Mushroom Shape EBG Structure and Right-Angled Slot Loaded Dual Band Notched UWB Antenna

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Abstract -A compact ultra-wideband micro strip antenna with dual band-notched characteristics is presented in this paper. A *Symmetrical Right Angled Slot Pair* (SRASP) and a pair of *Mushroom Electromagnetic Band Gap* (M-EBG) structure is used to produce dual band-notched characteristics for C-Band (3.8-4.2 GHz) and WLAN (5.1-5.8 GHz), respectively. Analysis of SRASP and M-EBG shows, EBG structure has advantages over SRASP to design band notches, in terms of tunable notched frequency and notch-bandwidth controllable capacity. The proposed antenna prototype is fabricated and measured. The measured and simulated results are presented to analyses the band notching characteristics.

***Keywords*— M-EBG Antenna; Dual Band-Stop Antenna; UWB Antenna; SRASP Antenna; Slot Loaded Antenna**

1. I. INTRODUCTION

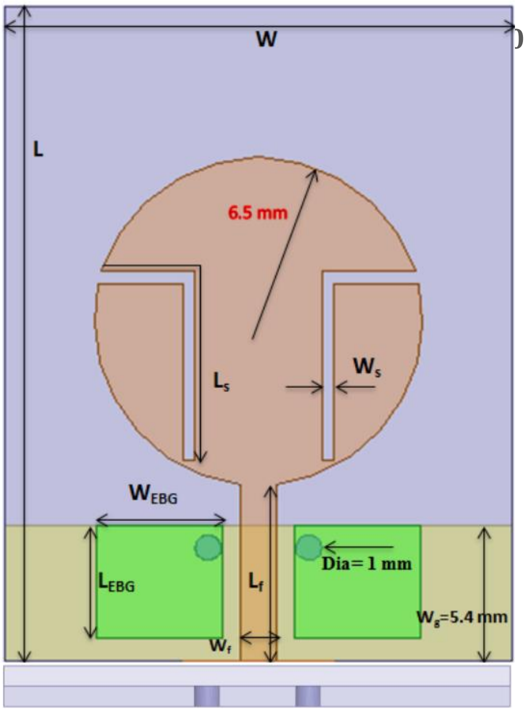
ANTENNA is an integral part of any wireless communication systems; nowadays short range wireless communication is very popular after the declaration of UWB as unlicensed for commercial applications by Federal Communication Commission (FCC) [1]. Printed antennas are favorable for designing of compact and low weight communication systems which make them great economical and portable. However micro strip antennas are good candidate to design UWB printed antenna due to their low cost and compatibility with various fabrication technologies [2]. UWB technology suffers from the electromagnetic interferences due to the other narrow band communications like, WiMAX, WLAN and C-Band satellite communication (downlink). To improve the interference problem various methods are available but designing of antenna with band notched characteristics are most popular among them [3]. Recently, researchers have proposed many methods to design antenna with band filtering characteristics such as, etching slots on radiating patch, defected ground structure, feed line miniature, open stubs, split ring resonators and many more.

Electromagnetic Band Gap (EBG) method is one of the popular techniques to design antenna with band notching feature. In literature, various type of EBG structures have been proposed like, an EBG structure is designed using feed line of CPW inspired antenna [4], a pair of mushroom shape EBG and modified EBG structure near the antenna feed line [5], a pair of slot loaded Mushroom EBG near feed line antenna in [6], rectangular Mushroom shape EBG for dual band notch characteristics in [7], C and reverse C slotted EBG metallic patch near feed line [8], a conventional EBG structure for band notch feature in [9], a tunable EBG structure with diagonal chamfered structure for reconfigurable characteristics [10] and square EBG near feed line [11].

