Journal of Informatics and Mathematical Sciences
Vol. 13, No. 3, pp. 157–165, 2021
ISSN 0975-5748 (online); 0974-875X (print)
Published by RGN Publications
DOI: 10.26713/jims.v13i3.2057

Research Article

Design of a ULB Diamond Monopoly Antenna

Belhadef Yamina* and Boukli Hacene Nourreddine

Department of Telecommunications, LTT Laboratory of Tlemcen, Abou-Bekr Belkaïd University, Tlemcen, Algeria
*__Corresponding author:__ belhadef_y@yahoo.fr

Received: October 15, 2021 **Accepted:** November 28, 2021

Abstract. In this paper a new diamond monopoly antenna consisting of a diamond patch fed by a CPW coplanar waveguide and matched at 50 Ω over a very wide frequency band is presented. Parametric studies are applied on this antenna to improve the desired bandwidth. The design is performed by the CST Microwave Studio software. The final antenna obtained can be used for Ultra Wide Band operation.

Keywords. Monopoly antenna; Parametric studies; Ultra broadband; CST Microwave Studio

Mathematics Subject Classification (2020). 78A50

1. Introduction

Ultra wideband (ULB) communications are different from other communication techniques because they use extremely narrow pulses (Radio Frequency) to communicate between transmitters and receivers. The use of short duration pulses like module for communications directly produces a bandwidth very big and offers several advantages, such as the big throughput, security, robustness to jamming, multipath immunity, multiple access possibilities, reduced price transceivers and precise positioning, motivate several applications of this technology. Until now, UWB technology has been mainly applied to military devices (particularly the radar [4]. Applications are generally classified into six groups namely: ad hoc network management, wireless sensor networks, radio frequency identification or RFID, consumer electronics, localization, medical applications and coexistence with usual radio services [6].

The recent boom in ultra-broadband communications requires specially adapted antennas for this technology [8]. At the national level, the United States was the first country to allow commercial use for ULB. In February 2002, the US Federal Communications Commission (FCC)) required that ULB radio transmission can legally operate in the of 3.1 to 10.6 GHz range [3,5], with a power spectral density (PSD) satisfying a specific spectral mask assigned by the FCC [7,9]. A signal is said to be ultra wideband if: its wideband is at least of 500 MHz (at −10 dB) and its relative bandwidth is greater than 0.2 (20%) [1,2].

$$BP_{\text{relative}} = 2 \cdot \frac{f_H - f_L}{f_H + f_L} > 0.2. \tag{1.1}$$

2. Study of a Diamond Monopoly Powered by CPW

The overall size of the initial geometry is around 50 × 57.8 mm. The basic element of the antenna is a conductive strip of diamond shape, deposited on a dielectric substrate of dielectric constant $\varepsilon_r = 4.3$, thickness $h_0 = 1.6$ mm, and fed by a coplanar waveguide. We based first on the dimensions presented in Table 1.

Table 1

Diamond		Coplanar waveguide			Ground plane	
d	h	l	w	g	E_1	E_2
28 mm	13 mm	29.8 mm	2 mm	0.33 mm	3.1 mm	5 mm

After, we made several modifications on the initial antenna in order to approach a broadband structure. For the first modification, we added two rectangular elements of width equal to 6 mm and which are perpendicular to the two lateral arms of the initial antenna. Similarly, many rectangular patches of 5.5 mm width are configured between these perpendicular elements and the coplanar waveguide according to Figure 1(ii). Finally, two other elements of sizes 14 × 3.3 mm parallels to the feed line are added to the previous geometry to finally arrive at the structure shown in Figure 1(iii). The structure of the diamond shape initial monopoly antenna and the proposed new structures in the CST Microwave Studio editor are represented by Figure 1.

