Design of 3.5 GHz Band-Notched Compact Monopole UWB Antenna for Wireless Applications

Pratap N.Shinde
Department of E & TC, Sinhgad Academy of Engineering,Pune,India.
+91-9890812929

B. K.Mishra
Thakur College of Engineering & Technology Mumbai, India
+91-9821285825

AbhinavShastrakar
Department of E & TC, Sinhgad Academy of Engineering,Pune,India
+91-9579158684

ABSTRACT
The WiMAX (3.5 GHz) interference free ultrawideband (UWB) antenna with simplex monopole structure is proposed. An attempt of defected coplanar ground plane with the use of open-ended half wavelength L-shaped slot and stepped pentagonal radiating patch have been made for pure and frequency notched UWB operation withcompact size of 32 × 22 × 1.6 mm^3. The full UWB and band-notched designs are discussed in detail along with VSWR curves, surface current distribution and radiation patterns. The full UWB antenna reports a -10 dB impedance bandwidth of 7.65 GHz (2.80-10.45 GHz) while a band-notch design realizes two band having VSWR≤ 2 bandwidth 710 MHz and 6.59 GHz, which corresponds to FRB 23.31% and 93.84% respectively.

General Terms
Compact, Design, Reflection coefficient, WiMAX.

Keywords
Monopole antenna, notch-band, open ended L-shaped slot, staircase step stubs,UWB

1. INTRODUCTION
The federal communications Commission (FCC) declared the resolution about the ultra-widebandwidth of 7.5 GHz from 3.1 to 10.6 GHz [1] for UWB communication. Though the UWB bandwidth is very high and no one needs to take a user license for it, antenna designer must have to take a care of existing band interference with UWB. WLAN (802.11a 5.15-5.85 GHz), WiMAX (3.5 GHz/5.25-5.85) GHz, are the major existing bands which conflicts with the spectrum of UWB. The solution over problem of interference is the segmentation of the whole UWB band into sub-bands having individual bandwidth 500 MHz or minimum fractional bandwidth 25%. The design of UWB antennas with frequency notch rejection characteristics having large sizemay cause unsuitability when interfacing with microwave integrated circuits (MIC).The well known techniques used to design a notch filter includes circular and rectangular C [2-3], U [4-5], V [6], and L[7-8] shaped slots in the radiating area or ground plane of the antenna. The length of such slotsis designed at λ/4 of centre rejected frequency of interfering band.While designing a notched monopole wideband or UWB antenna the reported literature usesa rectangularor modified rectangular geometry for radiating patch as it easily maps the resonant frequency.

In this paper we thus propose UWB monopole antenna with a rare used shape like pentagon, which will give approximately 7.5 GHz bandwidth as compact full UWB antenna. Further the proposed monopole UWB design is made free from the interference ofWiMAX communication system operating at centre frequency 3.5 GHz. The desired band-notch at 3.5 GHz is illustrated in this paper by making a defection in coplanar ground plane by L shaped slot, which operates at λ /2 of centre rejection frequency of 3.5 GHz. The details of the proposed antenna are discussed in the following sections.

2. ANTENNA DESIGN
The detail configuration of proposed UWB monopole band-notched antenna is shown in Figure1. The antenna is fabricated on a cheap and readily available FR4 substrate with a thickness of 1.6 mm, dielectric constant ε_r = 4.3 and loss tangent tanδ = 0.02. Antenna uses coplanar wave guide (CPW) feed with defected rectangular ground plane. The 50Ω impedance matching in between patch, ground plane and feed is achieved by mutual coupling, which is generated by tapered ground plane of length l_1, staircase step shaped stubs at the bottom of patch and electromagnetic coupling gap g. The stepped pentagonal patch is excited by a feed line of signal width w_f =2.6 mm. The UWB resonance frequency is sensitive to coupling gap g, since it changes the effective shunt capacitor value of UWB equivalent circuit.

The proposed antenna have the dimension of 32 mm × 22 mm and its performance is analyzed by FEM (finite element method) electromagnetic software HFSS v.11 with the measurements taken on the network analyzer ZVS 40.

3. FULL BAND ANTENNA
In order to have ultra-wide bandwidth according to the resolution of FCC, the antenna uses optimized parameter as listed in Table 1. The two staircase step shaped impedance matching stub at the bottom of patch with appropriate feed width and radiating patch side length S gives 7.65 GHz bandwidth. The resonant frequency 6.44 GHz of this UWB antenna depends on the radius and in turn on side length of pentagonal radiating patch.

