

CPW FED DUAL NOTCHED UWB ANTENNA: WIMAX AND X-BAND NOTCHED

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Abstract

This paper presents a Coplanar Waveguide (CPW) fed dual band-notched Ultra Wide Band (UWB) antenna. This antenna uses an anchor slot and a Complementary Split Ring Resonator (CSRR) in feed line to produce dual band-notched features in WiMAX (3.3-3.7 GHz) band and X-band (7.25-8.35 GHz) satellite communication applications respectively. The suggested antenna is very compact in size of 19.6×25 mm² which radiates over 3 to 11 GHz with VSWR less than 2. The presented antenna has very compact size which makes it suitable for the low profile systems and applications. A fabricated sample of recommended antenna is presented with its compared outcomes of simulation and measurement for VSWR and radiation patterns.

Keywords: Anchor slot antenna, SRR, CPW, WiMAX band, UWB antenna

Introduction

The current wireless communication scenario has a huge demand of antennas with a wide bandwidth. Predominantly for short distance communications wide bandwidth antennas are greatly demanded to communicate at high data rate and improves the limitations of narrow band antennas. Conversely these wide bandwidth antennas included the spectrum of narrowband applications (Chen and Chia, 2006). The wide bandwidth antennas are greatly appreciated for the UWB equipment to fulfill the requisite of high data rate and improve the other confines like data encryption, minimum prospect for data interception and many more (Ray, 2008). On February 14, 2002, an unlicensed band called UWB from 3.1 to 10.6 GHz with a span of 7.5 GHz declared by the Federal Communication Commission (FCC) for commercial applications

(Federal, 2002). Microstrip or planar antennas are highly recommended for UWB technology because of their undisputed advantages over other antennas and so forth (Chen, 2007).

The UWB technology devices suffers from electromagnetic interventions causes by other existing narrow band spectrum for communications such as WiMAX, WLAN systems, C and X-band satellite systems (3.8-4.2 GHz and 7.25-8.4 GHz respectively).

In the last few years, to resolve the EM interference barrier, researchers have offered different methods. To cultivate antenna with band filtering structures newly few approaches have been described namely, L slot in the ground plane (Shambavi and Zachariah, 2010), inverted U slot on radiating structure (Seo *et al.*, 2012), a C-shape

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slot on a metallic patch (Kelly *et al.*, 2011), simple vertical and horizontal rectangular etching on metallic patch for band stop feature at high frequencies (Yadav *et al.*, 2016), W and C slots (Pandey *et al.*, 2016), SRR slot on radiating patch and N shaped feed line miniature (Lin *et al.*, 2015), elliptical and rectangular CSRR to create triple band notch (Sarkar *et al.*, 2014), arc shape and elliptical SRR (Srivastava *et al.*, 2015), rectangular SRR near feed line (Kim and Kim, 2010), meander shape stub, rectangular SRR and inverted U slot with L shaped parasitic stubs (Wang *et al.*, 2016), CSRR, S shape feed line miniature and circular SRR near feed line (Chu *et al.*, 2008; Yadav *et al.*, 2016), L shaped slot (Gao *et al.*, 2019), window-shaped ring resonator (Salamin *et al.*, 2020), U-shaped slot (Mohamed and Zoubir, 2018), S shaped slot in feed line and asymmetric C-shaped stub near DGS (Devana *et al.*, 2020), and U shaped slot patch as well as L shaped slot in feed line (Srivastava *et al.*, 2020)

In presented antenna, a rectangular SRR etching on feed line structure and anchor shaped slot on metallic patch to produce dual band-stop in WiMAX and X-band notched feature is demonstrated. However, the analysis of dual band notched characteristics without affecting the other unlicensed frequency spectrum is achieved. In this paper analyses of the parametric deviations have been implemented on slots and their effects presented with current distribution. As mentioned above, many researchers have exhibited distinct methods to produce band notching characteristics in UWB antennas. Here we have suggested the anchor slot to produce band notched at WiMAX resonance frequency.

Antenna Design and Configurations

The design and optimizations of suggested antenna design has been completed and improved using the EM Software Ansoft HFSS 13 and is displayed through Figure 1. A designed antenna model has been depicted in Figure 2. The antenna prototype is completed with the FR-4 dielectric which has thickness of 1.6 mm, permittivity $\epsilon_r=4.4$ and loss tangent of 0.02.

