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Microstrip Rectangular Monopole Antennas with Defected Ground for UWB Applications

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ABSTRACT

This paper presents the design of new compact antennas for ultra wide band applications. Each antenna consists of a rectangular patch fed by 50Ω microstrip transmission line and the ground element is a defected ground structure (DGS). The aim of this study is to improve the bandwidth of these antennas by using DGS and the modification geometry of rectangular structure, which gives new compact antennas for UWB applications. The input impedance bandwidth of the antennas with S11<-10dB is more than 10GHz, from 3GHz to more than 14 GHz. The proposed antennas are investigated and optimized by using CST microwave studio, they are validated by using another electromagnetic solver Ansoft HFSS. The measured parameters present good agreement with simulation. The final antenna structures offer excellent performances for UWB system.

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1. INTRODUCTION

An important change occurred in February 2002, when the Federal Communication Commission (FCC) officially released the regulation for Ultra Wideband (UWB) technology, with a given spectral mask for both indoor and outdoor applications in the USA. UWB range covers 3.1 GHz-10.6GHz is released by FCC [1-2]. From then on, there is much interest today in developing ultra wideband (UWB) radio in both academia and industry for short-range high-speed wireless communication networks. UWB is increasing rapidly due to meets demands of wireless communication to provide information. This technology is based on signals from the low power spectral density. The UWB systems can coexist with narrowband radio systems operating in the same spectrum without causing strong interferences [1-4]. In other words, UWB communication technology holds great promise and extremely useful for a vast array of new applications that in which it can used for public safety, business and consumers, because of its various satisfying factures including high data, high precision ranging, low cost and the most important facture of the UWB systems is the immunity to multipatch interference [1], [2]. In recent years, UWB technology has mostly focused to design antenna for wireless communication operating over an ultra wide bandwidth as allocated by the FCC. Commonly the return loss for the entire ultra-wideband should be below the -10dB. Also satisfactory radiation properties over the entire frequency band defined by FCC. Designed antennas should be compact in size, and easy to integratewith monolithic microwave integrated circuit (MMIC). Printed microstrip antenna is widely used due to their numerous advantages such as low profile, lightweight, low cost, easy fabrication, and small size. Major operational disadvantage of microstrip antenna is very narrow frequency bandwidth. In some applications narrow bandwidths are desirable [5]. By consequent, the needs of UWB antennas have been proposed and investigated of new technologies to overcome these shortcomings.

There are several ways to enlarge the operating bandwidth of microstrip antenna, to design an UWB antenna, such as using notches or slots on patch antenna with different shapes as circular slot [6],U slot[7], Z slot[8] etc; using dielectric substrates with high permittivity [9]; using a planar monopole antenna fed by a coplanar waveguide tapered ring slot antenna [10], tuning stub [11], [7], L-probe feeding [12].Well as other methods of microstrip elements can also be used to increase the bandwidth [13], [14],

Defected Ground Structure (DGS) is one of the methods, which are used to improve the input impedance bandwidth of the microstrip antenna.DGS is realized by inserted a simple shape in the ground plane. The implementation of DGS in the ground plane can increase the input impedance bandwidth of the original microstrip antenna. Also DGS permits to reduce the size of an antenna, thus to lower resonance frequency. Further we can use the DGS to improve other parameters in the antennas. Finally the DGS in the ground plane plays an important role in the design of compact a high performance microwave circuits [15], [16].

In this paper, an application of the DGS to improve moreover the input impedance bandwidth of rectangular microstrip antennas are demonstrated. The proposed antennas showan acceptable reflection coefficient, wider input impedance bandwidth and stable radiation pattern throughout of the UWB frequency band. These antennas are successfully implemented. Details of the antenna designs; simulated results are presented and discussed.

2. DESTRIPITION OF UWB ATENNA DESIGN

This section presents the description of the proposed UWB microstrip antenna design and calculations methodology. The antenna structure designed is based on rectangular radiator patch. The rectangular patch is the most widely used configuration, for the reason that it can be easily to analyze.

