Dual Band Notched Ultra Wideband Microstrip Antenna with CSRR Slot and EBG Structure

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***Abstract*—In this paper a compact ultra-wideband (UWB) printed microstrip antenna with dual band-notched characteristics is presented. The antenna is constructed on an FR-4 epoxy substrate with thickness of 1.6 mm and ε_r =4.4. The antenna uses CSRR and an EBG structure to create dual band-notched characteristics in 3.3 - 3.6 GHz for WiMAX and 5.1-5.8 GHz for WLAN, respectively. Surface current distributions have been used to show the effects of these slots. The antenna shows broad bandwidth and good omnidirectional radiation patterns in the pass band, with a compact size of 30x30mm^2. The proposed antenna operates over 3.1 to 12.24 GHz for VSWR < 2. All simulations in this work have been carried out by using the electromagnetic software Ansoft HFSS 13. This antenna has advantages in simple design, wide bandwidth, and good band-notched characteristics, compact in size and easy in fabrication. Simulated and measured results of the proposed antenna have been presented.**

***Keywords*—EBG antenna, UWB antenna, band notched antenna, CSRR antenna, Microstrip antenna.**

I. INTRODUCTION

AFTER declaration byFederal communication commission (FCC)of unlicensed radio frequency band 3.1-10.6 GHz for commercial use, ultra-wideband (UWB) has been received great attention from academics and industries [1]. In recent years researchers have proposed and presented various methods to improve the UWB antennas characteristics like impedance bandwidth, radiation patterns, gain, matching characteristics and size of the antenna. UWB has attractive merits like, compact size, low cost, resistant to severe multipath and jamming, ease of fabrication, and good omnidirectional radiation characteristics which attracts researchers to work in UWB area [2]. An ultra-wide band system suffers from electromagnetic interferences with exciting narrowband wireless communication systems. So itis necessary to design antennas with multiband filtering characteristic to prevent interferences with applications working in this band. These narrow band wireless communication systems areWiMAX operating in 3.3-3.6 GHz band (IEEE 802.16), WLAN operating in 5.1-5.8 GHz band (IEEE 802.11a), C-band satellite and X-band satellite communication system operating in 3.8-4.2 GHz and 7.2-8.4 GHz band (7.25-7.745 GHz for uplink and 7.9-8.395 GHz for downlink) respectively. There are various types of alternative methods to solve interference problem like use of bandstop filter in UWB band, but this approach will increase the complexity, cost, size and weight of the system. Therefore it is necessary to design the UWB antenna with band notched characteristic to reduce the complexity, size and weight of the system and make it cost effective.

Recently, different methods have been proposed and presented to design UWB with band notched characteristics to solve the earlier described problems. Usually, people used mainly two methods these include different types of slots on the radiating patch or on the ground plane, use of split-ring resonators, tuning stubs, meandering, folded strips, and resonated cells on CPW [3-20]. For example, etching of U slot [3-4], V- shaped slot [5], C- shaped slot [6], S- shaped slot [7], a quasi-complementary split ring resonator (CSRR) in fed line [8], a quarter- wavelength tuning stub in a large slot on the patch [9], or compact folded stepped impedance resonators (SIRs) or capacitively loaded loop (CCL) resonators in fed [10-11], a parasitic slit along with tuning stub used [12], C shaped slot on patch and L shaped stub on ground [13], semi-circular slot on patch [14], rectangular slots on patch [15], M-EBG [16], L-type grounded resonator on patch plane [17], mushroom shape EBG structure on patch plane [18], rectangular EBG cell [19], CSRR slot on radiating patch [20].

In this paper, we have proposed a compact UWB planar microstrip antenna with dual notched bands for 5.1-5.8 GHz band (WLAN) and 3.3 - 3.6 GHz (WiMAX) using CSRR slot on patch and inverted L shape EBG single cell near radiating patch. The complete antenna size is 30x30 mm^2. The proposed antenna has used both methods etching slot on patch and ground on radiating patch plane through via to create dual notch band.

II. ANTENNA DESIGN AND ANALYSIS

The geometry and configuration of the proposed antenna has been simulated&optimized with the Ansoft HFSS 13 andis 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 1.6 mm, relative dielectric constant of ε_r =4.4 and loss tangent of 0.02. The proposed antenna is fed by a microstrip feeder, and the width of the microstrip feed line is 2.8 mm to achieve 50-Ω characteristic impedance. There is an inverted L shaped EBG grounded cell near the feed line and a Circular split ring resonator cut on radiating patch shown in Fig.1.A circular split ring resonator has been cut on radiating patch to create notch in WiMAX band. CSRR (circular split ring resonator) provides notch of 3.3-3.6 GHz for WiMAX applications. For notch at higher frequency we have used a grounded inverted L shaped EBG cell that provides a notch band for WLAN applications in 5.1-5.8 GHz band. The total length of inverted L shape resonator is 8.2 mm, which is approximately equal to the $\lambda_g/4$ calculated at 3.5 GHz for WLAN applications and has been calculated from equation (1) as given below.

