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A Compact CPW-Fed Printed UWB Antennas

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***Abstract*- In this work, we present the design and analysis of compact coplanar waveguide-fed ultra wideband rectangular antennas. These proposed antennas exhibit very wide operating bandwidth (return loss ≤ -10dB) which covers 3.2-15 GHz range, which means a relative bandwidth of 126% covering FCC defined UWB band with stable omnidirectional radiation patterns and important gain. The parameters of antennas have been investigated and optimized by using two electromagnetic solvers. A good agreement has been obtained between simulation and measurement results. These antennas are useful for UWB indoor applications, handheld and wireless communication requiring low profile antennas. The antennas achieved are low cost and easy to fabricate and integrate with RF circuit. The simulated and the experimental results are described and discussed.**

***Index Terms*- CPW-fed, ultra wideband (UWB), FCC, RF circuit, wireless communication**

I. INTRODUCTION

In present days, wireless communication considered as a recent technology for transmission of information, which has actually experienced several years of technological developments. This technology is increasing rapidly due to the need to support more users and applications, to transmission information with high data transmitting rates and also the number of type wireless has been growing. One of the best-know examples benefit from the advances in wireless technologies is the telecommunication industry to refer to telecommunications systems as remote monitoring system, remote control, radio transmitters and receivers. Also this technology is commonly used in energy transfer and medical technologies. Consequently the environment introduces a various challenges to the physical channel of a wireless communication system. Most notably, they are multi-patch single, spectrum limitation, energy limitation user mobility, noise limited systems and interference limited systems. Ultra-wideband (UWB) technology could be the most suitable technologies for future wireless communication system and extremely useful due to various satisfying factures such as ultra wide bandwidth, low power consumption, high data rate transmission as in the multimedia and admirable immunity to multi-patch interference. The regulation released by FCC assigned 7.5GHz bandwidth from 3.1GHz to 10.6GHz with maximum power spectral density (PSD) of -41dBm/MHz for indoor and hand-held, wireless communication since early February 2002. To meet requirement of wireless communication systems, a lot of researches is being given for designing the UWB antennas, since they are indispensable elements of any wireless communication systems to radiate and receive the signals. For UWB communication systems, the antennas have some challenges including the impedance bandwidth should be extremely wide, compact size, effective in transmitting, radiation stability, low manufacturing cost for consumer electronics application and easily embeddable into wireless devices or integrate with other parts of monolithic microwave integrated circuits (MMICs). Microstrip patch antennas are exceedingly attractive candidates for uses in UWB applications for their attractive futures such as low profiles, low height, low cost, easily integrated with other part of MMICs. It's well-know the microstrip antenna inherently has narrow bandwidth characteristic, to achieve the requirement for different UWB applications, various type of planar antennas were developed their impedance bandwidth to achieve the UWB characteristics. In other words, the needs of

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UWB antennas, many of the recent research efforts have been focused to overcome the problem of narrow bandwidth and various techniques have been presented to extend the bandwidth in order to meet requirement of multiple wireless system application, especially for indoor applications and applications of multimedia communications [1-8]. To enhance the bandwidth of a patch antenna, several ways have been proposed previously, such as using different tuning techniques or employing different notches or slots shapes on patch antenna as rectangular [9], circular [10],E-shape[11], U-shape[12] ,square-ring[13], cutting notch at bottom[14]. Another technique to increase significantly the slot of the planar monopole antenna feed by CPW-fed is to use tuning stub as the fork-like stub [15], the square stub [16], T-shaped stub [17], Tapered ring slot antenna [18], L-probe feeding [19]. The printed slot antennas exhibit wider bandwidth and lower radiation loss than microstrip antennas; they have an attractive property of providing a wide operating bandwidth. Well as other methods of patch antennas can also used to improve the bandwidth such as using a thick substrate with low dielectric constant and multiple resonators [20], defected ground structure (DGS) [21].