Anchor-Slot Loaded Antenna

An anchor-slot etched on the metallic patch to produce a notch band in WiMAX spectrum. The anchor-slot offers notched of 3.3-3.7 GHz for WiMAX features has been depicted in Figure 1. The anchor slot design and fabricated prototype has been displayed in Figure 2.

Anchor resonance slot length is almost $\lambda_g/2$ to produce a notch at WiMAX spectrum (3.3-3.7 GHz). The effective length of suggested anchor-slot can be calculated from Equation (1) and Equation (2).

$$f_{3.5GHz} = \frac{c}{2 * L_{eq} * \sqrt{\epsilon_r + 1}} \quad (1)$$

$$L_{eq} = 2\pi r_1 - (w_5 + w_6) + l_3 \quad (2)$$

Final value of $L_{eq} = 16.75$ mm and C is the speed of light.

CSRR Loaded Antenna Design

A CSRR has been etched in feed line of metallic patch to produce band notch in X-band for satellite communications and presented in Figure 1. The respective split ring resonator (SRR) structure and implemented prototype has been exhibited in Figure 2.

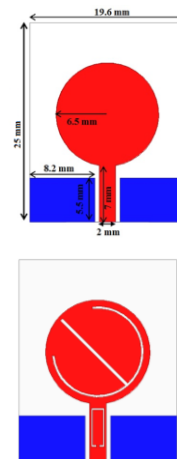


Figure 1. Simulated Design of Suggested Antenna

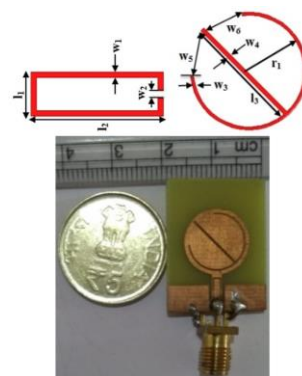


Figure 2. Antenna Band Stopping Structures and Fabricated Prototype of Proposed antenna

For notch at X-band (7.25-8.35GHz) a CSRR slot with electrical length of resonator L_{eq} CSRR=23 mm has been designed to produce notch at 7.5 GHz. The slot length is almost $\lambda_g/2$ calculated at 7.5 GHz, however the optimized CSRR resonator length L_{eq} CSRR=24 mm. The extension in resonator length is because of the other EM coupling influences on the patch radiator. The CSRR length can be determined with the Equation (3) and Equation (4).

$$f_{7.5GHz} = \frac{c}{2 * L_{eqCSRR} * \sqrt{\epsilon_r + 1}} \quad (3)$$

$$L_{eq} CSRR = 2 * (l_1 + l_2) - 4 * w_1 - w_2 \quad (4)$$

The designing variables of the suggested antenna have been mentioned in Table 1.

The theoretical and practical slot length variation of implemented slots is listed in Table 2.

Table 1. Design parameters of suggested antenna

Variable	Value (mm)	Variable	Value (mm)
l_1	1.6	w_1	0.2
l_2	4.6	w_2	0.3
l_3	11.5	w_3	0.3
w_4	0.4	w_6	3.5
w_5	3.5	r_1	5.4

Table 2. Theoretical and practical slot length error

Slot	Practical (mm)	Calculated (mm)	Error (%)
Anchor	16.75	13	22
CSRR	24	23	4

The suggested antenna with dual band notched features has been achieved through two steps on primary UWB antenna. An anchor slot has been etched on primary antenna which produces a band notch feature for WiMAX applications and result exhibited in Figure 3. To produce band notch feature for X-band satellite applications a CSRR slot in feed line has been etched. The VSWR results for step by step generation of proposed design on primary UWB antenna has been exhibited in Figure 3. The Anchor slot effectively produces one notch band feature in UWB spectrum for WiMAX communications, whereas CSRR in feed line offers a band notched feature for X-band satellite applications. The proposed dual band UWB antenna VSWR result has been shown by green line with star in Figure 3.

The width of anchor slot has been optimized and it is varied during the simulation to study and VSWR results are presented in Figure 4. It has been

observed from the slot width variation that it affects the band notching characteristics of the X-band. So here we have optimized it through simulation and find satisfactory band notched characteristics at $W_4=0.6$ mm.

