A Wideband Filtering-Antenna Inspired with Symmetric T-shaped Slots and Rotated L-shaped Strips for C and X-band Eliminations

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Abstract

In this paper, we present a modified UWB antenna with hexagonal slotted ground plane inspired with a double combined symmetric T-shaped slots and dual rotated L-shaped strip for dual band notched characteristics. Initially, the operating frequency range is from 3GHz to 12 GHz. To eliminate the unwanted C-band (3.625-4.2GHz) and the entire uplink and downlink of X-band satellite communication systems (7.25 -8.39 GHz) frequency bands, we are investigating the conventional UWB patch antenna and loaded it with a mentioned strips and slots respectively. The performances of the antenna are measured and optimized both by CST Microwave Studio and Ansoft HFSS. To further analyze the parametric effects of the slots and strips, the surface current distribution is presented and discussed. The antenna gain versus frequency gives an acceptable value except the notched band regions, these values are reduced from its normal to be a negative in the notched bands (3.625-4.2GHz) and (7.25 to 8.39 GHz).

1. Introduction

The UWB systems become very attractive since February 2002 when the Federal Communications Commission (FCC) allocated the frequency range from 3.1 GHz to 10.6 GHz to be a free band [1]. However, there are several other excite technologies for a long time that can interference with the UWB band systems, such as C-band in the frequency range of (3.625–4.2GHz) and (7.25-8.39 GHz) band for uplink and downlink of X-band satellite communication systems[2],[3]. Several researchers focus their work to eliminate the undesired frequency signals [4].Li et al presented a switched dual stopband coplanar waveguide (CPW) antenna using two inverted S-shaped slots , four switches with a T-shaped radiating patch and rectangular ring slot[5].Yadav et al creates dual band-notched using three rectangular slots loaded CPW – feed (UWB) antenna [6] . Cho et al studied the time-domain characteristics and 5-GHz band-rejection filter for a miniaturized UWB planar monopole antenna [7].Azim et al realize UWB antenna with 3.5/5.5GHz notch signals by inserting below the radiating patch a Single Tri-Arm Resonator [8].Yazdi et al investigates a circular UWB antenna with the WiMAX/WLAN notch bands by adding a pair of arc-shaped parasitic around the circular patch structure as well as pair of two slots in the ground plane[9].
A microstrip UWB monopole structures with dual band-rejected characteristics based on T-shaped stubs and capacitive-load strips [10],π-shaped slot [11], parasitic strips [12] etching Open-Looped Resonator structure in an UWB antenna [13] ,vacator diode[14] ,elliptical slit UWB antenna with half circular ring radiator element [15] ,hook-shaped defected ground structure (DGS) and semi-octagon-shaped resonant ring of the antenna have been investigated for bands eliminating purposes. Though these antennas can offer good features, they still possess some inherent drawbacks such as occupation of too big a space on the antenna, as well as the strong coupling between the rejecting loaded strips and slits.
In this article, a conventional UWB patch antenna with hexagonal slotted ground plane has been selected [16] and modified to obtain a dual filter factures by applying two aforementioned categories.
The double combined symmetrical T-shaped slots are investigated as a loaded slits in the radiating element to modify the antenna behaviors and to reject the undesired C-band .In order to eliminate the unwanted uplink and downlink bands of X-band satellite communication systems , the double symmetrical rotated L-shaped are used as a loaded strips in the hexagonal slotted ground plane to affect in the antenna response. However, the filtered bands can be adjusted easily by varying the dimension of the loaded stubs and slits. The antenna performances of the proposed structure have been presented, and the simulated results both in CST Microwave and Ansoft HFSS are compared to validate the obtained results. The proposed antenna has a miniature size and uses only two simple filter element to realize dual rejected band.

2. Antenna Design

The configuration of the proposed antenna is illuminated in Fig. 1. A simple UWB monopole antenna with a defected hexagonal ground plane is used as the base UWB antenna. The proposed design is printed on a 22x24mm^2 layer of dielectric substrate FR_4 with a permittivity of ε_r=4.3 ,loss tangent of tanδ =0.025 and height of h = 1.6mm. the width of the feed line is fixed at wf=3mm to achieve 50Ω impedance adaptation.The dimensions of the proposed rejected C-band/uplink-downlink of X-band are:Ws= 22mm, Ls=24mm, l_f=6mm, wg_1= wg_2=7.5mm, Lg=10.75mm, Wp=13mm, Lp=7mm, Lt_1= Lt_2=3.5mm, Wt=2mm, Wt_2= 1.25mm, A= 0.75mm, B= 5.5mm , A_2= 0.5mm, B_2= 0.75mm.

