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Design of Torus and U Shape Slotted Ultra-Wideband Antenna for Satellite Applications

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Abstract:
A novel approach of improving the gain of a UWB antenna is presented in this paper. The antenna consists of a rectangular patch imprinted on FR4 substrate. The rectangular patch has one round cut at each corner and edge with one slot in the ground plane. The antenna has a simulated bandwidth with return loss (RL) >= 10dB is 3-12 GHz. By introducing slots in the patch and feed, notching at X- band is achieved. The simulated results of the proposed antenna show a higher gain at the pass-bands while a sharp drop at the rejected bands. The radiation pattern obtained for this proposed antenna is Bi-directional. The design of the antenna and it's behaviour over different frequency ranges is analyzed using high frequency structure simulator (HFSS).

Keywords: *ground plane, notching, patch, slot, UWB antenna, wideband.*

I INTRODUCTION

In today's wireless communication systems, wide band antennas play a very important role in different areas such as pulse radars, radiometers, radio astronomy, frequency hopping, spread spectrum and OFDM wireless communication systems, monitoring systems and direct energy. Ultra Wide Band (UWB) has received greater responsiveness in wireless communication[17] as it provides high omni- directional radiation pattern with simple configuration and smaller size. UWB is a wireless communication technology which uses very little energy pulsation in addition to envision for small range with greater bandwidth communications by consuming enormous share of radio spectrum. Ultra-wide band antennas are more suitable for RADAR, PC peripherals and satellite applications. In 2002, the Federal Communication Commission (FCC) declared 3.1GHz -10.6GHz spectrum range as UWB range. In this paper, a novel design of a patch antenna which has semicircular slots in patch and a defective ground plane is proposed. A U-shaped slot is introduced in the feed to provide notching. Introduction of slots in the design, results in excellent bandwidth enhancement and gain improvement. The basic design of the antenna is presented in design. The slotted design is presented in design ii. The simulated results are discussed in Section III. Comparison table is represented in Section IV. Finally, a conclusion of the paper is given in Section V along with reference.

S. Siva Sundara Pandian and C. D. Suriyakala (2012) proposed UWB antenna for Cognitive radio wireless communication. The antenna resonates at three frequencies such as 32GHz, 55GHz, 70GHz. Octogonal loop rectangular patch antenna is used. The proposed antenna is designed and simulation is done using ADS.

Kailas Kantilal Sawant (2014) presented hexagonal microstrip fractal antenna for UWB application. The antenna is designed on a Polyamide substrate. The bandwidth of this antenna is about 9 GHz.

Yun - qiang, Tao-tang (2015) designed MIMO patch antenna which operates at 2.4 GHz and 3.5 GHz band. This antenna is used for LTE, Wi-max and Wi-Fi applications.

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Sukumaran(2015) proposed UWB antenna for WBAN application. Natural rubber is used as substrate and the result obtained using rubber substrate is compared with FR4 substrate.

Prashant Ranjan, Saurabh Raj, and Gaurav Upadhyay(2017) proposed UWB antenna and UWB filter. The proposed antenna is circular-slotted flower shaped patch(CSFS) antenna and CSFS antenna is combined with band-pass filter for UWB filtering. The radiation pattern obtained is Omni-directional.

T V Rao, A Sudhakar(2017) designed MIMO antenna with defected ground structure to notch Wi-Fi and WLAN bands. FR4 substrate with relative permittivity of 4.4 is used and line feeding is used as feeding mechanism. Simulation is carried on High Frequency Structure Simulator(HFSS).

Sudeep Baudha and Manish V. Yadav (2018) proposed planar antenna for UWB applications. The antenna dimensions are 20 x 25 x 1.5 mm^3 and it is made using FR4 substrate. The proposed antenna is applicable for WiMax band, WLAN band.

M S Aw, K Ashwath, T Ali (2019) presented wideband MIMO antenna. The antenna is compact, small and its dimensions are given by 55 x 20 mm^2. CPW feeding technique is used and built on FR4 substrate. The antenna resonates at two resonating frequencies which is applicable for WLAN and Wi-Fi applications.