In designing this type of antenna, there are various parameters needed to be considered, which is associated with the resonant frequency and bandwidth of the antenna. The width “W” and length “L” are critical parameters in determining the operating frequencies and input impedance of the antenna .The length of the antenna is about L=$\lambda/2$ for dominant TM_{10} mode. The length of the patch is very critical, it determines the resonant frequency.

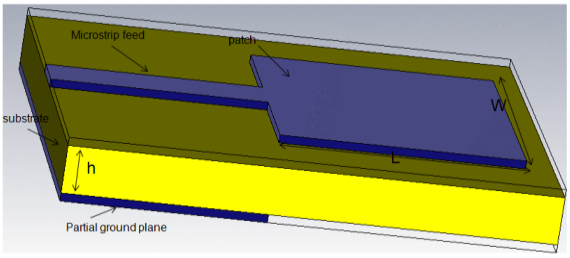


Figure 1. Microstrip rectangular patch antenna

Hence, to lead to practical designs of rectangular microstrip antennas, there’s a design procedure. The essential parameters for the design are the dielectric constant (ε_r), the resonant frequency (f_r) and height of substrate (h). The procedure is as follows [5]:

For an efficient radiator, a practical width that leads to good radiation efficiencies is:

$$W = \frac{C}{2\, f_r \sqrt{\frac{(\varepsilon_r+1)}{2}}} \tag{1}$$

Where C is the free space velocity of light.

The length has been extended on each end by a distance ΔL, the length of the patch is:

$$L = L_{eff} - 2\Delta L \tag{2}$$

The effective length of the patch is:

$$L_{eff} = \frac{1}{2f_r\sqrt{\varepsilon_{eff}}\sqrt{\varepsilon_0\mu_0}} \quad (3)$$

Normalized extension of the length ΔL is:

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (4)$$

For a rectangular microstrip patch antenna the effective dielectric constant for any TM_{mn} mode is give by as:

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2} \quad (5)$$

The aim of this study is to enlarge the operating bandwidth of the rectangular patch antenna presented in Figure 1 in order to achieve the UWB characteristics. At the same time the final antenna should be small, compact and easy to be integrated with passive and active components.
The Figure 2 shows the geometry and configuration of the final antennas. The proposed antennas are planar microstrip antennas with ultra-wideband radiation properties. These antennas are fed by a microstrip line with a characteristic impedance of 50Ω on an FR4 substrate anda thickness of 1.6mm, relative permittivity of 4.4 and a loss tangent of 0.025.The optimization parameters design is done by using CST-MW and the validation is verified by using another solver Ansoft HFSS. The final dimensions of the antenna structures are listed in Table 1.

Many techniques have been used to enlarge the operating bandwidth frequency. One way is the modification of the rectangular shape by using the stepped cut corner with two steps, and by using DGS. Figure 3 presents the evolution of the proposed antennas.

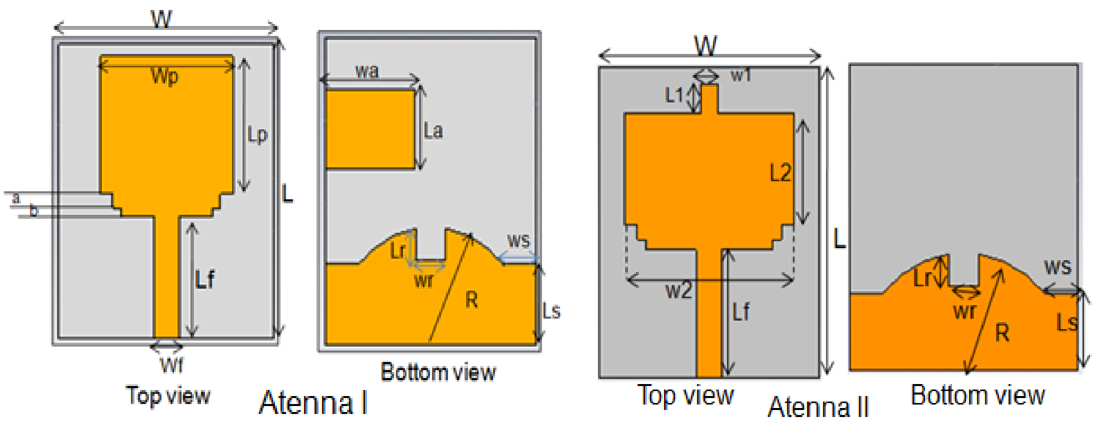
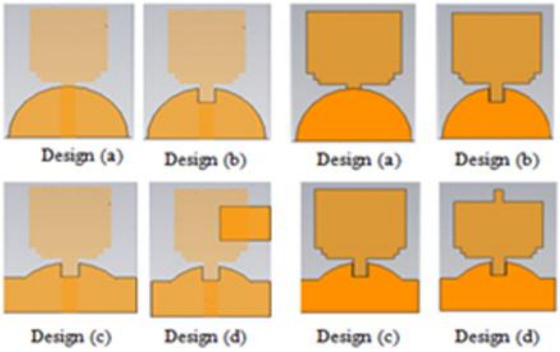


