Design and Modification of Circular Monpole UWB Antenna for WPAN Application

P.S.Ashtankar[1], Dr.C.G.Dethe[2]
[1]Department of Electronics &Communication Engineering, Kits, Ramtek(M.S.),India-44110
[2]Priyadarshini Institute of Engineering & Technology, Nagpur (M.S.), India-440019
psashtankar@gmail.com,cgdethe@gmail.com

Abstract:
The basic circular monopole antenna exhibits a 10 dB return loss bandwidth over the entire frequency band, the paper proposed a modified version of simple circular monopole antenna for WPAN application. The antenna offers excellent performance in the range of 2-12 GHz.. The antenna is designed on FR4 substrate and fed with 50 ohms micro strip feed line. The antenna is suitable for operating frequency of 7 GHz. It is shown that return loss of the antennas at 7 GHz is better than -10 dB and VSWR obtained is less than 2. Proposed geometry is design and simulated using HFSS11 Details of the proposed antenna design and measured results are presented.
Index Terms: Wireless communication, UWB, circular monopole, WPAN

1.Introduction:

In recent years, more interests have been put into WPAN technology. The future WPAN aims to provide reliable wireless connections between computers, portable devices and consumer electronics within a short range. Furthermore, fast data storage and exchange between these devices will also be accomplished. This requires a data rate which is much higher than what can be achieved by existing wireless technologies.UWB has an ultra wide frequency bandwidth; it can achieve huge capacity as high as hundreds of Mbps or even several Gbps with distances from 1 to 10 meters [26]. In spreading signals over very wide bandwidth, the UWB concept is especially attractive since it facilitates optimal sharing of a given bandwidth between different systems and applications. This caused an UWB technology is a promising technology for WPAN due to its unique characteristics. Ultra-Wideband (UWB) was approved by the Federal Communications Commission (FCC) in Mar. 2002 for unlicensed operation in the 3.1-10.6 GHz band subject to modified Part 15 rules. The rule limits the emitted *power spectral density (p.s.d)* from a UWB source measured in a 1 MHz bandwidth at the output of an isotropic transmit antenna at a reference distance to that shown in Figure1. Further, the transmitted signal must instantaneously occupy either i) a fractional bandwidth in excess of 20% of the center frequency or ii) in excess of 500 MHz of absolute bandwidth to be classified as a UWB signal. The maximum allowable p.s.d for UWB transmission of -41.3 dBm/MHz corresponds to approximately 0.5 mW of average transmit power when the entire 3.1-10.6 GHz band is used, effectively limiting UWB links to short ranges. Nevertheless, the potential for exploiting such low power UWB links for *high data rate* wireless PAN connectivity (in excess of 100 Mbps) at ranges up to 10 m particularly for in-home networking applications has led to considerable recent interest in this technology .Ultra-wideband (UWB) radio technologies draw big attentions considering the applications to the short range wireless communication, ultra-low power communication, ultra-high resolution radar etc., among them, the standardization of the UWB radio is ongoing under IEEE 802.15 WPAN High Rate Alternative PHY Task Group 3a (IEEE802.15.3a) [1,21,22] and wireless personal area network (WPAN) is originated by the Bluetooth (IEEE802.15.1). IEEE802.15.3a is trying to establish the new standard of WPAN to drastically increase the data rate, which is a weak point of Bluetooth. Now IEEE802.15.3a considers the use of UWB, following the tentative regulation of FCC (Federal Communications Commission, USA), to achieve the bit rate of 110 Mb/s at 10 m and 200 Mb/s at 4 m [3] Although the standardization has been at the final voting stage for more than half a year, the first candidate Multi-Band OFDM [4] has not been able to gain the required 75 % approval, and has been in competition with the second candidate DS-UWB [5].