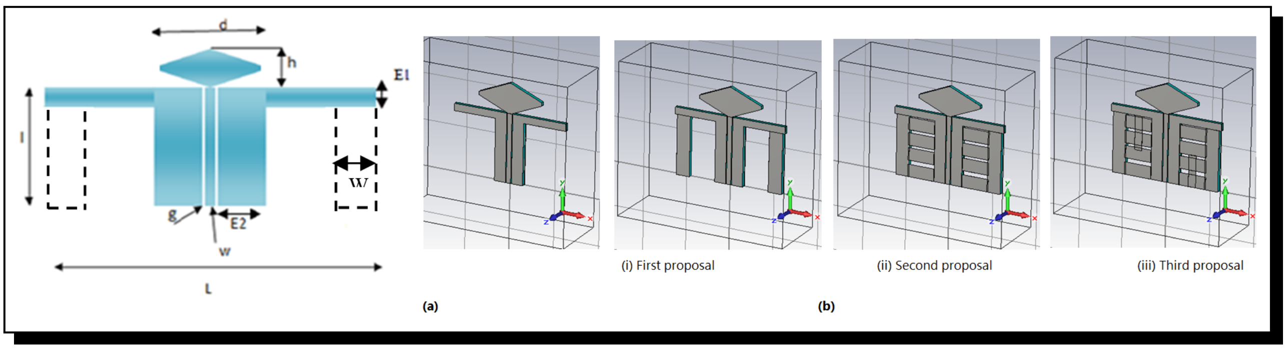

Figure 1. (a) Geometry of the initial diamond monopoly antenna, (b) Geometry of the proposed antennas

