Design and Analysis of Double Truncated Circular Patch for Ultrawideband Applications

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Abstract. In this article, a double truncated circular patch (DTCP) with a defective ground structure (DGS) and having a microstrip line feed was addressed. The proposed antenna is designed to operate from 2.75 to 14 GHz (11.25 GHz spectrum). The desired antenna is printed on FR-4 substrate. A (PGP) partial ground plane with a notch was printed on the backside of the substrate to approach the ultrawideband (UWB-3.1-10.6 GHz) characteristics. The patch was truncated on the top and left sides of the circular patch to attain the characterization of UWB. The performance and characteristics of this antenna can be evaluated through reflection coefficient (S_{11}), voltage standing wave ratio (VSWR), and radiation patterns and gain. The performance of this antenna is analyzed by using simulated results.

Keywords: Double truncated circular patch, defective ground structure, UWB.

1. Introduction

Wireless communication, in the recent years, is becoming more popular. Antennas are an essential part of any radio (wireless) communication systems. Ultra-wideband antenna is a radio technology that can be used at very low energy levels for short range, high bandwidth communications by using a large portion of radio spectrum which has been extensively used in wide variety of applications. After allocation of the frequency band from 3.1 GHz to 10.6 GHz for commercial utilization of ultra-wideband systems by the Federal Communication Commission (FCC) [1], UWB systems have received a phenomenal gravitation in wireless communication. Designing of an antenna for UWB communications is a challenging task because it has to satisfy some requirements such as ultra-wide bandwidth, constant group delay, constant gain, high radiation efficiency, Omni-directional radiation pattern, low profile, ease of fabrication and so forth [2]. Some of the wireless communication systems such as WiMAX (Worldwide Interoperability for Microwave Access) IEEE 802.11a Wireless Local Area Network (WLAN) bands in USA and High Performance Radio Local Area Network/2 (HIPERLAN/2) bands in Europe exist in UWB range. Hence, the potential interference from these bands should be avoided for better performance of UWB antenna. Various UWB antennas with band-notched techniques have been proposed such as cutting arc-slot in patch [3], inserting a slit in patch [4], embedding a tuning stub in slot [5]. The UWB characteristics can be obtained by using defected ground structure and radiation efficiency can be improved by placing impedance transformer in the feed line [6]. The UWB characteristics can also be obtained by cutting square slots on the patch and truncating the ground plane with notch [7].

In this paper, DTCP UWB antenna was designed and a defected ground plane and truncation of the patch is proposed to attain the UWB characteristics and to increase the impedance bandwidth.

2. Structure of antenna

The configuration of the proposed antenna is shown in Figure 1. It is designed on FR-4 substrate with dimensions (W × L × H) mm^3 and having ε_r=4.3, μ=1 and tanδ =0.025. The antenna is fed by a microstripline having dimensions (wf × lf) mm^2 with the input impedance of 50 ohm. The proposed antenna is constituted by truncating the conventional circularl patch along x- and y-direction along with partial defective ground plane.

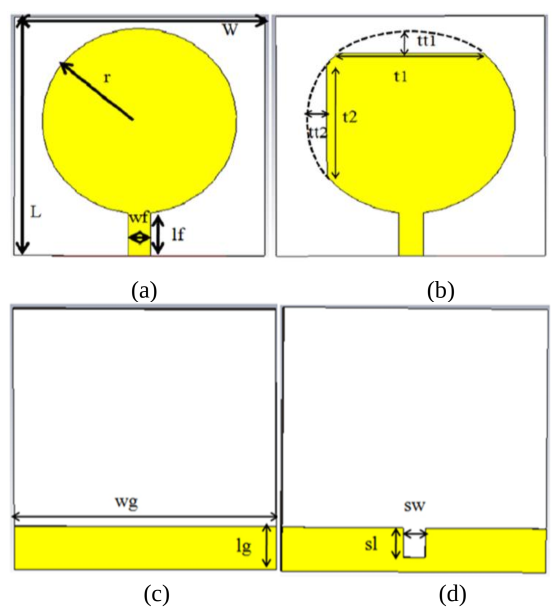

Fig.1. (a) Conventional circular patch (CCP) (b) DTCP (c) PGP (d) Defected ground structure (DGS)

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The patch is truncated along x-direction with t1=20 mm and y-direction with t2=14 mm to achieve UWB characteristics. A partial ground plane is printed on the back side of the substrate and a notch is cut on the ground plane with dimensions (sw × sl) mm^2 to improve the UWB characteristics. The dimensions of the proposed antenna are tabulated in Table 1. The physical parameters of the antenna are optimized and simulated by using CST (Computer Simulation Technology) Microwave Studio. The physical parameters of the patch are represented as width of the substrate (W), length of the substrate (L), height of the substrate (H), radius of the circular patch (r), width of the feedline wf), length of the feedline (lf), width of the ground (wg), length of the ground (lg), thickness of the patch and ground (tp), truncation along x- direction (t1), truncation along y- direction (t2), maximum length from circumference of patch to x-direction of truncation (tt1), maximum length from circumference of patch to y-direction of truncation (tt2), slot width (sw), and slot length (sl).