Indeed, the applications of coplanar waveguides to microwave circuits and antennas as well as MMICs have received considerable attention owing the CPW offers several advantages over microstrip feeds such as it simplifies fabrication, it provides an easy means of mounting electronic of parallel and series connection with active and passive devices, and ease of integration with MMICs. On the other hand, there are many CPW-fed antennas used for UWB applications due to their attractive merits its ultra-wide frequency band, lower dispersion, satisfactory radiation characteristics and easy integration with system circuits.

In this paper presents an overview of UWB technology and a vast array of new applications in which it can be used, for businesses and consumers. Also a preview of UWB antenna designs characterization, some novel CPW-fed UWB antenna designs were investigated and presented. The simulated and measured results show that the proposed antennas present characteristic of UWB antennas with a very wide impedance bandwidth.

II. DESTRIPITION OF UWB ATENNA DESIGN

A. CPW theory

The proposed antenna designs are constructed from a conventional CPW. A conventional CPW on a dielectric substrate of finite thickness consists of center strip conductor to radiating element with two conducting ground lines parallel to the strip, separated by a narrow gap, as shown in figure.1. This transmission line is that it's uniplanar in construction, which means that all of the conductors are on the same plan; only one layer of the substrate with thin metallic strip is deposited. The conventional CPW supports a quasi-TEM mode of propagation along the line. The ground plan should extend more than 5D with D should be less than λ/2 to preclude the propagation of higher-order modes [22][23].

The dimensions of the thickness (h), the gap (g) between CPW-fed wire and ground, relative permittivity (εr) and the center strip (Wf) of the dielectric substrate determined the effective dielectric constant (ε_{eff}) and characteristic impedance (Z0) of the line. The characteristic impedance of the line can be written as

$$Z_0 = \frac{30\pi K(k_0')}{\sqrt{\varepsilon_{eff}}\,K(k_0)} \qquad (1)$$

$$\varepsilon_{eff} = 1 + \frac{(\varepsilon_r - 1)}{2}\frac{K(k_1)K(k_0')}{K(k_1')K(k_0)} \qquad (2)$$

$$k_0 = \frac{\sinh\left(\frac{\pi g}{4h}\right)}{\sinh\left(\frac{\pi D}{4h}\right)} \qquad (3)$$

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$$k_0' = (1 - k_0^2)^{\frac{1}{2}} \quad (4)$$

$$k_1 = \frac{W_f}{D} \quad (5)$$

$$k_1' = (1 - k_1^2)^{\frac{1}{2}} \quad (6)$$

$$D = 2g + W_f \quad (7)$$

Where $K(k_0)$, $K(k_1)$, $K(k_0')$, $K(k_1')$ are the first complete elliptic integral function its complement function. We can calculate the width (Wf) and gap width (g) of the CPW signal line by using the above formula.

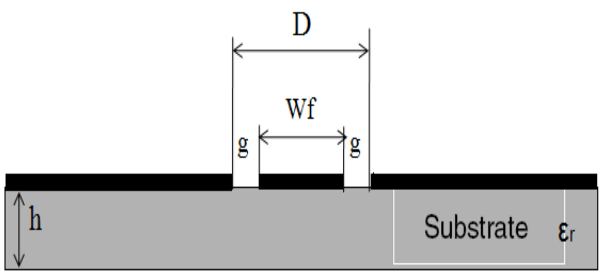

Fig.1. The definition of the main parameters for the analytic model

B. UWB antenna designs

The geometries of the rectangular UWB CPW-fed planar antennas are illustrated in fig.2. Substrate used for the design is FR4 epoxy with thickness of h=1.6mm, relative permittivity εr=4.4 and loss tangent tanδ=0.025. The rectangular microstrip antennas are fed by a coplanar waveguide with 50Ω input impedance that has a center strip having a width Wf=3mm, the gap between CPW-fed wire and ground is g=0.4mm. Here, the antenna structures and the feeding are uniplanar in construction, which implies that all of the conductors are implemented on the same side of substrate. The optimized and the analyzed parameters design is done by using CST Microwave studio. For validation and comparison, we have conducted another study by using Ansoft HFSS. The final dimensions of the antenna structures are listed in Table.1.