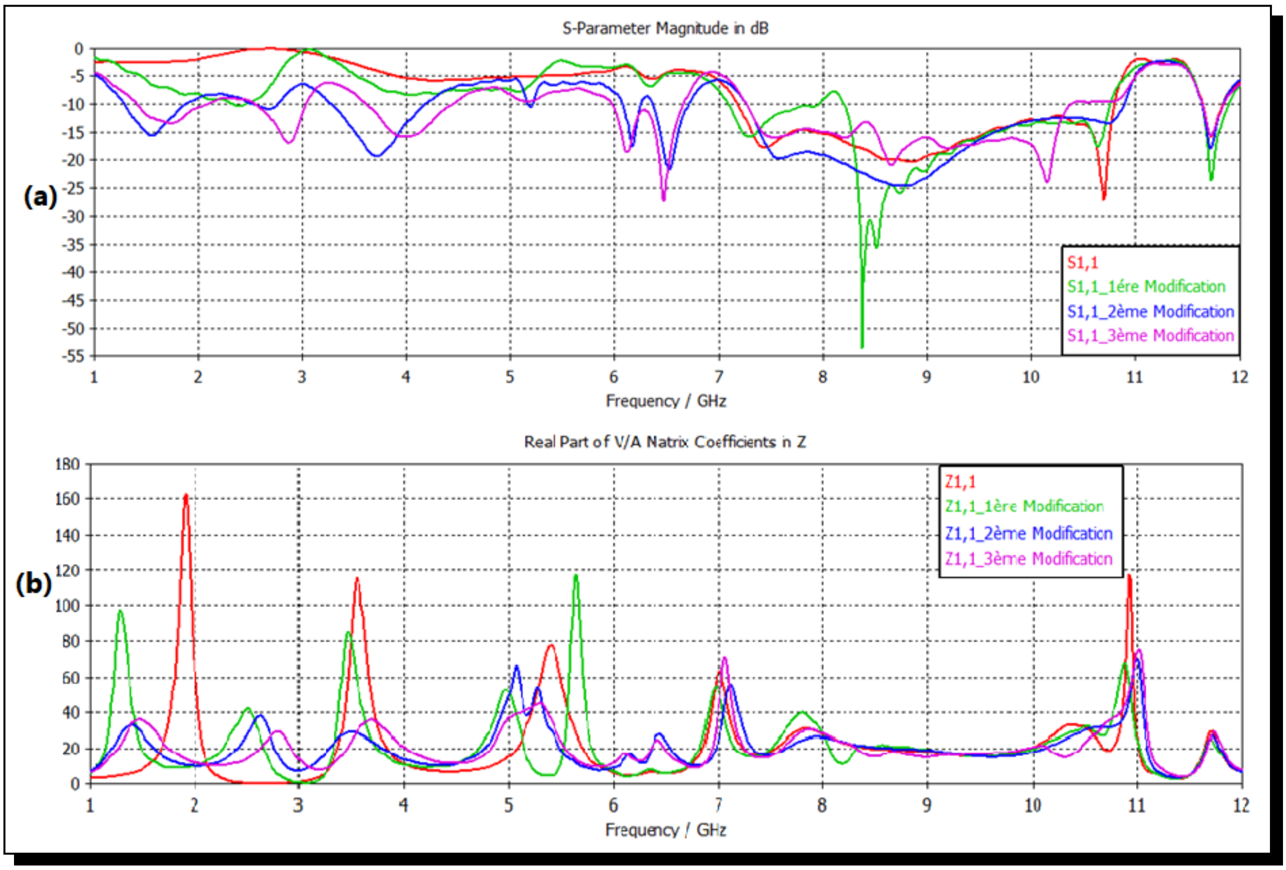

Figure 2. (a) Return loss, (b) Real part of the input impedance

On Figures 2(a,b), one respectively represents the return loss and the input impedance real part for the initial antenna and the proposed antennas.

The return losses of the four antennas are shown in Figure 2(a). The initial antenna curve (shown in red) encompasses two return loss peaks at resonant frequencies 10.69 GHz and 11.725 GHz with bandwidths exceeding 3.597 and 0.187 GHz, respectively. The second structure generates other resonance frequencies with lower levels of the return loss compared to the initial antenna in the low matching frequency band. We want to further improve the results found, for that we have modified the previous structure by adding rectangular patches according to Figure 1(ii). The design of the latter by CST Microwave Studio presents several more approximated resonances with almost identical adaptation levels, as well as a significant decrease of the return loss in the whole desired frequency band compared to the second designed structure. Similarly, the simulation of the final structure shows a considerable improvement if we want to compare it with the previous antenna, where the return loss curve presents a perfect adaptation with a very wide bandwidth of 3530 MHz between 7.27 GHz and 10.8 GHz. Figure 2(b) allows illustrates the shapes of the input impedance real parts obtained during the optimization process. A quasi-varying input impedance as a function of resonant frequency is observed. The multiband operation of the last configuration shows that the real part of the input impedance oscillates around 30 Ohms at each resonance frequency. Figure 2(b) illustrates the shapes of the input impedance real parts obtained during the optimization process. A quasi-varying input impedance as a function of resonant frequency is observed. The multiband operation of the last configuration shows that the real part of the input impedance oscillates around 30 Ohms at each resonance frequency. We can notice which these modifications which are carried out on the initial antenna gradually improve the proposed antennas radio responses but do not meet the intended objective. For this reason, we have based after on parametric studies to be able to define the role of some geometric parameters on the studied antenna adaptation.

2.1 Influence of the ε_r parameter

To increase the width bandwidth, it is necessary that ε_r is the more small possible. The bandwidth at -10 dB of the return loss for the value $\varepsilon_r = 3.1$ varies from 4 GHz to 12 GHz (bandwidth around 8 GHz). In this case, we see that this value ($\varepsilon_r = 3.1$) will have significant consequences on the antenna performance.