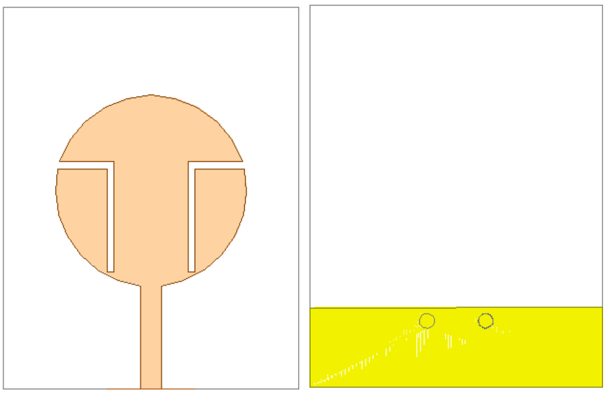
In this paper, we have proposed a pair of symmetrical M-EBG cell sandwiched between ground and radiating patch which produces band notched characteristics for WLAN. The symmetrical right angled pair of slots on radiating patch is used to create band notching characteristics for C-band (Satellite communication). The complete antenna size is 20x26x1.6 mm^3. This paper also shows that approach of EBG structure to create tunable notch is better over symmetrical slot on radiating patch. The proposed rectangular M-EBG is sandwiched between two dielectric plates the lower one has partial metallic ground one side and EBG structure printed on other side where as second dielectric sheet has only radiating patch is an added novelty of proposed antenna.

II. DUAL BAND NOTCH ANTENNA DESIGN AND ANALYSIS

All the simulation and optimization of the proposed antenna has been done with the Ansoft HFSS 13. Configuration and geometry of proposed antenna is shown in Fig. 1. Fabricated prototype antenna has been presented in Fig.2.This antenna is printed on the FR-4 substrate with thickness of 0.8 mm, dielectric constant ε_r = 4.4 and loss tangent of 0.02. Complete antenna design has been furnished in two steps, first we have designed ground structure on FR4 substrate with thickness 0.8 mm and other side of the substrate a pair of M-EBG, in second step a radiating patch etched on one side of the 0.8 mm substrate and other side of this substrate left without metal. A via of 1 mm diameter has been designed to complete the EBG geometry.



(a)



(b)

Fig.1. (a) Front View and (b) Back View of Proposed Antenna

Proposed antenna produces dual band notched characteristics which have been completed in two steps as described in two sections A & B. A micro strip feed line of 1.4 mm width has been used to achieve 50 Ω characteristic impedance.

A. *Symmetrical Right Angled Slot Pair (SRASP) Antenna Design (C-Band Notch)*

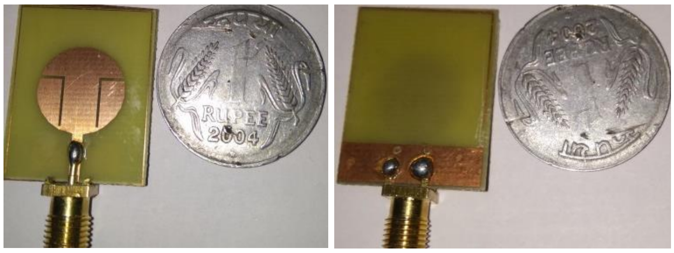
A right-angled slot provides a filtering characteristic so; we have used a SRASP on radiating patch to create notch for C- band. Fig.1 (a) shows the antenna with SRASP, and its length has been approximately $\lambda_g/4$. Length of proposed right angled slot resonator can be calculated from the equation (1).

$$\sqrt{} \qquad (1)$$

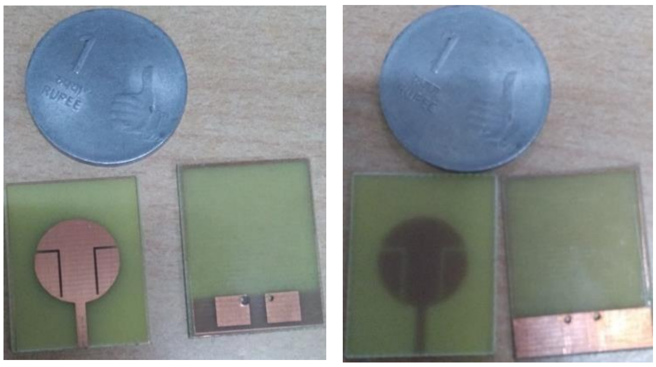
Where L_{eq} is 11.23 mm, and C is speed of light.
The value of equivalent length L_{eq} can be varied and optimized to create notch at C- band. All optimized dimensions of the proposed antenna has been listed in Table I.

B. *Pair of M-EBG Antenna (WLAN Notched Band)*

A pair of mushroom shape EBG cell sandwiched between radiating patch and ground has been shown in Fig.1 (a). To create band notch at WLAN applications (5.1-5.8 GHz), we have proposed an M-EBG cell grounded through via. The total size of M-EBG resonator cell is 5x4.5 mm^2.
A fabricated prototype of proposed antenna is presented in Fig.2.



