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Design Performance of UWB Antenna for Portable Devices Applications

K. Madhu Sudhana Rao[1*] and M. V. S. Prasad[2]

[1]KKR and KSR Institute of Technology and Sciences, Guntur – 522017, Andhra Pradesh, India; sudanrao65@gmail.com
[2]RVR and JC College of Engineering, Chowdavaram, Guntur – 522019, Andhra Pradesh, India; mvs_prasad67@yahoo.co.in

Abstract

Objectives: To review on the design of UWB antennas for the wireless applications and to propose suitable design. **Methods/ Statistical Analysis**: The study introduces a novel structure methods implementing the design are cutting multiple T-slots on a rectangular patch. The proposed structure occupied an area of 875 mm^2 produces a reflection coefficient is −44.58 dB and maintained $S_{11} \leq -10$ dB in the entire operating UWB region. The multiple T-slot antennas IBW's are 4.0–3.0 GHz (1000 MHz), 5.0–6.0 GHz (1000 MHz), 9.0–11.0 GHz (2000 MHz). **Findings:** The frequency considered from 3.1 GHz-10.6 GHz produces omnidirectional patterns of radiations with simple geometrical configuration. Proposed design produces higher performance compared to the narrow band systems. Produces a better return loss in the entire UWB region **Application/ Improvements:** The applications include the dielectric, planar, wearable antennas and paying specific attention to the areas of portable devices such as laptops, tablets, wearable computers, glasses and mobile phones etc.

Keywords: Impedance Bandwidth, Multiple T-Slots, Portable Devices, Reflection Coefficient, UWB Antenna

1. Introduction

The acceptance and definition released by FCC (Federal Communications Commission) for ultra wide band communication systems are inexpensive realizations which have become the key role topics in worldwide communication industry. However, UWB systems design becomes a challenging theme particularly for transmitting and receiving antennas. A UWB antenna are having advantages of a low manufacture cost, compactness, omnidirectional patterns of radiations in the operating bandwidth from 3.1–10.6 GHz. In[1], impedance match wideband technique was proposed with an area of 1200 mm^2 having a S_{11} value is −25 dB produced electrically compact active antenna. A wet performance bend UWB antenna is designed with area of 900 mm^2 for application of textile industry produced reflection coefficient value is −35 dB with range from 3.1–10.6 GHz[2]. Compact printed circuit board monopole[3] antenna designed with an area of 950 mm^2 produced S_{11} value is −32 dB in the operating band having VSWR is less than or equal to 2. Square shape monopole antennas[4] for UWB applications resonate at a frequency of 4.5 GHz and 7.8 GHz with reflection coefficient values are −41 dB and −35.5 dB. In[5] tan shaped F-design is for monopole radiator having the reflection coefficient value is −38 dB produced in the UWB system operating band from 2.3–10.5 GHz maintained VSWR value is less than or equal to 2. By considering the dispersion ultra wide band antenna with an overall size is 1350 mm^2 observed in[6] operated with a good return loss value is around −43 dB in the applications of biomedical implantable and waveguide resonators. A monopole circular shape disc antenna is printed in[7] with occupied antenna size 1600 mm^2 produced a value of S_{11} is −41 dB with an operating band from 2.0–10.0 GHz. In[8], a small compactness design antenna for UWB applications having a patch cutting at edges of the patch with rectangular slots and middle of the patch in a circular form of radius 3 mm produced a good return loss −42 dB

*Author for correspondence

with IBW is 800 MHz. A tapered U shaped slot is cutting on the patch with a very small compactness in size is 960 mm^2 produces a return loss is −32 dB observed[9]. Planar circular antenna having reconfigurable pattern[10] designed with an area of 900 mm^2 produced a S_{11} value is −37 dB which maintained a VSWR value is 1.19 and entire band of UWB region is less than or equal to 2. In the deigns[11–14], the different UWB systems are designed with an over all sizes of the antenna are around 1000 mm^2 to 1600 mm^2 are observed the reflection coefficient are varying from −25 dB to −43 dB is observed.

Finally, a concise UWB antenna is designed for the applications of on-body in biomedical area having the size of the antenna is considered 60 mm × 30 mm which produced a return loss is −34 dB. Table 1 shows the comparison of different antenna parameters with other existing systems. In the proposed system of multiple T-slots antenna proposed a very small compact design having an area 875 mm^2 produced an efficiency around 89%, VSWR value is 1.03, impedance bandwidths are 1000 MHz, 1000 MHz and 2000 GHz for the entire operating band range from 2.0–12.0 GHz.