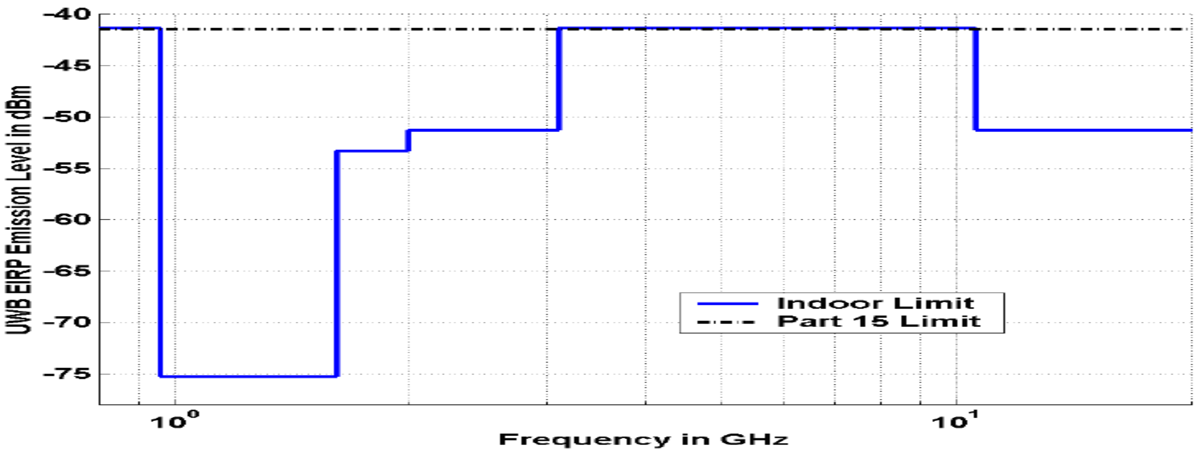


Figure 1: UWB Spectral Mask Per FCC (Modified) Part 15 Rules [1]

1.1 IEEE 802.15 WPAN STANDARDS:

Originally, the IEEE 802.15 group was the Bluetooth™ group, but it has evolved to include other short-range Wireless Personal Area Network (WPAN) systems. The initial version, 802.15.1, was adapted from the Bluetooth specification and is fully compatible with Bluetooth 1.1. As it is now described by the IEEE, “The IEEE 802.15 Working Group proposes two general categories of 802.15, called TG4 (low rate) and TG3 (high rate). The TG4 version provides data speeds of 20 Kbps or 250 Kbps. The TG3 version supports data speeds ranging from 11 Mbps to 55 Mbps. Additional features include the use of up to 254 network devices, dynamic device addressing, support for devices in which latency is critical, full handshaking, security provisions, and power management. There will be 16 channels in the 2.4-GHz band, 10 channels in the 915-MHz band, and one channel in the 868-MHz band.” The 802.15.3 Standard for high data rate services, which continues to be reviewed and enhanced, includes the following features and goals: • Data rates of 11, 22, 33, 44 and 55 Mbps.

- Quality of Service (QoS) isochronous protocol
- Ad hoc peer-to-peer networking
- Security
- Low power consumption
- Low cost

The higher data rate of this standard is designed to meet the requirements of portable consumer imaging and multimedia applications. The IEEE 802.15 Task Group 5 is studying mesh networking, determining the necessary mechanisms that must be present in the PHY and MAC layers of WPANs to enable mesh networking, in both full mesh and partial mesh topologies. Mesh networks are useful for intending network coverage without increasing transmit power or receive sensitivity, enhancing reliability with redundant routing, easy network configuration and, ultimately, longer device battery life due to fewer retransmissions. The IEEE 802.15.3 Study Group 3c, formed in March 2004, is developing a millimeter-wave-based alternative physical layer (PHY) for the existing 802.15.3 WPAN Standard 802.15.3-2003. This mm- Wave WPAN will operate in a band that includes the 57-64 GHz unlicensed band. The millimeter-wave WPAN will allow very high data rate applications such as high-speed internet access, streaming content download (video on demand, HDTV, home theater, etc.), real time streaming and wireless data bus for cable replacement. Optional data rates in excess of 2 Gbps are to be provided.