(a) Front and Back view of Proposed Antenna Prototype



(b) Front view, Sandwiched EBG and Back view

Fig.2. Fabricated Prototype of Proposed Antenna

TABLE I
OPTIMIZED DIMENSIONS OF PROPOSED ANTENNA (mm)

Variable	W	L	L_S	W_S	Dia.
Size (mm)	20	26	11.23	1	1
Variable	L_f	W_f	Wg	W_{EBG}	L_{EBG}
Size (mm)	7.04	1.4	5.4	5	4.5

we have first designed a primary antenna (a circular patch antenna) which provides the UWB band as VSWR result shown in Fig.3. To create band notched characteristic for C-band applications, we have etched symmetrical right angled slot pair on circular patch, VSWR result due to the SRASP on patch has been shown in Fig.3. Second band notched characteristic for WLAN applications has been achieved by drawing a pair of M-EBG through via back side of ground structure loaded substrate. The VSWR due to the M-EBG has been shown in Fig.3. Proposed antenna is a combination of both the methods to create band notching characteristics and the VSWR of proposed antenna has been presented in Fig.3. by line with circle.

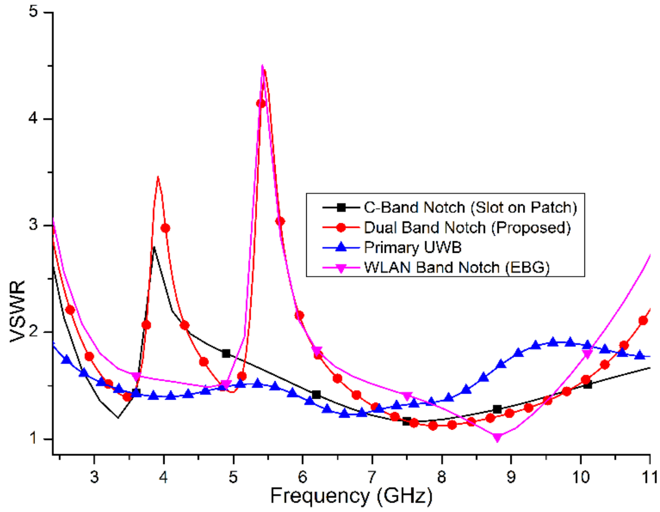


Fig.3. VSWR of Proposed antenna

The length and width of the mushroom shape EBG played a crucial role in optimization of proposed antenna. We have varied the length and width of the EBG structure over a range. The optimization of L_{EBG} and its effects on VSWR result have been shown in Fig.4. From Fig.4, it can be observed that band notch frequency is a function of length of the EBG structure and it varies inversely with the length. However, we have tuned the length of EBG for WLAN band center frequency 5.5 GHz.

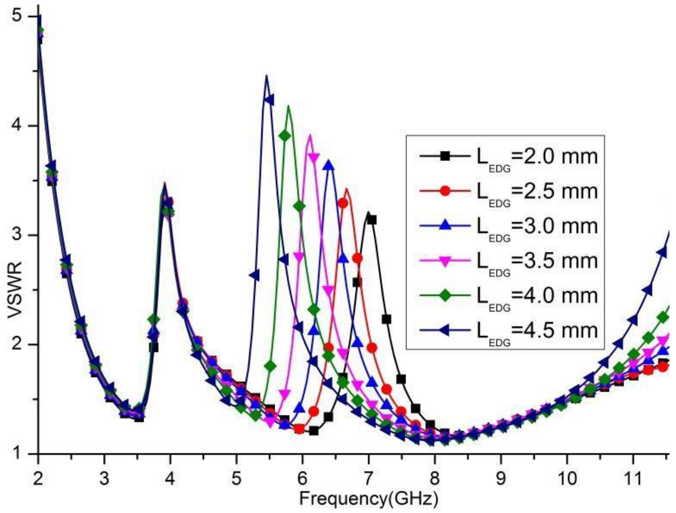


Fig.4. VSWR variation due to EBG Length.

Width optimization of the proposed EBG has been present in Fig.5. From Fig.5 it can be seen that the EBG width has a great impact on the frequency tuning of the proposed antenna. The width of the proposed EBG is function of frequency. It can be verified from the Fig.5 that center frequency of band notch inversely varied with the EBG width.