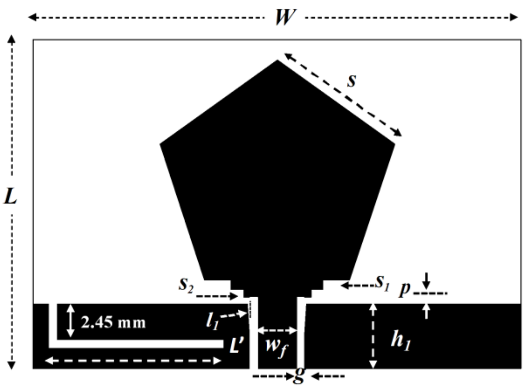


Fig 1: Geometry of the proposed monopole band-notched antenna. (*W*=32 mm, *L* = 22 mm, h_1 = 4.35mm, w_f=2.6 mm, *g* = 0.5 mm , *S* = 9.52, *p* = 0.45 mm, s_1 = 0.64 mm, s_2 = 0.5 mm, l_1 = 1.85 mm, *L'* = 11 mm)

Figure2 shows performance of antenna in terms of reflection coefficient S_{11} with respect to change in feed width. It indicates that the upper cutoff frequency of UWB band is sensitive to feed width with negligible shift in resonant frequency in the vicinity of 6 GHz. Such a wide band antenna can be a good candidate for indoor wireless communication system such as WiMAX, WLAN, and HIPERLAN, with high data rate.

Table 1. Optimized Parameters of notch-band monopole Antenna

Parameter	*W*	*L*	h_1	w_f	*g*	*S*
Unit (mm)	32	22	4.35	2.6	0.5	9.52
Parameter	*p*	l_1	s_1	s_2	*L'*	
Unit (mm)	0.45	1.85	0.64	0.5	11	

4. ANALYSIS OF NOTCH-BAND ANTENNA

Use of dedicated UWB spectrum for specific wireless communication system will be injustice with the antenna efficiency and results into wastage of bandwidth also. Hence segmentation of whole UWB with the use of notch filter will give rise dual advantage of multiple bands for various wireless communication system and interference avoidance with existing wireless bands. The full band antenna spectrum is modulated into band-notch behaviour with a small defection in ground by inserting an L shaped slot as shown in Figure1. The response of notch-band in comparison with full UWB band is shown in Figure.3. The centre frequency of rejected notch band is decided by the peripheral length of L-shaped slot which is embedded in ground. In this design the length L' of the slot is optimized to 11 mm with a total peripheral length 26.9 mm, which is close to λ /2 of 3.5 GHz resonant frequency of notch band. In order to reject a 3.5 GHz signal frequency, slotted ground act as a parallel LC resonator circuit, excited by fringing fields, which is coupled by a capacitor existing in between feed and CPW ground plane. The value of slot inductor is in relation with physical modified length of ground and width of slot decides the value of capacitor. The center rejected frequency f_r is given by equation (1)

$$f_r = \frac{c}{2\times(4.9+2L')\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (1)$$

Where *c* is the speed of light in free space and $\varepsilon_r$is the dielectric constant. Figure4 depicts the simulated VSWR against the frequency for different values of slot length L'. By increasing the length the length L' from 10.5 mm to 12 mm the notched band center frequency decreases from 3.72 GHz to 3.23 GHz. At optimized value of slot length the bandwidth of notch-band results into 320 MHz with center frequency 3.5 GHz. The desired destructive interference at 3.5 GHz is presented in Figure5, in the form of excited surface current distribution having maximum current concentration on slot length, which indicates rejection of notch-band of 3.5 GHz center frequency.