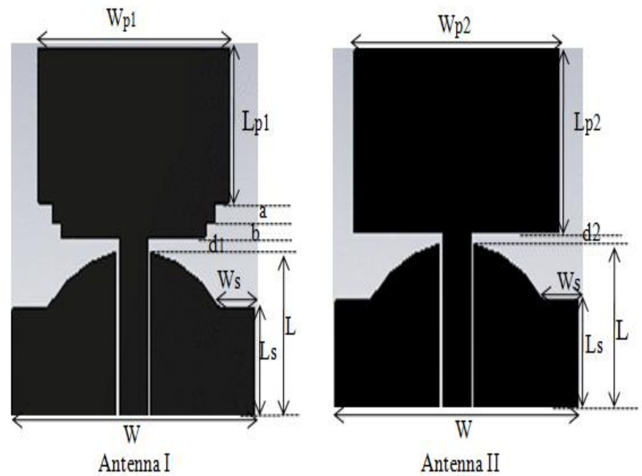

Fig.2. Geometry of CPW-fed the proposed antennas

Table 1: Optimized antenna parameters

Parameter	Value (mm)	parameter	Value (mm)
W	22	Lp2	17
WP1	16	Wp2	18
LP1	11	d2	0.4
L	12	d1	0.7
Ws	4	a	1
Ls	8	b	0.5

III. SIMULATION RESULTS AND DISCUSSIONS

In this section parametric study is given in more detail about the rectangular UWB CWP-fed planar antennas. The shape of the ground plane of these antennas is chosen to be a modified semicircular with a symmetric rectangular next to the semicircular in ground, have effect on the enhancement of the impedance bandwidth of the antennas. In order to enhance the performance of these antennas, a parametric study has been

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carried and the numerical results of the input impedance and radiation characteristics have been obtained. The key design parameters used for the optimization are length and width of the rectangles in ground plane and the feed gap between the patch and coplanar waveguide. The parameters are studied by changing one parameter a time and fixing the others, in order to investigate the influence of the parameters on antenna performance. The effects of parameters d_1, d_2, Ls and Ws on bandwidth characteristics are simulated and shown in figures 3, 4 and 5 respectively for both proposed antennas.

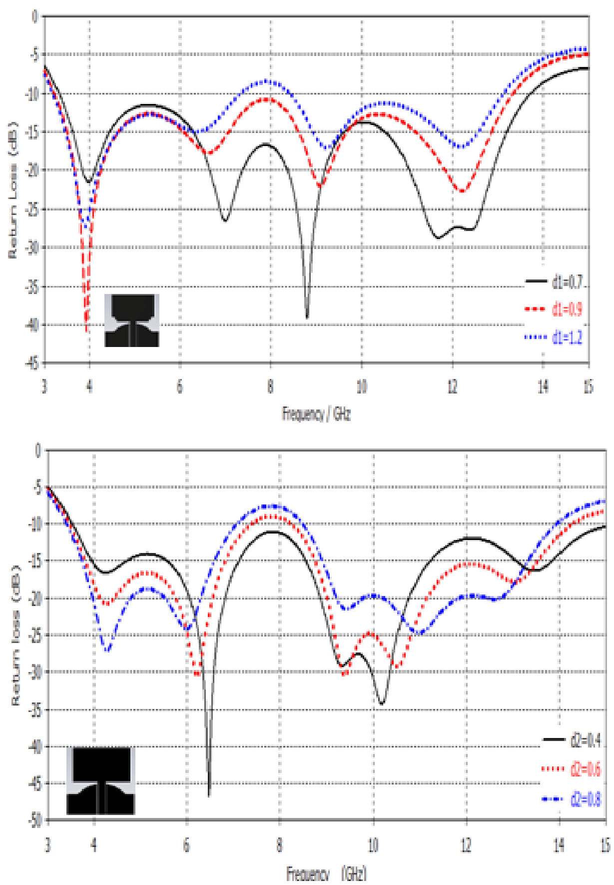

Fig.3. Effects of parameters d1 and d2 on the reflection coefficient of antennas

The feed gap (d) between the patch and coplanar waveguide has a significant effect on the antenna's matching input impedance. Figure 3 describes the variation of return loss (S11) with parameter d1 for antenna I and d2 for antenna II. The upper values of d relative to its optimized value (d1 =0.7 and d2=0.4) decrease the operational bandwidth of proposed antennas.