In order to generate the desired filtering bands in the frequency ranges of (3.625-4.2) GHz for C-band elimination ,a double combined symmetric T-shaped slots are perforated in the radiating element as depicted in (fig. 2.Ant II). The undesired eliminated uplink and downlink of X-band satellite communication systems (7.25 to 8.39 GHz) is achieved when the researchers have been loaded the top edge of the ground plane with a dual rotated L-shaped strips as shown in (fig. 2.Ant III). To design a band-notch in C and X frequency bands, there should be [17], [18]:

$$L_{Total-C-Band} = \frac{\lambda_g}{2} = \frac{c}{2f_{notch-C-Band}\sqrt{\frac{\varepsilon_{r+1}}{2}}} \quad (1)$$

$$L_{Total-X-band} = \frac{\lambda_g}{2} = \frac{c}{2f_{notch-X-band}\sqrt{\frac{\varepsilon_{r+1}}{2}}} \quad (2)$$

Where $L_{total\_C\text{-}band}$ is the total length of the double combined symmetric slots and $L_{total\_X\text{-}band}$ is the total length of the loaded roteted L-shaped strips .

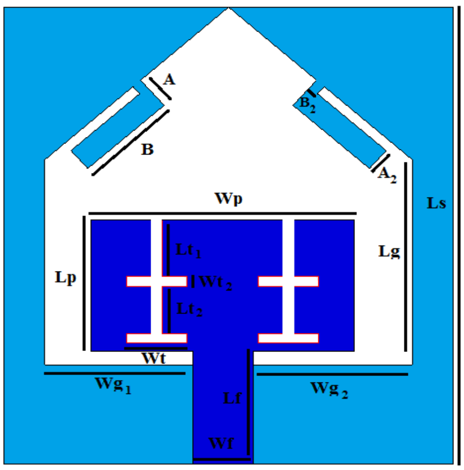


Figure 1: The geometry of proposed dual band notched antenna

Fig. 2. shows the evolution stages step by step of the proposed C-band/ uplink and downlink of X-Band designs.

The return loss parameters for different structures are displayed in the fig. 3. Including those of the initial reference antenna (fig.3.Ant I) [16]. As shown in this figure, a double symmetrical T-shaped slots inserted in the patch radiating element to exhibits a single filtered band covering the entire C-band (fig. 3.Ant II), the eliminated uplink and downlink of X-band is achieved when loading a dual symmetrical rotated L-stubs on top edge of the ground plane (fig. 3.Ant III).

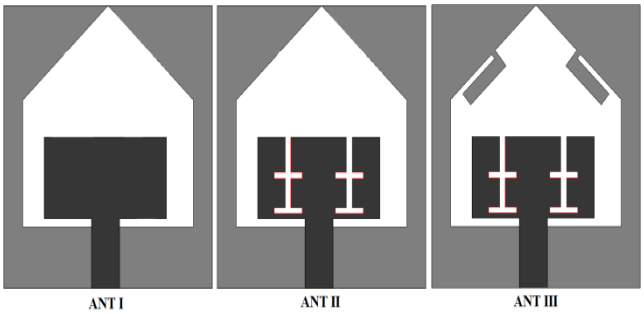


Figure 2: The structures of the proposed antennas. Ant I: reference antenna. Ant II: antenna with Double combined T-shaped slots only. Ant III: antenna with both loaded T-slots and rotated L-stips.

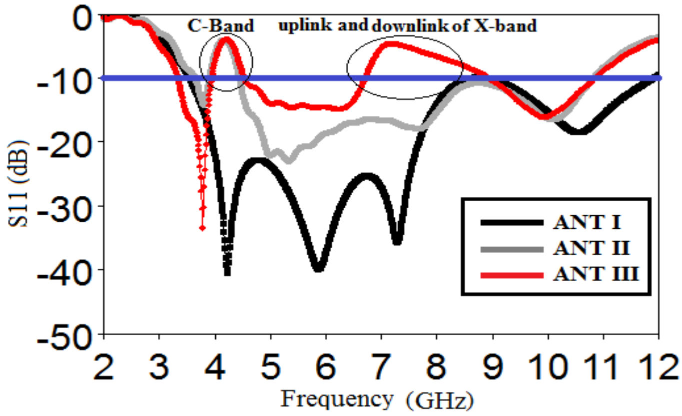


Figure 3: The simulated return loss for Ant I, Ant II and Ant III.