Aman K Goswami (2019) proposed Dual-band antenna, which resonates at two resonating frequencies. The antenna dimensions are 15 x 20 x 1.5 mm^3 and built using FR4 substrate. T shaped slots are introduced in ground for lower frequency bands. The applications of this antenna includes S-band, WiMax and Wi-Fi bands.

Karthigai Pandian, T.Chinnadurai(2019) proposed an antenna which resonates at 9.5 GHz using three different substrate. The main target is to play out the structure and reenactment of a rectangular microstrip fix radio wire at a thunderous recurrence of 9.5 GHz. The antenna is designed and simulation is done using High Frequency Structure Simulator(HFSS).

R.Udaiyakumar, R Maheswar, T Janani, Preecha Yupapin(2019) proposed performance enhancement of polygonal spiral antenna using hybrid reflector. In the proposed work, two arms of polygonal winding receiving wire are shorted at an external octagonal conductive ring supporting in size decrease of polygonal winding. The half breed reflector assists with improving the addition of the radio wire fundamentally at low frequencies without trading off the increase of the reception apparatus at high frequencies.

Sumathi K, Malathy S, Jaipriya S, Priyanka B(2019) proposed omega shapped slotted multiband antenna. The antenna resonates at four different frequencies and notch at three different frequencies by using different slots. The antenna is designed and simulated using Advanced Design System.

R Udaiyakumar, T Janani, R Vigneshram, R Maheswar, Iraj S. Amiri(2019) designed an array antenna which is applicable for X-band radar applications. The antenna cluster is involved 2 × 8 emanating components to create a fan shaft which is restricted in the azimuth and more extensive in the rise. The results shows that the antenna resonates at 10.0-10.6 GHz and gain of about 6.3dBi.

R Vadivelu, G Santhakumar(2019) presented monopole antenna with defective ground plane for wireless applications such as Bluetooth, Wi-fi, WLAN, etc., The antenna is imprinted on RT/duroid 5880 substrate, and the antenna dimensions is given by 40x28.4x1.575 mm^3. High Frequency Structure Simulator (HFSS) software is used for simulation.

II METHODOLOGY AND PROPOSED DESIGN

HFSS is a tool used for the design of antenna and its implementation. It is used to measure various antenna parameters such as return loss, VSWR, gain, radiation pattern and current distribution.

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Three antenna designs are presented by introducing different slot shapes in patch and the ground plane.

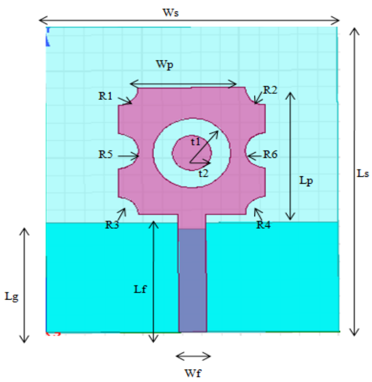

Figure 1. Proposed torus and U- slotted antenna

In Figure.1 the proposed antenna design is shown after 3 modifications. The antenna is built on a FR4 substrate with relative permittivity of ε=4.4 and loss tangent of tan δ=0.02.

Antenna dimensions are

PARAMETERS	DIMENSIONS(mm)
L_s	35
W_s	30
H	1.6
L_g	12.5
W_g	30
L_f	13.5
W_f	2.85
L_p	14
W_p	14.5
R_1,R_2,R_3,R_4	1.8
T_1	2.5
T_2	0.5

Design

A rectangle shaped patch is used in this design. To improve the resonant bandwidth and return loss of the antenna a partial ground is introduced. The representation of top view is shown in Figure.2. The overall size of the antenna is 35x30x1.6mm. The simulated results show that the antenna operates from 3.1 GHz to 10.6 GHz with return loss of -20 dB.