Effect of rectangle from ground plane on the bandwidth performance is studied by varying Ls and Ws parameters. The optimum values were obtained by parametric study. It is obvious from Figure 4 and Figure 5 that by decreasing both parameters from its optimized value, that the optimal values are obtained for Ls equal to 8 mm and Ws equal to 4 mm for both proposed antennas. Thus, we sign that the variation in the size of rectangle changes the matching characteristics and the bandwidth varies correspondingly.

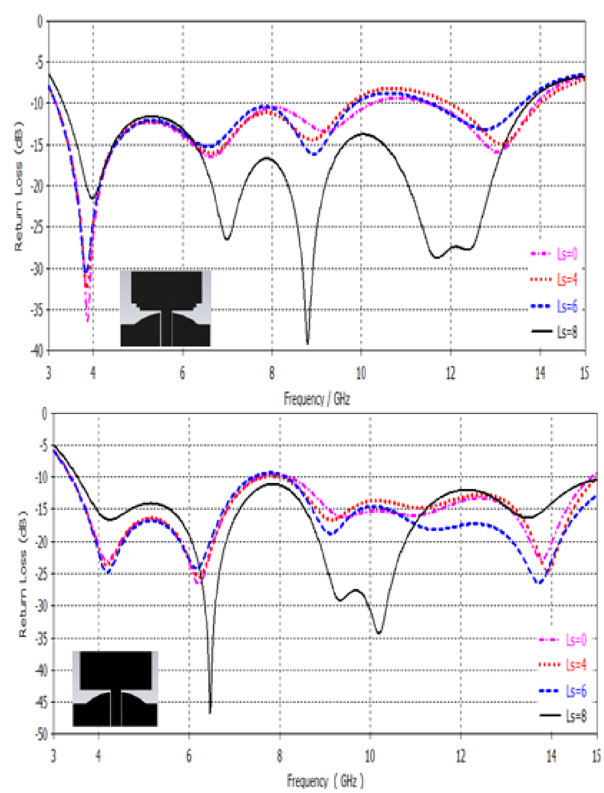

Fig.4. Effects of parameter Ls on the reflection coefficient of antennas

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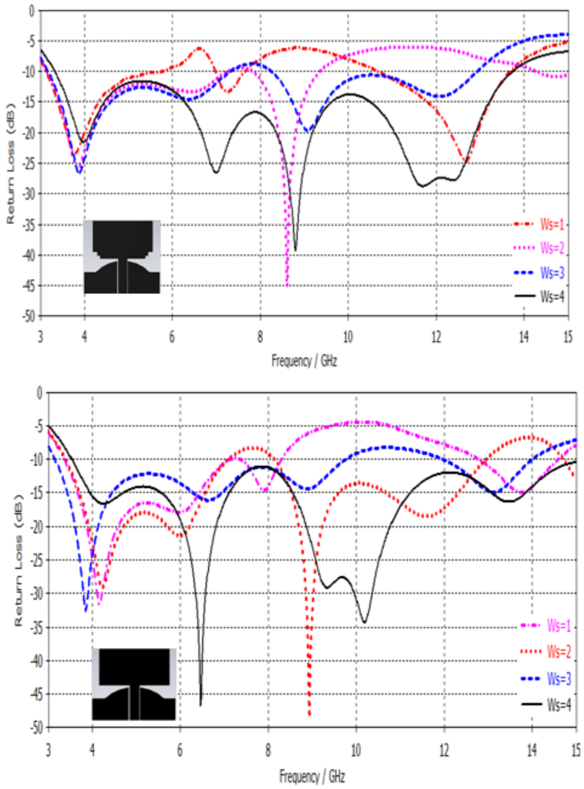


Fig.5. Effects of parameter Ws on the reflection coefficient of antennas

Finally, all optimal parameters of the proposed antennas are summarized in Table 1.