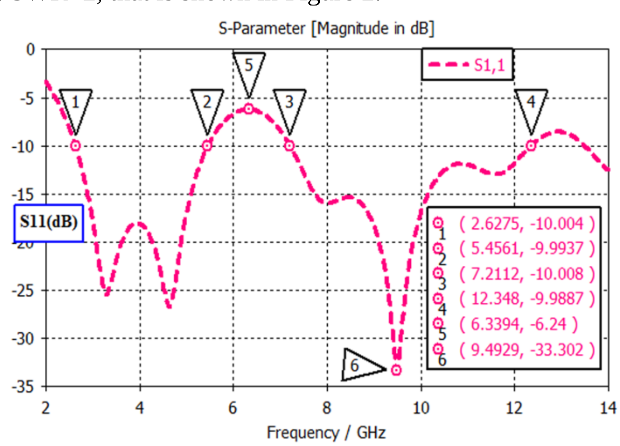
Table 1: Antenna dimensions (all dimensions are in mm)

Parameter	Value (mm)	Parameter	Value (mm)
W	36	tp	0.1
L	36	t1	20
H	1.6	t2	14
r	14	tt1	4
wf	3.2	tt2	3
lf	6.6	sw	3
wg	36	sl	4

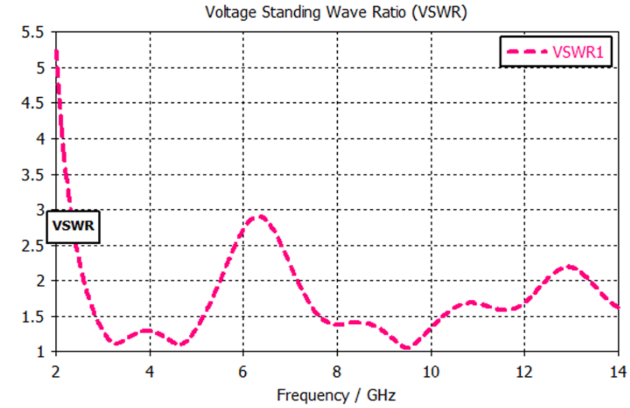
3. Antenna design, results, and analysis

3.1. Step 1: Circular patch and partial ground plane

In step 1, a circular patch with a partial ground plane as shown in Figure 1 (a) and (c) is designed and simulated by using CST microwave studio. The simulation results of reflection coefficient and VSWR verses frequency are shown in Figure 2 (a) and (b), which shows a hump above -10 dB between the frequencies 5.45 GHz and 7.2 GHz. In this case, the curve violates the UWB characteristics. Here the maximum value of hump is at -6.24 dB at 6.3 GHz and VSWR>2, that is shown in Figure 2.



(a)

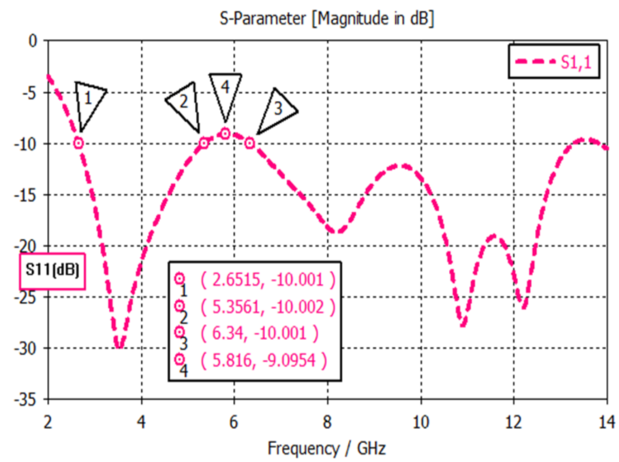


(b)

