CPW-FED UWB ANTENNA WITH WiMAX BAND-NOTCHED CHARACTERISTICS

Sarah Jacob[1], Anila P.V.[2], S. Mridula[3], P. Mohanan[4]

[1]*Department of Electronics, Cochin University of Science & Technology, Cochin, Kerala, India*
[2]*Department of Electronics, Cochin University of Science & Technology, Cochin, Kerala, India*
[3]*Division of Electronics, School of Engineering, Cochin University of Science & Technology, Cochin, Kerala, India*
[4]*Department of Electronics, Cochin University of Science & Technology, Cochin, Kerala, India*

Abstract

A coplanar wave guide fed (CPW) UWB antenna with provision for rejecting WiMAX band is proposed. The antenna consists of a circular disc which is truncated at the top and a rectangular ground plane with semi-elliptically shaped upper edge. Overall size of the antenna is 25 mm x 20 mm x 1.6 mm. Folded U-slot etched on the radiating patch produces the band rejection characteristics at WiMAX. The S_{11} (< -10 dB) bandwidth of the antenna varies from 3.1 GHz to greater than 12 GHz with satisfactory band rejection over the range of 3.35 GHz to 3.8 GHz. The extent of pulse distortions due to the antenna is analysed by the antenna transfer functions and group delay measurements. Effects of folded U-slot on the antenna characteristics both in frequency domain and time domain are presented.

Keywords: *Band-notched characteristics, coplanar waveguide, transient analysis and ultra wideband antenna.*

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1. INTRODUCTION

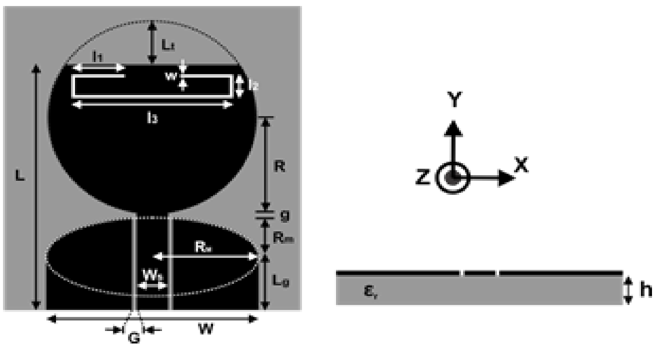
The frequency band of 3.1 – 10.6 GHz is allocated to the UWB application by the Federal Communications Commission (FCC) in 2002 [1]. Major challenges for an efficient UWB antennas are broad impedance bandwidth (S_{11}< -10 dB), flat gain response and less variation in group delay over the allocated bandwidth. In addition to these, antennas with reduced sizes are desirable to satisfy the trends in the size reduction of communication gadgets. Printed antennas are suitable for UWB applications due to their excellent mechanical and electrical characteristics, compatibility for integration with other RF systems and mass production [2].

However, narrow band wireless service such as WiMAX operating in the frequency band 3.3 – 3.7 GHz can cause interference with UWB systems. To overcome this problem, various band-notching techniques can be incorporated within the UWB planar antennas such as etching slots of different shapes on the radiating patch or ground plane, inserting quarter wavelength stubs, placing parasitic elements in the vicinity of radiating structure etc.[3] – [10]. These band-rejection elements are actually resonant structures designed to operate at the middle frequency of the notched band.

In this paper, a compact CPW fed UWB antenna with a WiMAX band-notched function is presented. The geometry of the proposed UWB antenna is simple and compact with less design parameters as compared to [3] – [10]. The antenna consists of a CPW-fed circular disc truncated at the top and a rectangular ground plane with semi-elliptically shaped upper edge which produces an impedance bandwidth (S_{11}< -10 dB) extending from 3.4 to 12 GHz. To realize the band-notched characteristics, a folded U-slot is etched near the truncated edge of the disc. This not only produces a notched band (3.35 – 3.8GHz) at WiMAX but also decreases the lower cut off frequency of the initial operating band from 3.4 to 3.1 GHz. From the measured results, it is observed that the proposed UWB antenna operates from 3.1 to 12 GHz with frequency rejection from 3.35 to 3.8 GHz for eliminating the unwanted signals from WiMAX band.

