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A Compact Circular Disc Shaped Monopole Antenna for UWB Applications

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Abstract

This article presents a compact size UWB antenna with circular patch containing four L-shape and a circular slot for ultra wide-band (UWB) applications. Ground plane is also modified with diagonal edges, rectangular slot and I-shaped slots. It has found that the L-shape and circular cut on radiator improves the bandwidth of antenna. Bandwidth is further improved by cutting rectangular slots and truncated ground at top corners. The proposed antenna operates from 2.63 GHz to12.1GHz. Results are validated through simulations and measured results. Reflection coefficients of −30.38 dB,-29.13dB and −40.25 dB for the 3.3 GHz, 7.0 GHz and 9.2 GHz resonant frequencies respectively are achieved. The proposed antenna provides a 26.26% wider bandwidth than FCC standard.

Keywords: Monopole Antenna, Ultra Wide-band (UWB)

INTRODUCTION

Wireless communication has assumed such huge proportions that it is being used in various domains covering several facets of human life. The requirements of wireless communication have changed with time and at present require such devices to operate over a large band of frequency, wideband, or over multiple bands, multiband. This has been brought due to personal communication devices aiming to provide image, speech and data communications ubiquitously. Microstrip patch antennas have low profile which has led to their possible integration with many electronic equipment's and are also the most popular antenna for various technologies. Patch antenna has an inherent disadvantage because of its low profile; low gain and low bandwidth. In some applications higher bandwidth is required. So it is desired to improve the existing designs to provide higher impedance bandwidth. However, antenna designing becomes not easy when we have to enhance the number of operating frequency bands and cover an octave or more [1].

With FCC releasing its guidelines for a sufficiently ultra wide band antenna (UWB) operating in a frequency range of (3.1-10.6) GHz [2] mandatorily, there has been thrust on designing of such antenna structures. A suitable UWB antenna should be capable of operating over an ultra-wide bandwidth as allocated by the FCC. Concurrently, reasonable efficiency and satisfactory radiation properties is also desired over the entire frequency range. UWB antennas also need to have good time domain performance, i.e., a good impulse response with minimal distortion [3]. UWB antennas with small height and compact size are also useful for body area networks especially mobile assisted health applications [4].Bandwidth improvement Has been achieved by implementing various techniques like use of a modified ground structure with circular patch [6-7], use of inset feed [8] and use of open stubs [9].

In this research work of ours, an antenna structure in the UWB domain has been designed and its results are discussed. Section 2 and 3 discuss antenna design and results.

ANTENNA DESIGN

The proposed antenna is printed on opposite side of FR4 Epoxy substrate with εr= 4.4 and tan ξ = 0.02 and thickness of 1.6 mm. Figure 1 shows the configuration of proposed antenna design and photograph of fabricated antenna. The dimensions of substrate are 32.0 mm X 36.0 mm X 1.6 mm. The design uses a truncated ground with several slots. The feed strip is 3.0 mm wide to provide 50 Ω impedance matching. Impedance matching is achieved by using truncated ground structure which provides a capacitive load that reduces the effect the inductive nature of the patch. The patch is circular in shape with four L shaped and a circular slot cut in to increase the electrical length. In absence of these slots cut on the circular patch, the current density in the entire patch was diminished.

