A Fractal Slot Antenna for Ultra Wideband Applications with WiMAX Band Rejection

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Abstract – In this paper, design of printed monopole antenna based on fractal structures, is introduced as an approach for the use in ultra wideband communication systems, that depends on Koch fractal type.

This antenna fed with a 50Ω microstrip line, designed to be used in frequency range from 3.1 GHz to 10.6 GHz, also band notched characteristics to reject the WiMAX band is realized by etching a slot of a C-shaped rotated with 90^o clockwise. It is printed on FR4 substrate of (4.4) dielectric constant, (1.6) mm thickness, and the fractal geometry is employed in the form of a second iteration Koch curve.

The antenna has a small dimensions of (20mm × 25mm × 1.6mm), with return loss ≤ -10 dB, which offers a bandwidth from 2.84 GHz to 13.28 GHz with nearly Omni directional radiation pattern. The simulation of the design is accomplished through the microwave studio suite of computer simulation technology CST simulator, which is based on finite integration technique.

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Keywords – UWB, Microstrip Antenna, Fractal Slot Antenna, WiMAX band

1. Introduction

Ultra wideband (UWB) radio is one of the promising technologies for many wireless applications, which have characteristics such as, large bandwidth, high data rate transmission, and material penetration [1].

The only authority which already admits UWB devices is the Federal Communication Commission (FCC) that allocates the frequency range from 3.1 GHz to 10.6 GHz to unlicensed use for UWB applications. The FCC regulated power levels are very low being below -41.3 dBm/MHz. This limits the range of UWB devices to about 10m for high data rates [2].

The release of an extremely wide spectrum of (3.1-10.6) GHz for commercial applications has generated a lot of interest in the research and development of UWB technology for short-range wireless communications, imaging radar [3]. The FCC released the part 15 that allows the operation of UWB devices, which defines the UWB as any wireless communication technology that occupies either a fractional bandwidth greater than 20% of the center frequency or more than 500 MHz of absolute bandwidth [4]. However, there is a possibility of an electromagnetic interference with the allocated wide bandwidth of the UWB system with some narrow bands for other communication systems, such as WiMAX operating in (3.4-3.69) GHz [5], WLAN operating in (5.15-5.825) GHz. A band stop filters connected to a UWB antenna can be used to reject these bands. However, this increases the complexity of the system. A simpler way to solve this problem is to design the UWB antenna with band-notched characteristics [6].

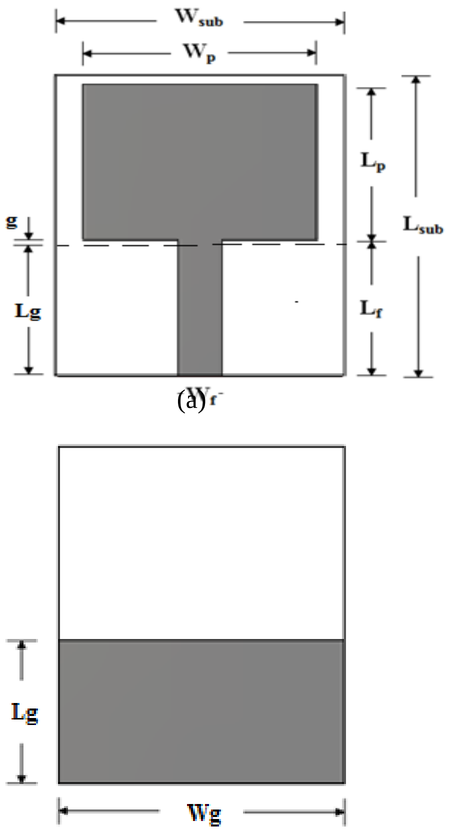
One of the main components of UWB communication systems is an antenna. There are several critical parameters affecting UWB antenna performance that can be adjusted during the design process. These are operating frequency, impedance, gain, radiation pattern, polarization, efficiency and bandwidth. Fulfilling the requirements of UWB antenna that involve smaller antennas for the ultra wideband, according to the FCC regulation, with return loss (RL) response ≤ -10 dB, thus the design, simulation and fabrication of these antennas are very important. This is the cause of widespread researches on UWB antennas in recent years. One of these methods is using fractal geometry to design of UWB antennas [7].