Figure 2. Geometries of the proposed antennas, Top view, Bottom view

Table 1. Parameters of the proposed antennas

Parameter	Value (mm)	parameter	Value (mm)
W	26	L	30
Wp	16	Wa	11
Lp	15	La	8.25
Lf	13.25	R	12.2
Wf	3	Wr	3.5
Ls	8	Lr	3.5
Ws	4	a	1.5
W1	2	b	1
L1	3	W2	20
		L2	11



Atenna I Atenna II

Figure 3. Design evolutions of the proposed antennas

3. SIMULATION RESULTS AND DISCUSSION

In this part a discussion is given in more detail about the microstrip antennas with defected ground structure (DGS). The reflection coefficient results of the proposed antennas simulated by using the optimization techniques integrated in CST-MW. The reflection coefficient simulation results of all designs of the proposed antennas (Antenna I and Antenna II) are shown in Figure 4.Therefore, the first step in designing the antennas, we have started from the design (a). The reflection coefficient of design (a) is showing good matching at the first bandwidth from 3GHz to 4GHz, for both antennas, while the second bandwidth is from 6GHz to 15GHz for antenna I and 5.2GHz to 15 GHz for antenna II with reflection coefficient less than -10dB, a semicircular shaped ground with a rectangular notch and a symmetric rectangular next to the semicircular in ground have effect on the enhancement of the impedance bandwidth of the antennas, the design (b) and the design (c),it can be seen that the reflection coefficients were improved.

At the end, we have completed the DGSof the antenna I by associating an additional patch design (d), whereas for antenna II we modified geometry of antenna to achieve design (d) .These techniques permit to enlarge the bandwidth and to get the best resonant frequencies.

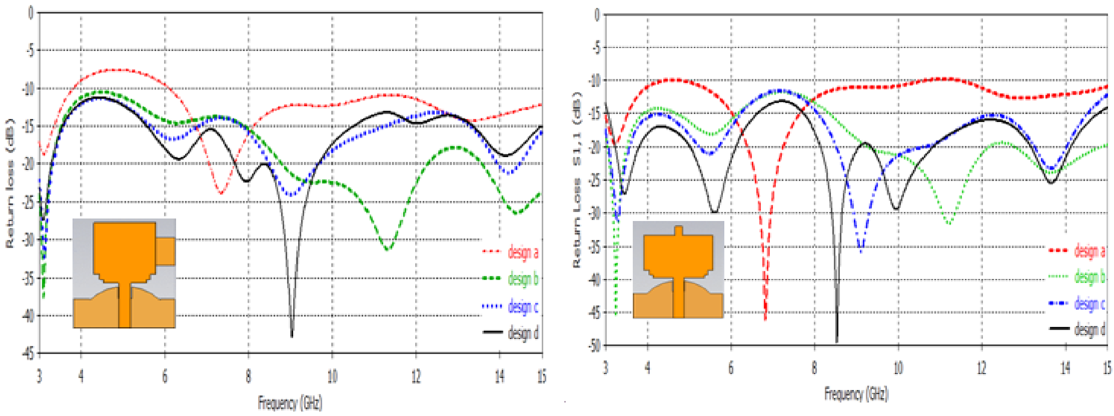


Figure 4. reflection coefficients for different designs of the proposed antennas

Figure 5 shows the effect of the stepped cut corner on the proposed antennas in term of the reflection coefficient. We can observe the stepped cut corner has the good effect to improve the bandwidth and to get the best resonant frequencies mostly in band between 6GHz to 10GHz.