Table 1. Comparison with existing methods

Published Literature	Total occupied size (mm^2)	Band-width (GHz)	Return loss (dB)	VSWR	Efficiency (%)
[2]	900	2.0–8.0	−35	1.28	75
[5]	1225	3.1–10.6	−38	1.15	73
[7]	1600	2.0–10.0	−41	1.09	82
[10]	900	3.0–10.6	−37	1.19	81
[12]	880	3.0–10.6	−43	1.23	84
[15]	1800	2.0–8.5	−34	1.14	74
Proposed antenna	875	2.0–10.0	−45	1.03	89

Table 2. Geometrical values of proposed system

Design parameters	L	W	L_P	W_P	A	B	C	D	E	F	G	H	I	J
Value (mm)	25	35	20	30	3	3	3	3	3	3	3	3	3	3
Design parameters	K	L	L_P	W_P	L_1	L_2	L_3	L_4	L_5	L_6	W_1	W_2	W_3	W_4
Value (mm)	3	3	5	3	4	9	9	9	4	4	6	6	4.5	20

2. Analysis and Antenna Design

2.1 Antenna Configuration

The proposead structure consists of a dimensions 25 mm × 35 mm with an overall area of the system is 875 mm^2. The design area of the patch is considered as 600 mm^2. The material used to substrate is FR-4 (lossy) having relative permitivity of 4.3, loss tangent is 0.025 and the patch substrate is Pefect Electric Conductor (PEC) with height of the antenna is considered as 1.6 mm. In the entire patch four T-shaped slots are cutting on all the four edges of the patch in order to improve the return loss parameter of the proposed desgin. The micro strip line having a lenghth and width of the strips is taken as 5 mm and 3 mm.

2.2 Procedure to Antenna Design

To investige antenna analysis design, the different satages of evaluation is shown in Figures 1 and 2. Initially, a basic patch antenna is designed with a compact dimensions of 30 × 20 mm^2 depicted in Figure 3 is antenna 1. It provides a single resonant frequency at 6.1 GHz having the reflection coefficient −42 dB. Antenna 2 cutting the rectangular and square slots at the top and bottom patches to create a multiple slots in the patch to produced a return loss −30 dB and −28 dB at two resonant bands at 2.5 GHz and 9.1 GHz. To obtain the T-slots in the patch at the middle of the patch both on left and right sides of the patch taking a dimensions of 6 mm and 3 mm to create multiple T-slots resonate at 3.5 GHz and 7.2 GHz used in the applications of Wi-Fi and C-band produces a reflection coefficient values are −32 dB and −17 dB is observed in antenna 3. Again to create sub T-multiple slots in the patch on all the four corners of the modifications with parametric analysis produced a return loss at 5.8 GHz for WLAN application in antenna 4. Finally, a paramrtris analysis take a parameter to design a UWB antenna four corners T-slots and middle of the patch on left and right create multiple T-slots is observed in antenna 5 produces three resonant band in UWB range of antenna.

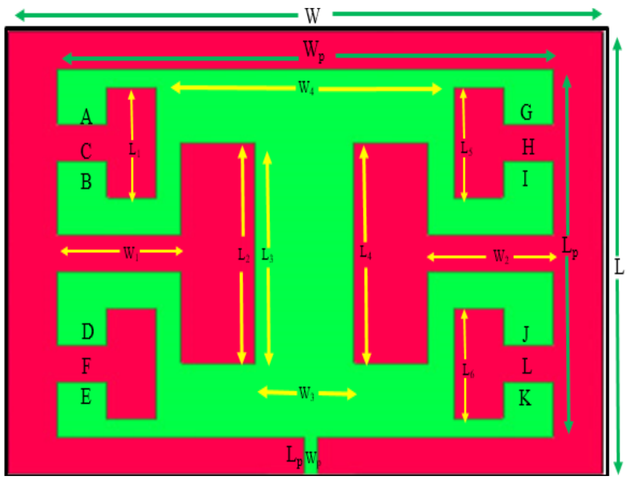

Figure 1. Geometry of multiple T-slots antenna.