Figure 6 shows the simulated reflection coefficient of the rectangular monopole antennas with optimal parameters. We have applied two methods to analyze these antennas, then we have use the CST-MW and the FEM (Finit Element Method) introduced by HFSS software. After the simulation, it is clearly observed that simulation results on CST and HFSS are agreement in terms of bandwidth results. Figure.7 shows the simulated VSWR of the proposed antennas. We can be seen that the simulated results give a VSWR≤ 2 for the bandwidth from 3.4 GHz to more than 14GHz.

Figure 8 presents the simulated gain for proposed antennas versus frequency for different values of frequencies along the operating frequency band. It is clearly observed that the antenna gain has increased by the increasing of frequency for the both antennas. The simulation results provide the maximum gain variation is approximately 5 dB for antenna I and 4.42 dB for antenna II.

Figure.9 Show the radiation patterns of the proposed antennas at azimuth and elevation planes for different frequencies (4, 7 and 9 GHz). Generally, the radiation patterns are symmetric and nearly omnidirectional. The radiation is relatively stable along the operating frequency band defined by FCC. On the other hand, in E-plane the simulated results show an almost omnidirectional in low frequencies which are 4 GHz, 7 GHz and similar to the bi-directional for high frequency which is 9 GHz. In H-plane the radiation patterns is quasi- omnidirectional for all frequency bands.

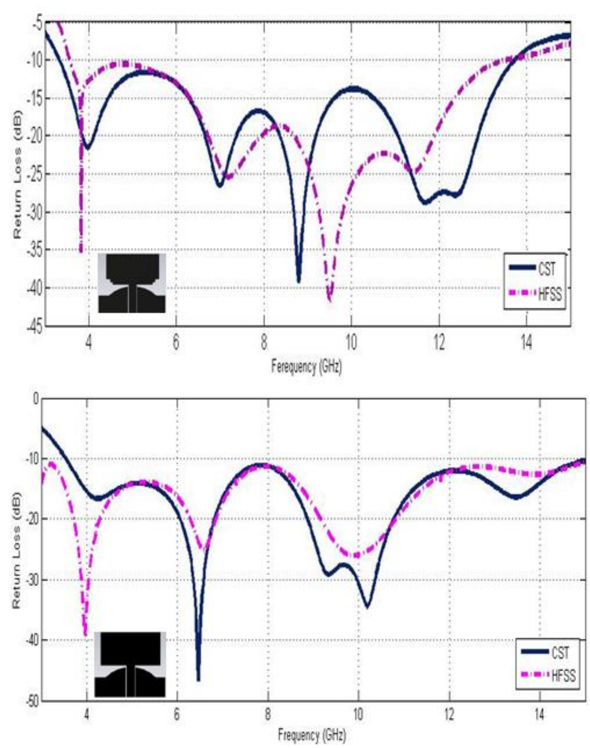


Fig.6. Comparison between reflection coefficients obtained by HFSS and CST-MW for the proposed antennas.

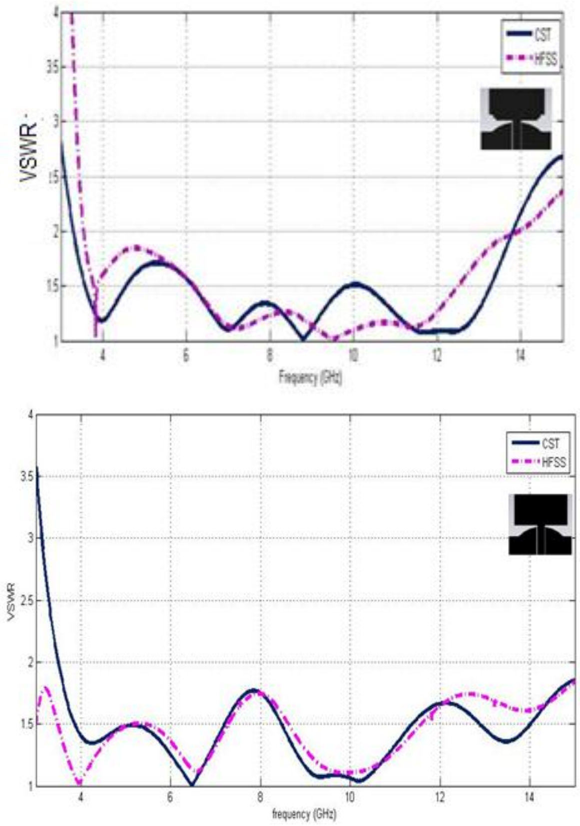


Fig.7. Comparison between VSWR obtained by HFSS and CST-MW of the proposed antennas