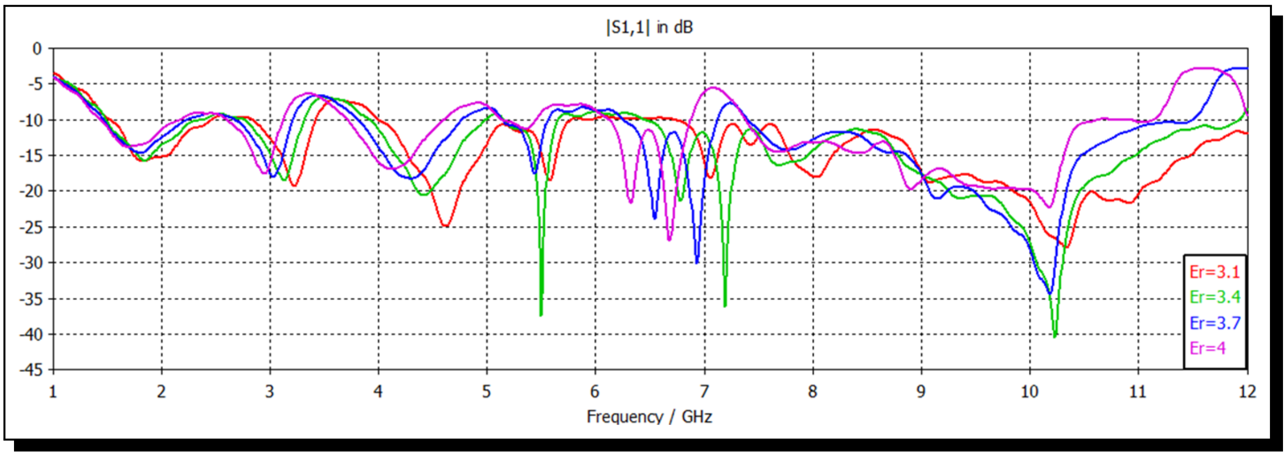

Figure 3. Variation of the return loss according to the parameter ε_r

2.2 Other variations

Several parameters are modified in order to improve the results found. Among these changes then, we added an element of dielectric permittivity $\varepsilon_r = 3.1$, of size $14 \times 3.3\,\text{mm}^2$ and height 1.6 mm below one of the two rectangular elements added last in the third structure represented by Figure 1(iii), and we modified also the width g of the coplanar waveguide slits which we set to 0.32 mm (Figure 4). All these changes have made it possible to obtain two bandwidths, the first starts from 1.517 GHz to 3.365 GHz in the adaptation low frequencies and the other from 4.102 GHz to 12 GHz with an SWR < 2 in the adaptation high frequencies. In Figure 5(a,b), one represent the return loss and the SWR standing wave ratio of the modified antenna.