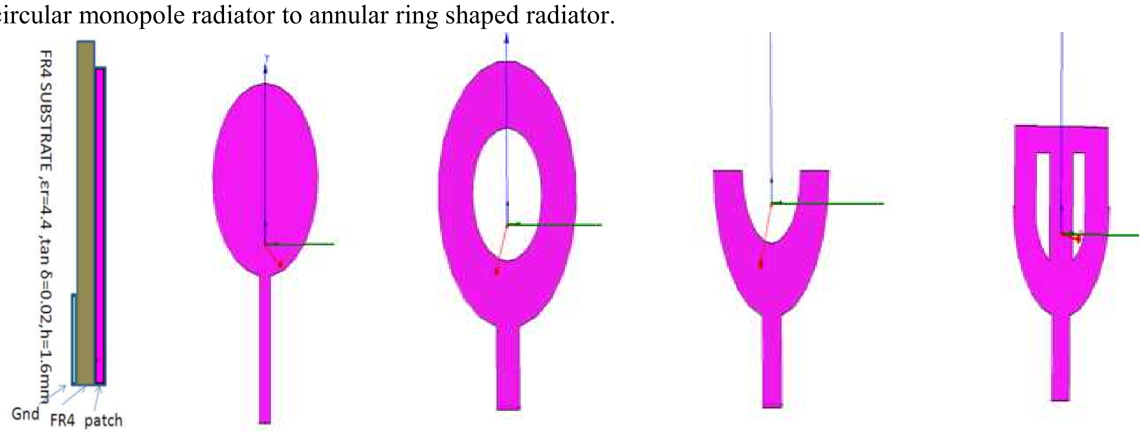
Table 1 lists a variety of wireless applications in the WPAN space and their estimated requirements for data rates.

Application	Min Data Rate	Max Data Rate
H.323 / T.120 Video Conferencing	188+ Mbps	1.4+ Gbps
Home Theater	43 Mbps	56.8 Mbps
Interactive Application (e.g. gaming)	76.8+ Mbps	unknown
Content Downloading (e.g. photos, MP3, CD, movies)	90+ Mbps	unknown

Table1: Estimated Data rates for various WPAN applications [21, 22, 23]

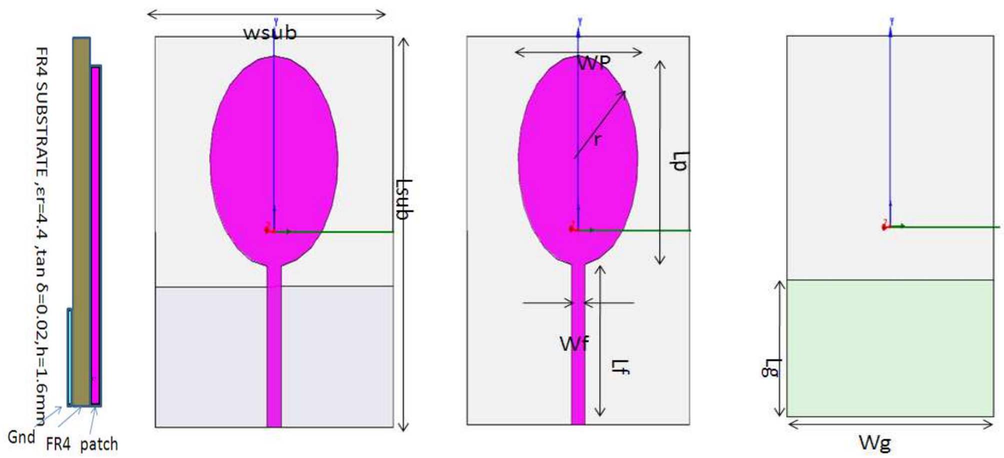
2.Antenna design and configuration:

Figure2: shows the evolution of the proposed printed monopole antenna. The structure is evolved from the circular monopole radiator to annular ring shaped radiator.



Circular monopole annular monopole Fork proposed

Figure 2:.Evolution of the proposed dual band antenna.



(a) Whole structure (b) Top view (c) Bottom vi

Figure 3: Geometry of circular monopole antenna

The geometry of the proposed antenna is shown in Fig. 4 is fed by a 50- microstrip line and fabricated on a 1.6-mm-thick FR4 substrate with 25× 25 mm surface area. The relative permittivity and loss tangent of the substrate is 4.4 and 0.02, respectively. The antenna structure is a variation of a circular monopole antenna. The radius (r) of the circular monopole [10] is obtained by using the equation no 1.