3. Parametric Study and Observation

3.1. The Rejected C-Band

To determine the influence of the essential parameters on the impedance adaptation(using CST MW) as shown in fig. 1. Witch depicts the configuration of the proposed antenna. Fig. 4 illuminates the width effects Wt of the T-shaped slot dimensions. As illustrated, the eliminated band is shifted from 5 to 4 GHz when Wt increase from 2 to 3.5mm.

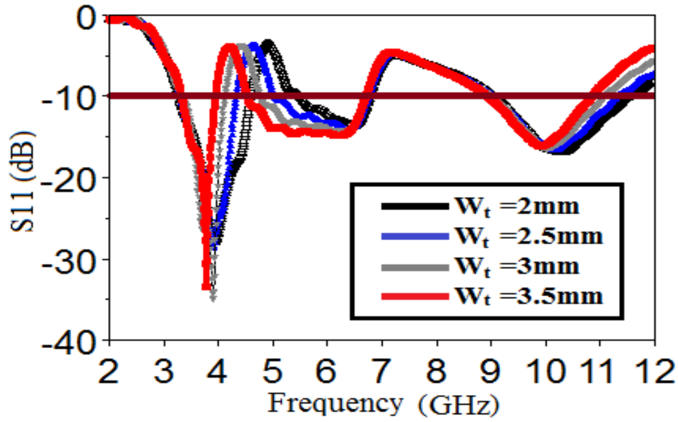
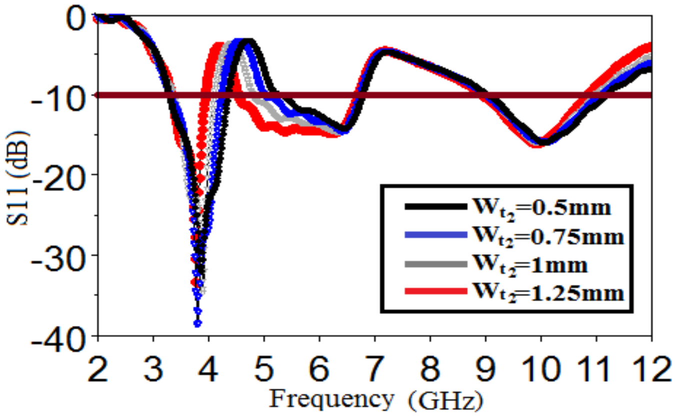


Figure 4: Simulated reflection coefficient for different Wt

Moreover, the coefficient reflection can be affected and shifted to the lower frequencies when the width Wt_2 of the combined T-shaped slots increases from 0.5 to 1.25mm (fig. 5.). Fig. 6 illustrates the coefficient reflection parameters for different values of the length Lt_1 slot, It can be seen that the S_{11} at the stop band are significantly dependent on the Lt_1 values with good rejection property (the S_{11} traces increases from 6dBi to



-3dBi).

Figure 5: Simulated reflection coefficient for different Wt_2

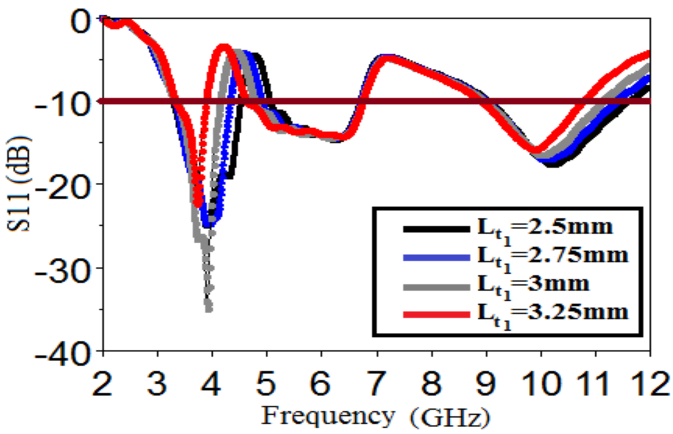
Figure 6: Simulated reflection coefficient for different Lt_1