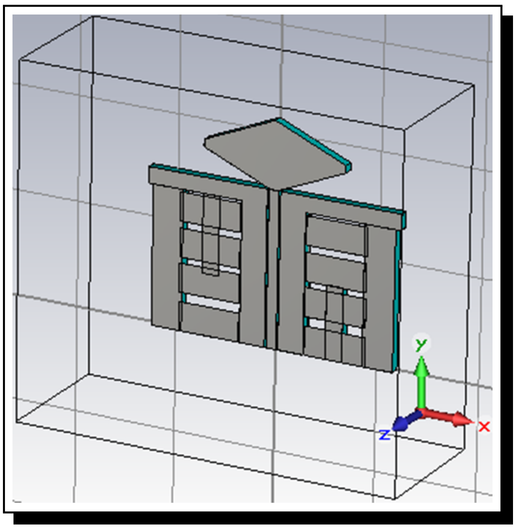

Figure 4. Modified antenna geometry

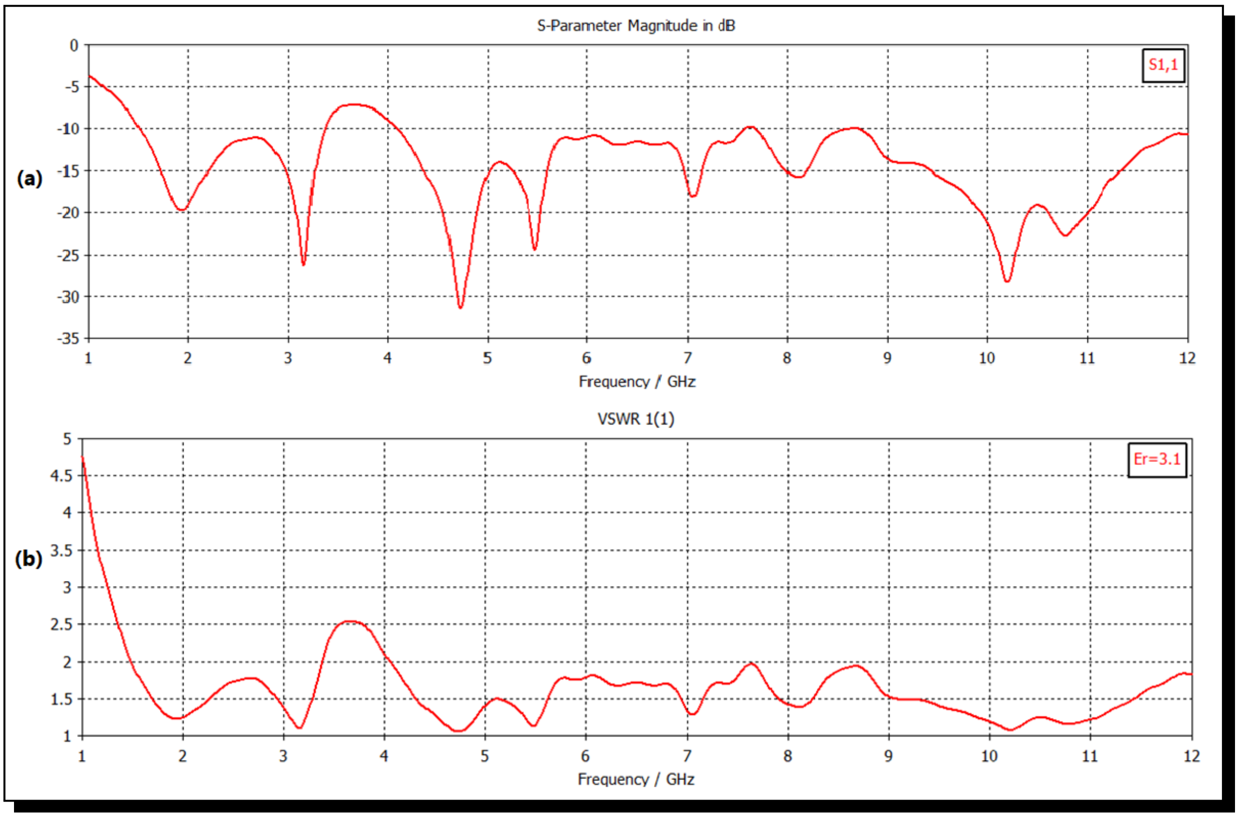

Figure 5. Return loss, Stationary wave ratio

2.3 Influence of parameter W_0

The influence of W_0 which symbolizes the lower position of the two arms perpendicular to the initial antenna relative to the abscissa axis according to frequency is shown in Figure 6. The antenna dielectric permittivity ε_r is set at 3.1. The best configuration in this case corresponds to $W_0 = 18$ mm where the width W_1 of the two perpendicular arms becomes equal to 6 mm. The antenna include several resonances, the widest are located between 1,484 GHz at 3,266 GHz (1782 MHz), and between 3,981 GHz at 11,934 GHz (7853 MHz). Therefore this structure finds its application in ULB systems.

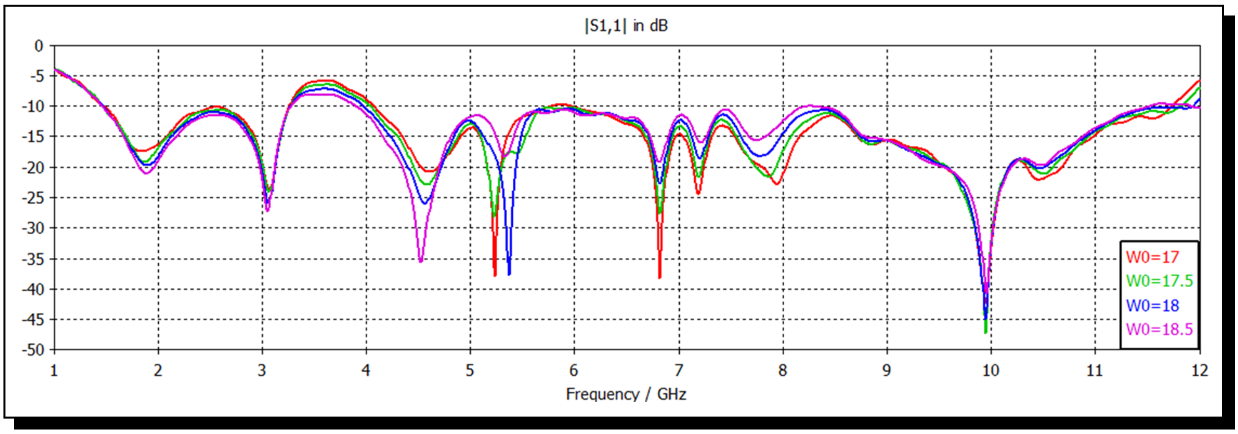

Figure 6. Return loss variation according to the parameter W_0

In Figure 6 and Figures 7(a,b), one respectively represent the return loss and the final antenna gain ($W_0 = 18$ mm).