Fractal geometries have found an intricate place in science, as a representation of some of the unique geometrical features occurring in nature. Applying fractal that has some unique geometrical properties like self-similarity and space-filling to the antenna elements allow for smaller size, multiband and broadband properties [8], [9], [10].

In this paper, a slot antenna has been proposed based on a Koch curve as a candidate for use in ultra wideband applications; also a slot of a C-shaped rotated with 90° CW is introduced to reject the band (3.4-3.69) GHz.

2. The Antenna Design

The design process of the proposed printed monopole antenna is implying a radiating patch with dimensions($W_p \times L_p$)mm, printed on a substrate with dimensions ($W_{sub} \times L_{sub}$)mm, fixed on the FR4 material with a dielectric constant $\varepsilon_r = 4.4$ and a thickness of h mm. The antenna is fed by a microstrip line for a 50 Ω impedance, with a length of $L_f$mm and a width of $W_f$mm. On the other side of the substrate a semi-circular ground plane is printed with overall dimensions ($W_g \times L_g$)mm. The gap between rectangular patch and ground plane is g mm, as shown in Figure 1.



(b)

Figure 1 The geometry of the printer monopole (a) Front view, (b) Back view

A rectangular (a) with dimensions ($W_s \times L_s$) mm is introduced in the radiating patch and then a Koch fractal curve is applied on the edges with second iteration.

Figure 2 illustrates the simulated return loss response that shows the bandwidth extended from 3.2 GHz to 8.98 GHz.

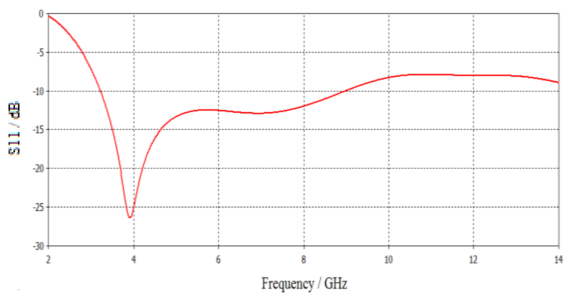


Figure 2.S11 of the antenna

For widening the bandwidth, a Koch fractal curve is applied again on the lower side of the patch that is contacted with the feed line, with a second iteration and steps in the form of a rectangular cutting with dimensions (Wse × Lse) mm at the lower corners, to make the antenna resonating at a frequency above 8.98GHz. The return loss response shows that the antenna bandwidth extends from 3.1GHz to 14 GHz, as shown in Figure 3.

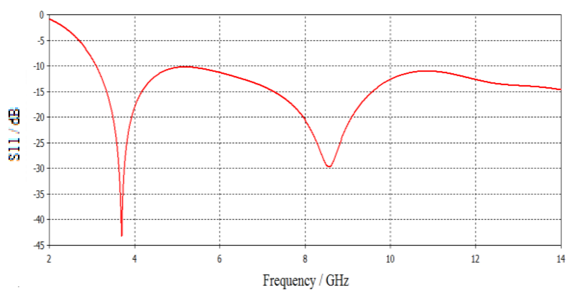


Figure 3 S11of the antenna

To improve the matching, a rectangular slot is etched in the upper edge of the ground plane with dimensions ($Wsg \times Lsg$) mm. It is obvious from Figure 4 that the impedance bandwidth extends from 3.03 GHz to 13.75 GHz, which cover the UWB frequency range.