2. ANTENNA GEOMETRY AND DESIGN

Fig.1(a) shows the geometry of the proposed single band-notched UWB antenna having a size of 25 mm x 20 mm, fabricated on a substrate of relative permittivity 4.4, loss tangent 0.02 and thickness h = 1.6mm. The antenna consists of a circular disc of radius R which is truncated at a point L_t below the topmost point on its circumference and a rectangular ground plane with semi-elliptically shaped upper edge.



(a) (b)

Fig.1 Geometry of the proposed dual band-notched antenna (a) top view (b) side view

In a conventional circular disc monopole, the current flows mainly near the lower portion of the disc [11] for the fundamental mode. So the antenna can be made more compact by removing the upper portion of the disc without disturbing the radiation characteristics severely. A 50Ω-CPW feed line is used to excite the antenna. W_s and G are the width of the feed line and gap between the feed line and the ground plane respectively. R_M and R_m are the major and minor axes of the semi-elliptical shape at the upper edge of a rectangular ground plane of size L_g x W with a feed gap 'g' in order to maintain the S_{11} < -10 dB over the desired frequency range. Fig.2 shows the photograph of the fabricated antenna.

Fig.2 Photograph of the fabricated antenna

Folded U-slot inserted in the radiating patch as shown in Fig.1(a) results in band notched characteristics at WiMAX. When the length of the slot is half the guide wavelength at the designed notch frequency, it behaves as a resonator circuit [12]. As a result, it offers high impedance mismatch to the antenna feed point and thus provides less radiation [13]. The simulations are performed using CST Microwave Studio. The optimized design parameters are L = 25 mm, W = 20 mm, R = 9.8 mm, L_t = 4.4 mm, W_s = 3 mm, G = 0.4 mm, L_g = 5.5 mm, R_M = 10 mm, R_m = 4 mm, g = 0.3 mm, w = 0.4 mm, $l_1 = 0.08\lambda g_1$, $l_2 = 0.04\lambda g_1$ and $l_3 = 0.29\lambda g_1$, where λg_1 is the guide wavelength corresponding to the center frequency of the rejected WiMAX band.

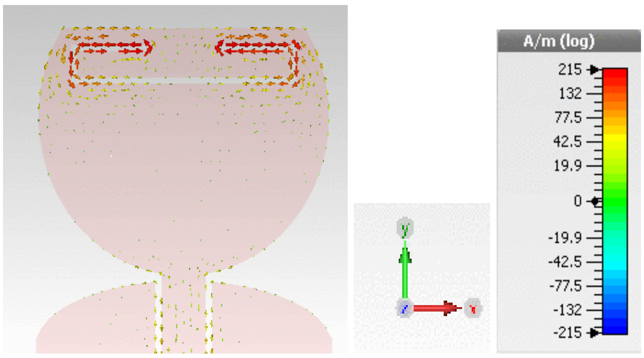


Fig.3 Simulated current distribution at notched frequency

The simulated current distribution at the center frequency of WiMAX band (3.5 GHz) for the optimal design is presented in Fig.3. It is observed that the major part of the surface current flows on the folded U-slot than any other portion of the proposed antenna and it flows in opposite directions. This in turn results in radiation fields which are out of phase, leading to signal rejection at that frequency [14].

3. RESULTS AND DISCUSSIONS

Measurement of the proposed single band-notched antenna is carried out using Rhode & Schwarz ZVB 20 vector network analyzer.

