A Compact Ultra Wide Band Antenna Using Slots For Internet of Things Applications

[1]Raksha S. Sherke,[2]Ms. Prachi C. Kamble,[3]Dr. Lakshmappa K Ragha

Department of Electronics Engineering
Terna Engineering College
Navi Mumbai,India
E-mail-(1) rakshasherke@gmail.com

Abstract— **In this paper, a small size and low cost antenna is proposed suitable for Ultra Wide Band (UWB) short-range communication applications having reduced interference for multiband operation at WiMax, C-band and X-band systems. The designed antenna covers the ultra wide band range (3.1 GHz to 10.6 GHz) and has Voltage standing wave ratio less than 2 and the return loss is less than -10db, reducing the interference due to narrow band systems. The L and U shaped slots creates multiple bands at 3.36 GHz and 4.4 GHz respectively, due to which a notch is created at 3.6 GHz to reduce interference at this frequency. The C-shaped slots are inserted to obtain multiband in X-band at 7.36 GHz frequency ,thereby notching the region of 7.7 GHz to 9 GHz. The antenna shows nearly omni-directional radiation pattern in H-plane. The simulation results are done by using the ANSOFT High Frequency Structure Simulator (HFSS) and measurement is done using Agilent N9916A FieldFox handheld vector network analyzer.**

Keywords— Slot Antenna; Ultra-Wide Band; Multi-band antenna; Band-notch.

I. INTRODUCTION

At present, there is an increased interest in Ultra-wideband (UWB) technology for its use in several applications. In 2002 the US Federal Communication Commission permitted the authorization for using the unlicensed frequency band from 3.1GHz to 10.6 GHz for commercial communication band, since then there has been a great development in UWB technology [1].

The existing third-generation (3G) communication technology provides us with many wide services such as video telephony, enhanced video/music download, fast internet access, as well as digital voice services, but UWB –as a new technology is very promising for many reasons. The FCC has allocated an absolute bandwidth of up to 7.5 GHz which is about 110% fractional bandwidth of the center frequency. This large bandwidth is available for radar and safety applications as well as for high data rate communications. The UWB technology has advantage from the power consumption point of view also [2]. There are many challenges in dealing with the new emerging technologies like UWB technology. One of these challenges in UWB technology is to design an antenna element that can operate effectively in the entire UWB frequency band. Secondly, to design an antenna which can operate at multiple frequencies with reduced interference.

Recently, Ultra wide band antenna with upper WLAN band notched is presented, where the band notched is realized using meander shaped slots in the radiation patch[3]. A Microstrip antenna included with L shape slot, where slots used in the design gave rise to Multiband behavior[4]. A new technique of converting from Wideband to Multiband behavior is observed in the design. Initially a wide range from 3.5 GHz to 6 GHz is covered in the original design by manipulating the design it is made dual band antenna, by initiating a new slot in the design the size of slot is nearly $\lambda g/2$ [4].

For obtaining wideband, a circular monopole patch is used along with variations in the patch design and the wideband antenna has covered all Wi-Fi and WiMax frequency bands has been designed and implemented on FR4 substrate successfully, where the wideband antenna covers the frequency range of 2.3 to 6 GHz[5]. Wideband characteristic is obtained by modifying the circular patch with square ground plane by truncating the patch and also by adjusting the square ground plane for widening the bandwidth at the higher frequency band[5]. An antenna is presented with two C-shaped slots in the ground plane and a bevel structure in the ground plane, where the use of bevel structure is to enhance the bandwidth and a pair of C-shaped slots is etched in ground plane to get a notch in X-band satellite communication band (7.1 to 7.76 GHz)[6]. Planar monopole antennas are of simple structure, low costs and wide Bandwidth. Diamond shaped patch is used to cover ultra wideband range and for better impedance matching steps are provided near the feed point[7]. A diamond shaped microstrip patch antenna with narrow strips leads to a small size planar multiband monopole antenna[7].

To overcome the electromagnetic interferences with existing systems, it is necessary to design antennas with multiband filtering characteristic. Recently, various types of L-shaped , U-shaped ,C-shaped and meander shaped slot loaded antennas have been presented and implemented in different applications such as, extinguish spurious responses of filtering characteristics, to create frequency band notching characteristics[8-10].

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Here in this paper, we propose an UWB antenna which consists of three slots namely L-shaped, U-shaped and C-shaped slots etched on the ground plane to obtain multi band operation and notching the narrow band region of 3.30 GHz to 3.80 GHz and 7.7 GHz to 9 GHz and reducing interference due to narrow band systems.