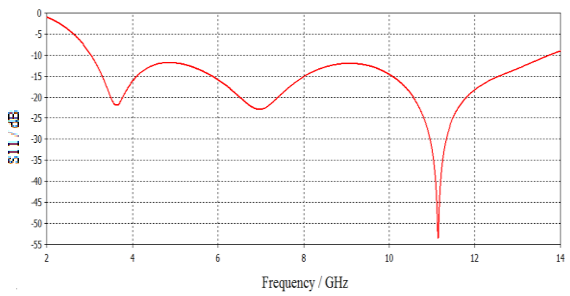


Figure 4 S11of the proposed UWB

A slot of a C-shaped rotated with 90° CW is introduced in the upper portion of the radiating patch to reject the band for WiMAX band. The geometry of the proposed antenna is shown in Figure 5. Table 1 listed the dimension of the antenna with its optimum parameters.

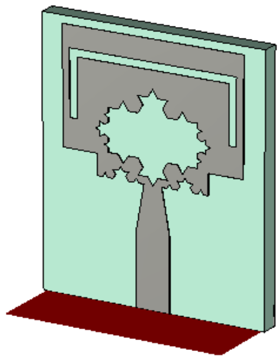
The proposed printed monopole antenna has been designed to resonate with a lower frequency at 3.1 GHz, as a starting step. Observing the influence of the various parameters on the antenna performance, it has been found that the dominant factor in this antenna is the monopole element perimeter, $2(W_p + L_p)$, in terms of the guided wavelength λ_g:

$$\lambda_g = \frac{\lambda_0}{\sqrt{\epsilon_{reff}}} \quad (1)$$

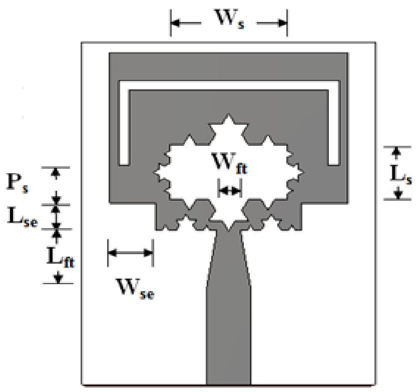
Where ϵ_{reff} is the effective relative dielectric constant, then the lower resonant frequency f_L relative to the radiating patch can be determined by [11]:

$$f_L \approx \frac{c_0}{2(W_p+L_p)\sqrt{\epsilon_{reff}}} \quad (2)$$

where, c_0 is the speed of light in free space.



(a)



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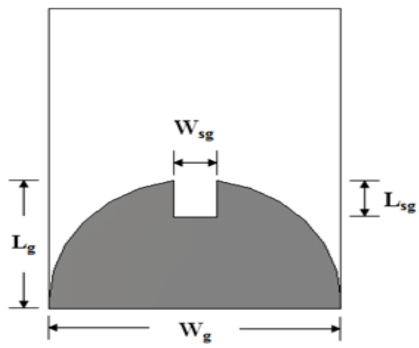

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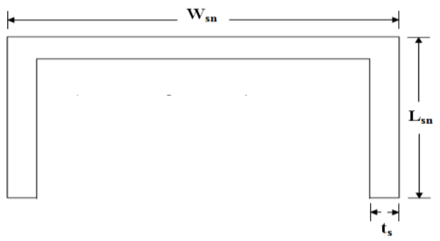


(d)

Figure 5 The geometry of the proposed printed monopole Notched-band UWB antenna (a) 3D view, (b) Front view, (c) Back view, (d) Shape of the slot

Table 1. Dimensions and parameters values of the proposed printed monopole otched-band UWB antenna