3.2. The Uplink and Downlink Eliminated X-band

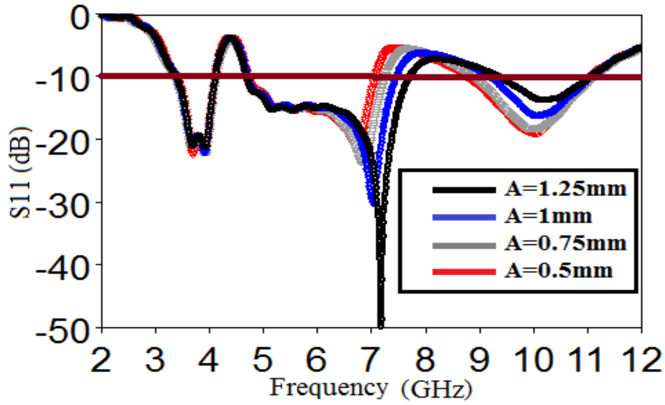
Fig. 7 displays the A value effects of the symmetrical dual loaded rotated L-strip. As observed, the stopped signal shift to the lower frequency with desired worse impedance when A decrease from 1.25 to 0.5mm.

Thereafter, the effect of loaded rotated L stub lengths B is illustrated in fig .8, it can be seen that the return loss S_{11} at the stopped bands shift to upper WLAN band 5.72-5.84GHz when B values increase from 5 to 6.5mm with a little effect on the low frequency due to the couplage between loaded slot and stub elements[19].

Fig. 9 illustrates the S_{11} traces parameters with varying



A_2 values of the loaded rotated L-strip , the unwanted bands of (7.25-8.39GHz) are significantly affected and



rejected when the A_2 value changes from 0.5 to 1.25GHz with a step of 0.25mm. Finally,the influence of B_2 parameters is displayed in fig. 10, as seen as in this figure ,the eliminated band can be controlled by increasing the B_2 values from 0.5 to 1mm.

Figure 7: Simulated return loss for different A values

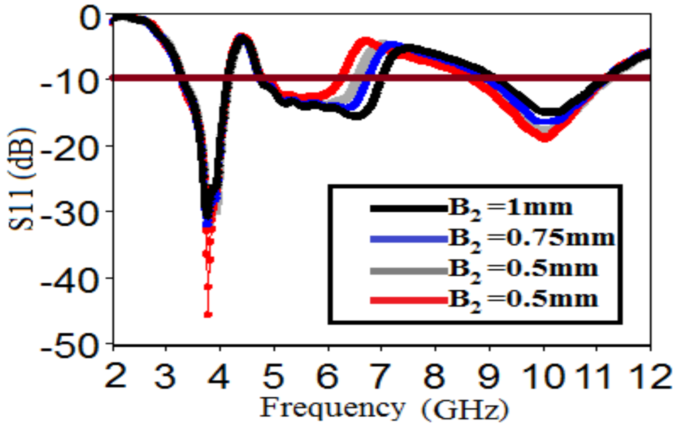
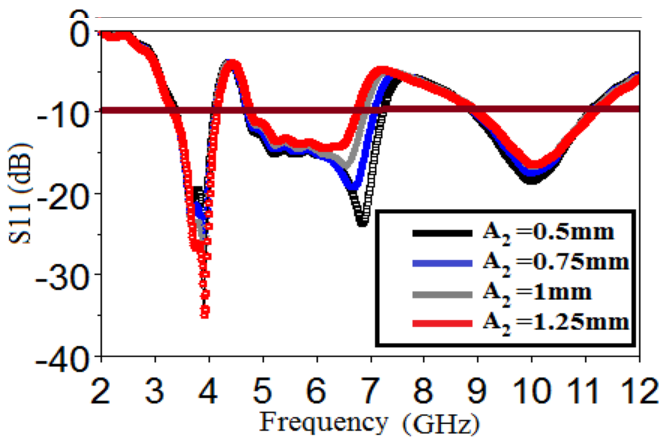