II. ANTENNA CONFIGURATION AND DESIGN

All the simulation and optimization of the proposed antenna has been done with the Ansoft HFSS 13.The geometry of the proposed compact UWB antenna is illustrated in Fig.1. and Fig.2. The photograph of the fabricated antenna is shown in Fig.3.

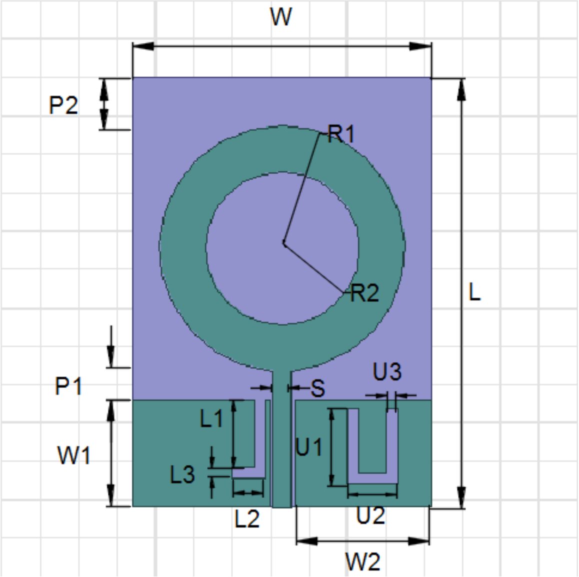

Fig. 1: Front view of proposed antenna.

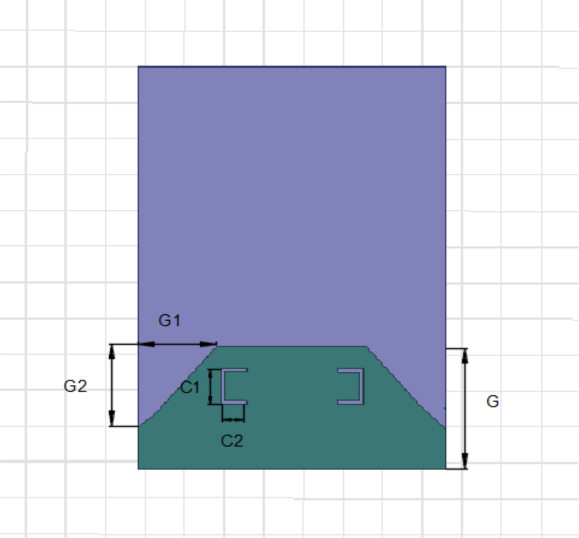

Fig. 2: Back view of proposed antenna.

The proposed antenna consists of a ring shaped patch in order to obtain the wide band characteristics. The proposed antenna is designed on the FR4 substrate with a relative dielectric constant of 4.4, loss tangent of 0.02 and thickness of 0.8 mm. The radiating patch is fed by a 50 Ω microstrip transmission line with a width of 2.4 mm. The overall dimensions of the proposed antenna is 55.9 mm × 39 mm.

An R2 circular slot is etched from the design to make it an annular ring. Further, an L-shaped slot has been etched with defected ground [4] in design with another U-shaped slot near the feed point for bands at 3.36 GHz and 4.4 GHz respectively. Notch is created at 3.6 GHz due to the insertion of L-shaped and U-shaped slots in the ground plane. The performance of the antenna such as return loss, Voltage Standing Wave Ratio (VSWR), radiation efficiency, radiation plots, and Smith chart are addressed in this work. The antenna designed in this project uses two C-shaped slot for obtaining multiband at 7.36 GHz [6]. For supporting wider applications upper bevel cut was made in the ground plane.

The dimensions of the proposed antenna after optimization are given in Table I.

TABLE I. DIMENSIONS OF THE PROPOSED ANTENNA (UNIT: MM)

W	L	R1	R2	P1	P2	L1	L2	L3	S
39	55.9	16	10	1.9	1	12.25	3	1.5	2.4

W1	W2	U1	U2	U3	C1	C2	G	G1	G2
16	15.1	10	5.5	1.5	7	3	17	7	8.5

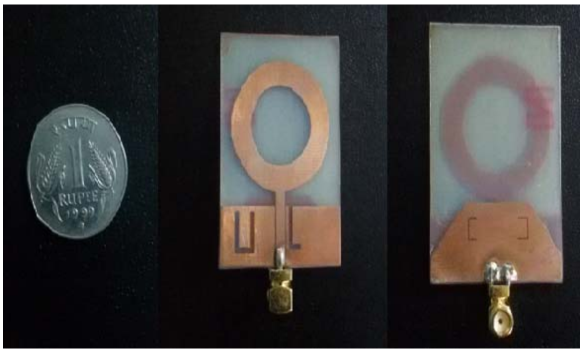

Fig. 3: Photograph of fabricated prototype antenna.