Antenna Parameters	**Symbols, its values (mm)**
Radiating patch	W_p = 16.25, L_p = 13
Feed line	W_f = 3, L_f = 11.25
Feed line tapper	W_{ft}=1.6, L_{ft} = 4.25
Patch slot	W_s = 8, L_s= 4
Patch step	W_{se}= 3.125, L_{se} = 2
Ground plane (gp)	W_g= 20, L_g = 10.65
Ground plane slot	W_{sg}= 3, L_{sg} = 3
Gap, patch-gp	g = 0.6
Substrate	W_{sub}= 20, L_{sub} = 25
Substrate thickness	h = 1.6
Length of the notch slot	W_{s_n} = 15 L_{s_n} = 6.2
Total length of notch slot	d_s = 27.4
Width of notch slot	t_s = 0.7
Position of notch slot	P_s = 2.75

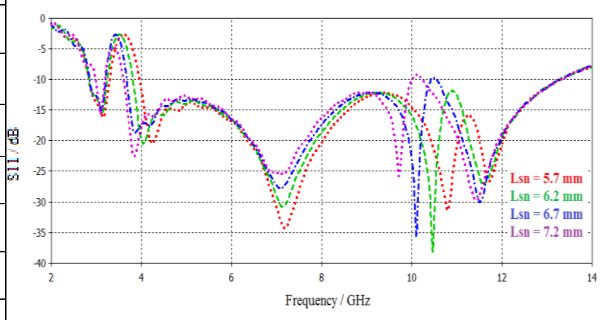
3. Performance Evaluation

Figure 6 shows a parametric study that has been carried out on the length, width, thickness and position of the slot, to investigate the effects of varying of these parameters on the notch band of the proposed antenna. It is obvious that the position of the notched band depends on the slot length d_s, where:

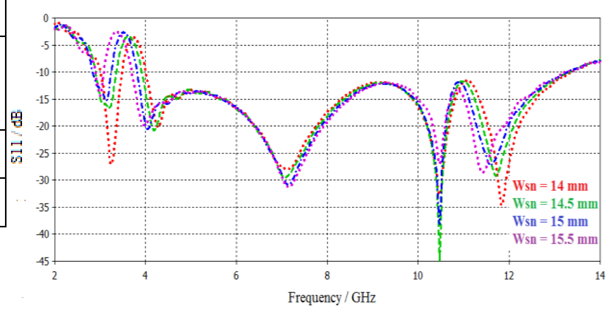
$$d_s = W_{s_n} + 2 * L_{s_n} \qquad (3)$$

As the slot length increases, the center frequency of notched band shifts to lower frequency side, and as the slot width increases the notched band shifts towards higher frequency.

Thus the notch bandwidth depends upon the width of the slot, as shown in Figure 6 a, b, and c respectively, also slot position affected the bandwidth and the center frequency of the notched band, as illustrated in Figure 6 d.



(a)



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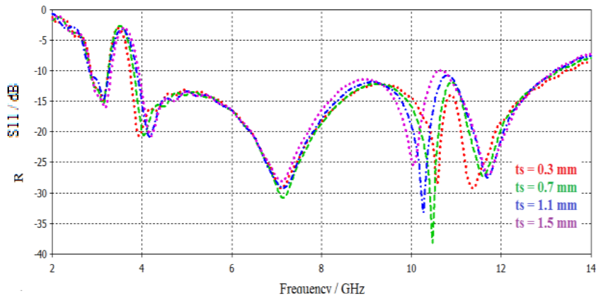

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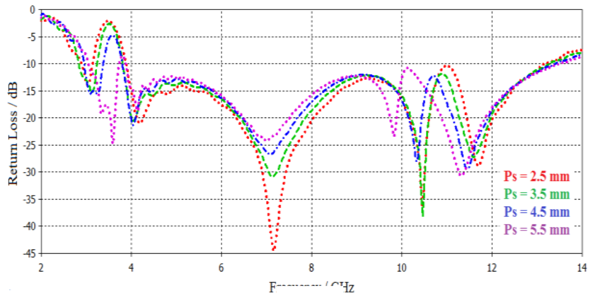


(d)

Figure 6 Effects of the variation of the slot parameters on S11 of the proposed printer monopole notched-band UWB antenna (a) with variation of L_{s_n}, (b) with variation of W_{s_n}, (c) with variation of t_s, (d) with variation of P_s

The simulation results of the proposed printed monopole notched band UWB antenna with its optimum parameters, shows that the impedance bandwidth of the proposed antenna extended from 2.84 GHz to 13.28 GHz which covers the UWB frequency range and the rejected band extended from 3.24 GHz to 3.81 GHz, that for the WiMAX band, as shown in Figure 7.