Figure 8: Simulated return loss for different B values

Figure 9: Simulated return loss for different A_2 values

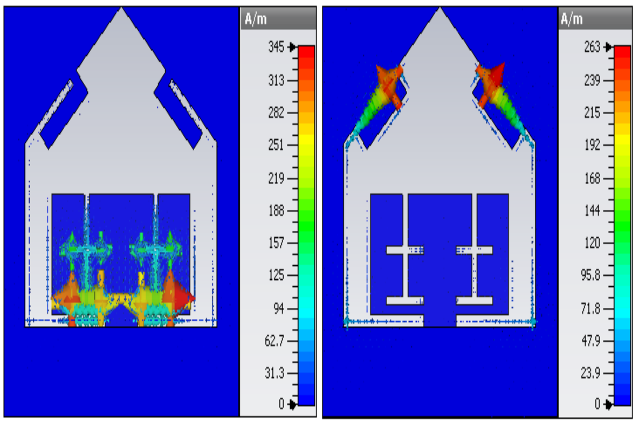
Figure 10: Simulated return loss for different B_2 values



The optimized values of double combined T-slots and dual rotated L-strips are : Wt=2mm , wt_2=1.25mm, Lt_1=3.5mm, A=0.75mm, B=5.5mm , A_2=0.5mm , B_2=0.75mm.

3.3. The Current Distributions and Radiation Patterns

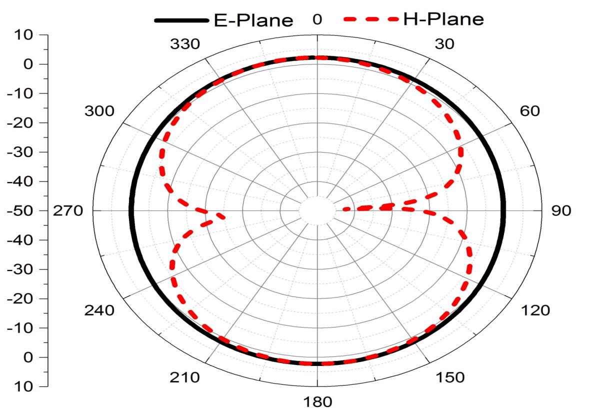
To get an idea of the generation of filtered frequency bands .Fig.11 illustrates the current distribution density at 4 GHz and 7.5 GHz, The current is significantly concentrated strongly around the double combined T-slots with opposite direction to that of the radiating patch (fig.11.a), a very weak currents in the rest part of the antenna can be observed which denotes that the loaded slots filter the 3.625-4.2GHz for C-band applications. In the other hand , the surface currents at 7.5 GHz is illustrated in fig.11.b .As observed in this figure the currents is important and highly distributed around loaded dual rotated L-resonators comparing to the other part of the antenna with opposite direction to that of the hexagonal ground plane.As a results , the loaded stubs and slots are the essential parts of the C-band and X-band rejections[20] .



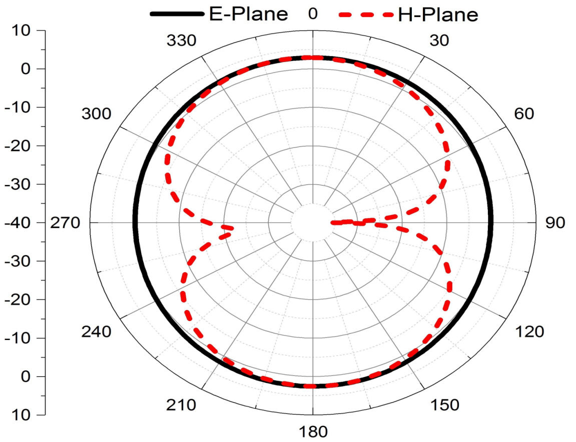
(a) (b)

Figure 11: The Current distributions (a) 5.5 GHz, (b) 8 GHz.

Fig. 12 displays the radiation patterns both in E-plane (phi=0°) and H-plane (phi=90°) of the rejected band design using CST software at each selected frequency of 3.5, 5.2 5.8 and 10GHz.