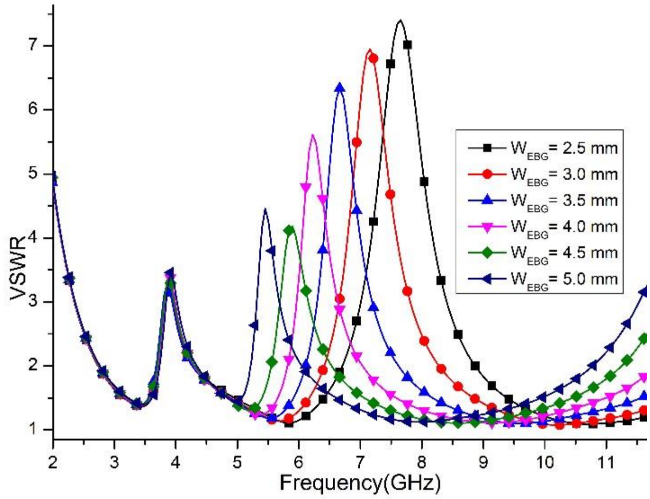


Fig.5. VSWR variation with EBG Width

Dimensions of symmetrical right angled slot pair can be varied over a range of optimization values. The length of the slot L_s and width W_s is optimized and their effects on VSWR have been presented in Fig.6 and Fig.7 respectively.

From Fig.6 it can be observed that effect of slot length can be used to tune the center frequency of the notched band, however it has negligible effect on other band notch frequency.

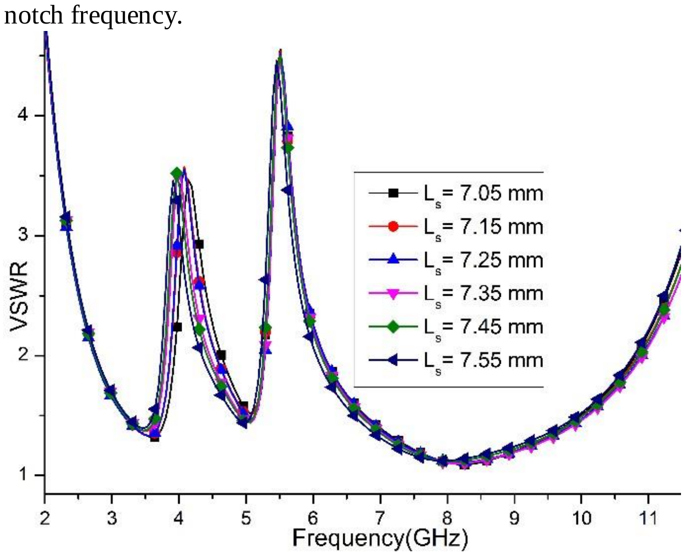


Fig.6. VSWR variation for L_S

Effects on VSWR due to variation in W_s of slot width during optimization have been presented in Fig.7. Width optimization shows that slot width has negligible effect on WLAN frequencies.

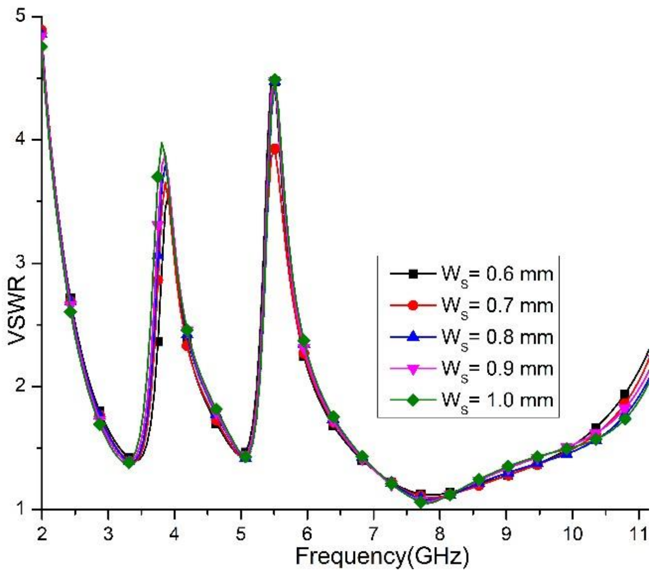
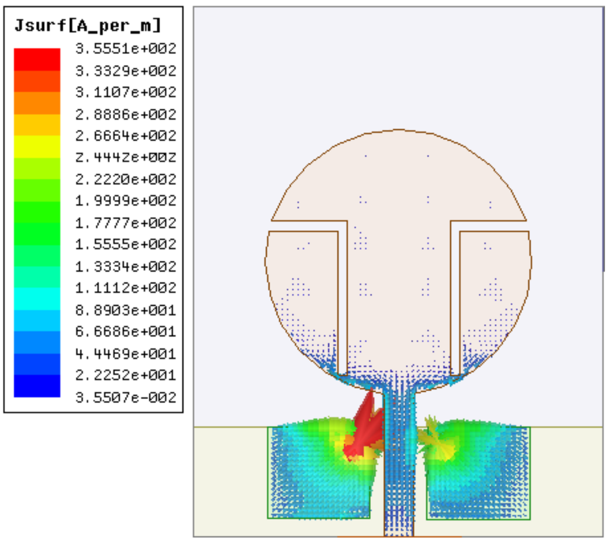