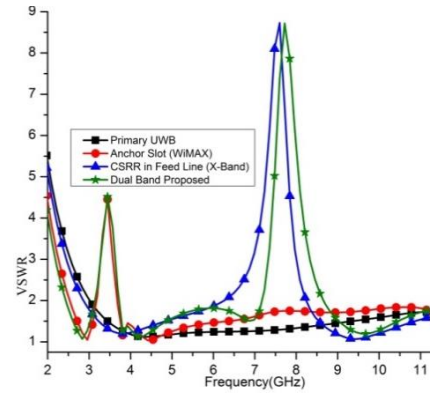


Figure 3. Simulated VSWR of suggested antennas

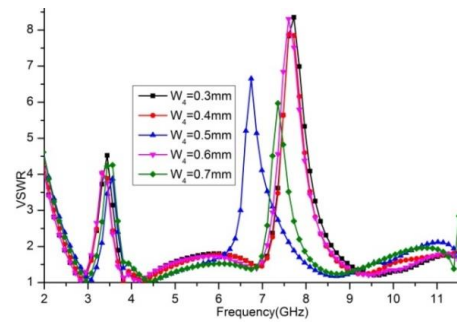


Figure 4. Variation in width of anchor slot

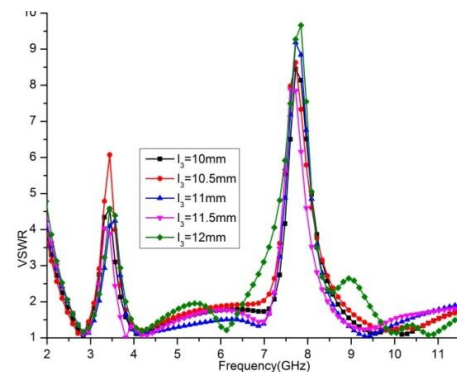


Figure 5. Anchor slot length variation

Length of anchor slot is varied to observe its effect on band notched characteristics of antenna and result exhibited in Figure 5. The length and width of CSRR slot etched in feed line has been optimized through simulation. The VSWR results of CSRR length variation with variation in gap W_2 has been presented in Figure 6.

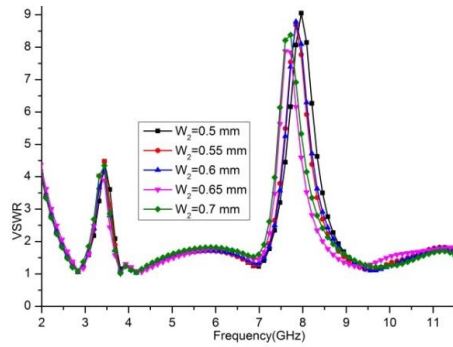


Figure 6. Simulated VSWR of suggested antenna with CSRR Gap (W_2) Variation

It can be observed that there are no any significant effects on other band notch characteristic due to the anchor slot.

The width of CSRR slot in feed line has a key role to produce band notch characteristics in X-Band satellite communication and it can be seen from Figure 7.

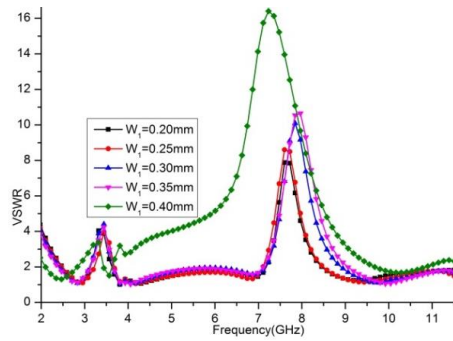
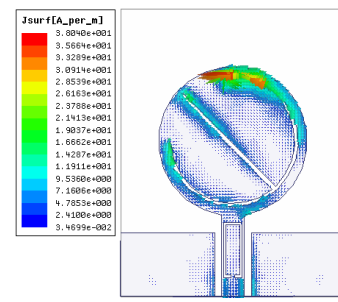
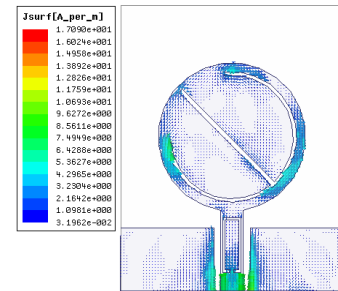