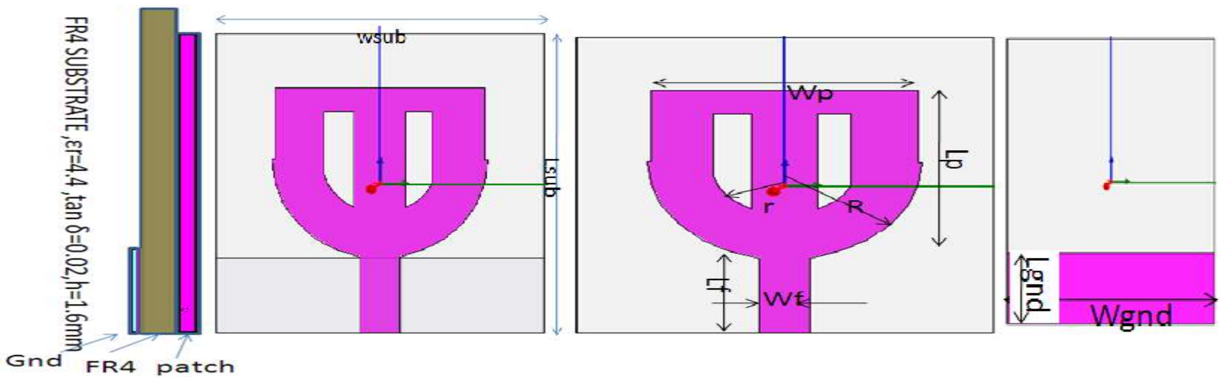
$$f_L = \frac{7.2}{2.25.\, r + g}\ \text{GHz} \qquad (1)$$

The proposed UWB antenna is a variation of circular monopole antenna. Initially a circular monopole antenna of radius `r' is designed and optimized to achieve the desired UWB response. Since the current is mainly concentrated along the periphery of the circular monopole antenna, therefore, central portion of the circular monopole of radius `r' can be removed with negligible effect on impedance bandwidth or radiation characteristics and resulting in an annular ring
Monopole antenna.

Table 2. Optimum dimensions of the proposed antenna (all dimensions are in mm).

Parameter	Wsub	Lsub	Wp	Lp	r	R	Wg	Lg	Wf	g
Circular monopole	50	50	27	21	13.5	--	25	20	3	0.5
Proposed Antenna	25	25	14	12	4.2	8.4	25	6.2	3	1

There after U-shape monopole antenna is designed without affecting the UWB impedance bandwidth.Where g is the gap between the radiating patch and ground plane, with the change in Lg value(length of ground plane) the g will change and fL is the lowest resonant frequency corresponding to VSWR=2 .