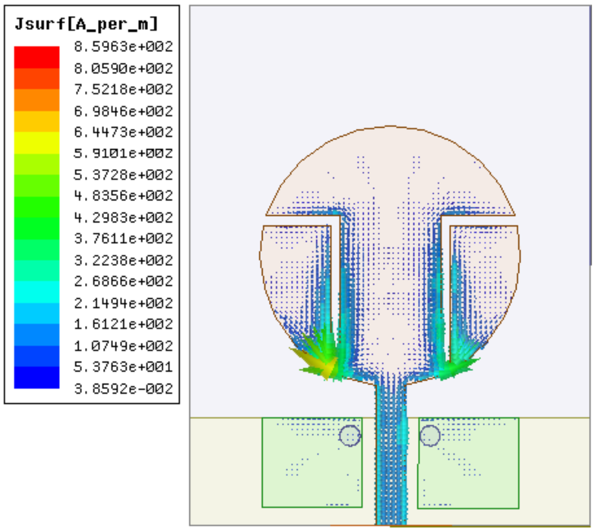
Fig.7. VSWR variation with W_S

From above optimization processes of SRASP slot, we can say that to create tunable band notched, EBG structure approach is better over conventional slot methods.

SRASP slot & M-EBG cell have been used to create the notched bands. The effects of SRASP & M-EBG can be observed through the vector current distributions on the radiating patch. Vector current effects on the proposed antenna at three different frequencies have been presented in the Fig.8. At a passband frequency of 7.5 GHz i.e. outside the notched band, the distribution of the vector current is uniform shown in Fig.8 (c). Fig. 8 (a-b) represents the effects of SRASP and M-EBG on current distribution of notched band frequencies at 4 GHz and 5.5 GHz. From Fig.8 (a) and (b) it can be observed that a stronger current density concentrated near the EBG at 5.5 GHz and at 4 GHz near the edges of the slots.



(a)



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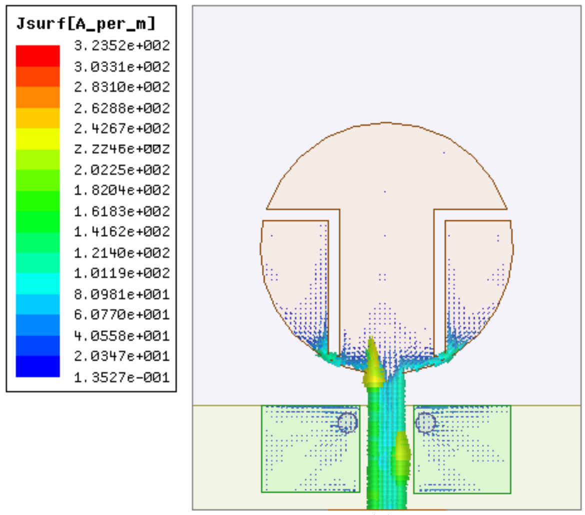


(c)

Fig.8. Current Distribution (a) 5.5 GHz, (b) 4 GHz and (c) 7.5 GHz

III. RESULT AND DISCUSSION

The measurement of the proposed antenna was performed with Key sight vector network analyzer for VSWR, and anechoic chamber for radiation pattern (E and H field co & cross polarization). Measured results show good agreement with the simulated result. The discrepancy between measured and simulated results is due to the cable & connector losses during measurements and tolerance in fabrication.