III. RESULTS AND ANALYSIS

A. *Return Loss (S11)*

Reflection coefficient, Γ, or S- parameters, S11 is determined by the impedance mismatch to the antenna. The performance of the antenna can be characterized by the return loss, $RL = 20\log(|\Gamma|)$, or by the voltage standing wave ratio, $VSWR = (1 + |\Gamma|)/(1 - |\Gamma|)$. A good return loss of about -16 dB at 3.36 GHz, -15 dB at 4.4 GHz and -17 dB at 7.36 GHz is obtained for the proposed antenna. A return loss of suggested antenna has been displayed in Fig.4 that shows that simulated results are in good agreement with measured results. The discrepancy in simulated results and measured results is resulting due to the cable & connector losses not considered during measurements and tolerance in fabrication.

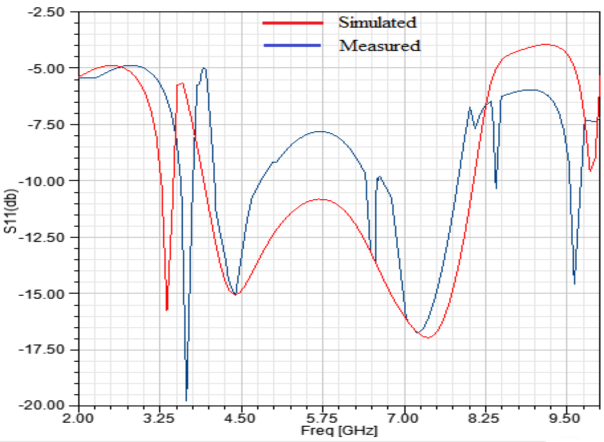

Fig. 4: Simulated and measured S11 parameter.

B. *Voltage Standing Wave Ratio*

The Voltage Standing Wave Ratio (VSWR) of the proposed antenna is shown in Fig.5. The VSWR shows that how well are the two transmission lines matched. The VSWR value ranges from one to infinity, where the value of one means that the two transmission lines are perfectly matched. With regards to antenna design, any reflections between the antenna and the load will reduce the effectiveness of the antenna, so a VSWR that is as low as possible is desired. The suggested antenna successfully exhibits multiband behaviour at Wi-Max (3.8 GHz – 4.2 GHz), C-band (4.4 GHz – 5 GHz) and X-band (7.1GHz-7.6 GHz) systems , maintaining broadband performance for VSWR less than 2.

C. *Smith Chart Analysis*

The smith chart is used to find the impedance of the antenna. The input impedance must be as close as possible to the characteristic impedance in order to minimize the signal reflections. Fig. 6 shows the smith chart of the proposed antenna. The smith chart shows 40.1 ohms impedance at 3.36 GHz , 64.9 ohms impedance at 4.4 GHz and 40.8 ohms impedance at 7.36 GHz which is close to characteristic impedance 50 ohms marked as m1,m2 and m3 respectively.

D. *Radiation Efficiency*

The return loss (S11) and radiation efficiency are shown in Fig.7. It is clear that the antenna has a good radiation efficiency in the passband which is above 80%. While in rejection band it drops drops to 46% at 3.6 GHz and to 65 % at 7.7 GHz to 9 GHz.

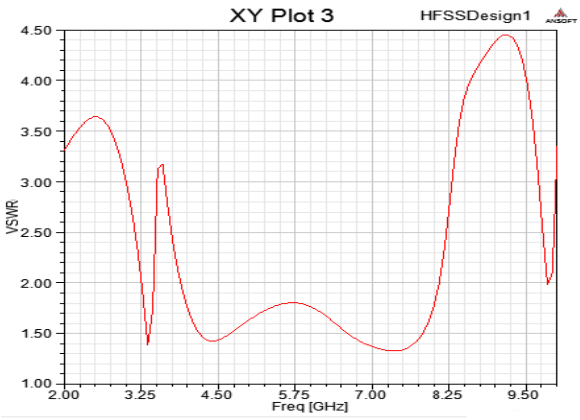

Fig. 5: Simulated VSWR parameter.

