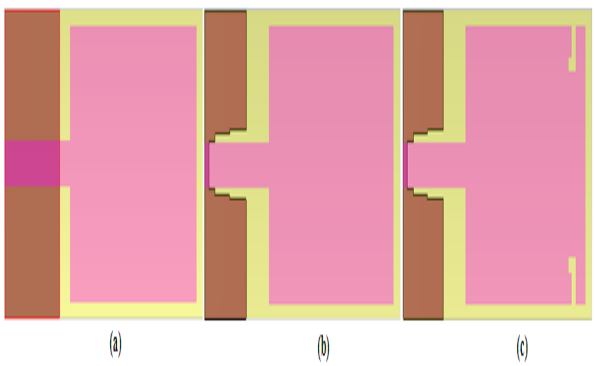

Fig. 2 The geometric shape of the rectangular antenna: (a) simple rectangular antenna, (b) simple rectangular antenna with periodic slots in the ground, and (c) simple rectangular antenna with periodic slots in the ground and tow inverted L-shaped slots in the radiator

Since the main goal is to design an antenna with UWB radiation, we need to apply techniques that will improve the impedance bandwidth performance of the antenna. One way is to use a reduced ground with periodic rectangular slots, and a symmetric pair of inverted L-shaped slots in the radiator. This increases the impedance bandwidth of the antenna, especially at the upper frequencies (Fig. 2).

All the physical dimensions of the proposed antenna are listed in Table I.

TABLE I
Optimized Antenna Parameters

Parameter	Dimension(mm)
L_S	47
W_S	20
L_P	30
W_P	18
L_F	15.5
W_F	3
L_{S1}	3
W_{S1}	1
L_{S2}	1.75
L_G	10
L_{G1}	4.5
L_{G2}	4.5
L_{G3}	1.5
W_{G1}	4
W_{G2}	3.5
W_{G3}	3

III. Simulation Results & Discussion

As a first step in designing the antenna, we have started from the antenna (a) that shown in Fig. 2 and after several series of optimizations by using CST simulation tool a dualband antenna has been achieved. The first bandwidth is from 2.11GHz to 2.69GHz with return loss less than -10dB (VSWR< 2) while the second bandwidth is from 4.38GHz to 6.58GHz, Figs. 3, 4. Further to increase the impedance bandwidth of the antenna obtained we have applied two techniques, the first is to use a periodic slots in the ground as shown in Fig. 2. This technique has turned the antenna (a) from a dualband to a UWB antenna which has a bandwidth from 1.878GHz to 6.904GHz with return loss less than -10dB (VSWR< 2), the second technique is to introduce a symmetric L-shaped slot in the radiator to increase moreover the impedance bandwidth especially for the upper frequencies. The antenna has been achieved after optimization of the dimensions of the L-shaped slots has a bandwidth from 1.875GHz to 7.115GHz with a return loss less than -10dB (VSWR< 2) as shown in Fig. 3 and a bandwidth of 5.24GHz.