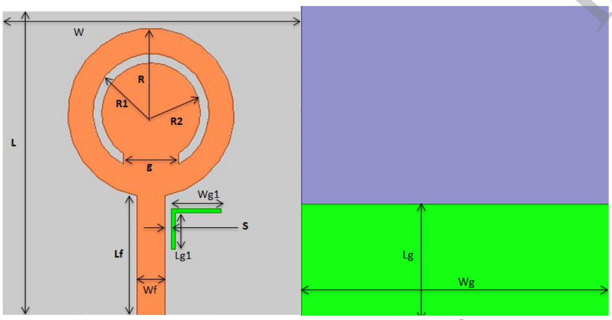
$$L = \frac{C}{4f\sqrt{\frac{\varepsilon r+1}{2}}} \quad \text{.. (1)}$$

CSRR length has been approximately $\lambda_g/2$, used to create a WiMAX notched band (3.3 to 3.6 GHz). Length of proposed circular split ring resonator has been calculated from equation (2) and equation (3).

$$Leq = 2\pi r\text{-}g \quad \text{.. (2)}$$

$$f_c = \frac{C}{2*L_{eq}*\sqrt{\frac{\varepsilon r+1}{2}}} \quad \text{.. (3)}$$

Value of optimized g is 5.5 mm, value of r is 4.9 mm and C is speed of light.
The value of g is 5.5 mm optimized to create notch at WiMAX band. Optimized dimension of the proposed antenna has been presented in table 1.



(a) (b)

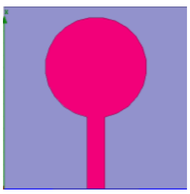
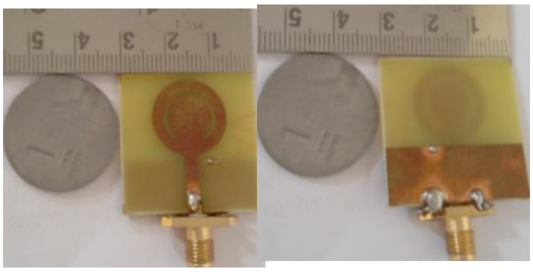


Fig.1. (a) Front view of Proposed Antenna (b) Back view of Proposed Antenna (c) Primary Antenna



(a) Top view (b) Back view

Fig.2. Fabricated Prototype Antenna (UWB)

Optimized dimensions of the proposed antenna have been presented in table.1 that also shows that proposed antenna ground is a partial ground.

Table 1 Optimized dimensions of proposed antenna

Variable	W	L	R	R1	R2	g
Size (mm)	30	30	8.3	5.8	4.9	5.5
S	L_f	W_f	Wg	Lg	Wg1	Lg1
0.6	11.8	2.8	30	11	5	4

To achieve the dual band notch characteristic through proposed antenna, we first cut a CSRR slot on primary antenna shown in Fig.2, which provides the UWB band notched characteristics for WiMAX applications. Second band notched characteristic for WLAN applications has been created by drawing an inverted L shape grounded resonator through via near the right side of feed line.The return loss (S_{11} in dB) and VSWR due to the primary antenna, due to the CSRR slot only, due to the EBG and the proposed antenna (combined both CSRR & EBG) have been presented by Fig.3 and Fig.4 respectively. From Fig.3 and Fig.4, we can see that CSRR slot provides a single band notch characteristic in UWB band for WiMAX Applications, where as an EBG provides a single band notched at WLAN band. From Fig.3 and Fig.4, one can be see that a single notch at frequency band 3.3-3.6 GHz and 5.1-5.8 GHz provided by CSRR slot & EBG cell respectively. Now to achieve the dual notch band in UWB for WLAN band and WiMAX band, we have combined CSRR and EBG on radiating patch. The returnloss and VSWR of combined slots on radiating patch have been presented in Fig.3 and Fig. 4 respectively by dark line.

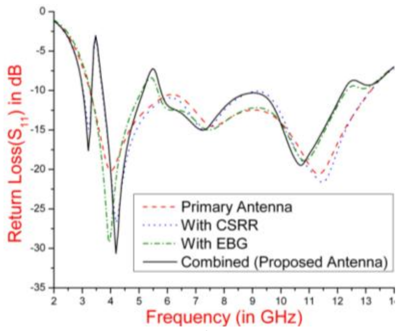


Fig.3. Return loss of proposed antenna

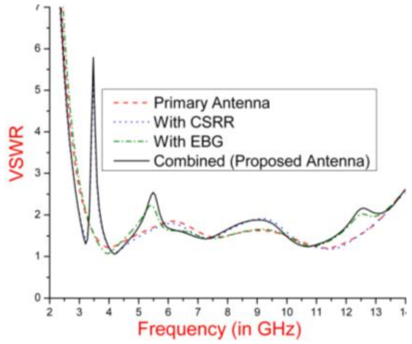


Fig.4. VSWR of Proposed antenna

Length of EBG namely L_{g1}, W_{g1} andgap between feed line and EBG shown by S varied over a range of optimization values and results have been presented in fig.5 and fig.6 for return loss and VSWR respectively. Gap between antenna feed line and EBG structure play a great role to create band notch characteristic, Fig.5 & 6, shows the effect of gap variation on the band notch characteristics.