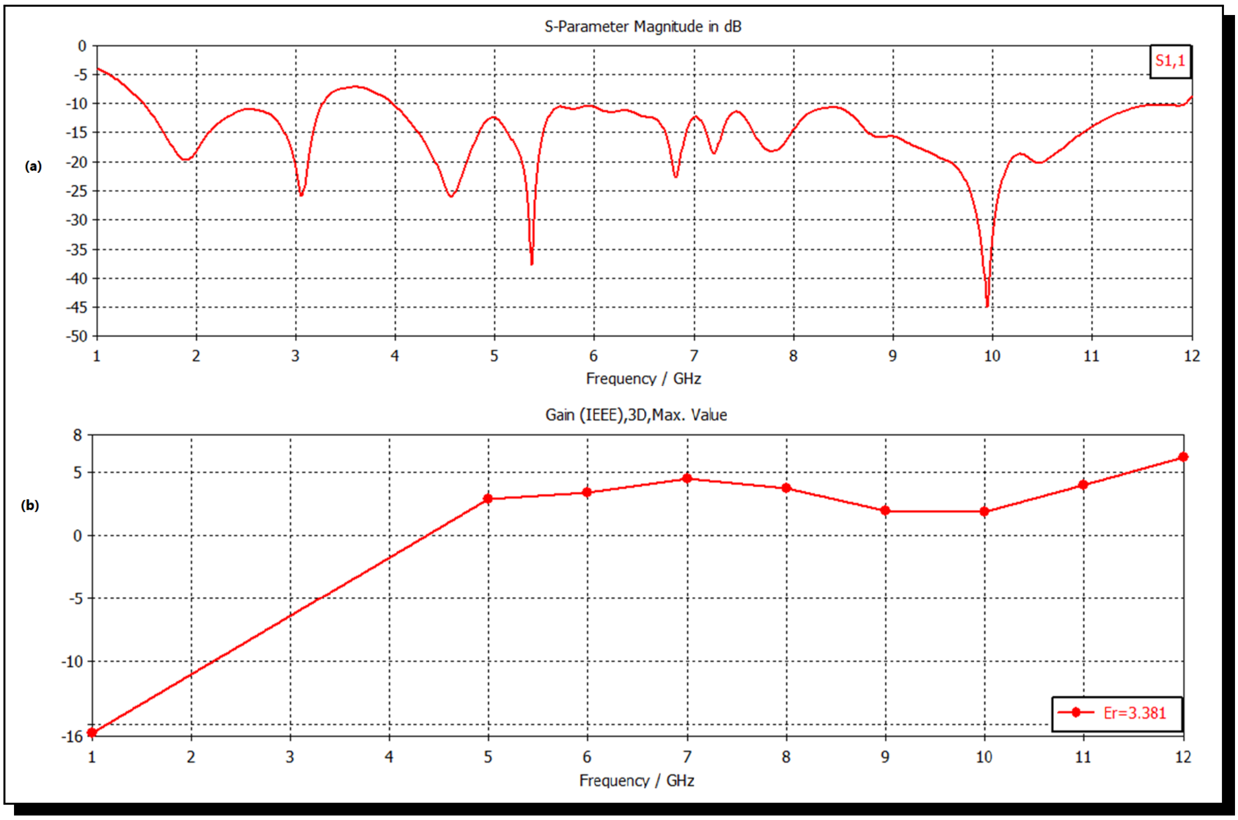

Figure 7. Return loss, Final antenna gain

The radiation patterns in polar coordinates in 2D and 3D are shown in Figure 8.