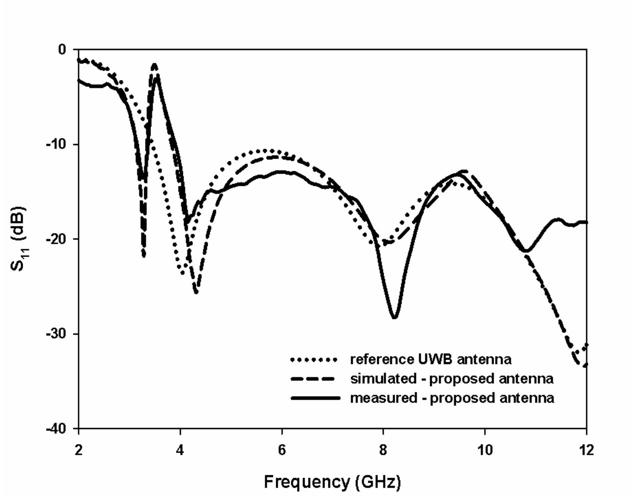
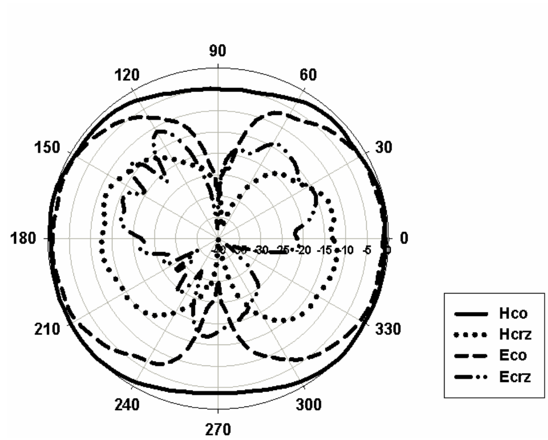
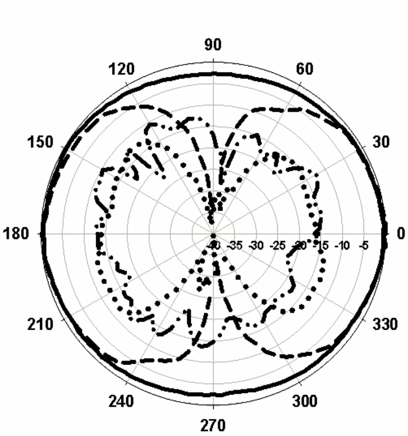


Fig.4 Measured and simulated S_{11} of the proposed band-notched UWB antenna and reference UWB antenna

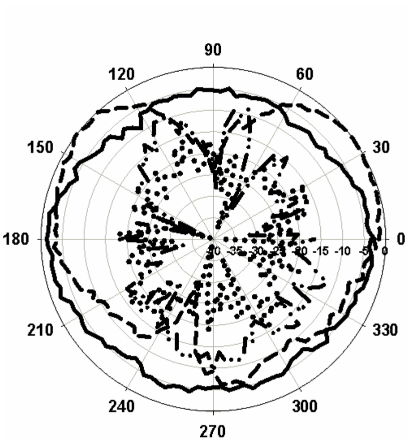
Simulated and measured reflection coefficients of the proposed single band-notched antenna are shown in Fig.4 and compared with the simulated result of the reference UWB antenna without notched characteristics. For the reference antenna, the impedance bandwidth is from 3.4 to greater than 12 GHz. Compared to the reference antenna, it is observed that the folded U-slot etched on the patch introduces a notched band at WiMAX while maintaining S_{11}<-10 dB from 3.1 to greater than 12 GHz. The measured reflection coefficient agrees very well with the simulated results. It is also observed that the folded U-slot structure decreases the lower cut off frequency of the antenna from 3.4 to 3.1 GHz.



(a)



(b)



(c)

Fig.5 Measured radiation patterns of the proposed antenna at frequencies (a) 4 GHz b) 7 GHz and (c) 10 GHz

Fig.5 (a) - (c) show the measured radiation patterns in the H-plane (x-z plane) and E-plane (y-z plane) for three different frequencies 4 GHz, 7 GHz and 10 GHz respectively. Nearly omni-directional radiation patterns with slight reduction in radiation along 90^o and 270^o are observed in the H-plane (x-z plane). The measured E-plane (y-z plane) patterns have 'figure of eight' shape with maximum radiations along 0^o and 180^o. For 10 GHz, the patterns are slightly distorted due to the higher order modes excited within the antenna structure.

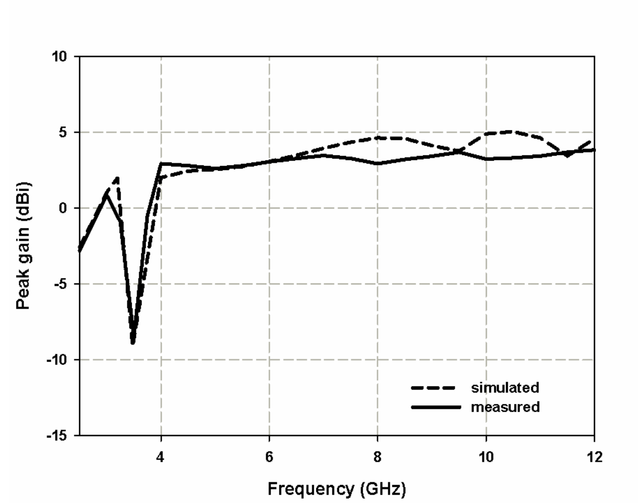


Fig.6 Measured and simulated gain of the proposed antenna

The simulated and measured peak gains are described in Fig.6. The gain is measured by gain comparison method and the response is almost stable over the entire UWB band outside the rejection band. At 3.5 GHz, gain decreases sharply to -9 dBi indicating the capability of proposed antenna to avoid the interferences from the WiMAX systems.