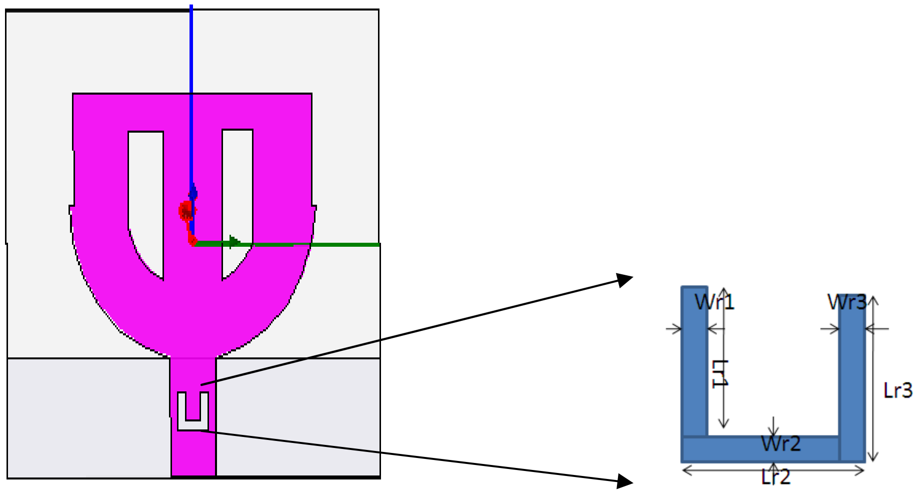


a) Whole structure (b) Top view c) Bottom view

Figure 4: Geometry of proposed antenna without U slot

3. Slotted uwb antenna design:

Recently, more and more band-notched UWB antenna designs have been proposed [9,16,17]. In this paper, we propose a low cost and compact microstrip line fed printed antenna with the U shape slot on the feed line. . The U shape slot in the feed line patch is used to reject the frequency band (2-4.26 GHz) limited by WiMAX and C-band systems. Details of the antenna design and simulation are presented and the measured results are given in order to demonstrate the performance of the proposed antenna. Equation 2, which is based on the perfect magnetic wall assumption, yields resonant frequencies



a) Whole structure c) Bottom view

Figure 5: Geometry of proposed antenna with U slot

which differ from measurements by about 20%. To take into account the effect of fringing field, an effective radius was introduced. This was obtained by considering the radius of an ideal circular parallel plate capacitor which would yield the same static capacitance after fringing is taken into account. A detailed calculation yields the formula.[26,27,28]

$$f_{\mathrm{WiMAX-notch}} = \frac{c}{2M\sqrt{\varepsilon_{\mathrm{eff}}}} \qquad (2)$$

where M= [Wr1×Lr1+Wr2×Lr2+Wr3×Lr3] is the total length of the U-shaped slot, εeff is the effective dielectric constant, and c isthe speed of the light

$$\varepsilon_{\mathrm{eff}} = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2}\left(\sqrt{1 + \frac{12h}{W_g}}\right)^{-1} \qquad (3)$$

Table 3. Optimum dimensions of the proposed U- SLOT (all dimensions are in mm).

Parameter	Wr1	Lr1	Wr2	Lr2	Wr3	Lr3
U-slote	0.6	1.5	1.5	0.6	0.6	1.5

4.Paramentic study

Parametric study has been conducted to optimize the design of the antenna. This study is crucial as it gives approximation measure before antenna fabrication can be done. The performance of annular shaped dual band antenna with WLAN band notched characteristic depends on number of parameters, such as gap (g) between radiating patch and ground plane, width (ws) and length (ls) of the substrate, length and width of the ground plane, width (w) and length (l) of the symmetrical step slot in radiating patch (rectangular strip inside circular annular ring and inner (r) and outer radius (R) annular ring. Beside these, antenna performance also depends on ground plane size and shape. The parameters which have significant effects on dual band with WLAN band notched characteristic are discussed and their parametric studies are reported in this section. The gap `g' between the radiating patch and the ground plane affects the impedance bandwidth as it acts as a matching network. The impedance bandwidth of the proposed antenna at different Lg is shown in Figure7. The optimum impedance bandwidth is obtained at Lg=6mm, the capacitance that results from the spacing between edge of ground plane and radiating patch reasonably balances the inductance of the antenna. Figure 8 shows return loss S11 (dB)