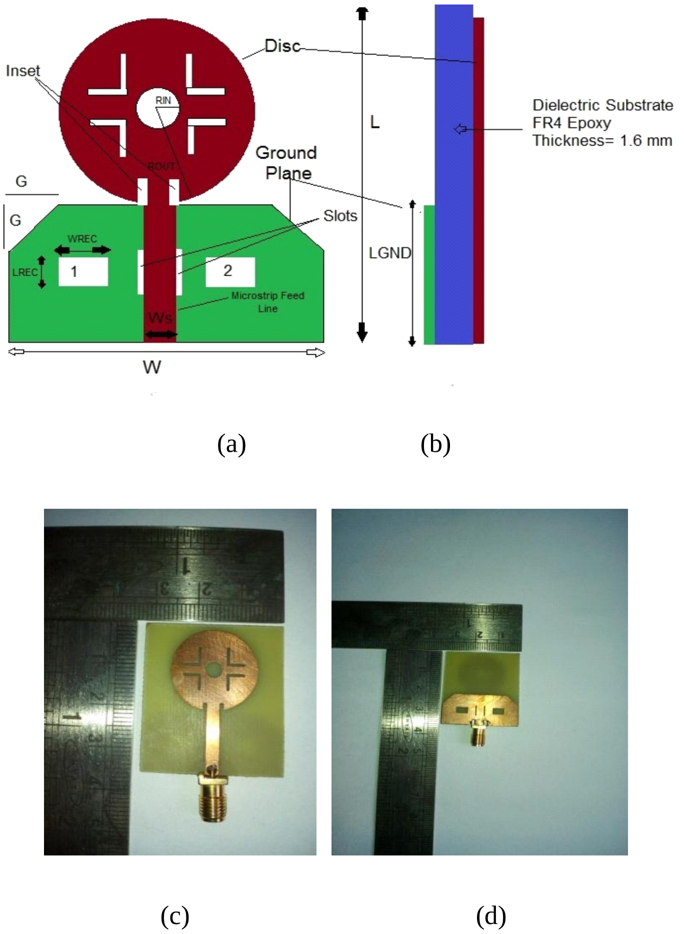

Figure 1. Geometrical views of the proposed antenna (a) Front view (b) side view(c) Top view of fabricated antenna (d) Back view of fabricated antenna

In order to diminish the reflection of the surface current, two slots are cut in ground plain. It also improves the return loss [10-11]. Diagonal shapes on top ground plain affect reflection coefficients at higher frequencies.

Table 1: Dimensions of the proposed antenna

Parameter	Value (mm)	Parameter	Value (mm)
G	5.0	W	32.0
LREC	5.0	LGND	15.0
WREC	3.0	RIN	1.9
Ws	3.0	ROUT	10
L	36.0		

The optimized dimensions and details of each parameter of the antenna are given in Table I. The width of each section of L shaped slots if 0.5 mm and their length is 4.0 mm. The design incorporates a diagonal cut on the ground plane, parameterized ground on either side to increase impedance bandwidth and provide lower return loss. There is evenness in the circular patch across the horizontal and vertical diameter of the circular disc.

Impedance matching is obtained via the truncated ground structure for controlling the impedance bandwidth of circular monopole [5]. Two rectangular slots with length of 5.0 mm and width of 0.5 mm on the ground plane are cut such that they lie on both side of the microstrip feed line.

RESULTS AND DISCUSSION

Ansoft's HFSS tool is used for simulation of proposed antenna. Tool works on on finite element method (FEM) solver for electromagnetic structures. Figure 3 shows the measured and simulated reflection coefficient values. It is observed that there exists good agreement between simulated and measured results. Due to mismatching tolerance and SMA connector, there is slight variation in simulated and measured results.

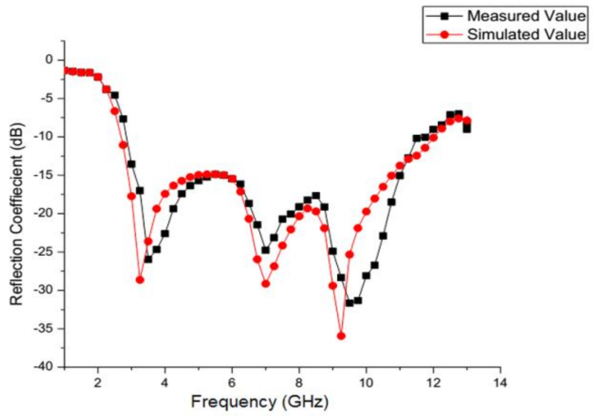

Figure 2. Comparison between simulated and measured reflection coefficient

It is also found that -10 dB bandwidth from 2.63 GHz to12.1GHz which is 26.26 % more than the FCC guidelines. We observe resonant harmonics at 3.3 GHz, 7.0 GHz, 9.2 GHz and reflection coefficient of -30.38 dB, -29.13 dB, and -40.25 dB respectively.