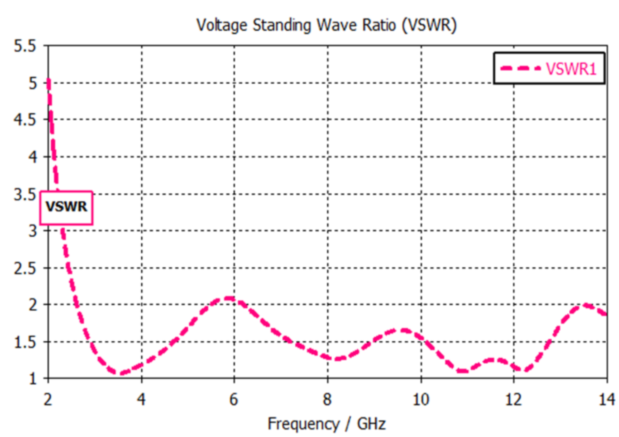
Fig.2. (a) Return loss & (b) VSWR of conventional circular patch (CCP).

3.2. Step 2: Circular patch with defected ground structure

In step 2, the circular patch was not modified, but the ground plane was etched with the slot to improve the UWB characteristics and hump is shifted down to a value -9.09 dB from -6.23 dB. In this case S_{11} >-10 dB and VSWR>2, that are shown in figures Figure 3 (a) & (b). In this case also UWB characteristics are not achieved.



(a)



(b)

Fig.3. (a) Reflection coefficient (b) VSWR of CCP with defected ground structure.

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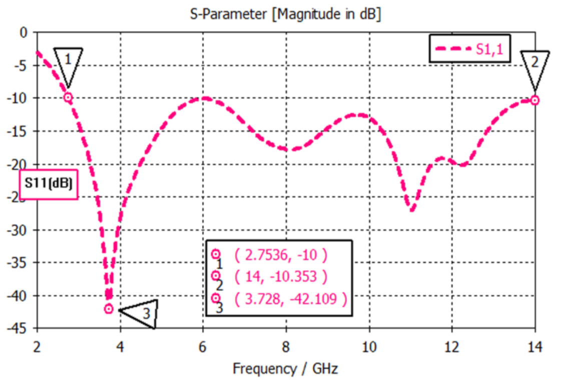
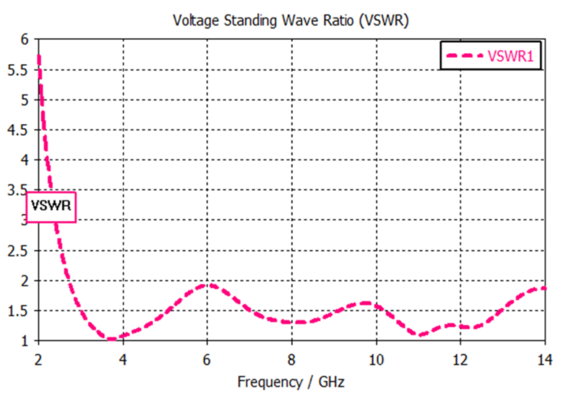
3.3. Step 3: Double Truncated Circular Patch

In this case the antenna is truncated on top and left side from the circumference to inward of the patch with tt1=4 mm & tt2= 3 mm to attain the UWB characteristics. In this case S_{11}<-10dB and VSWR<2, which satisfied the ultrawideband characterization and are shown in Figure 4 (a) and (b).



(a)

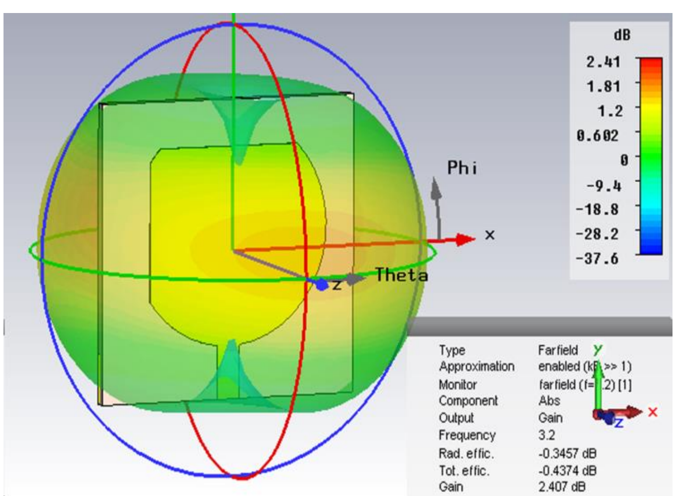


(b)

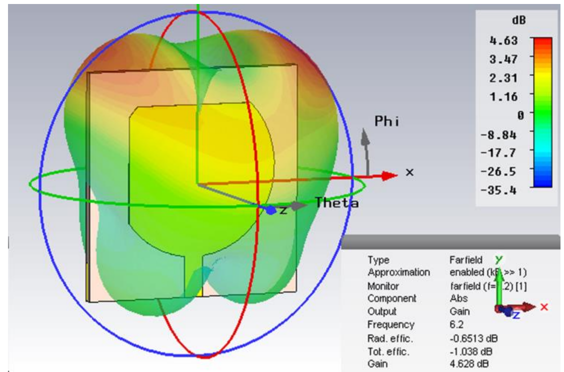
Fig.4. (a) S_{11} (Return loss) (b) VSWR of DTCP.