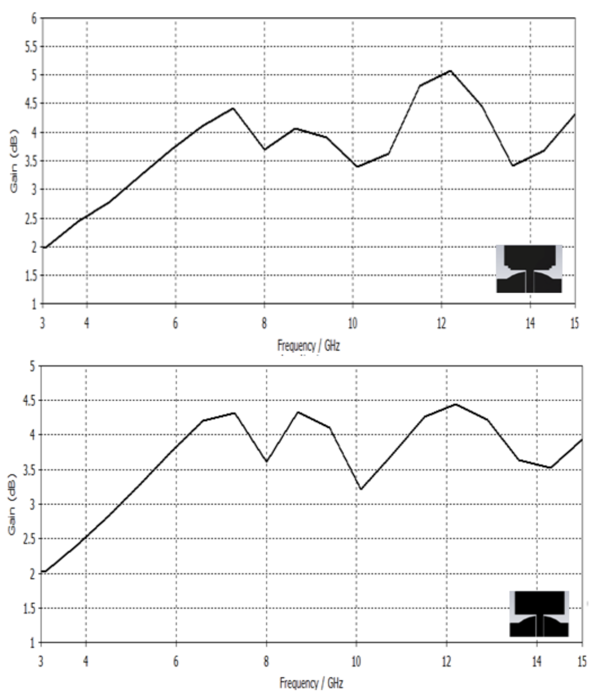
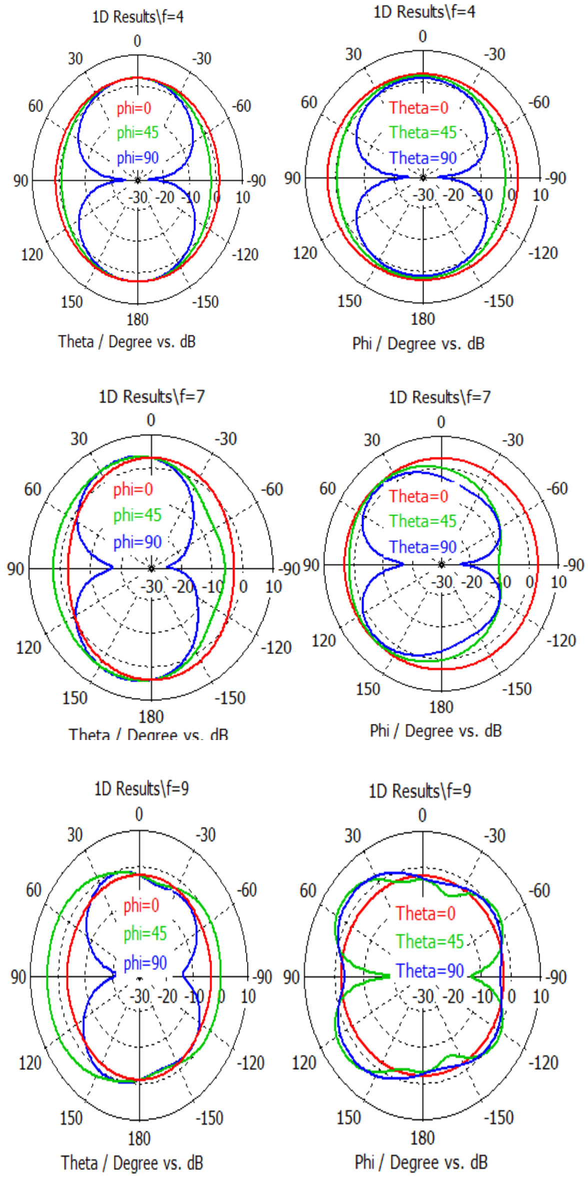
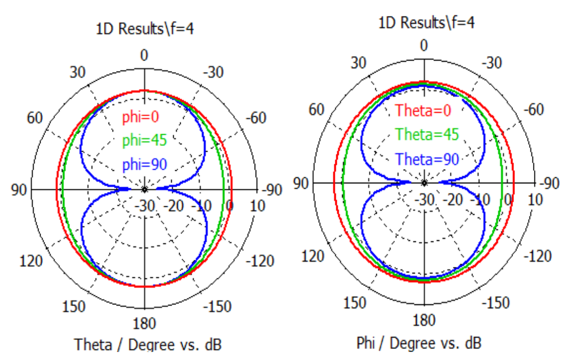