Figure 7. VSWR of suggested antenna with CSRR width (W_1) variation

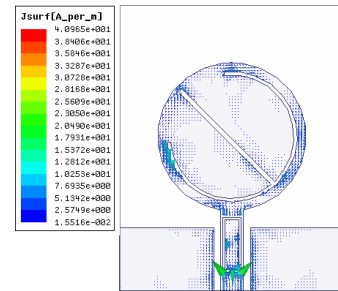
The accumulation of surface current effects on radiating patch due to the band notch structures have been exhibited in Figure 8. An uniform surface current distribution has been noted for the proposed antenna at pass band frequencies like 4.5 GHz or 5.5 GHz as presented in Figure 8(b) and Figure 8(c). We have noted a significant current accumulation at the boundaries of the anchor slot and CSRR slot which also shows a positive sign to create band notch features and results are shown in Figure 8(a) and Figure 8(d). There is maximum current accumulation at the edges of the slots for the center frequencies like 3.5 GHz and 7.5 GHz. The surface current distribution noticeably displays the constructive effects to create the band stop features.



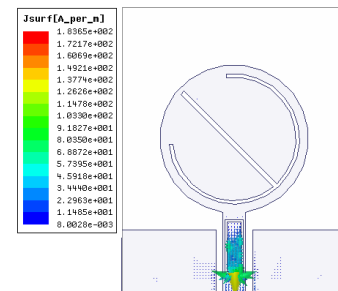
(a) 3.5GHz



(b) 5.5 G



(c) 4.5 GHz



(d) 7.5 GHz

Figure 8. Current density distribution over patch

The input impedance characteristics of the antenna is presented in the Figure 9, it is observed that the real and imaginary (resistance and reactance) part of the impedance is negative derivative which produces the band stop feature at

the 3.5 GHz (WiMAX) whereas a positive derivative of the impedance is presented at 7.5 GHz (X-band). The antenna input impedance characteristic must have to follow the approximately 50Ω resistance and around 0Ω reactance for proper radiation. The equivalent lumped model of the input impedance characteristic is presented in Figure 9 which shows that the negative derivative of the impedance produces the parallel resonance and a series resonance for positive impedance to create band stop characteristics.

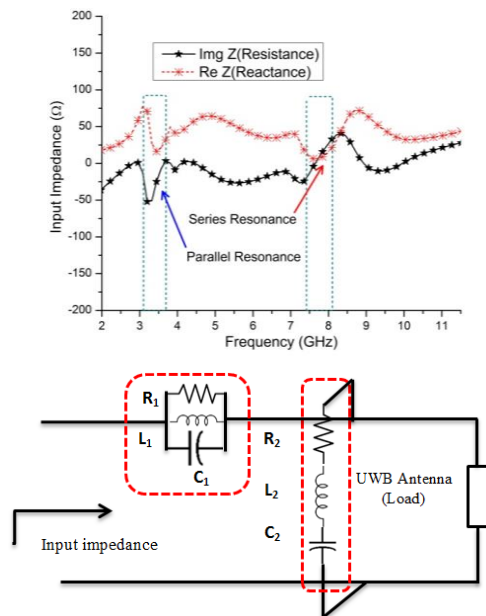


Figure 9. Input Impedance Characteristics and equivalent Lumped Model of Band Notched Antenna

Measured Results and Discussion

To verify the simulated results fabricated prototype has been performed with vector network analyzer for VSWR results. There is specific discrepancy among simulated and measured outcomes of reflection coefficients and radiation pattern due to the fabrication tolerance and cable losses at high frequencies.

A simulated VSWR result compared with measured one is presented in Figure 10. The compared results of simulation and measurement of radiation pattern (E and H plane) has been exhibited in Figure 11. The suggested antenna effectively exhibits dual notched at WiMAX (3.3-3.7 GHz) and X-band (7.25-8.35 GHz) with keeping the broadband presentation from 2.5 to 11 GHz.

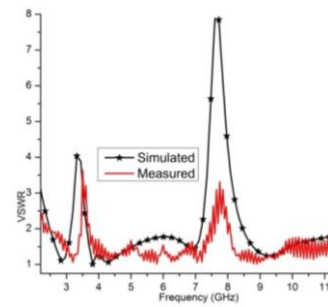
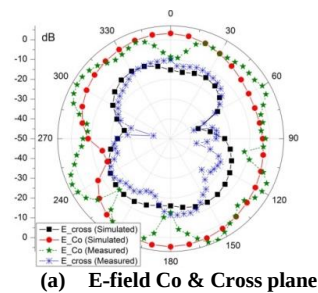
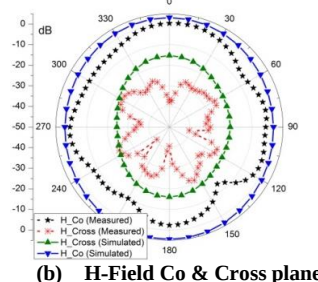