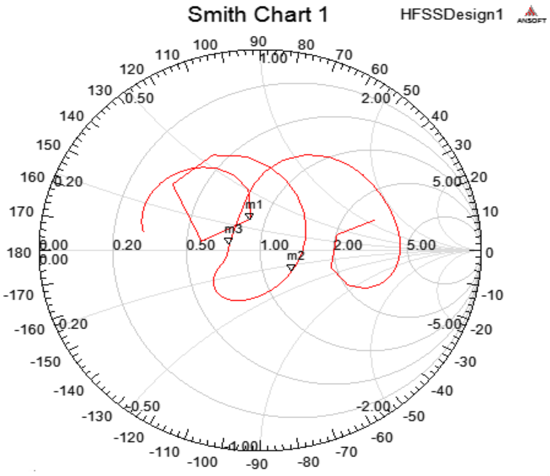

Fig. 6: Smith chart for impedance measurement.

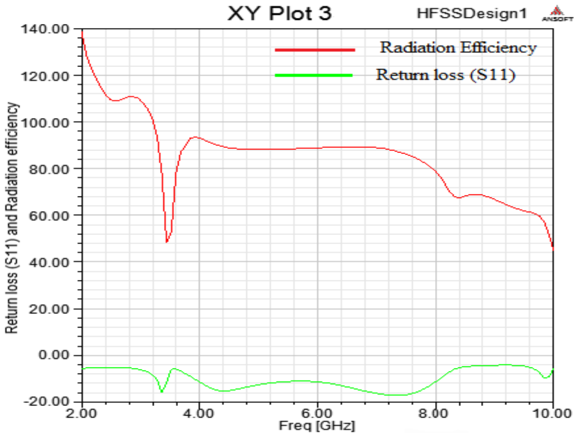

Fig. 7: Return loss (S11) and Efficiency of proposed antenna.

E. Radiation Pattern

Also, the antenna radiation patterns at 3.36 GHz, 4.4 GHz and 7.36 GHz were simulated for H-plane and E-plane and illustrated in Fig.8, Fig.9. and Fig.10. respectively. It is noted that the radiation pattern in the y-z plane (H-plane) is nearly omni-directional. But, the antenna exhibits a dipole-like radiation pattern in the x-y plane (E-plane).

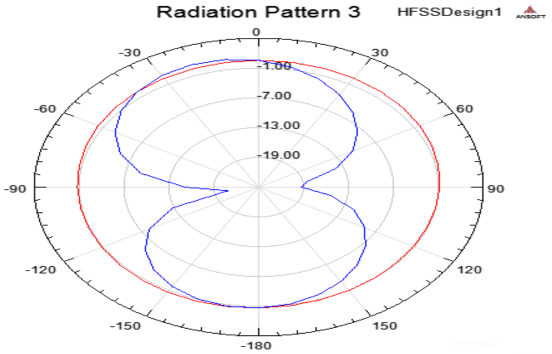

Fig. 8: Radiation pattern of proposed antenna at 3.36 GHz.

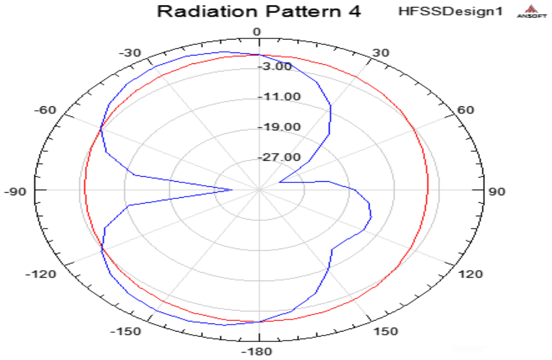

Fig. 9: Radiation pattern of proposed antenna at 4.4 GHz.

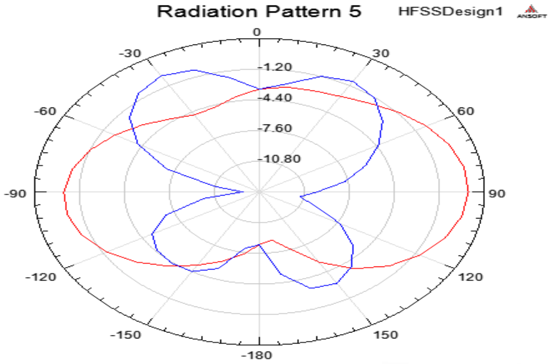

Fig. 10: Radiation pattern of proposed antenna at 7.36 GHz.

IV. CONCLUSION

The antenna presented in this paper can operate at multiple frequencies effectively in the ultra wide band frequency range with reduced interferences. The proposed antenna is a low cost and has small size which is easy to be integrated in small devices. The antenna shows a good return loss and VSWR parameters at Wi-Max, C-band and X-band frequency bands which indicates it's usefulness for communication in these areas. The radiation pattern in the y-z plane (H-plane) is nearly omni-directional and has a good radiation efficiency which is above 80%. With these merits, the proposed antenna system can be a good candidate for UWB applications.

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