A simulated and measured result of proposed antenna for VSWR has been shown in Fig.9. Proposed antenna shows the successful band notch creation and broad bandwidth with VSWR < 2. The simulated & measured normalized E-field & H-field co and cross polarization patterns at 4.5 and 6.5 GHz have been shown in Fig.10. (a-d). The antenna displays good omnidirectional radiation patterns in the H-plane and dipole like radiation patterns in E- plane. Measured radiation pattern shows the good agreement with simulated results.

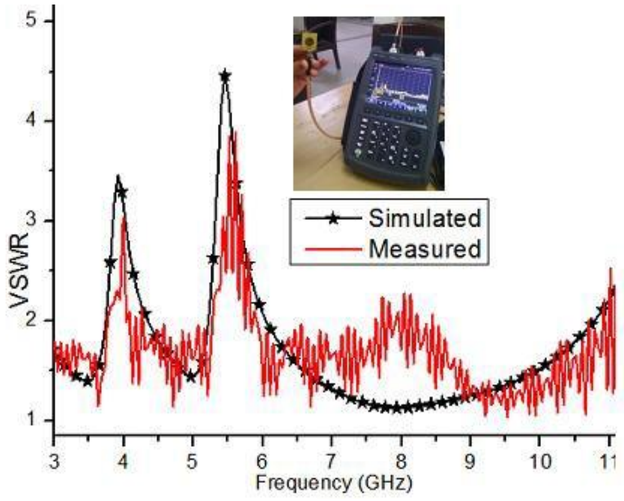
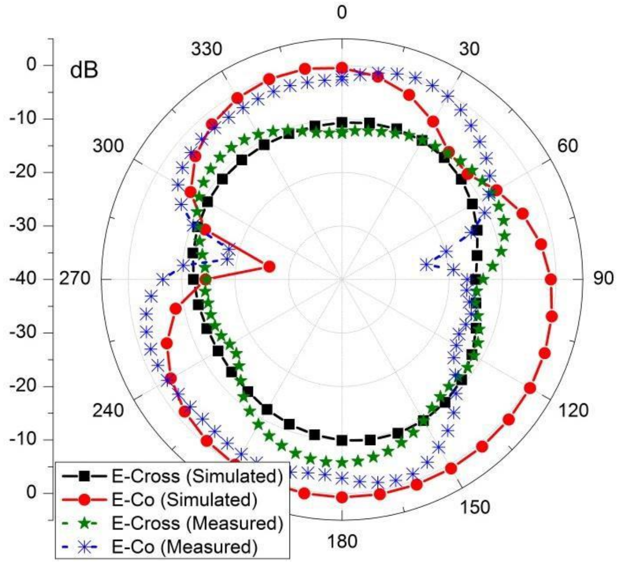
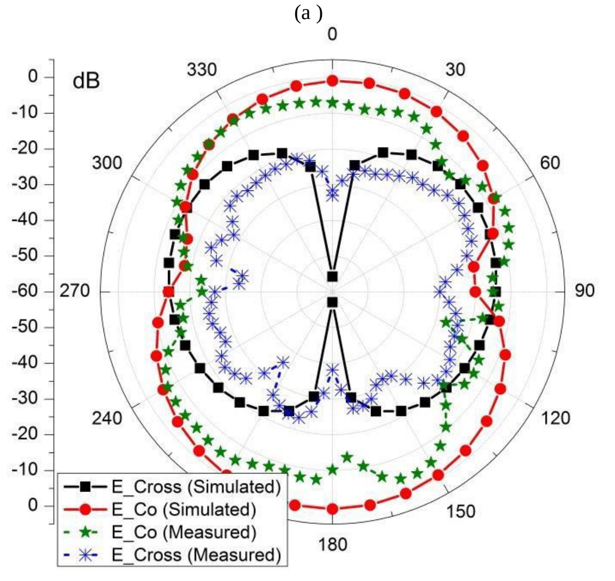


Fig.9. VSWR Vs frequency



(a)