2.3 Surface Current Distributions

To clarify the characteristics of radiation mechanism, the distribution of surface vectors of antenna 5 (final) at three resonant frequencies 3.7 GHz, 5.8 GHz and 10.25 GHz have been depicted in Figure 4. From Figure 4 (a) observes that the maximum current is flowing at the middle of the patch in y-axis in the representation of parameter 'L' with a length of 20 mm at this is resonate at 3.7 GHz. From Figure 4(b), it can be observed that maximum current flows in the direction of bottom of the patch in horizontal direction of left and right sides through the feeder location. This represents how the current is distributed in the antenna at bottom side observed at a frequency of 5.8 GHz. Finally, from Figure 4(c), the current is distributed equally almost at the horizontal and vertical axis at a frequency of 10.25 GHz.

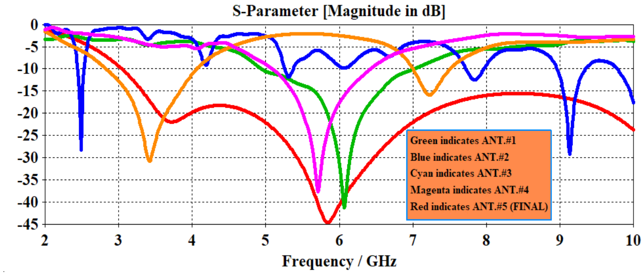

Figure 3. Evoutation stages S-parameters of multiple T-slots antenna.