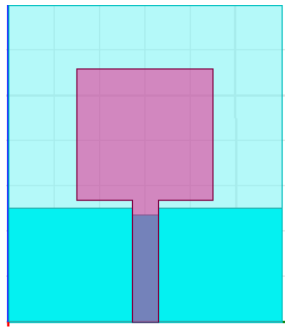

Figure 2. Top view of rectangular patch antenna

Design (i)

Semi-Circular slots are introduced at all corners of the patch and a slot is cut in the ground plane in order to increase the gain of the antenna. This design is presented in Figure.3(a) and Figure.3(b). The return loss characteristic is presented in Figure.3(c).The gain of the antenna is presented in Figure.3(d).

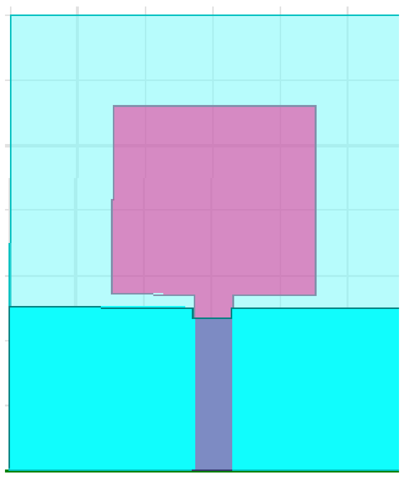

Figure 3(a). Bottom view of Rectangular Patch antenna with slotted ground

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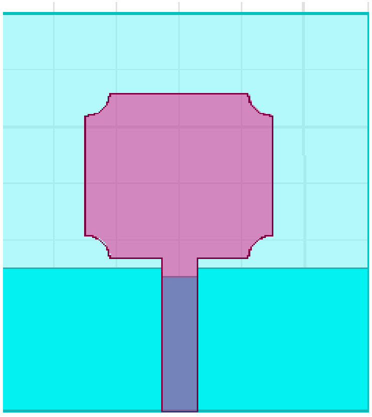

Figure 3(b). Semi-circular slots at corners

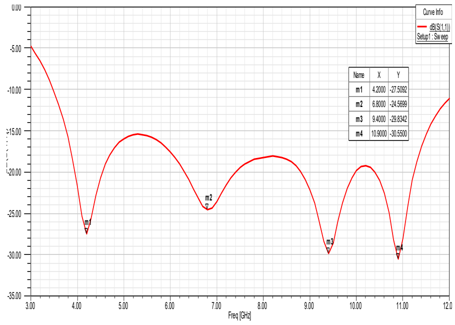

Figure 3(c). Return Loss Graph

The graph shows that the antenna resonates at four different frequencies within the UWB range.

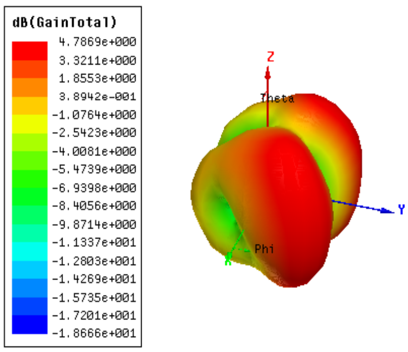

Figure 3(d). 3D Gain Plot

The plot shows that the gain for the resonatant frequency 4.2 GHz is 4.7869dB.

Design (ii)

Further, the antenna design is modified by introducing semi-circular slots at the edges of the rectangular patch and it is presented in Figure.4(a). The return loss and gain for this design are presented in Figure.4(b) and Figure.4(c).This design is found to resonate at 4.1GHz, 9.1GHz and 10.6GHz.