Figure 8 illustrates the simulated surface current distribution of the proposed antenna at frequencies 3.1, 3.5, 9 GHz. Also the simulated far–field radiation patterns for the total electric field and three-dimensional far–field radiation directivity patterns of the proposed antenna at the same frequencies are shown in Figure 9 and Figure 10, respectively.

The Figures show a near Omni directional radiation pattern that fulfills the requirements of the UWB antenna design.

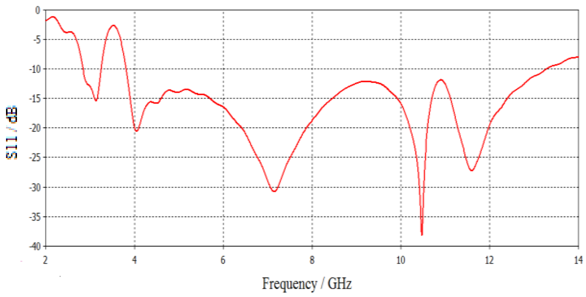
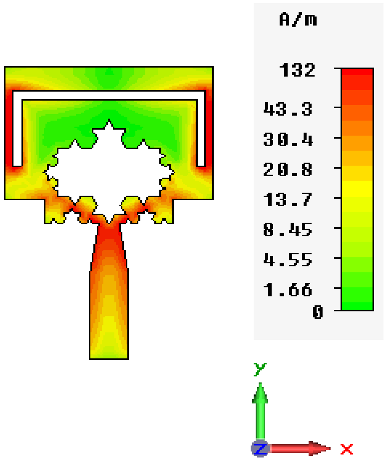
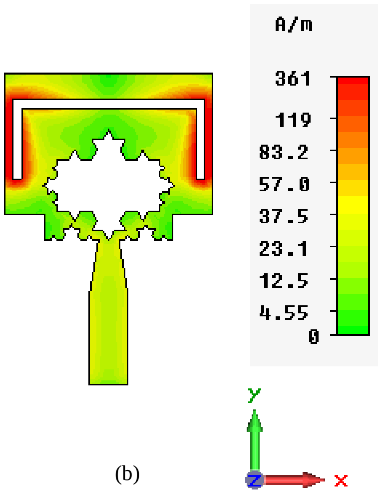


Figure 7 S11of the proposed printer monopole notched -band UWB antenna



(a)



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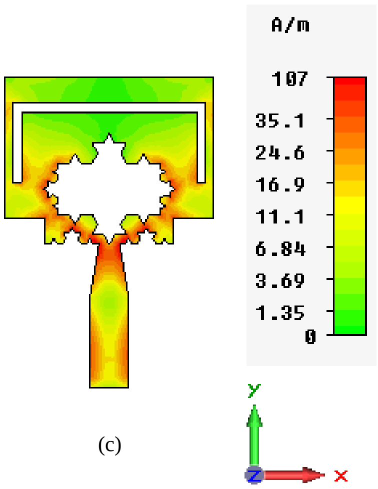
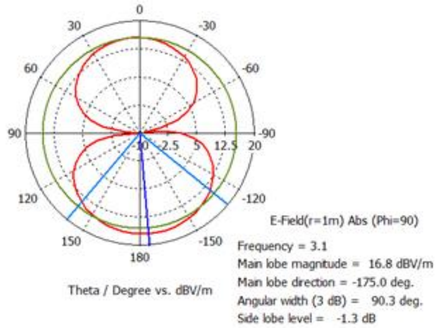