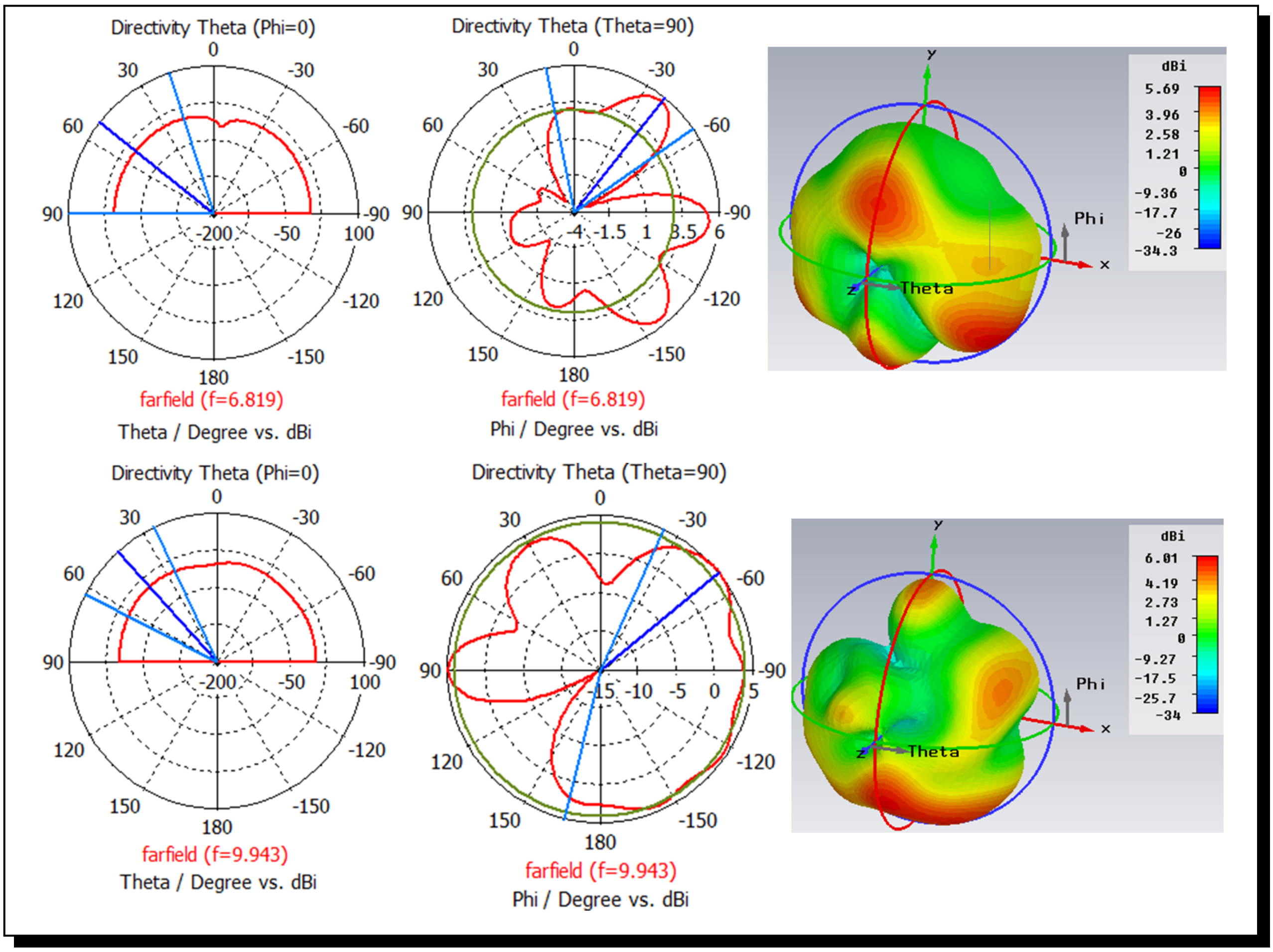

Figure 8. Radiation diagrams in 2D and 3D at the different frequencies

The return loss $|S11|$ dB curve in the chosen frequency range [1-12 GHz] of the optimized antenna is shown in Figure 7(a). We can notice that the new rectangular elements placed on the initial structure with dielectric permittivity equal to 3.381 lead to an antenna good operation. The calculated frequency bandwidths are 1782 MHz and 7853 MHz, these show that the final antenna can be adapted to ULB communication systems. In Figure 7(b), one plot the gain for different frequencies, the gain varies between 1 dB and 6 dB over the frequency range from 4.6 GHz to 12 GHz. For $\varphi = 0°$, the radiation diagrams are almost omnidirectional in a half-plane and for $\theta = 90°$, the radiation diagrams present several lobes according to the graphs indicated by Figure 8, those which give almost omnidirectional radiation.