(a)



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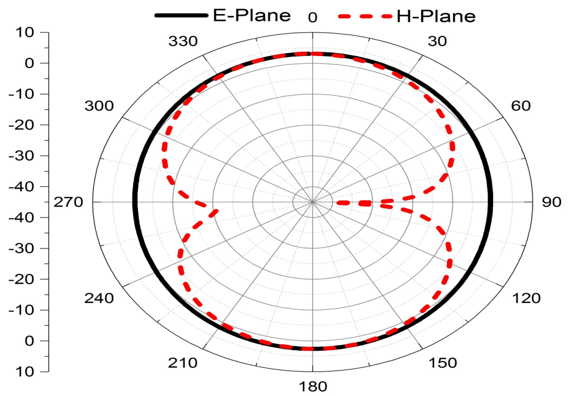
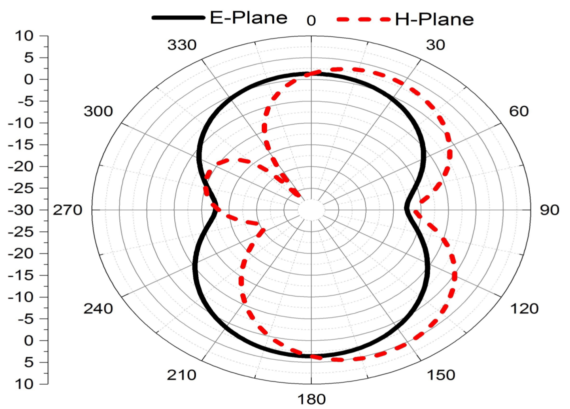


(c)



(d)

Figure 12: Simulated radiation pattern in E-plane and H-plane at: (a) 3.5 GHz, (b) 5.2 GHz (c) 5.8 GHz, (d) 10 GHz.

It is seen that the UWB antenna with dual rejected band provide an acceptable omnidirectional radiation patterns E-plane and acceptable bi-directional radiation patterns in H-plane with a little inaccuracy at the high frequency of 10GHz[21] .which is similar to those of ordinary dipole antennas.

The simulated peak gain and efficiency of the initial UWB structure and the proposed filtered signals antenna versus the UWB frequency range are illuminated in figure.13. The obtained results shows that substantial reductions in peak gain and efficiency can be observed at the notched frequency bands.

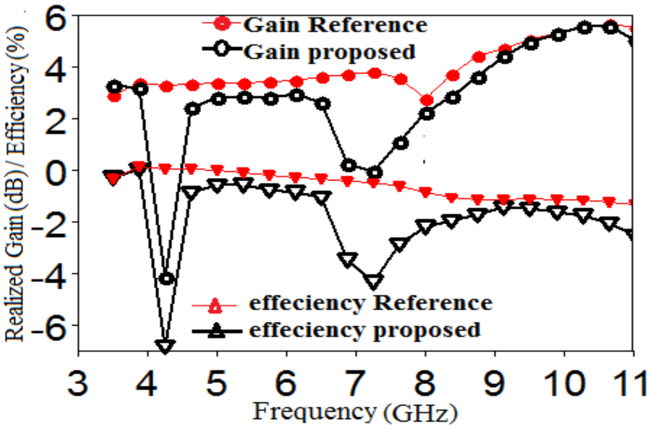


Figure 13: The simulated gain and efficiency values of the reference and modified dual notched UWB antenna.

The photograph of fabricated antenna as well as simulated and measured reflection coefficient parameters are depicted in Figures. 14 and 15. The S_{11} parameters are tested using the ZVB 20 - Vector Network Analyzer 20 MHz-20 GHz. The presented results shows that the simulated and measured parameters are in quasi consistent .The inaccuracy between the simulated and measured results is due to the condition of measurement.