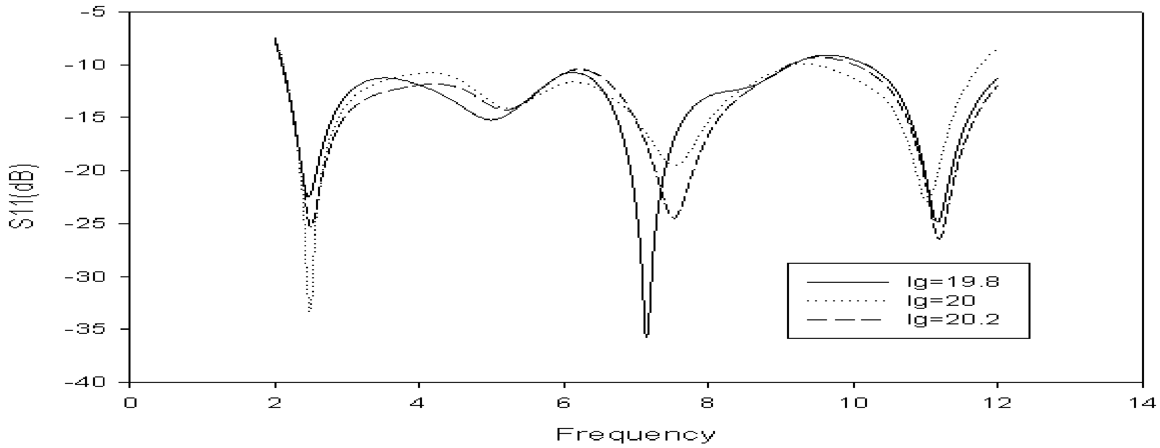


Figure6: Simulated return loss (S11) curves of Circular monopole antenna for different ground length (ref to fig3)

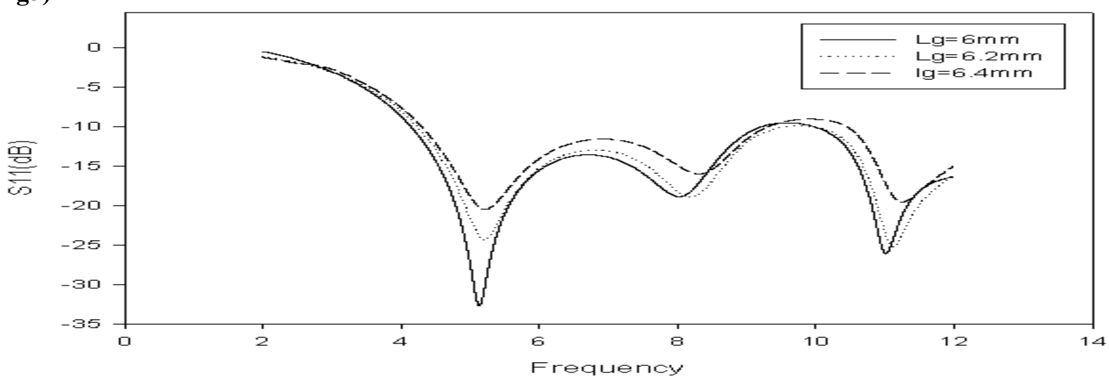


Figure7: Simulated return loss (S11) curves of proposed antenna (without U slot) for different ground length

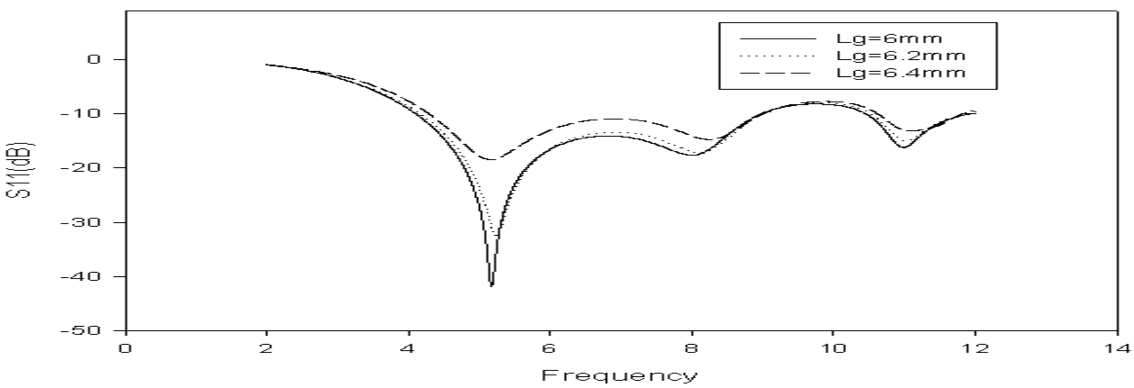
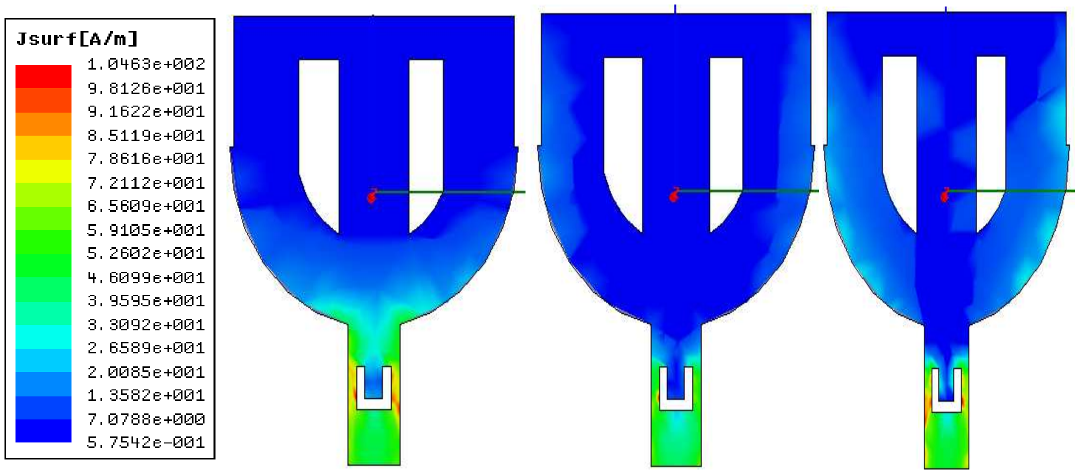