Fig.8. Simulated Gain of the proposed antennas.



Antenna I



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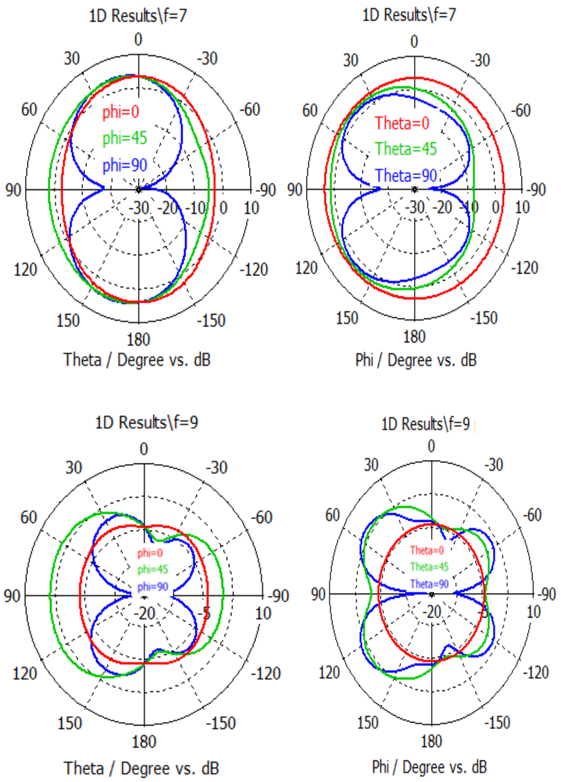


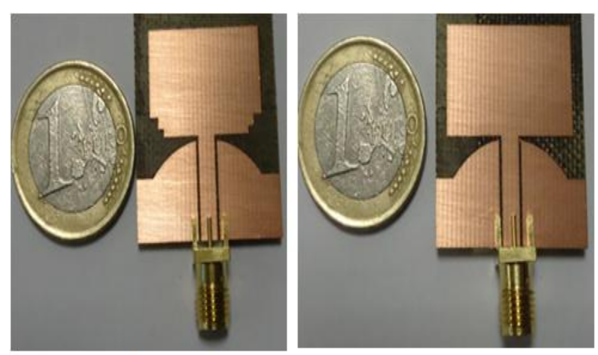
Antenna II

Fig.9. simulated radiation patterns for the proposed antennas at different frequencies on E-plan and H-plan: (4 GHz, 7 GHz and 9 GHz).

IV.ACHIEVEMENT AND MEASUREMENT RESULTS

After the design, optimization of the UWB antenna structures by using CST and HFSS, we have been achieved the proposed antennas by using LPKF machine. The prototypes of the proposed antennas are illustrated in figure.10. In order to use scattering parameters of the proposed antennas, we have used the Agilent Technologies VNA N5230A. The calibration used is the 3.5mm Agilent technologies calibration kit. Figure.11 shows the simulation by using two electromagnetic solvers CST-MW and Ansoft HFSS and measured reflection coefficients results. It can be observed that the measurement and the simulation results are not exactly the same, the bandwidths they define are approximately equals, mainly between CST and measurements however, in terms of bandwidth the results remain very comparable one across the whole operating band. However disagreement between the simulated and measured results is mainly due to the measurement of a small antenna is very sensitive to the presence of the RF cable connected to the input of the antenna, creating an additional inductance. It may be attributed to the fact that the substrate FR4 used for the fabrication of the antenna does not possess uniform characteristics in terms of its material properties. It may also be due the fabrication tolerance.