4. Antenna radiation patterns

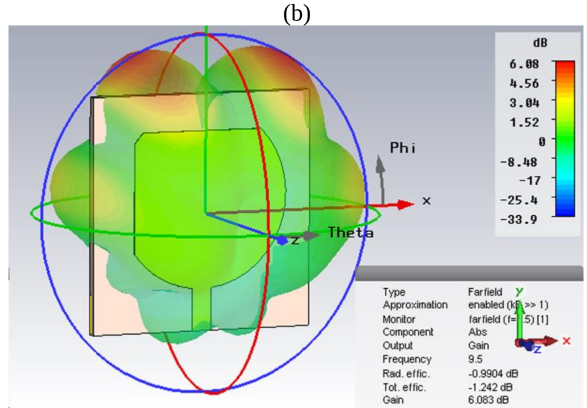
The simulated 3D (Figure 5) and polar (Figure 6) gain patterns for DTCP antenna at different frequencies such as 3.2, 6.2, 9.5 and 11.2 GHz are observed. It was identified that the patterns are almost nearly Omni-directional.



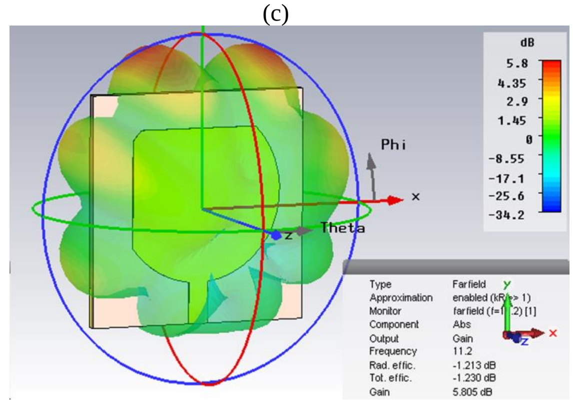
(a)



(b)

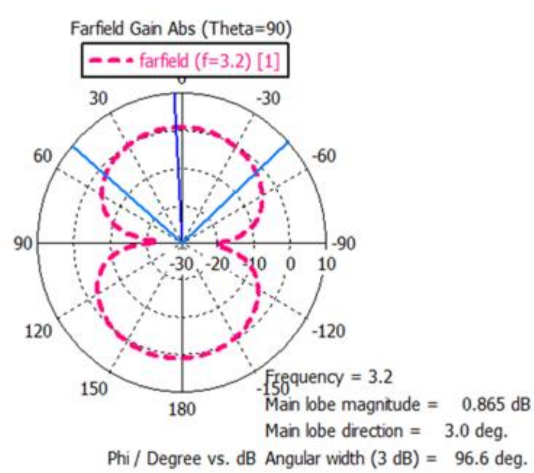


(c)



(d)

Fig.5. 3-dimensional radiation patterns at (a) 3.2 (b) 6.2 (c) 9.5 (d) 11.2 GHz frequencies.



(a)