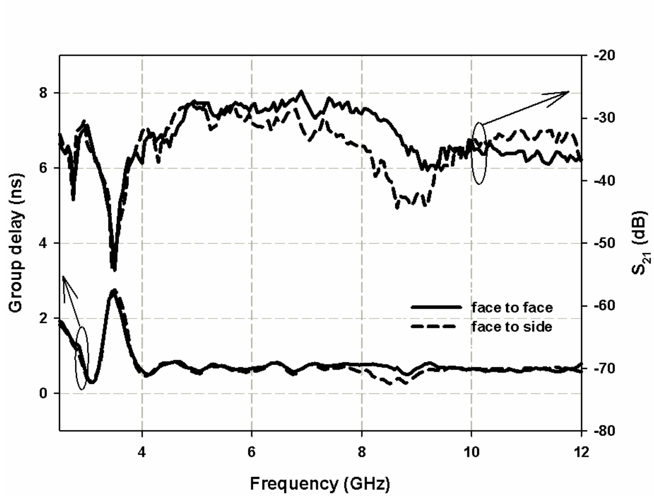


Fig.7 Measured group delay and antenna transfer function (S_{21}) for two different orientations of a pair of identical proposed antennas

Since UWB technology is envisioned for high data rate communication it uses narrow pulses to transmit signals. Group delay and antenna transfer function (S_{21}) are the two important parameters used to evaluate the extent of pulse dispersion due to the antenna [15]. For UWB applications, antennas with small group delay and flat transfer function responses are desirable. Fig.7 describes the measured overall group delay and transfer function (S_{21}) for two different orientations of a pair of identical proposed antenna, face to face and face to side with a separation of 15 cm. The measured S_{21} is almost same for both the orientations except over the frequency range 8 to 9.5 GHz. It is also seen that S_{21} retains a flat response outside the notched band with variations limited to 10 dB approximately. Fig.7 also reveals that the antenna has small group delay with variations in the order of less than 1ns over the UWB band, where it exceeds 2 ns at the rejection band. Therefore, the transmitted pulses can be received without degrading its quality.

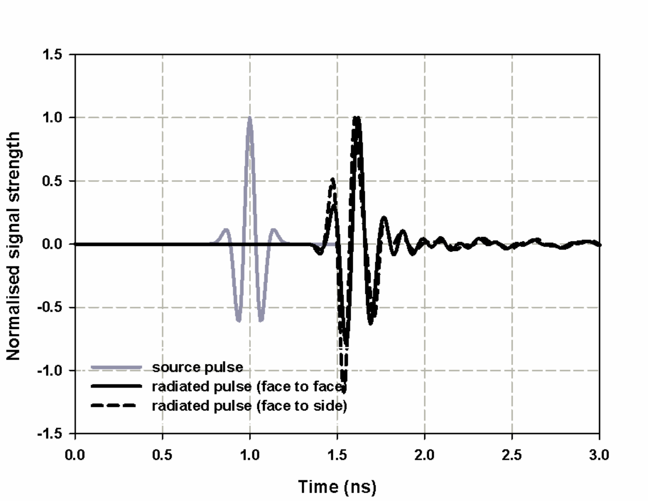


Fig.8 Normalized source pulse and radiated pulses for two different orientations of a pair of identical proposed antennas

The transient response of the antenna is analyzed in CST by placing probes around the proposed antenna in H-plane with a separation of 45^o. A fourth order Rayleigh pulse with pulse width = 67 ps is used as the source pulse and is generated mathematically. Fig.8 compares the source pulse with the simulated radiated pulses for two different orientations, face to face and face to side. It is observed that the shapes of the simulated pulses are almost similar to source pulse with negligible variations.