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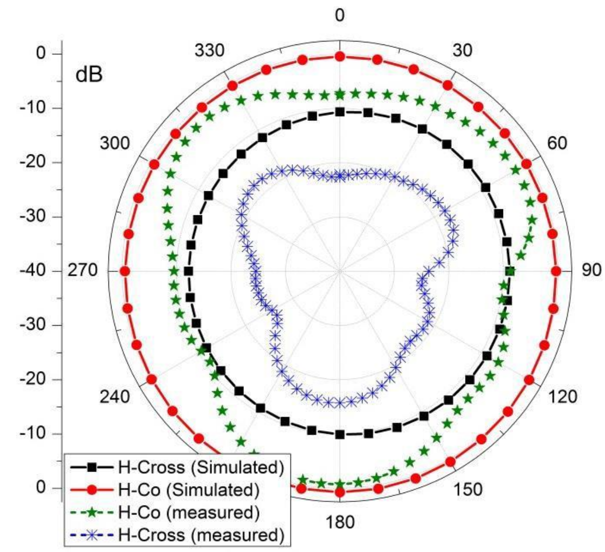

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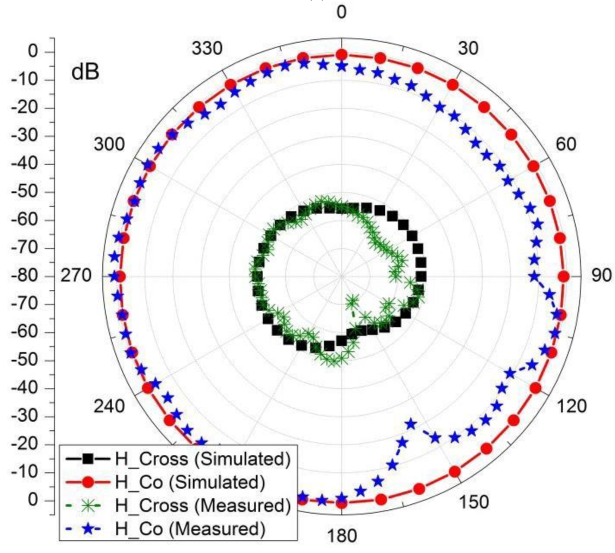
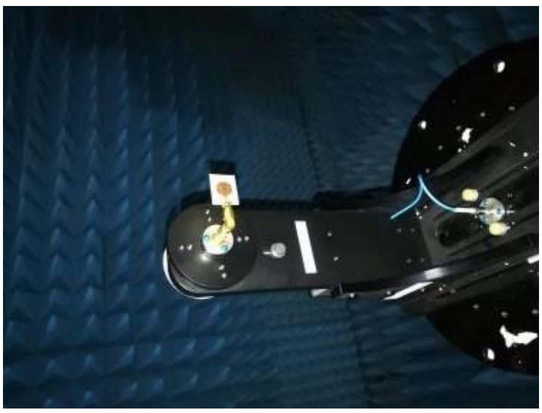


(d)

Fig.10. Measured and Simulated, Normalized E & H field patterns of proposed antenna (a)E-field at 4.5 GHz (b) H-field at 4.5 GHz (c)E-field at 6.5 GHz (d) H-field at 6.5 GHz



Radiation Pattern Measurement in anechoic Chamber at IIT Kanpur, India.

Fig.11 shows the realized gain and radiation efficiency of the proposed antenna.

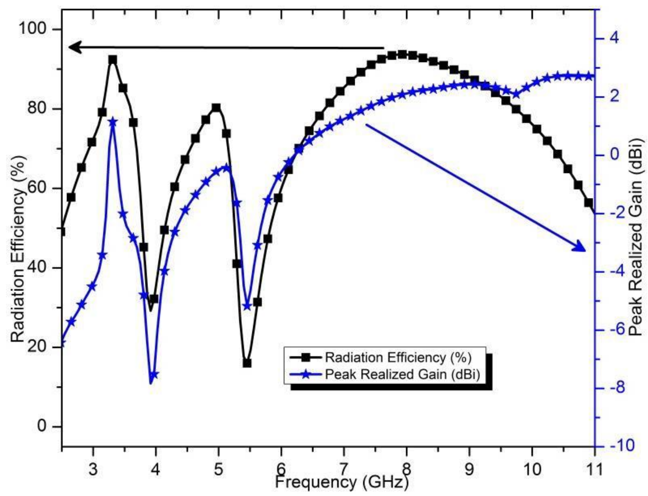


Fig.11. Radiation Efficiency and Realized Gain of Proposed Antenna

TABLE II
COMPARISON OF PROPOSED ANTENNA WITH REFERENCE ANTENNAS

Ref []	Size	Permittivity (ε_r)	Notched Band
[4]	48x50x1	2.65	WLAN, X-Band
[5]	42x50x1.6	4.4	WiMAX, WLAN
[6]	40x40x1	2.6	X-Band
[7]	32x52x1.6	4.4	WiMAX, WLAN
[8]	35x39x0.813	3.55	WLAN
[9]	35x39x1.8	3.38	WLAN
[11]	38x40x1	4.5	WLAN
Proposed	20x26x1.6	4.4	C-Band, WLAN