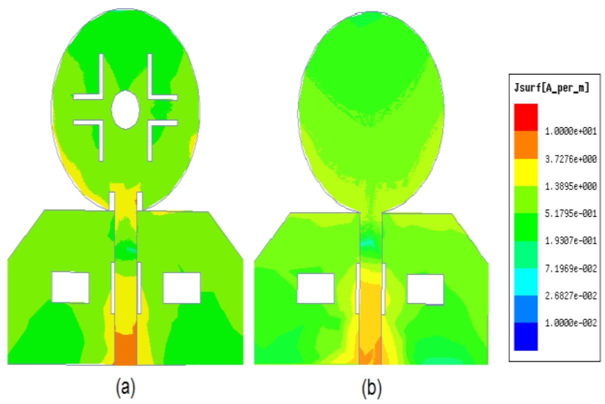

Figure 3. Current distribution at 3.3 GHz (a) In proposed Antenna (b) Simple Disc

The effect of L shaped slots and circular slot on circular patch is evidently visible in the current distribution plot shown in figure 3(a) and 3(b). Figure shows that current are mainly present on the micro-strip line and periphery of the circular patch. The length of L-shaped slots has been optimized to achieve wide band and good radiation performance. The L-shaped slots also extensively improve the impedance matching at higher frequencies.

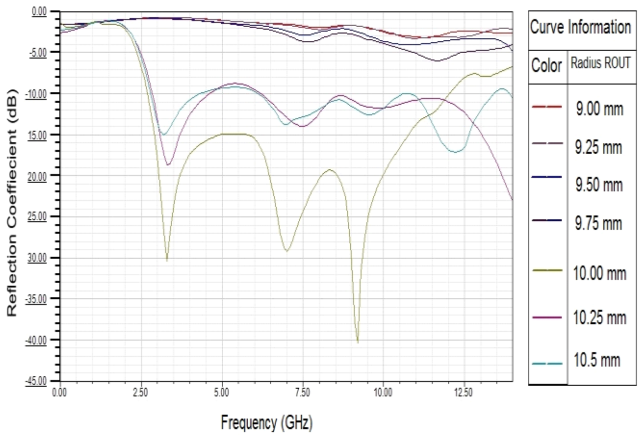

Figure 4. Variation in reflection coefficient of proposed antenna with ROUT.

Figure 4 leads to the fact that the reflection coefficient characteristics of the antenna depends on the radius of disc. Parametric variation of ROUT provides best result in reflection coefficient and peak realized gain for 10 mm.

Empirical equations have been developed manually using methods such as Least Squares Fit and Polynomial Regression for the data set consisting of the design parameter (Radius R_{OUT} in mm) and the corresponding resonant frequencies (f1, f2 and f3 in GHz) lying in the UWB Band. The equations in polynomial form of degree 3 are:

$$f1 = -15.99996081\ x^3 + 476.2273957\ x^2 - 4717.359679\ x + 15553.20946 \quad (1)$$

$$f2 = -43.73337149\ x^3 + 1302.972574\ x^2 - 12921.70668\ x + 42658.56953 \quad (2)$$

$$f3 = -48.00004194\ x^3 + 1430.972687\ x^2 - 14197.44115\ x + 46884.05332 \quad (3)$$

Where x is R_{out} .It is found that calculated resonant frequencies (f1, f2 and f3) are almost same to simulated resonant frequencies.

Table 2. Comparison between proposed design and similar designs

	Parameters		
	Bands	Impedance Bandwidth	Reflection Coefficient(Min.)
Proposed Design	UWB	9.47 GHz	-40.25 dB at 9.2GHz
[6]	UWB	9.41GHz	-26 dB at 6.4 GHz
[12]	UWB	8.0GHz	-28 dB at 10.6 GHz
[13]	Wideband	4.8 GHz	-27 dB at 3.8 GHz
[14]	UWB	8.55 GHz	-26 dB at 8.25GHz
[16]	UWB	8.8 GHz	-35 dB at 6 GHz

A comparison between impedance bandwidth and reflection coefficient of proposed design and similar designs are presented in the Table above. It is found that proposed antenna impedance bandwidth more than the other similar reported designs and a significant improvement is also observed in return loss.