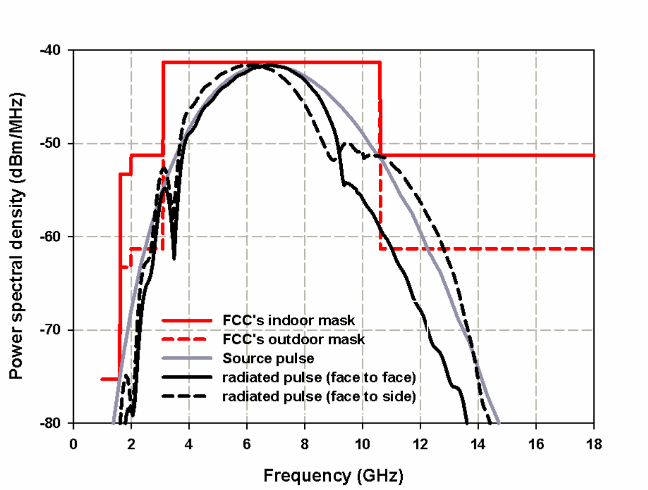


Fig.9 Power spectral density of source pulse and radiated pulses (face to face & face to side) normalized to FCC's emission masks

Fig.9 shows the power spectral density (PSD) of the source pulse and simulated radiated pulse normalized to FCC's emission mask. It is seen that the spectrum of the radiated pulses completely complies with FCC's indoor emission mask.

Table -1 Performance comparison of proposed antenna with other structures reported

Refs.	Overall size in λ_o w.r.t lower cut off	Gain suppression at notched frequency (dBi)	Group delay outside the notched band (ns)
[5]	0.19 x 0.16 x 0.009	-1.8	---
[6]	0.37 x 0.28 x 0.014	-6.5	< 2
[7]	0.4 x 0.36 x 0.01	-5.5	----
[8]	0.35 x 0.3 x 0.016	-1.5	< 1
[9]	0.22 x 0.16 x 0.012	-4	-----
[10]	0.41 x 0.28 x 0.016	-10	< 2
proposed	0.25 x 0.2 x 0.016	-9	< 1

From the Table1 it is clear that the proposed antenna is comparably small in size and has improved performance in terms of gain suppression at the notched band and group delay in the UWB band compared to several structures [5] – [10] reported earlier. From the frequency domain and time domain results discussed so far, it is clear that the proposed antenna is useful for various UWB applications in WiMAX environment.

3. CONCLUSION

A simple CPW fed UWB antenna with a folded U-slot on the radiating patch, for achieving band-notched function is proposed. The fabricated antenna holds a band-notched function at the WiMAX while maintaining -10 dB S_{11} characteristics over a frequency range of 3.1 to 12 GHz. The proposed antenna has nearly omnidirectional radiation pattern with moderate gain response across the entire UWB bandwidth. The measured group delay (<1ns) and the antenna transfer characteristics (S_{21}) demonstrate almost flat response which indicate that the proposed antenna exhibits very good transient response. Hence a favorable choice for UWB pulse communication applications.

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BIOGRAPHIES

Sarah Jacob received M.Tech degree in Microwave and Radar Systems in 1995 from Cochin University of Science and Technology (CUSAT), Kerala, India. She is currently working towards her Ph.D degree with the CUSAT. Her area of research includes UWB technology and planar antennas.

Anila P V received her M.Tech degree in Microwave and Radar Engineering from Cochin University of Science and Technology (CUSAT) in 2011. She is currently working towards her Ph.D degree from CUSAT. Her areas of interest include Computational Electromagnetics, Multi band antennas, Planar antennas, Metamaterials and its applications in the field of compact antennas etc.

S Mridula received her Ph.D. in Microwave Electronics from Cochin University of Science and Technology (CUSAT) in 2006. She is presently serving as Associate Professor, Division of Electronics Engineering, School of Engineering, CUSAT. Her areas of interest include Planar antennas, Dielectric Resonator Antenna, Radiation Hazards of Mobile handset antennas and Computational Electromagnetics.

P Mohanan (SM'05) received the Ph.D. degree in Microwave antennas from CUSAT in 1985. Currently, he is a Professor in the Department of Electronics, CUSAT. He has published more than 150 referred journal papers and numerous conference articles. He also holds several patents in the areas of antennas and material science. His research areas include microstrip antennas, uniplanar antennas, ultrawideband antennas dielectric resonator antennas, superconducting microwave antennas, reduction of radar cross sections, and polarization agile antennas.