For the validation and the comparison of the results obtained by CST, we have applied another method e to analyze these antennas,then we have use the FEM (Finit Element Method) introducedby HFSS software. After the simulation, the following results are shown in Figure 6, it is clearly observed that simulation results on CST and HFSS are closest 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 3GHz-15GHz.

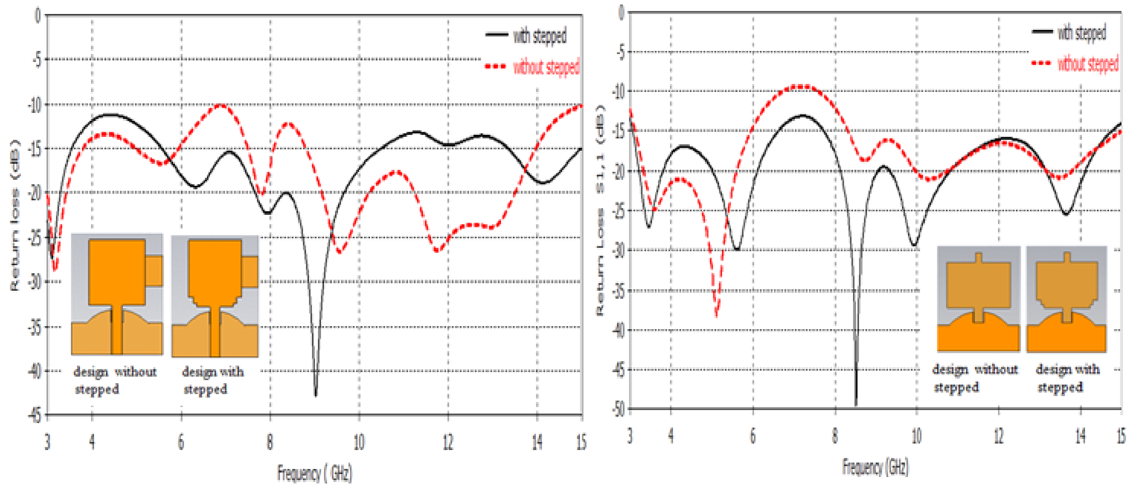


Figure 5. Reflection coefficients of the antenna with the stepped and the antenna without the stepped