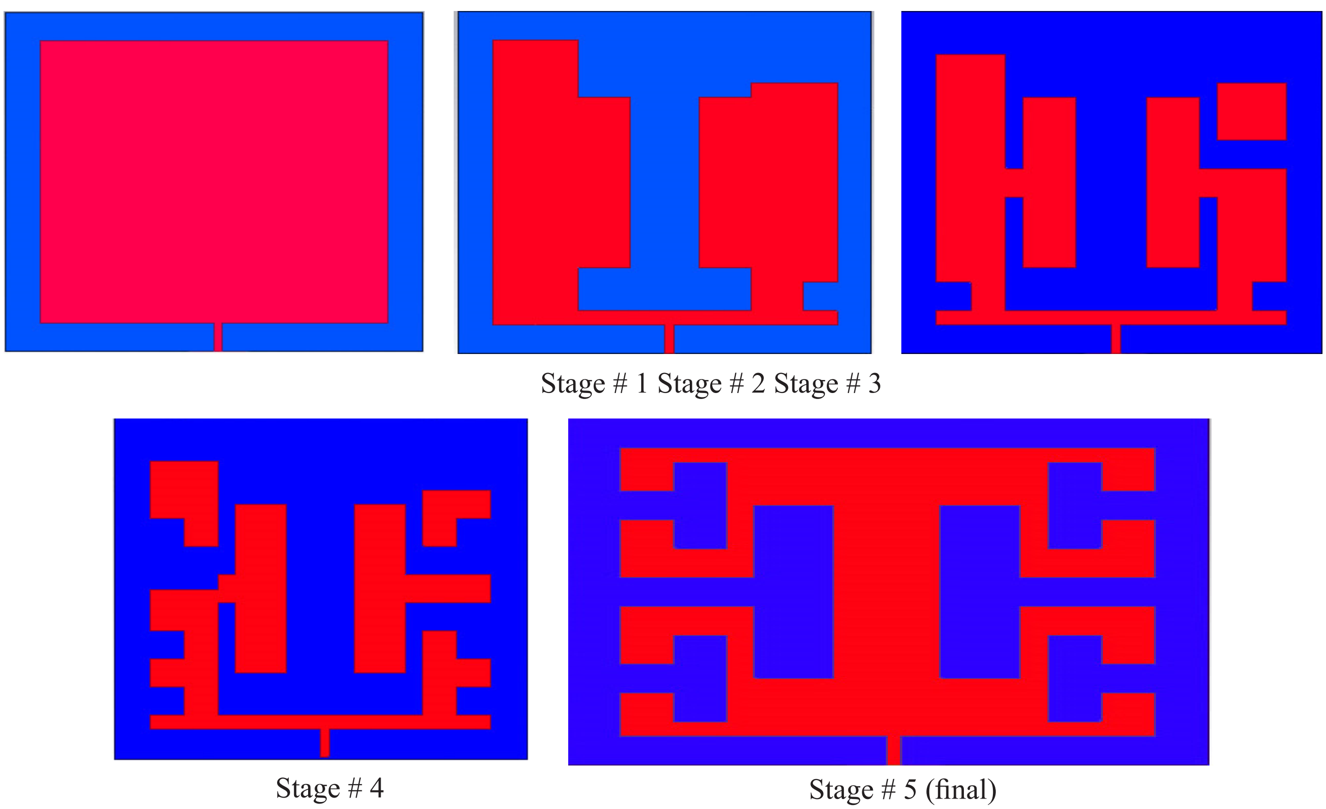

Figure 2. Step by step analysis of multiple T-slots antenna.

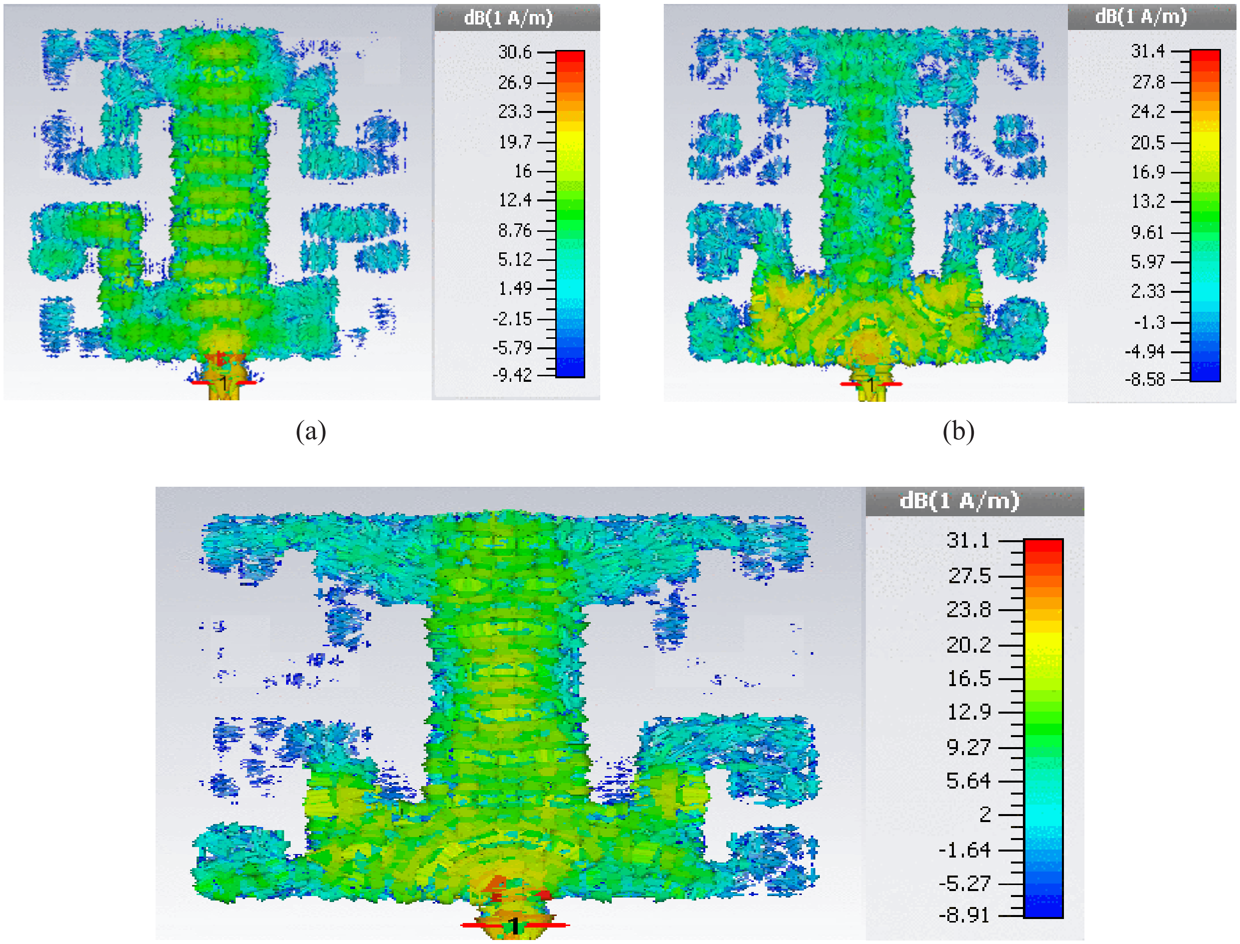

Figure 4. Surface current distribution of multiple T-slots antenna (a) 3.7 GHz (b) 5.8 GHz (c) 10.25 GHz.