Figure8: Simulated return loss (S11) curves of proposed antenna (with U slot)

Over function of outer radius. It is observed that for Lgnd of 6.4 mm, the antenna is able to operate as a narrowband antenna. However, the return loss of the antenna improves dramatically when the length ground patch reduces gradually and the best result is obtained at the height of ground plane, Lgnd of 6 mm. The partial ground shows better return loss compared to full ground patch on the bottom because the antenna is transformed from patch-type to monopole-type by the partial ground. In order to further improve its overall bandwidth two steps of feed line can be used but that may be used for different application. The feed line is connected to SMA center pin with width of 3 mm.



(a) 3GHz (b) 5GHz (c) 7GHz

Figure 9: Surface current distributions of proposed antenna at 3, 5 and 7 GHz

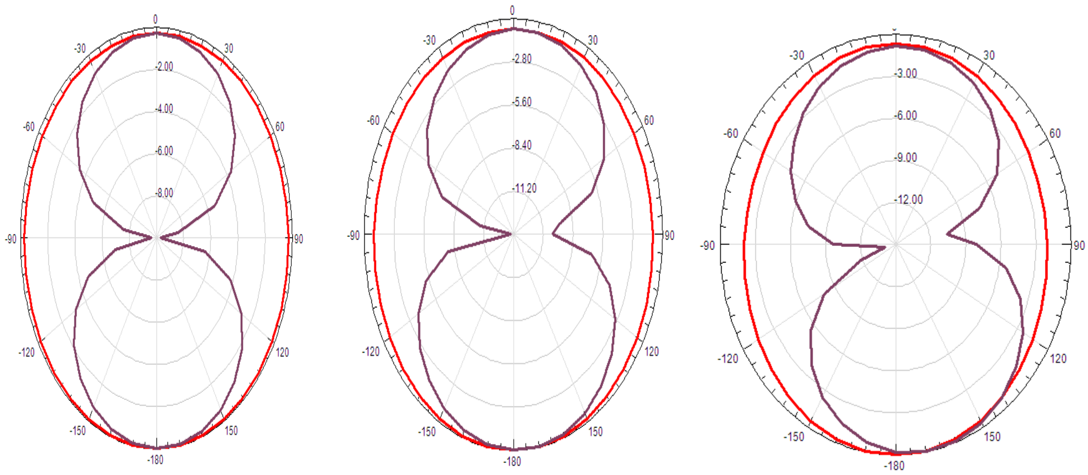


Figure10: radiation patterns (retotal) with 10 dB normalized value in the φ =0°and φ =90° planes of a proposed patch with εr =4.4 at 3,5,7GHZ