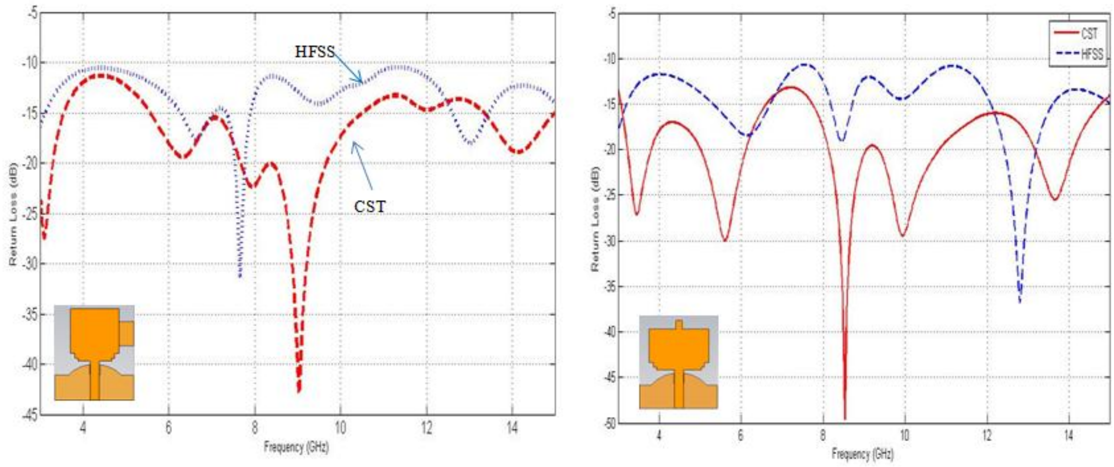


Figure 6. Comparison between reflection coefficients obtained by HFSS and CST-MW

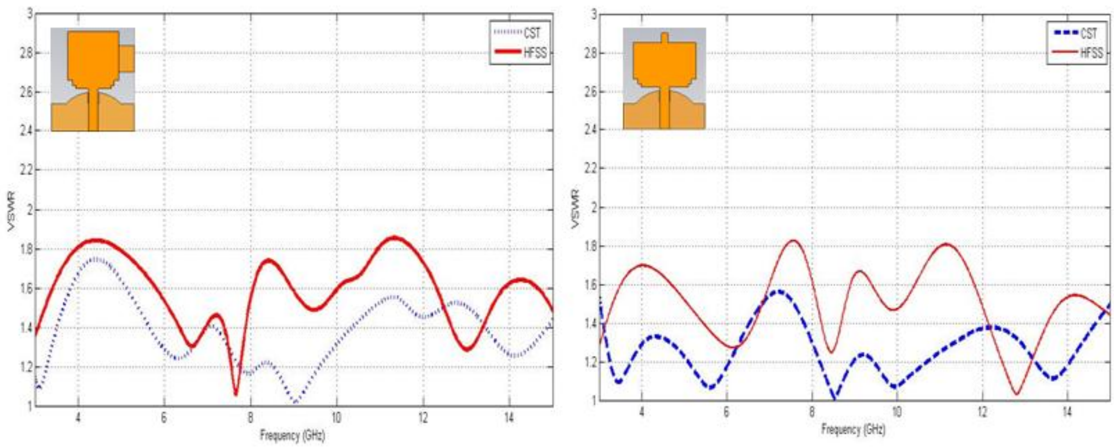


Figure 7. Comparison between VSWR obtained by HFSS and CST-MW

The Figure 8 presents the simulated antenna gain, for the frequencies between 3 to 15GHz.The maximum value obtained is approximately 3.8 dB for antenna I and 3.9 dB for antenna II.