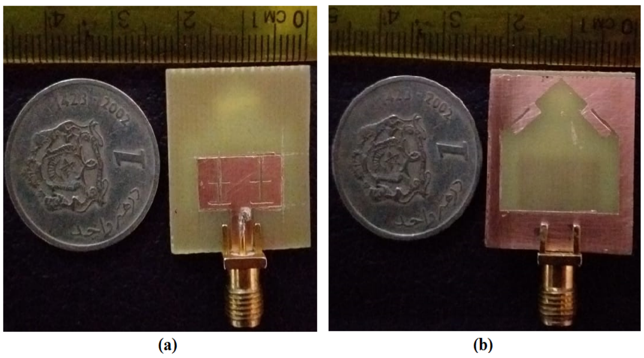


Figure 14. Fabricated model of the proposed antenna (a) front part (b) back part

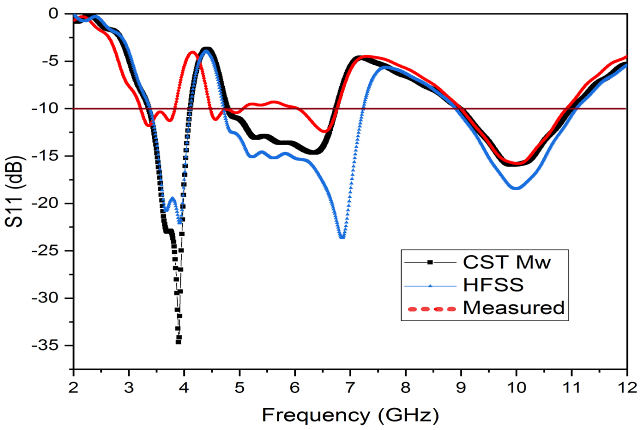


Figure 15: Comparison between the S_{11} versus frequency.

4. Comparison with recently proposed antennas.

As a summary, the proposed dual band rejected signals antenna and the recently antennas cited in this paper are compared in Table. 1.As seen as in the table below, the geometry investigated in this communication not only can resonate in the UWB with filtered (3.625-4.2) and (7.25-8.39) bands, but also has the advantages of good band notched ranges and acceptable gain charactestics with a miniaturized size and low coupling with the loaded resonators.

Table 1: Comparison between recently proposed antennas and this antenna.

Antennas	Dimensions (mm^3)	Operating Bands	Gain(dB) (Except WLAN Band)
This paper	22X24X1.6	UWB with dual band notched	2.5-5.8
Ref[2]	30X40X1.4	UWB with dual band notched	2.8-6.3
Ref[6]	35X30X1.6	UWB with dual band notched	About 3
Ref[7]	26X30X1.6	UWB with dual band notched	2.5-5
Ref[8]	25X26X1	UWB with single band notched	2-5
Ref[9]	29X20.5X1.6	UWB with dual band notched	1.5-5.8
Ref[12]	30X27X1.6	UWB with single band notched	2.5-5
Ref[15]	38X40X1.6	UWB with dual band notched	Not defined
Ref[18]	45X45X1.6	UWB with single band notched	4-7
Ref[19]	30X20X1.59	UWB with triple band notched	3-4
Ref[21]	24X42X1.6	UWB with triple band notched	2.7-3.6

5. Conclusion

In this letter, a modified UWB antenna with sharp dual rejected band features have been studied and investigated , a double combined T-slots has been defected in the radiating patch structure and dual rotated L-shaped has been loaded as a stub on the top edge of the hexagonal ground plane to avoid interference with the unwanted C-band (3.625-4.2GHz) and uplink and downlink of X-band satellite communication systems (7.25 to 8.39 GHz) signal bands. The bandwidths of these eliminated bands can be tuned and controlled by the dimensions of the strips and slots. The prototype of the proposed antenna has been fabricated and measured.an acceptable agreement with the simulated and measured parameters in the term of the reflection coefficient.Result and analysis of this design show that it is applicable in miniature devices with very compact size as added advantage.

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References

[1] Federal Communications Commission Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission System from 3.1 to 10.6 GHz Federal Communications Commission. Washington, DC, ET-Docket, pp. 98–153, FCC, Feb.2002.

[2] G.P. Gao, Z. L .Mei and B. N. Li, "Novel Circular Slot UWB Antenna With Dual Band-Notched characteristic", Progress In Electromagnetics Research C, vol. 15, pp.49-63, Jul .2010.

[3] W.T. Li, X.W. Shi and Y. Q. Hei, "Novel Planar UWB Monopole Antenna With Triple Band-Notched Characteristics," IEEE Antenna. Wireless Propag. Lett , vol . 8, pp.1094 – 1098, Oct.2009.

[4] M. Elhabchi, M. Srifi, and R. Touahni, "A Novel Dual Band Hexagonal Antenna for Bluetooth and Uwb Applications With Single Band Notched", Advanced Electromagnetics, vol. 7, no. 5, pp. 63-68, Nov. 2018.

[5] B. Li, j. Hong and B. Wang, "Switched Band-Notched UWB/Dual-Band WLAN Slot Antenna With Inverted S-Shaped Slots ", IEEE Antennas and Wireless Propagation Letters, vol .11,pp.572-575, Mai .2012.