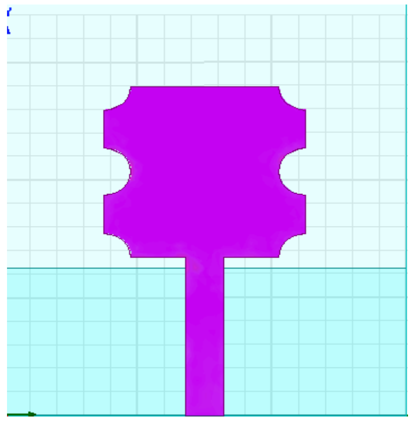

Figure 4(a). Semi-circular slots at edges

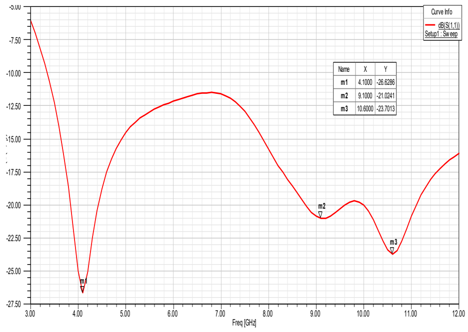

Figure 4(b). Return Loss Graph

This graph shows the return loss after the introduction of semi-circular slots at edges of patch and it is found that the antenna resonates three other frequencies.

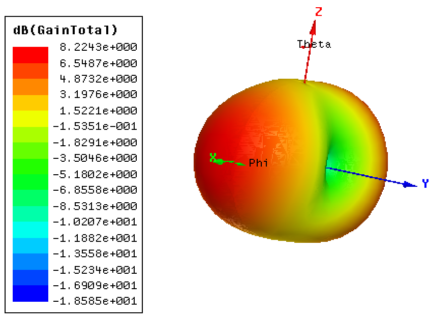

Figure 4(c). 3D Gain Plot

The antenna shows an excellent improvement in gain for this design.

Design (iii)

Finally, a torus shaped slot is introduced at the centre of the patch and U-shaped slot is introduced in the feed to reject X-band. This design is presented

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in Figure.5(a).The return loss is presented in Figure.5(b).The gain is presented in Figure.5(c).