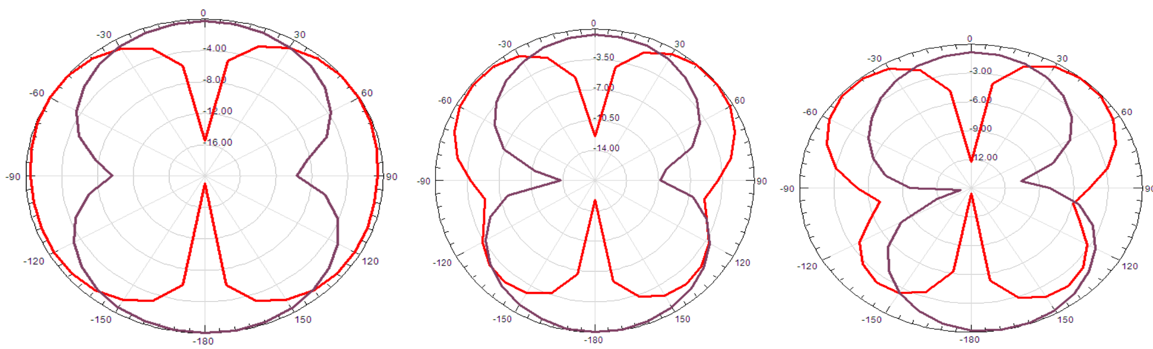


Figure11: radiation pattern (re Phi with 10dB normalized value) in the φ =0°and φ =90° planes of a proposed patch with εr =4.4 at 3,5,7GHZ

5. Fabrication and measured result

The antenna structure is fabricated on a printed circuit board (PCB) using Photolithography technique and tested. The fabricated antenna is shown in Figure12. Below fig clearly show the process for S11 (dB) measurement. The measured results reasonably agree with simulated results. The proposed antenna rejects the WiMAX band and still performs good impedance matching over the UWB band.

(a)Top View (b) Bottom View (c) Antenna under Test

Figure12:.Photograph of the proposed antenna

6.Conclusion:

The printed spatula shape monopole antenna fed by microstrip line is investigated in this paper. It has been shown that the performance of the antenna in terms of its frequency domain characteristics is mostly dependent on the feed gap h, the width of the ground plane W and the dimension of the ant. The first resonant frequency is directly associated with the dimension of the two slots on the radiating patch of the antenna because the current is mainly distributed along the edge of the radiating patch. This paper investigates the effect of U slot on the feed line to antenna performance in terms of the radiation pattern and reflection coefficient. To control antenna behavior, it is necessary to observe the current distribution. The proposed antenna is fabricated on FR4 with εr=4.4, tanδ=0.02 and the thickness is 1.6mm with the proposed dimension of 25 x 25 mm×1.6mm. The simulated results of proposed antenna for return loss is less than -10 dB and VSWR is less than 2 satisfies the system requirements for S-DMB, WiBro, WLAN, CMMB and WPAN application at the operating frequency of 7 GHz.

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Bio date of author(s)

Dr. Chandrasekhar G. Dethe received his M.Tech. Degree in Electronics Engineering from VNIT, Nagpur. ,and Ph.D. degree from Amravati University, Amravati.His Ph.D. Thesis titled "***IP NETWORK TRAFIC MEASUREMENT, ANALYSIS AND MODELING"***. He worked as an Assistant Professor at SSGM, College of Engineering Shegaon from 1999 to 2005, later on he joined as a professor and in charge of research and development activity at YCCE, Nagpur. He is currently working as a principal of PIET, Nagpur. His field of specialization includes digital communication, Data network, Signal Processing. His papers are published in National and International Journals including IEEE proceedings. He is a fellow of IE and IETE and Life member of ISTE.

Mr. Pankaj S. Ashtankar obtained his Bachelor's and master's Degree in Electronics Engineering from RTM, Nagpur University. He is Pursuing Ph.D. in the field of UWB antenna design. He is Asst. Prof. in ECE Dept. KITS; Ramtek He attended and presented several papers in National, international conferences and symposium. He has been closely Associated with various continuing education programmes in the area of communication Engineering conducted by K.I.T.S, Ramtek. His area of interest is Ultra wide band and RF antenna design. He is member of IETE, Member of IE (India), Member of International Association of Engineers, Member of Antenna test and measurement society of India, Member of System society of India and Life member of ISTE.