(c)

Figure 8 Simulated current distributions on the surface of the proposed printed monopole notched -band UWB antenna at (a) 3.1GHz, (b) 3.5 GHz, (c) 9 GHz



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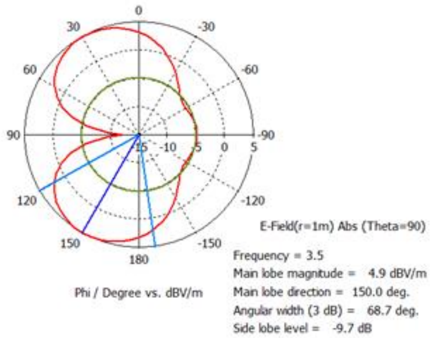

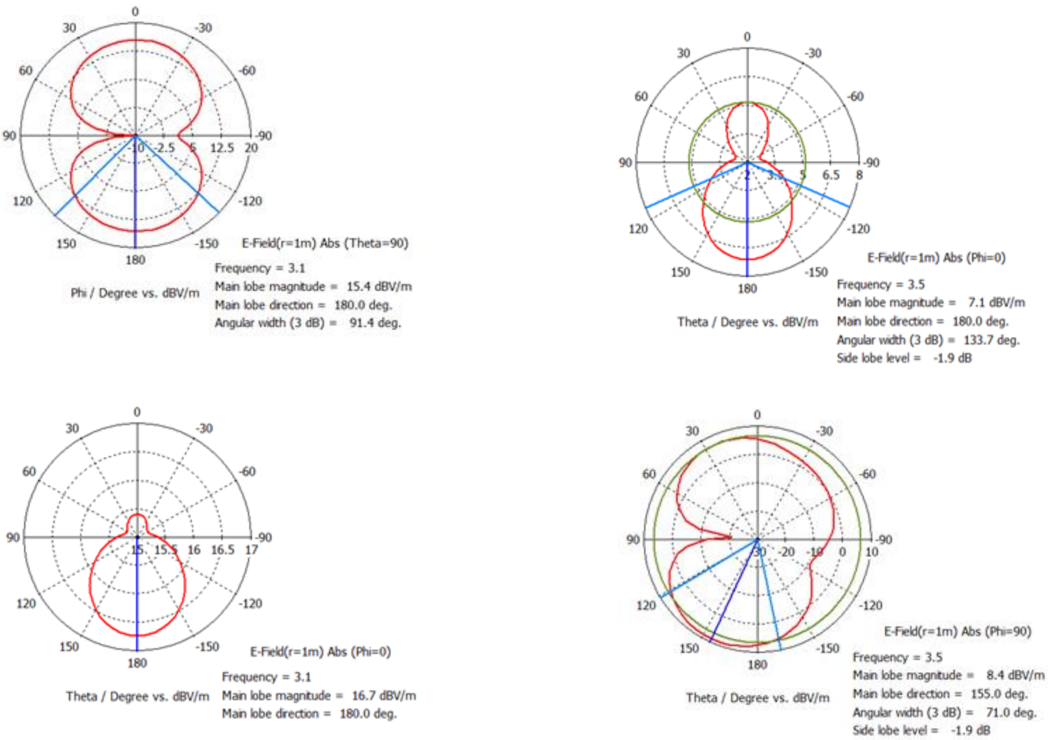

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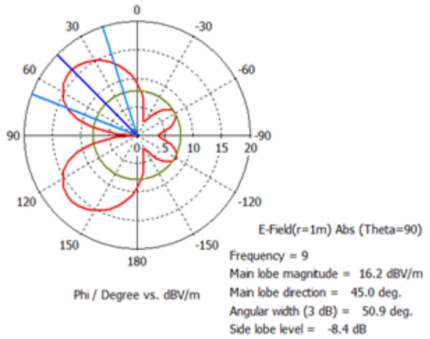
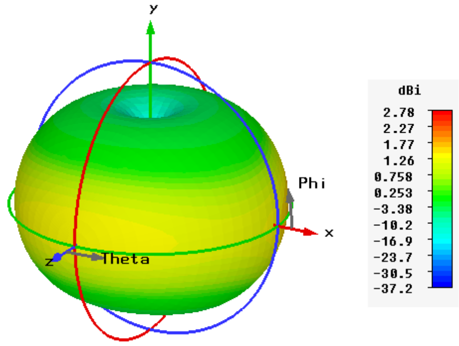
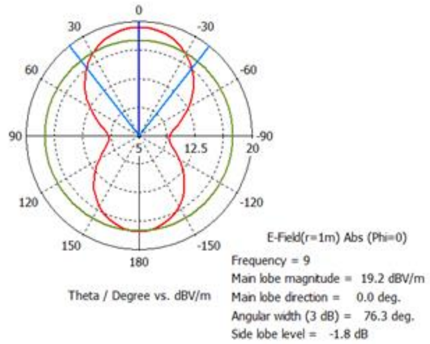
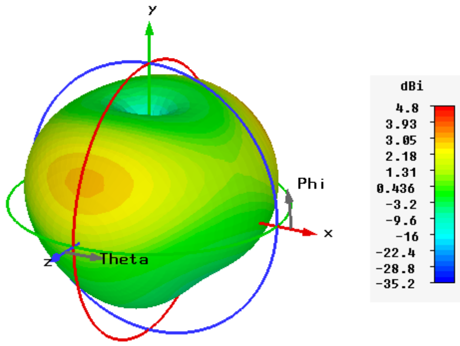




(a)





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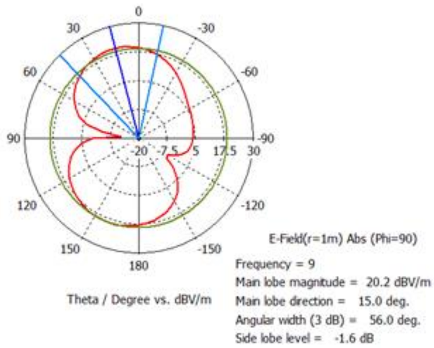

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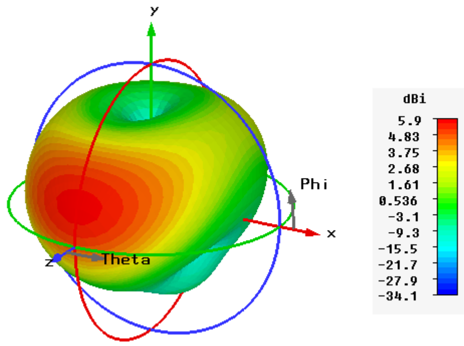

(c)

Figure 9 Simulated far – field radiation patterns for the total electric field of the proposed printed monopole notched-band UWB antenna at (a) 3.1 GHz, (b) 3.5 GHz, (c) 9GHz,in XY,XZ and YZ plane

Figure 10 Simulated 3D directivity patterns of the proposed printed monopole notched-band UWB antenna at (a) 3.1GHz, (b) 3.5 GHz,(c) 9 GHz, The simulated gain versus frequency response are illustrated in Figure 11, which shows an acceptable antenna gain in the UWB range, while a decrease in the gain at the notch frequency band.

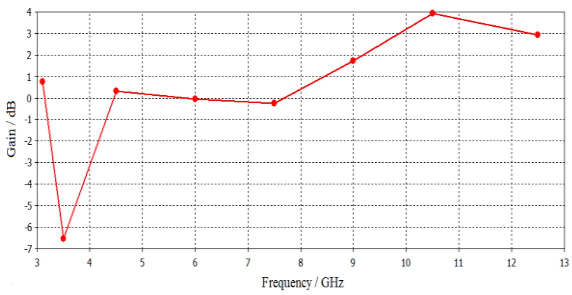

Figure 11 Simulated peak gain of the proposed printed

4. Conclusion

In this paper, a proposed structure is presented to design antenna for ultra wideband (UWB), utilizing the unique properties of fractal geometry. This antenna can be characterized by small size that makes it suitable for operation in mobile and portable devices in wireless communication applications.