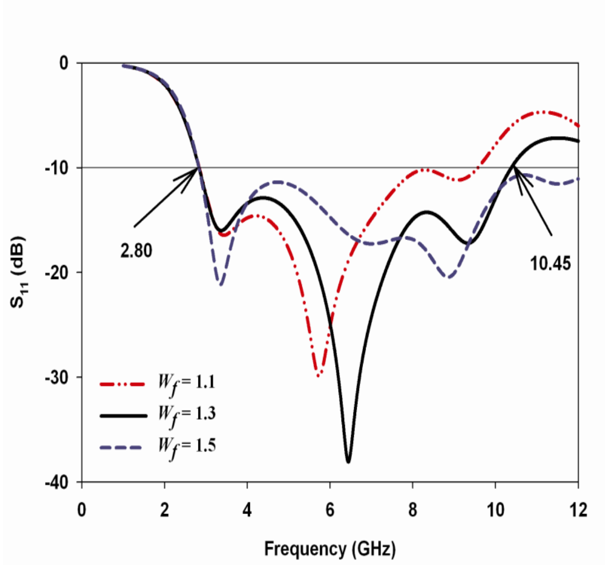


Fig 2: Simulated reflection coefficient of monopole full band antenna

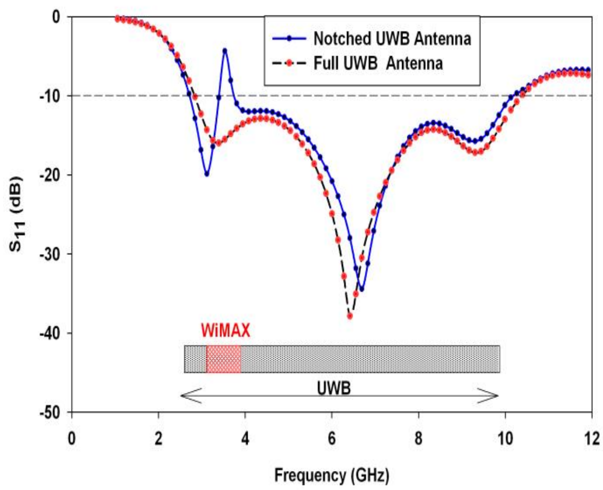


Fig 3: Comparison between simulated reflection coefficient of monopole full UWB antenna and band-notched UWB antenna

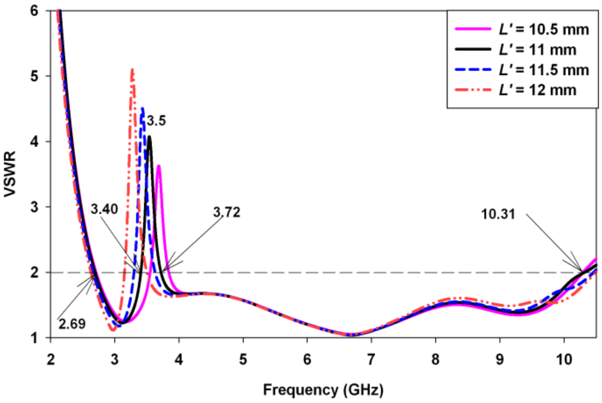


Fig 4: Effect of ground slot length on VSWR of monopole band-notched UWB antenna. Other parameters are as listed in Table 1

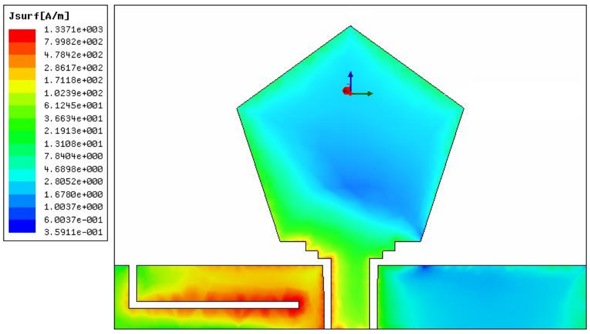
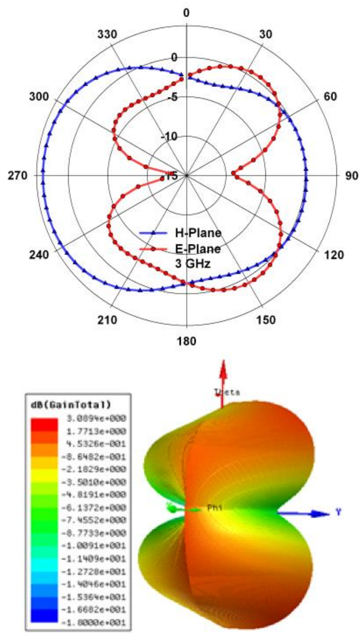
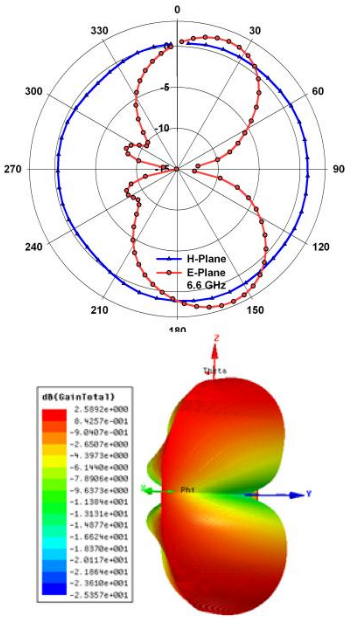