From Fig.11 it can be observed that for the notched frequency bands antenna produces negative gain, it means antenna is radiating approximately negligible power or receiving avoidable level of power. However, for other than notched frequency band its radiating gain is approximately more than 2 dBi. Similarly, antenna radiation efficiency is approximately 20% for the notched frequency band where as it radiates more than 80% power for other than notched bands. A useful information in comparison to used reference has been provided in Table-II.

IV. CONCLUSION

Proposed antenna covers UWB band and significantly suppresses the interference problems from C-Band and WLAN applications. SRASP and M-EBG structures have been successfully designed to produce dual band stop filtering characteristics. Simulated results are good in agreement with measured results. This antenna has simple structure and compact size of 20x 26 mm^2, Results & analysis of this antenna indicates that EBG approach is better than slot method to produce band notch. It is applicable in miniature devices, simple design & compact size as added advantage.

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REFERENCES

[1] First report and order, Revision of part 15 of the commission's rule regarding ultra-wideband transmission system FCC 02-48, Federal Communications Commission, 2002.

[2] Z. N. Chen, "UWB antennas: From hype, promise to reality," in *IEEE Antennas Protag. Conf.*, 2007, pp. 19–22.

[3] W.S. Lee, K.J. Kim, D.Z. Kim, and J.W. Yu, "Compact frequency notched wideband planar monopole antenna with an L-shaped ground plane," *Microw. Opt. Technol. Lett.*, vol. 46, no. 4, pp. 340–343, 2005.

[4] Lin Peng, Bao-Jian Wen, Xiao-Feng Li, Xing Jiang, and Si-Min Li, "CPW Fed UWB Antenna by EBGs With Wide Rectangular Notched-Band," *IEEE Access*, vol.4, 2016 doi: *10.1109/ACCESS.2016.2646338*

[5] Naveen Jaglan, Binod Kumar Kanaujia, Samir Dev Gupta, Shweta Srivastava, "Design and Development of an Efficient EBG Structures Based Band Notched UWB Circular Monopole Antenna" *Wireless Pers Commun, May 2017* doi: 10.1007/s11277-017-4446-2

[6] Chun Yan Song, Ting Yi Yang, Wei Wei Lin, Xiao Lin Yang, "Design of a Band-Notched UWB Antenna Based on EBG Structure", *Proceedings of 2013 IEEE International Conference on ID3106 Applied Superconductivity and Electromagnetic Devices* Beijing, China, October 25-27, 2013.

[7] Tapan Mandal1 and Santanu Das, "Design of Dual Notch Band UWB Printed Monopole Antenna Using Electromagnetic-Band Gap Structure", Microwave and Optical Technology Letters / Vol. 56, No. 9, September 2014, doi: 10.1002/mop

[8] M. A. Abdalla, et. al, "Dual Notching of UWB Antenna Using Double Inversed U-Shape Compact EBG Structure", *10th International Congress on Advanced Electromagnetic Materials in Microwaves and Optics – Metamaterials 2016* Crete, Greece, 17-22 September 2016

[9] Mohammad Yazdi and Nader Komjani, "Design of a Band-Notched UWB Monopole Antenna by Means of an EBG Structure", *IEEE Antennas and Wireless Propag. Letters*, vol. 10, 2011. Doi: 10.1109/LAWP.2011.2116150.

[10] Krishnamoorthy K, Basudev Majumder, Jayanta Mukherjee, "Dual Polarized Reconfigurable Dual Band-Notched UWB Antenna with Novel Tunable EBG Structure", *IEEE Conference* 2013, doi: 978-1-4799-3267-2/13

[11] Lin Peng and Cheng-Li Ruan, "UWB Band-Notched Monopole Antenna Design Using Electromagnetic-Bandgap Structures", *IEEE Trans. On Microwave Theory and Techniques*, vol. 59, no. 4, April 2011. doi: 10.1109/TMTT.2011.2114090.