Besides, the measured bandwidth of these antennas covers the FCC commercial UWB band with a fractional bandwidth of 126%. These antennas can easily be integrated with RF/microwave circuits for compact design and fabricated at a very low manufacturing cost.



Antenna I Antenna II

Fig.10. Photographs of the achieved UWB antennas

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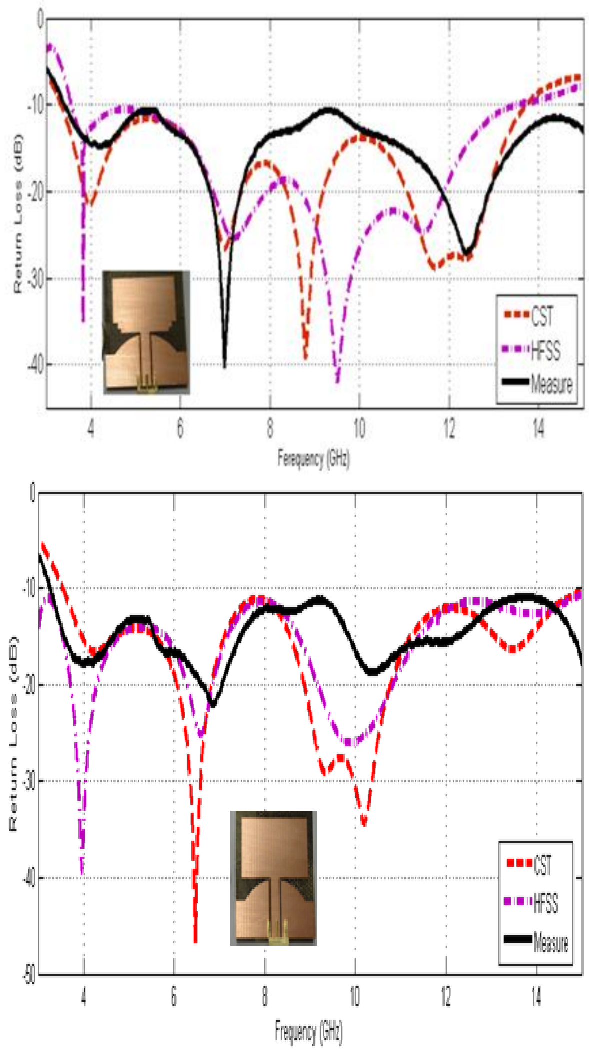

Fig.11. Simulated and measured reflection coefficients vs frequency of the proposed antennas

Table 2. Comparison between recently proposed antennas and this antenna

References		Operating bandwidth	Structure Size (mm2)	Gain (dB)
[8]		3-12.8 GHz	14x18	0.5-3
[7]		2.7-9.3 GHz	40x50	1-5.5
[5]		4.5-20GHz	22x19	2.5-6.3
[18]		3-12GHz	26x26	Not reported
This work	Antenna I	3.4-15GHz	26x22	2-5
	Antenna II	3.2-15GHz	27x22	2-4.5

The performance comparison of proposed antennas with some other UWB antenna is shown in Tab. 2. It is found that the proposed antennas show wide impedance bandwidth, compact size, and good gain features.

V. CONCLUSION

In this work, we have developed and validated CPW-fed rectangular monopole antennas for UWB band applications. The proposed antennas have been successfully achieved and improved with a wide bandwidth more than 126%, in which UWB frequency spectrum covers the range from 3.4 to 15 GHz with excellent performance in term of return loss and gain. The radiation patterns have good stability over the entire frequency band defined by FCC. The simulated results are nearly in agreement with the measured results in term of reflection coefficients. Therefore, these antennas are suitable candidates for UWB bands applications and can easily be integrated with RF/microwave circuits for compact design and fabricated at a very low manufacturing cost.

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