2.4 Parmatric Analysis

In order to observe the effect of varying the different parameters in the proposed design to produce the return loss characteristics better in the UWB antenna design. Here, by varying the parameters on each T-slot on the radiating patch represent with different lengths L_1, L_2, L_3, L_4, L_5 and L_6, widths are W_1, W_2, W_3 and W_4. Applying parametric study analysis on lengths and widths on the patches for different values observe that the return losses are varying. It can be observed that five different cases varying the values of 'L' and 'W' is depicted in Figure 5. Consider the lengths L_1 = 3.5 mm and W_1 = 6.7 mm, the antenna is resonate at three different frequencies 3.2 GHz, 6.8 GHz and 9.2 GHz with all the resonate conditions $S_{11} \leq -10$dB. In the second case, the lengths L_1 = 9.0 mm and W_1 = 10.0 mm, the antenna is resonate at three different frequencies 4.0 GHz, 6.2 GHz and 10.2 GHz with all the resonate conditions $S_{11} \leq -10$ dB. In the third case, the lengths L_1 = 4.5 mm and W_1 = 5.8 mm, the antenna is resonate at three different frequencies 3.8 GHz, 5.8 GHz and 10.24 GHz with all the resonate conditions $S_{11} \leq -10$ dB. In the fourth case, the lengths L_1 = 7.0 mm and W_1 = 5.0 mm, the antenna is resonate at three different frequencies 3.7 GHz, 4.6 GHz and 9.8 GHz with all the resonate conditions $S_{11} \leq -10$ dB. In the final case (proposed multi T-slot antenna), the lengths L_1 = 4.0 mm and W_1 = 6.0 mm, the antenna is resonate at three different frequencies 3.7 GHz, 5.8 GHz and 10.25 GHz with all the resonate conditions $S_{11} \leq -10$ dB. Similarly, by varying in other diffrent cases the S-paramerters of the proposed system resonate at out of the UWB systems. In order to design an improvement in the pararametes like directive gain, efficiency of the antenna, VSWR, impedsnce bandwidth, IEEE gain of the analysis is observed the better results when designed the mutliple T-slot antenna taking a parametric study L_1 = 4.0 mm and W_1 = 6.0 mm is observed.

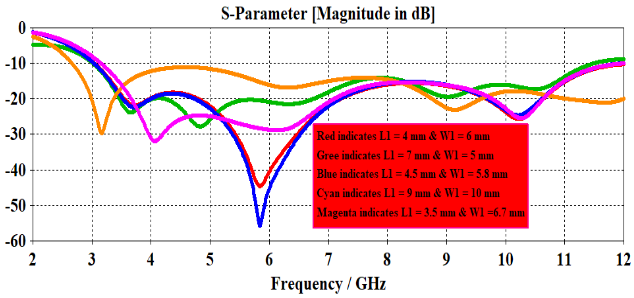

Figure 5. Parametric analysis of multiple T-slots antenna.

3. Results and Discussion

To validate the multiple T-slots, the proposed system simulated using CST Microwave Studio. Figure 6 shows the return loss of the proposed system in the range of UWB antenna. This results show that the antenna is resonate in the entire UWB system is $S_{11} \leq -10$ dB which produces a maximum value at the frequency of 5.8 GHz around −45 dB. The impedance bandwidths are observed at three resonant frequencies are 1000 MHz, 1000 MHz and 2000 MHz in the entire UWB region. For the entire band of resonant frequencies in the UWB region the VSWR value is almost ≤ 2 and which produces particularly at a maximum resonant frequency VSWR is 1.03 which is depicted in Figure 7.