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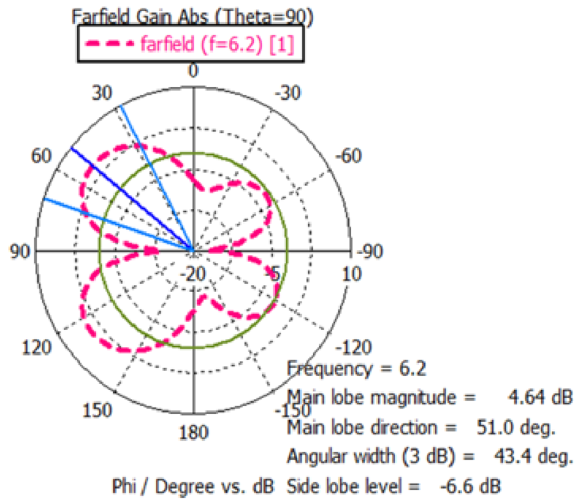
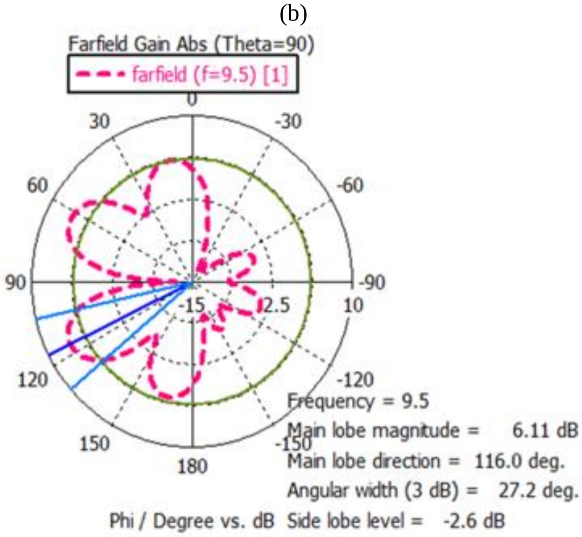
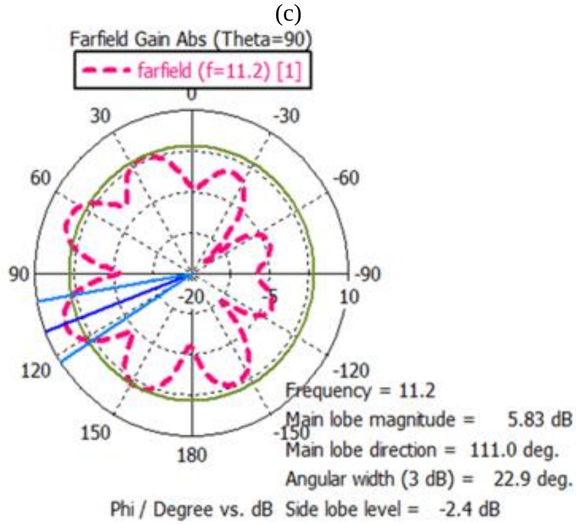


(b)



(c)



(d)

Fig.6. Polar patterns at (a) 3.2 (b) 6.2 (c) 9.5 (d) 11.2 GHz frequencies

The simulated gain values at these frequencies are tabulated in Table 2. The antenna radiates the maximum radiation efficiency of 92.3% at 3.2 GHz that is shown in Figure 7. The peak gain of 6.3 dBi is observed at 8 GHz, which is depicted in Figure 8.

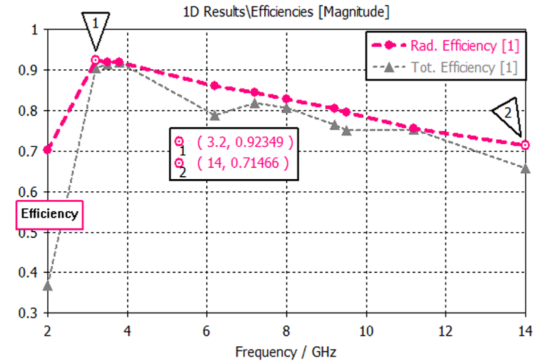


Fig.7. Radiation efficiency of required antenna.

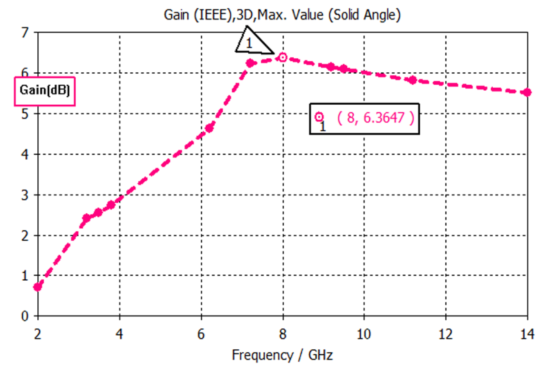


Fig.8. Gain vs. frequency plot.

Table 2: Antenna Gain at various frequencies

Frequency (GHz)	Gain (dBi)
3.2	2.41
6.2	4.63
9.5	6.08
11.2	5.8

5. Conclusion

The proposed double truncated circular patch (DTCP) with defective ground structure (DGS) for UWB applications was designed and analyzed using MS-CST. A relatively 11.25 GHz (2.75 to 14 GHz) wide spectrum was obtained. The antenna provides satisfactory omni-directional radiation patterns. This antenna yields S11< -10 dB and VSWR < 2. These UWB characteristics was obtained by modifying the circular patch with DGS. The simulation results show that the proposed antenna is suitable for UWB applications.

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