Fig 5: Surface current distribution of monopole UWB antenna with slot in ground



(a)



(b)

Fig 6: Radiation pattern of UWB band-notched antenna in 2D and 3D at (a) 3 GHz (b) 6 GHz

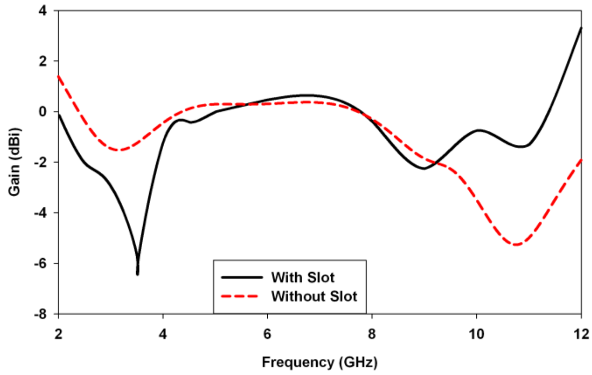


Fig 7: Gain of proposed band-notched monopole UWB antenna with and without slot

The measured two dimensional radiation patterns in E-plane and H-plane along with simulated three dimensional radiation patterns at 3 GHz and 6.6 GHz are presented in Figure6(a) and Figure6(b) respectively, indicating stability of antenna operation at higher frequency through omnidirectional pattern in the H-plane. It is also observed that proposed antenna exhibits bidirectional radiation pattern in E-plane.Figure7 shows the measured gain plot of notched band in comparison with simulated gain plot of full UWB band. The gain sharply decreases at 3.5 GHz with a magnitude of -6.4 dBi, while in the rest of the passband the gain is stably close to 0.7 dBi.

5. CONCLUSION

A compact monopole band-notched UWB antenna was proposed and successfully demonstrated for ultrawideband wireless applications with simplex geometry. The 320 MHz notch-bandwidth centered at 3.5 GHz was realized to remove WiMAX system interference with FCC UWB. It is achieved by embedding a simple open ended half wavelength L- shaped slot in coplanar ground plane. The magnitude of VSWR as well as the gain needs enhancement for maximum coverage in indoor wireless applications.

6. REFERENCES

[1] First Report and order, “Revision of part 15 of the commission’sRule Regarding Ultra-Wideband Transmission System FCC 02-48,” Federal Communications Commission, 2002.

[2] Qing-Xin Chu and Ying-Ying Yang, “A Compact Ultrawidwband Antenna With 3.4/5.5 GHz Dual Band-Notched Characteristics,” IEEE Trans. Antennas Propag., vol. 56, no. 12, Dec. 2008,pp. 3637–3644.

[3] Y. C. Lin and K. J. Hung, “Compact ultra-wideband rectangularaperture antenna and band-notched designs,” IEEE Trans Antennas Propag., vol. 54, no. 11, Nov. 2006, pp. 3075–3081.

[4] Y. J. Cho, K. H. Kim, D. H. Choi, S. S. Lee, and S. O. Park, “A miniature UWB planar monopole antenna with 5-GHz band-rejection filter and the time-domain characteristics,” IEEE Trans. Antennas Propag., vol. 54, no. 5, May 2006, pp. 1453–1460.

[5] W. S. Lee, D. Z. Kim, K. J. Kim, and J. W. Yu, “Wideband planar monopole antennas with dual band-notched characteristics,” IEEE Trans. Microw. Theory Tech., vol. 54, no. 6, Jun. 2006, pp. 2800–2806.

[6] Y. Kim and D. H. Kwon, “CPW-FED planar ultra wideband antenna having a frequency band notch function,” Electron. Lett., vol. 40, no.7, April 2004,pp. 403–405.

[7] Reza Zaker, ChangizGhobadi, and JavadNourinia, “Bandwidth Enhancement of Novel Compact Single andDual Band-Notched Printed Monopole AntennaWith a Pair of L-Shaped Slots”, IEEE Trans. Antennas Propag., vol. 57, no. 12, pp., Dec. 2009, 3978–3983.

[8] M. Mehranpour, J. Nourinia, Ch. Ghobadi, and M. Ojaroudi, “ Dual Band-Notched Square Monopole Antennafor Ultrawideband Applications”,IEEE Antennas Wireless Propag. Lett., vol. 11, 2012, pp. 172–175.