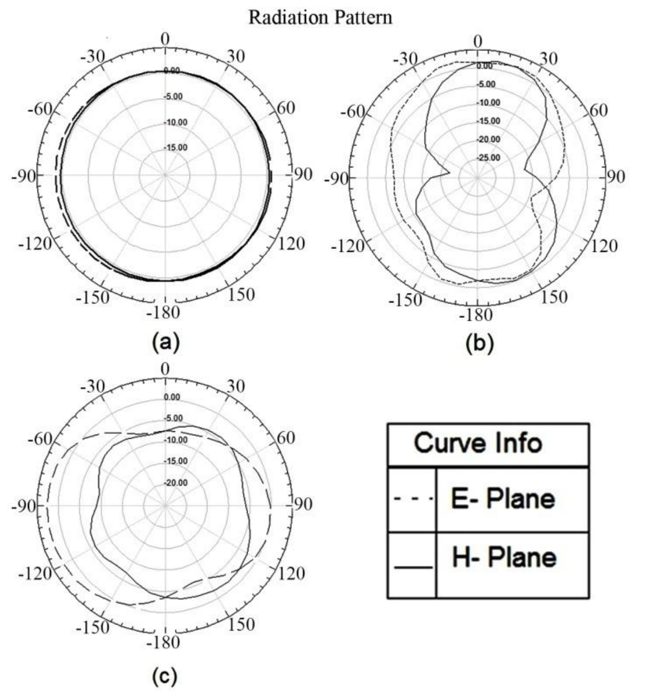

Figure 5. Simulated Radiation pattern of proposed antenna (a) 3.3 GHz (b) 7.0 GHz (c) 9.2 GHz

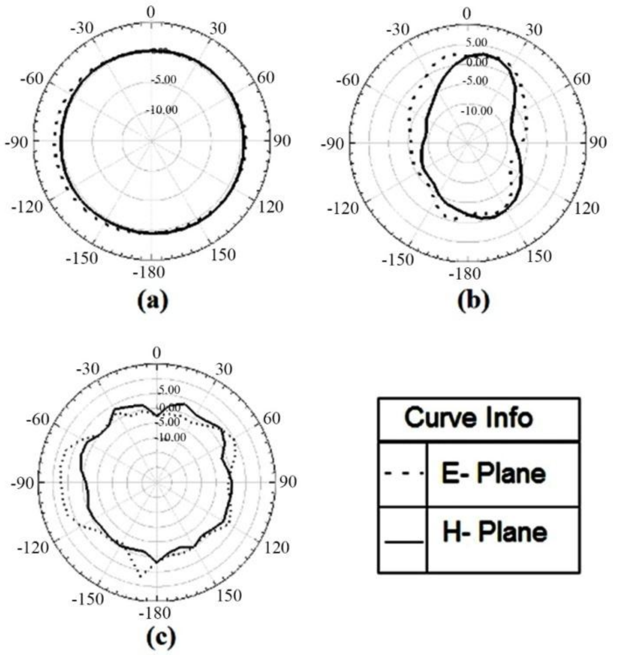

Figure 6. Measured Radiation pattern of proposed antenna (a) 3.3 GHz (b) 7.0 GHz (c) 9.2 GHz

Figure 5 shows the simulated E plane and H plane radiation pattern of the proposed antenna at 3.3 GHz, 7.0 GHz and 9.2 GHz. It is found that the radiation patterns are almost Omni-directional over the entire -10 dB bandwidth. It has been observed that the performance of the proposed antenna in terms of its frequency domain characteristics is mostly dependent on the dimension of the disc, width of the ground plane and the feed gap. Measured radiation patterns are almost identical to simulated patterns except at 3.3 GHz.

CONCLUSION

A compact UWB antenna which covers the frequencies from 2.68 GHz to 12.1GHz has been proposed. It covers not only entire ultra wideband but offers 26.26 % wider bandwidth than FCC standard. The antenna design consists of circular disc as a patch with four L-shaped slots and circular slot on it and rectangular slots on ground. The ground is also truncated on top corners. Results show that the bandwidth can be tunable depending on the radius of circular disc and circular cut on patch and dimensions of L-shape slots on patch. With the presence of rectangular slots and truncated corners of the ground plane, the bandwidth has been further improved. The radiation pattern is also nearly omnidirectional. The dimension of antenna is 32.0 mm X 36.0 mm X 1.6 mm which is acceptable size for many terminal devices. So antenna is useful UWB applications.

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