The directivity of the proposed antenna system at the three resonant frequencies of 3.7 GHz, 5.8 GHz and 10.25 GHz are 3.3 dBi, 2.1 dBi, 5.8 dBi is depicted in Figure 8. The radiation efficiencies of multiple T-slot antenna resonates at 3.7 GHz, 5.8 GHz and 10.25 GHz are 90%, 87% and 74%. The radiation efficiency and total radiation efficiency of proposed system is simulated using CST MW studio, similarly this is also obtained by using the mathematical relation is the ratio pf radiation resistance to the loss resistance and radiation resistance is also got same approximately. The radiation efficiency of a multiple T-slot antenna system is depicted in Figure 9.

Figure 10 represents the multiple T-slot antenna radiation patterns in xz–plane and yz–plane which indicates the both E-field and H-field measurement. In the xz-plane the radiation pattern of E-plane is measured by considering theta is varying from 0° to 360° and phi is equal to zero and H-field is measured similarly theta is varying from 0° to 360° and phi is equal 90° is obtained in the yz–plane at the three resonant frequencies 3.7 GHz, 5.8 GHz and 10.25 GHz is observed. From the Figure 10(a) the xz–plane having the value is –37 dB, yz–plane value is −150 dB at the resonate frequency of 3.7 GHz. From the Figure 10(b) the xz–plane having the value is −122.7 dB, yz–plane value is −137 dB at the resonate frequency of 5.8 GHz. Similarly, From the Figure 10(c) the xz–plane having the value is −10 dB, yz–plane value is −135 dB at the resonate frequency of 10.25 GHz is observed.

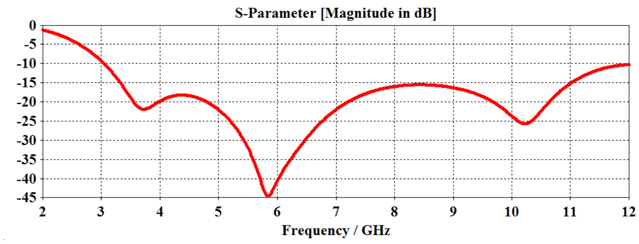

Figure 6. Reflection coefficient of multiple T-slots antenna.

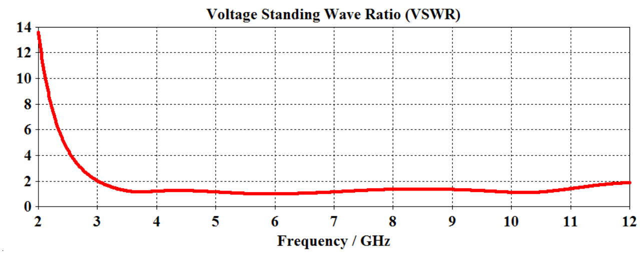

Figure 7. VSWR of multiple T-slots antenna.

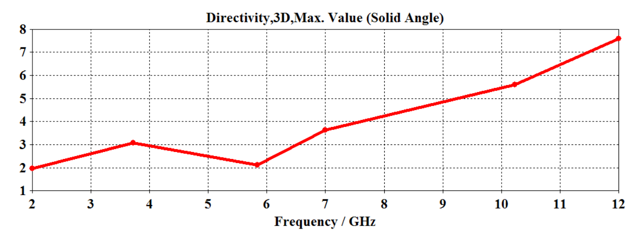

Figure 8. Directivity, 3D, maximum value of multiple T-slots antenna.

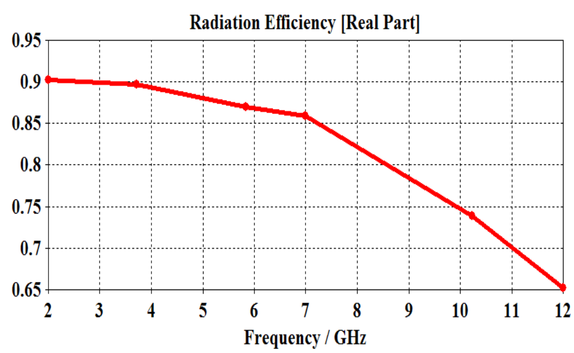

Figure 9. Radiation efficiency of multiple T-slots antenna.