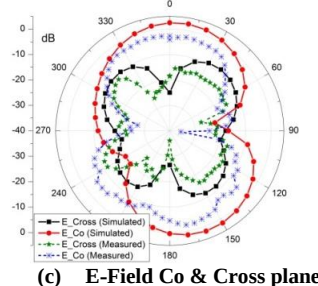
Figure 10. Simulated and Measured VSWR Vs frequency



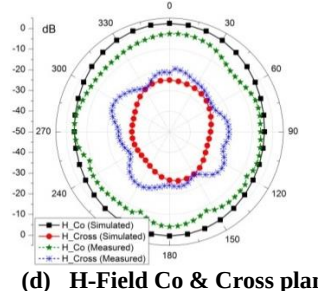
(a) E-field Co & Cross plane



(b) H-Field Co & Cross plane



(c) E-Field Co & Cross plane



(d) H-Field Co & Cross plane

Figure 11. E & H plane results antenna (a) at 4.5 GHz (b) at 4.5 GHz (c) at 6.5 GHz (d) at 6.5 GHz.

The compared results of E and H plane polarizations with measured one have been exhibited for frequencies like 4.5 and 6.5 GHz in Figure 11. The antenna has low cross polarization approximately 20dB in comparison to co-polarization pattern which is highly recommended for the UWB antennas. The E-plane pattern of antenna has dipole like shape whereas it produces approximately circle like shape for H-plane pattern which is validated as omni-directional pattern and it is also recommended for UWB antennas. The peak realized gain of antenna is approximately -12dBi for notched bands whereas a consistent gain of approximately 3dBi throughout the UWB spectrum is presented by the antenna.

The antenna efficiency is around less than 20% for notched bands whereas more than 90% for pass band displayed in Figure 12.

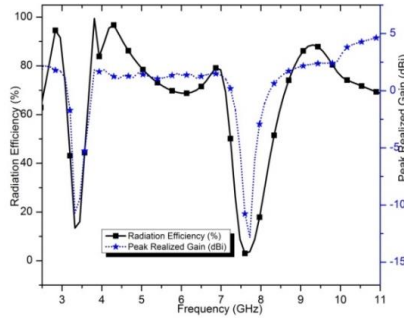


Figure 12. Peak Realized gain and antenna efficiency antenna with respect to frequency

Conclusions

An antenna with dual notched features and radiating over the entire UWB spectrum is demonstrated in this manuscript. The presented antenna is compact in size of 19.6×25 mm² which makes it favorable for the low profile devices and miniature devices. The presented antenna has wide bandwidth which covers a spectrum of UWB applications with band stop characteristics of WiMAX band and X-band applications. The anchor slot to produce band stop feature is first time presented in this paper and it is a very effective method to produce band notch characteristics. The presentation of surface current shows that the band notched structures are not interfering each other and produces a favorable result. The proposed antenna significantly reduces the electromagnetic interference caused by the narrow band applications in UWB spectrum. The antenna low cross polarization is an added

advantage for the sort range communications. Some useful information are listed in below Table 3.

Table 3 Peak Realized gain and antenna efficiency antenna with respect to frequency

Ref. ()	Size (mm ³)	ϵ_r	No. of Notch	Band Notch Gain (dBi)	Frequency Band (GHz)
Seo et. al.	24x26x1.6	4.2	1 (WLAN)	-1.58	3-12
Kelly et. al.	31x40x0.635	10.2	1 (WLAN)	NA	3-10.28
Yadav et. al.	26x30x1.6	4.4	2 (WLAN, X-Band)	0, -16	3.1-10.6
Pandey et. al.	37x40x1.6	4.4	2 (WiMAX, WLAN)	-7, -6	2.5-11.5
Lin et. al.	30x40x1	4.5	2 (WiMAX, WLAN)	-11, -9	2.0-10.6
Xin et. al.	26x30x1.6	4.4	2 (WiMAX, WLAN)	-7, -4	3-11
Present Work	19.6x25x1.6	4.4	2 (WiMAX, X-Band)	-10, -12	2.5-11

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