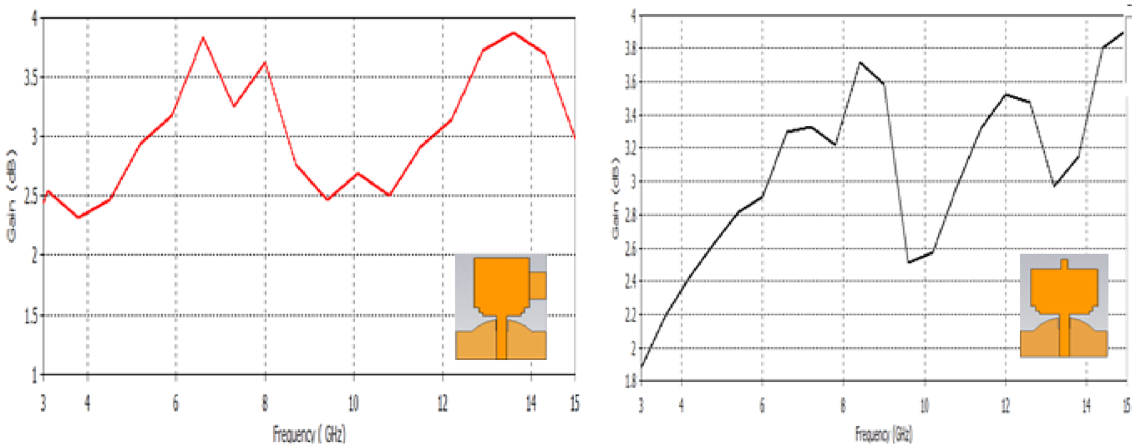
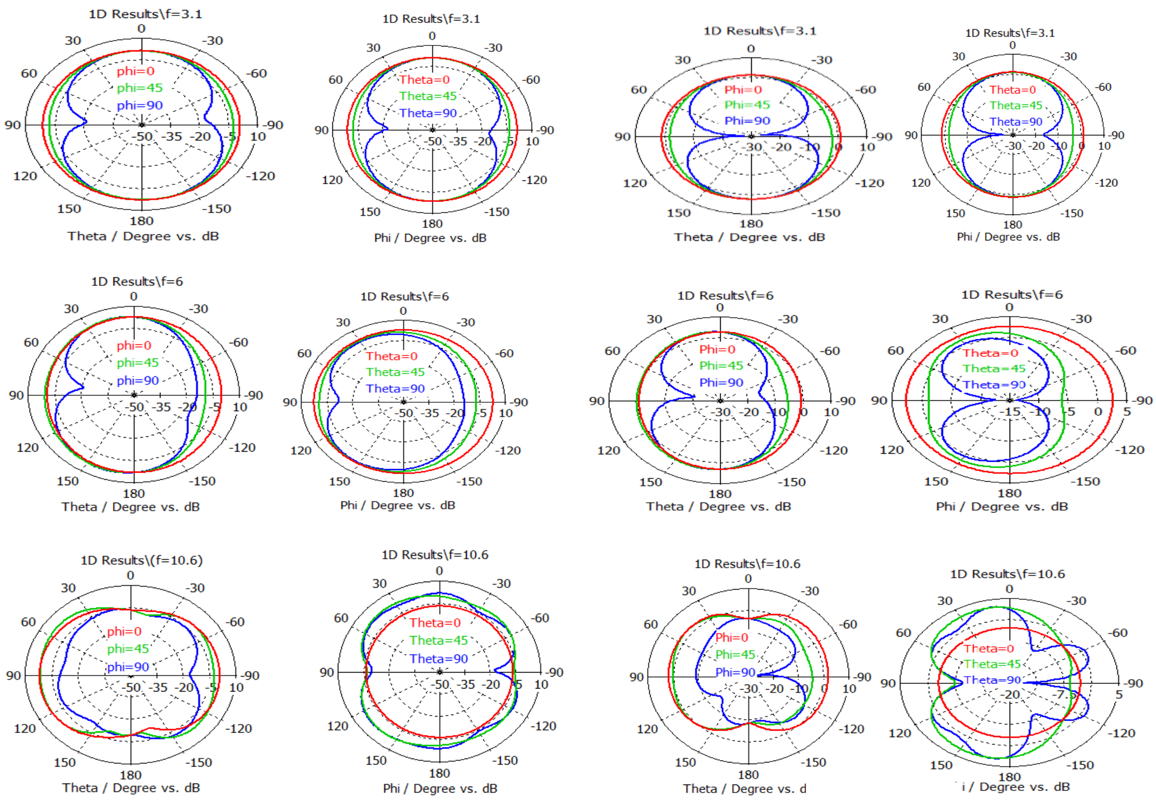


Figure 8. Simulated Gain of the proposed antennas

The Figure 9 Show the radiation patterns of the proposed antennas on E-plane and H-plane at different frequencies (3.1, 6 and 10.6 GHz).

Generally, the radiation patterns are symmetric and nearly omnidirectional. The radiation is relatively stable over the band defined by FCC. On the other hand,in E-plane the simulated results show an almost omnidirectional in low frequencies which are 3.1 GHz, 6 GHz and lose the omnidirectionality for high frequency which is 10.6 GHz. In H-plane the radiation patterns is nearly bidirectional for all frequency bands.



Antenna I Atenna II

Figure 9. Simulated radiation patterns for the proposed antennas on E-plane and H-plane at: 3.1GHz, 6GHz and 10.6GHz

4. ACHIEVEMENT AND MEASURMENT RESULTS

We fabricated the proposed antennas by using LPKF machine, after the design, optimization by using CST and HFSS. The prototypes of the proposed antennas are illustrated in Figure 10. We measured the reflection coefficientusing the Agilent Technologies 2-port PNA-L Vector Network Analyzer N5230A. The calibration used is the 3.5mm Agilent technologies calibration kit composed from Open, Short and Load components. Figure 11 shows the simulation by using two electromagnetic solvers CST-MW and Ansoft HFSS and measuredreflection coefficients results. It can be observed that the simulation results are inagreement with measurement in terms of bandwidth results. Besides, the proposed antennas have wideband performance from 3.1GHz to 14 GHz covering the entire UWB frequency band.These type of antennas can easily be integrated with RF/microwave circuits for compact design and fabricated at a very low manufacturing cost.