[6] A. Yadav , D. Sethi and R.K. Khanna , " Slot Loaded UWB Antenna: Dual Band Notched Characteristics", AEU-International Journal of Electronics and Communications,vol .70(3),pp.331-335. Mar. 2016.

[7] Y.J. Cho, K.H. Kim, D.H. Choi, S.S. Lee and S.O. Park, "A miniature UWB planar monopole antenna with 5-GHz band-rejection filter and the time-domain characteristics", IEEE Trans. Antennas Propag,vol. 54, no. 5, pp. 1453–1460. May. 2006.

[8] R. Azim, M.T. Islam and A.T. Mobashsher, "Dual Band-Notch UWB Antenna With Single Tri-Arm Resonator", IEEE Antenna. Wireless Propag. Lett ,vol. 13 . pp.670-673. Mar.2014.

[9] M. Yazdi and N. Komjani, "Planar UWB monopole antenna with dual band-notched characteristics for UWB applications", Microw. Opt.Technol. Lett, vol. 55, no. 2, pp. 241–245, Dec.2013.

[10] C. C. Lin, P.Jin and R. W. Ziolkowski, "Single, dual and tri-bandnotched ultrawideband (UWB) antennas using capacitively loaded loop (CLL) resonators", IEEE Trans. Antennas Propag, vol. 60, no. 1, pp. 102–109. Jan.2012.

[11] Y. L. Zhao, Y. C. Jiao, G. Zhao, L. Zhang, Y. Song, and Z. B. Wong , "Compact planar monopole UWB antenna with band- notched characteristic", Microwave Opt. Technol. Lett,vol. 50, pp.2656-2658. Jul .2008.

[12] M. T. Islam, and R. Azim and A.T. Mobashsher, "Triple band-notched planar UWB antenna using parasitic strips", Progress In Electromagnetics Research,vol. 129 . pp.161-179. Jun .2012.

[13] Q. X. Chu, and Y. Y. Yang, "A compact ultrawideband antenna with 3.5/5.5 GHz dual band-notched characteristic", IEEE Trans. Antennas Propag,vol. 56, no. 12, pp. 3637–3644. Dec .2008.

[14] A. Elkorany, S. Saad, and D. Saleeb,"Compact Reconfigurable Band Notched UWB Cylindrical Dielectric Resonator Antenna Using Single Varactor Diode", Advanced Electromagnetics, vol.7, no. 3, pp. 35-39, Aug. 2018.

[15] A. Elboushi, O. M. Ahmed and A. R. Sebak, "Study of elliptical slot UWB antennas with a 5.0-6.0GHz band-notch capability ", Progress In Electromagnetics Research C ,vol. 16, pp.207-222, Jan.2010.

[16] R. Azim, M.T. Islam and N. Misran, "Compact Tapered-Shape Slot Antenna for UWB Applications", IEEE Antenna. Wireless Propag. Lett, vol. 10. pp.1190-1193 ,Oct.2011.

[17] M. Debab and Z. Mahdjoub, "Characteristics UWB Planar Antenna with dual notched bands for WIMAX and WLAN", Advanced Electromagnetics, vol. 7, no. 5, pp. 20-25, Sep .2018.

[18] Peng Gao, L.X., J. Dai, S. He and Y. Zheng, "Compact Printed wide slot UWB antenna with 3.4/5.5 GHz dual band-notched characteristics", IEEE Antennas Wireless Propag. Lett, vol. 12, pp. 983–986, Aug.2013.

[19] K. Jangid, P. Jain, B. Sharma, V. Saxena, V. Kulhar, and D. Bhatnagar, "Triple-Notched Band CPW fed UWB Antenna with Metallic Reflector for High Gain Performance", Advanced Electromagnetics, vol. 6, no. 4, pp. 15-21, Oct. 2017.

[20] Y. Sung, "UWB monopole antenna with two notched bands based on the folded stepped impedance resonator", IEEE Antennas Wireless Propag. Lett, vol. 11, pp. 500–502, May .2012.

[21] M. Elhabchi, M.N. Srifi and R. Touahni, "A tri-band-notched UWB planar monopole antenna using DGS and semi arc-shaped slot for WIMAX/WLAN/X-band rejection," Prog Electromagn Res Lett, vol 70, pp. 7–14, Aug .2017.