It has the attribute of simple shape, which simplifies its fabrication process in comparison to lots of antennas that fulfill the same purpose but they have complex shapes and structures. This antenna offers a bandwidth from 2.84 GHz to 13.28 GHz for return loss ≤ -10 dB, and the evaluation of proposed antenna performance, shows that the antenna behavior tends to meet the requirements of UWB systems like stable and nearly Omni directional radiation pattern over the UWB band.

Also eliminating the undesirable frequency band within the band of ultra wideband can be obtained, where the band rejected in the range from 3.4 GHz to 3.69 GHz, for WiMAX applications, therefore no interference expected with the WiMAX band for the proposed antenna, and this leads to reduce the cost and complexity of the circuit design in UWB system.

References

[1] D. Cassioli, M. Z. Win, and A. F. Molisch, "The ultra wide bandwidth indoor channel: from statistical model to simulations", *IEEE Journal on Selected Areas in Communications*, vol. 20, no. 6, Aug., 2002.

[2] C. R. Berger, M. Eisenacher, S. Zhou, and F. Jondral, "Improving the UWB pulse shaper design using non-constant upper bounds in semi-definite programming", *IEEE JSTSP: Performance Limited of Ultra Wideband Systems*, 2007.

[3] S. K. Mishra, R. K. Gupta, A. Vaidya, and J. Mukherjee, "A compact dual band fork-shaped monopole antenna for bluetooth and UWB applications, "*IEEE Antennas and Wireless Propagation Letters*, vol. 10, 2011.

[4] H. Arslan, Z. N. Chen, M.-G. D. Benedetto, *Ultra Wideband Wireless Communication*, John Wiley and Sons, Inc., Hoboken, New Jersey, 2006.

[5] X. Zhang, T.-L.Zhang, Y.-Y. Xia, Z.-H.Yan, and X.-M. Wang, "Planar monopole antenna with band-notch characterization for UWB applications," *Progress In Electromagnetic Research Letters*, vol. 6, 149-156, 2009.

[6] T. D. Nguyen, D. H. Lee, and H. C. Park, "Design and analysis of compact printed triple band notched UWB antenna," *IEEE Antennas and Wireless Propagation Letters*, vol. 10, 2011.

[7] T. E. Nur, S. K. Ray, D. Paul and T. Mollick, "Design of fractal antenna for ultra wideband applications," *IJRRWC*, vol. 1, no. 3, pp. 66-74, Sep. 2011.

[8] R. Kumar, G. Gupta, "Study of fractal circular patch microstrip antenna over traditional antenna", *IJITEE*, vol. 1, Issue 5, pp. 50- 55, Oct. 2012.

[9] R. S. Aziz, M. A. S. Alkanhal, and A. F. A. Sheta, "Multiband fractal-like antennas," *Progress In Electromagnetics Research B*, vol. 29, 339-354, 2011.

[10] A. H. Ramadan, K. Y. Kabalan, A. EL-Hajj, S. khoury and M. AL- Hsseini, "A reconfigurable U-kochmicro strip antenna for wireless applications," *Progress In Electromagnetics Research*, *PIER*, vol. 93, pp. 355-367, 2009.

[11] J. K. Ali, A. J. Salim, A. I. Hammoodi, and H. Alsaedi, "An Ultra Wideband Printed Monopole Antenna with a Fractal Based Reduced Ground Plane", Progress in Electromagnetics Research Symposium Proceedings, Moscow, Russia, Aug. 19-23, 2012.