3. Conclusion

The interest of wideband antennas is confirmed day after day. Many antennas use a wide frequency range, among them frequency independent antennas, directive antennas and omnidirectional antennas which are divided into 2 big categories, biconical antennas and dipole/monopole antennas. In this case, we have studied a printed antenna structure inspired by diamond-shape monopoles adapted in Ultra Wide Band frequency bands. The studied structure is a diamond shaped antenna simulated by the CST Microwave Studio software. The addition of two arms perpendicular to the lateral ground planes and other metallic and dielectric rectangular elements on the initial structure with the optimization of the antenna dielectric substrate permittivity present a perfect adaptation with two very wide bandwidths (of the order of 1782 MHz and 7853 MHz, respectively). This work has therefore led to the design of a small dimensions antenna, and almost omnidirectional radiation that can meet the Ultra Broadband communications.

Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

All the authors contributed significantly in writing this article. The authors read and approved the final manuscript.

References

[1] S. Chaimool and P. Akkaraekthalin, CPW-Fed antennas for WiFi and WiMAX, *Advanced Transmission Techniques in WiMAX*, R.C. Hincapie and J.E. Sierra (Eds.), (2012), DOI: https://doi.org/10.5772/28456.

[2] A. Chami, *Miniaturisation et Intégration d'Antennes Imprimées pour Systèmes Communicants ULB Pulsés*, Thèse de Doctorat en Sciences Option Electronique, Université de Nice-Sophia Antipolis, 25 Novembre (2011), URL: `https://tel.archives-ouvertes.fr/tel-00668605/file/These_CHAMI_UNS.pdf`.

[3] P.A. Chaudhari, S.R. Gaykhe, A.N. Darekar and S.K. Bagal, Printed circular monopole antenna, *International Journal of Innovative Research in Computer and Communication Engineering* **5**(2) (2017), URL: `http://ijircce.com/admin/main/storage/app/pdf/WosscSOPLHyOFxycDDWbIkBY6qFfidtBrslKyRZh.pdf`.

[4] K.N. Dhirgham, An alternative look to design of wideband planar monopole antennas based on parasitic elements for c-band wireless applications, *International Journal of Electromagnetics and Applications* **4**(3) (2014), 61 – 69, URL: `http://article.sapub.org/10.5923.j.ijea.20140403.02.html`.

[5] S. Ghosh, Performance analysis of different ultra wideband planar monopole antennas as EMI sensors, *International Journal of Electronics and Communication Engineering* **4**(5) (2012), 435 – 445, URL: `https://www.ripublication.com/irph/ijece/ijecev5n4_07.pdf`.

[6] R. Singh and G. Kumar, *Broadband Planar Monopole Antennas*, M.Tech. Credit Seminar Report, Electronics System Group, EE Deptt, IIT Bombay (2003), URL: `https://www.ee.iitb.ac.in/~esgroup/es_mtech03_sem/Sem03_paper_03307421.pdf`.

[7] K.P. Ray, Design aspects of printed monopole antennas for ultrawideband applications, *International Journal of Antennas and Propagation* **2008** (2008), Article ID 713858, DOI: 10.1155/2008/713858.

[8] K.P. Ray, S.S. Thakur and S.S. Kakatkar, Bandwidth enhancement techniques for printed rectangular monopole atennas, *IETE Journal of Research* **60**(3) (2014), 249 – 256, DOI: 10.1080/03772063.2014.914700.

[9] R.P. Roopesh and S. Bharti, Printed monopole antenna technology for wideband applications, *International Journal of Students Research in Technology & Management* **3**(5) (2015), 2321 – 2543, pp. 377-381.