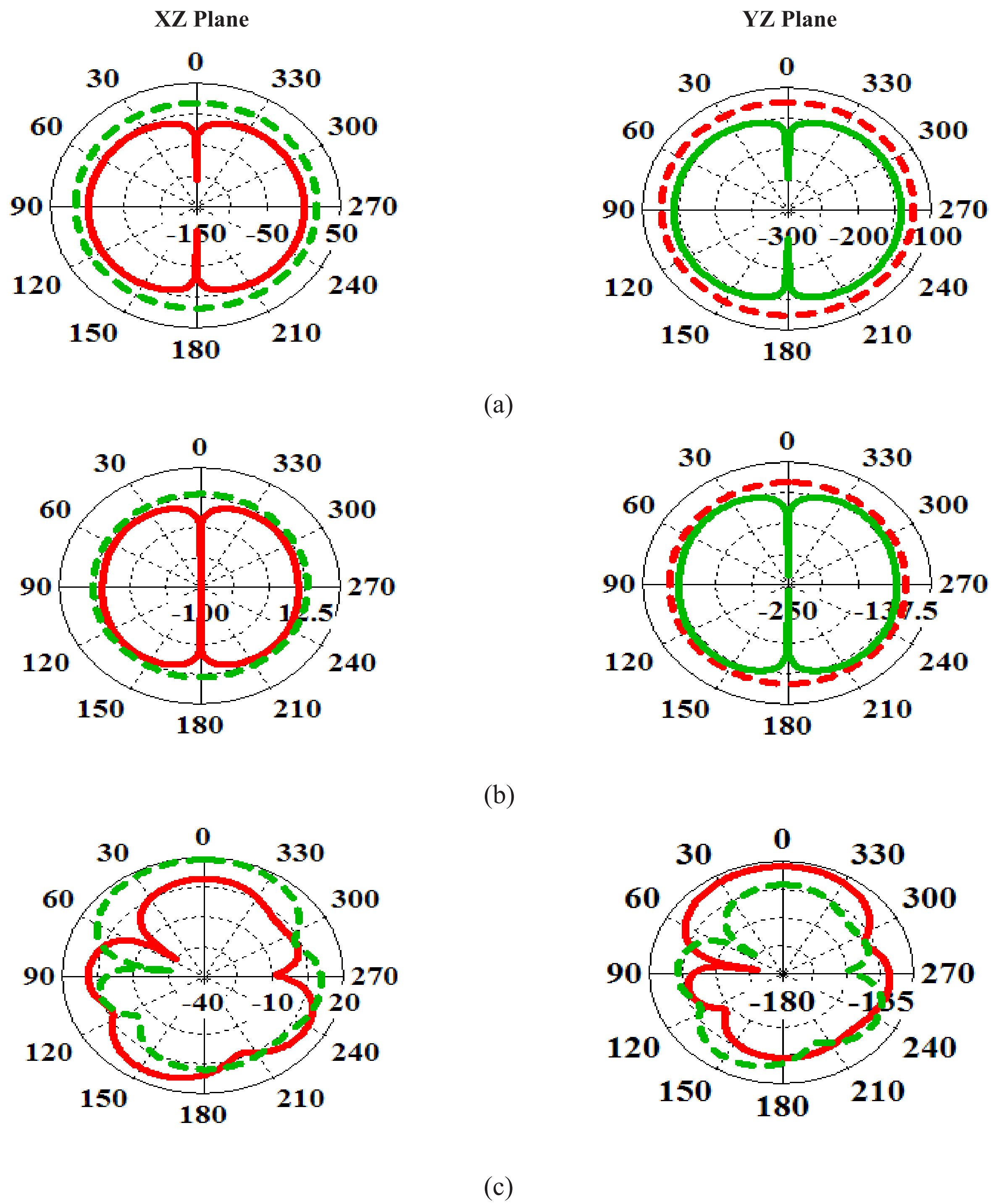

Figure 10. Radiation patterns of of multiple T-slots antenna at (a) 3.7 GHz (b) 5.8 GHz (c) 10.25 GHz.

4. Conclusion

The compact multiple T-slot monopole antennas for UWB applications are proposed here. By inserting four different T-slot structures, the radiator can produced a tri-band performance and using the similar geometry another two T-slots are cut left and right sides of middle of the patch can produce the same tri-band frequency with improvement in return loss. The proposed structure is simulated using a CST MW studio produces a better return loss in the entire UWB region. The proposed system has compactness in size, have better impedance bandwidths 1000 MHz, 1000 MHz and 2000 MHz and a stable radiation patterns in the three resonate frequencies.

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