This measurement was done by using a 50Ω SMA (Surface Mount Adaptor), which is connected to the end of the microstrip transmission-line and grounded to the ground plane. However some differences in the simulated and measured results are observed. One of the reasons is that 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. Another reason, since the antenna is fed by a microstrip line so, misalignment occurs because etching is required on both sides of the dielectric substrate. This gives rise to degradation of antenna performance.

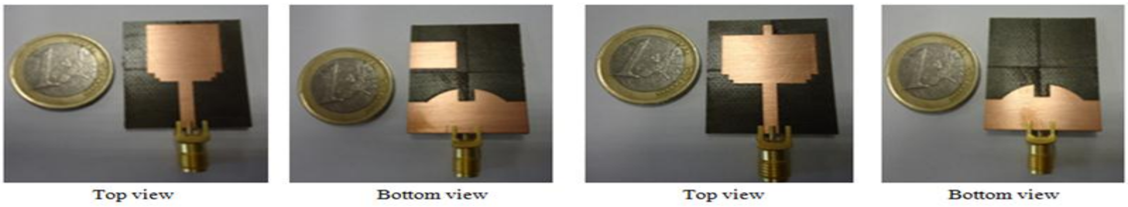


Figure 10. Photographs of the achieved UWB antennas

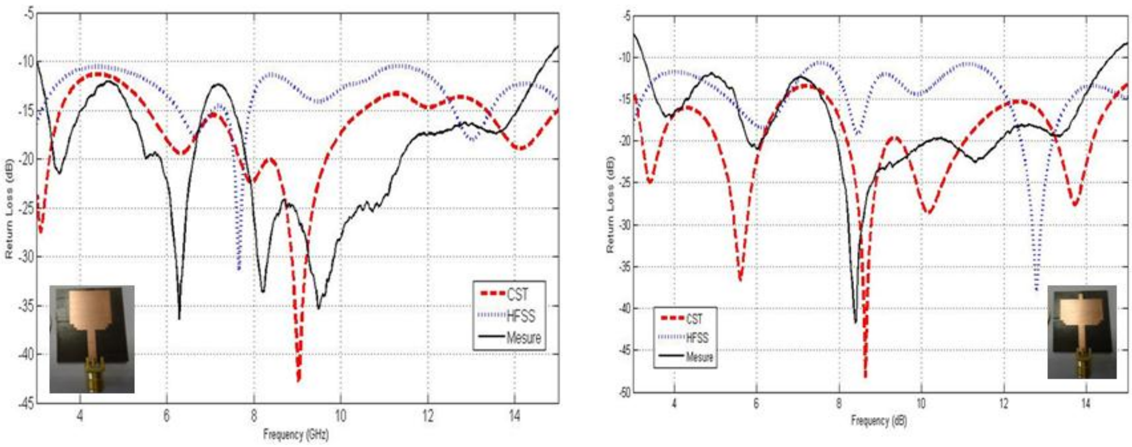


Figure 11. Simulated and measured reflection coefficients vs frequency of the proposed antennas

5. CONCLUSION

Two compact UWB monopole antennas have been proposed, analyzed and validated for UWB band applications. The defected Ground Structure (DGS) in the ground plane plays an important role in the design of compact and high performance microstrip antenna. Hence, these new patch antennas with DGS have these properties: improved reflection coefficient, VSWR bandwidth, gain of the antenna as compared to the conventional antenna. The simulated and the measured results are in agreement in term of reflection coefficients which validate the novel compact antenna structures with a bandwidth of (3-14.5GHz) for antenna I and (3.2-14.5GHz) for antenna II. These antennas are suitable candidate for UWB band applications.

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