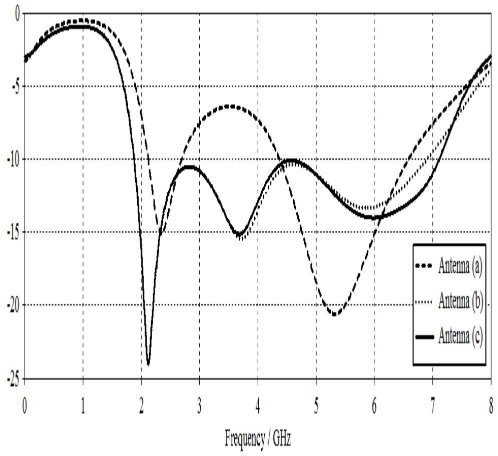

Fig. 3 The return loss for the different antenna structures

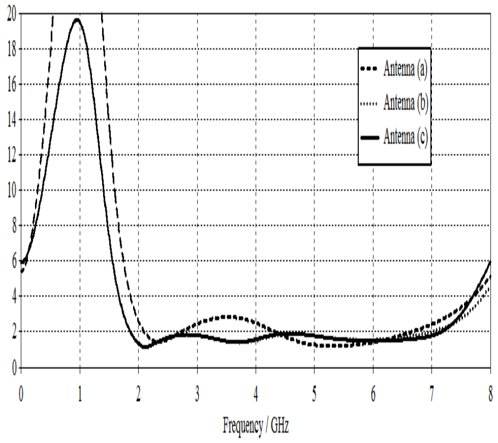

Fig. 4 The VSWR of the three antenna structures

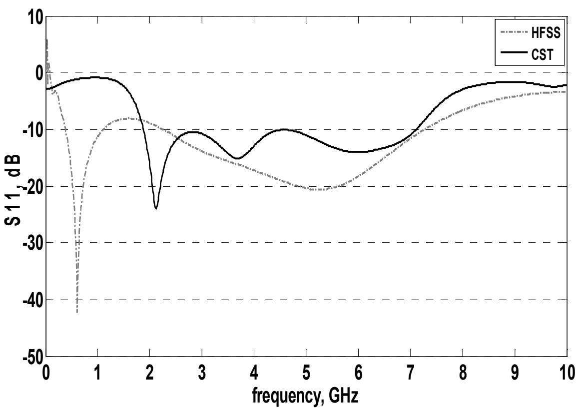

Fig. 5 The return loss of the proposed antenna with CST&HFSS

We have applied another method to analyze this antenna, then we have use the FEM (Finit Element Method) introduced by HFSS software. Figs. 5 and 6 show the comparison results between the two methods.

Fig. 7 presents the gain variation of the proposed antenna that is almost around 3dB in the frequency range below 2.5GHz and with a peak gain of 4.22dB at 4.35GHz.

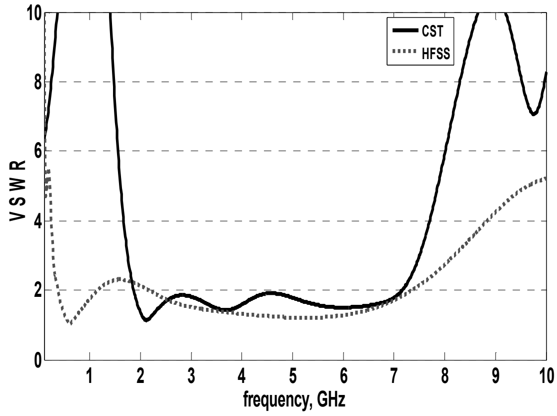

Fig. 6 VSWR of the proposed antenna with CST&HFSS

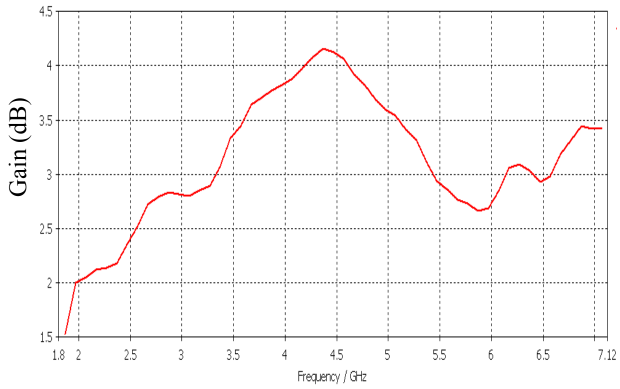

Fig. 7 The proposed antenna gain versus frequency

This antenna is suitable for applications in ISM Band, in radar detection, imaging systems and for GSM1900, UMTS, Wimax, Bluetooth, furthermore for WLAN systems and RF energy harvesting systems such as UWB rectenna. Because of a good impedance bandwidth and the constant gain over its whole frequency band, with some further optimization and manufacturing aspect, this antenna can serve in several UWB applications.