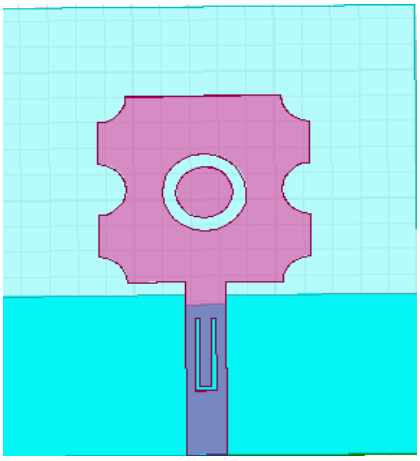


Figure 5(a). Torus Shaped antenna

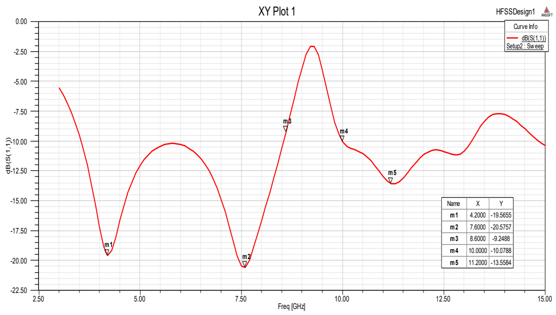


Fig.5(b). Return Loss Graph

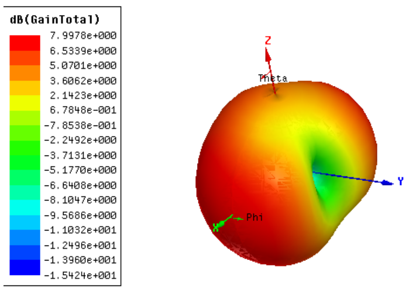


Figure 5(c). 3D Gain Plot

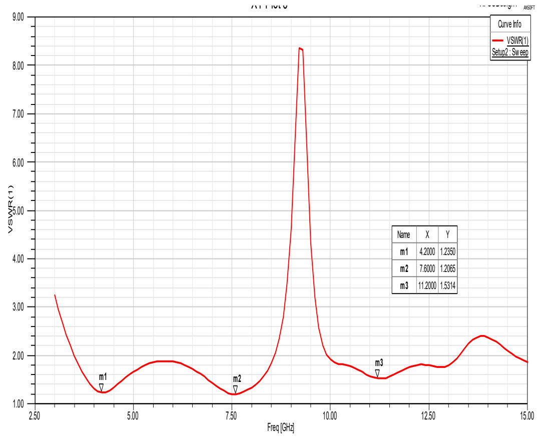
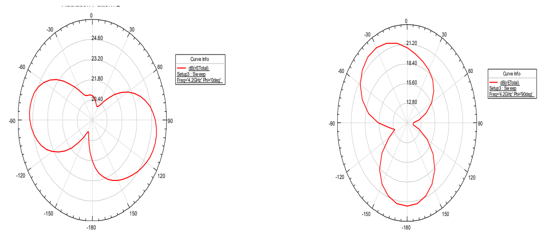


Figure 5(d). VSWR Plot

At all resonating frequencies the VSWR is found to be less than 2, which is an ideal requirement.

III SIMULATION RESULTS

In design (i) the antenna tunes at four different resonant frequencies 4.2GHz, 6.8GHz, 9.4GHz and 10.9GHz with the return loss maximum of -35dB. For the improvement of the antenna performance further designs are proposed with some modifications. In design (ii) the resonating frequencies are at 4.1GHz, 9.1GHz, 10.6GHz. The gain is found to be maximum at these resonating frequencies. Hence, for the rejection of X-band third design is considered. The third design is tuned at frequencies 4.2GHz, 7.6GHz and 11.2GHz with a maximum return loss of -22.5dB. The radiation pattern for final design is showed in figure 6. The radiation pattern for all the resonating frequency is measured and it is found to be bi-directional pattern.



(i) Radiation Pattern for 4.2 GHz when pi='0 deg & 90 deg'.

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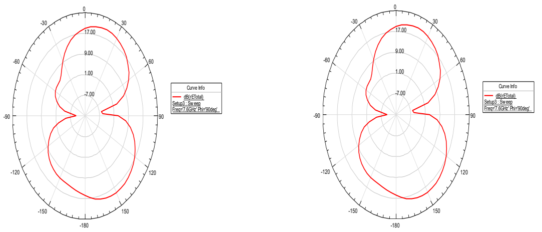
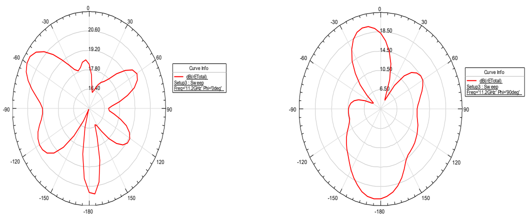


(ii) Radiation Pattern for 7.6 GHz when pi='0 deg & 90 deg'.



(iii) Radiation Pattern for 11.2 GHz when pi='0 deg & 90 deg'.

Fig.6. Radiation Pattern

IV COMPARATIVE STUDY

Patch Design	Resonating Frequencies (GHz)	Return Loss(dB)	VSWR
(i)	4.2 6.8 9.4 10.9	- 27.5092 - 24.5699 - 29.8342 - 30.5500	1.078 5 1.132 5 1.052 1 1.452 1
(ii)	4.1 9.1 10.6	- 26.6266 - 21.0241 - 23.7013	1.097 8 1.195 1 1.139 7
(iii)	4.2 7.6 11.2	- 19.5655 - 20.5757 - 13.5684	1.235 0 1.206 5 1.531 4

V CONCLUSION

The torus shaped antenna is designed to operate over UWB frequency range and resonates at three different frequencies with excellent return loss. Four different designs are proposed for Satellite applications. The simulated results show that the modified torus antenna has multiband tuning, better return loss and a good gain. Thus this concludes that the antenna is suitable for present UWB applications.

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