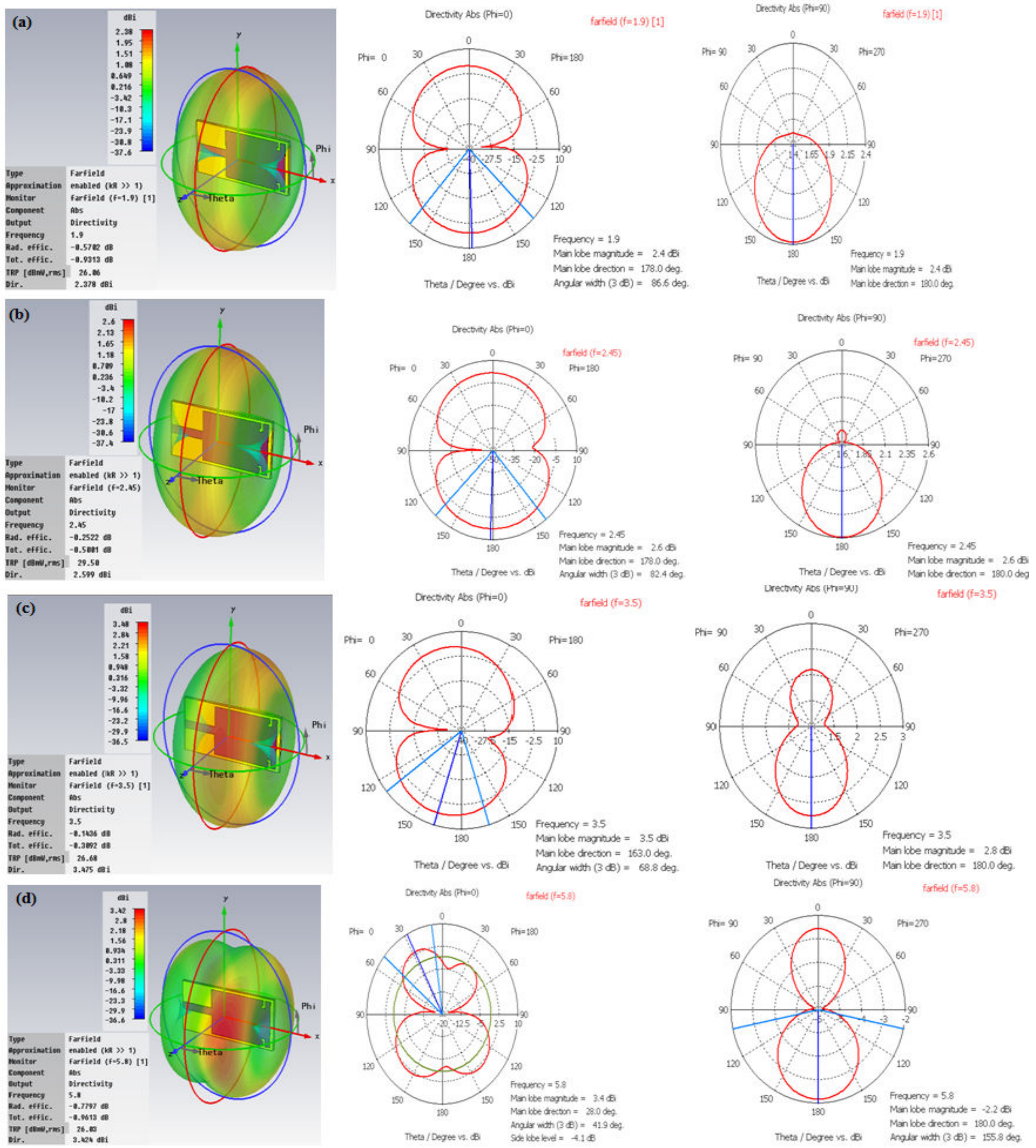

Fig. 6 3D&2D(φ=0° , φ=90°) simulated radiation patterns for the proposed antenna at different frequencies : (a) 1.9 GHz, (b) 2.45 GHz, (c) 3.5GHz, (d) 5.8 GHz

Fig. 6 shows the far-field radiation patterns of the proposed antenna. It can be observed that the proposed antenna radiates equally in all directions at 5.8 GHz. However, the radiation pattern peak shows around a 163° titled radiation pattern at 3.5GHz.

IV. Conclusion

A compact UWB monopole antenna has been proposed and analyzed. Simulations have shown that the proposed antenna has attractive features such as an impedance matching bandwidth of 116.5% covering the frequency range from 1.87 to more than 7.11 GHz (|S11| ≤−10 dB), with a constant gain and stable radiation patterns over its whole frequency band.

The antenna dimensions are 20mmX47mm. These attributes makes the antenna suitable for UWB wireless systems that require low-profile antennas. Future research will systematically focus in evaluating this antenna under various parametric and experimental conditions and the comparison of the measured and simulated data.

ACKNOWLEDGMENT

The authors would like to thank the professor Mohamed LATRACH of ESEO of Angers in France and the staff members of the LITEN Laboratory, University HASSAN the first, FST of SETTAT Morocco also the STRS Laboratory of INPT in RABAT Morocco for providing the facility and technical assistance in this research.

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