From Fig.5 & 6, it can be seen that with the gap Svaries from 0.3 mm to 0.8 mmandgap spacing of 0.6 mm have been proposed. we have achieved desired notched band with the proposed spacing of 0.6 mm.

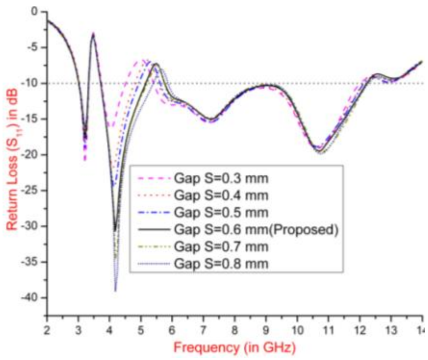


Fig.5. Return loss variation with gap distance

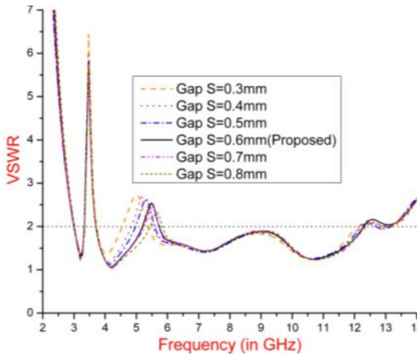


Fig.6. VSWR variation with gap distance

Dimensions of EBG structure namely L_{g1}& W_{g1} has been optimized. The effect of variation in length namely L_{g1} on return loss and vswr has been shown in Fig.7&8, respectively. Through the optimization, variation in length from 2 mm to 6 mm, wehave proposed a length of the EBG at 4 mm, which provides desired band notched characteristic with width of W_{g1} = 5mm.

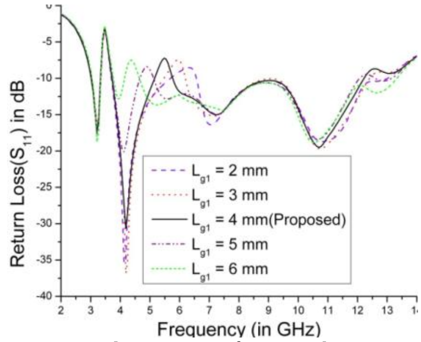


Fig.7. Return loss variation for L_{g1} with W_{g1}=5mm

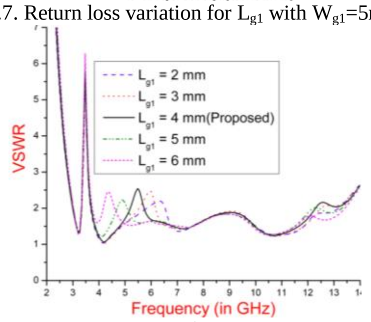


Fig.8. VSWR variation for L_{g1} with W_{g1}=5mm

Width of EBG W_{g1} has been optimized over a range of values with keeping L_{g1} constant at 4mm. The effect of variation in length namely W_{g1} on return loss and vswr has been shown in Fig.9&10, respectively. From Fig.9&10, we can say that proposed length of the EBG at 5 mm provides desired band notched with length of L_{g1} = 4mm.

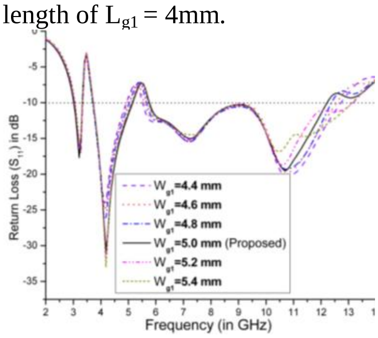


Fig.9. Return loss variation for W_{g1} with L_{g1}=4mm

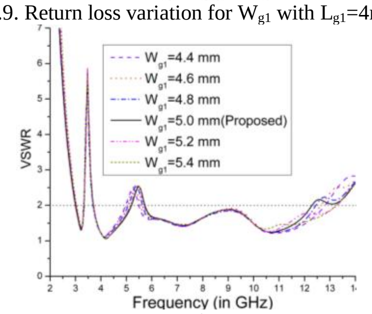
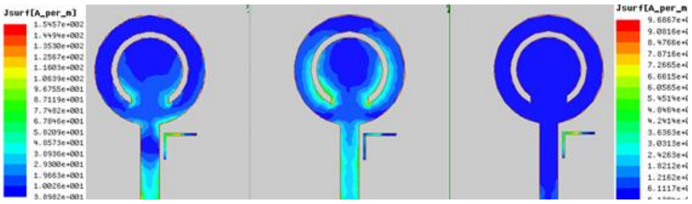


Fig.10. VSWR variation for W_{g1} with L_{g1}=5mm

In order to observe the effects of CSRR slot and EBG cellin getting the notched bands, the surface current distributions on the radiating patch of the proposed antenna at three different frequencies have beenpresented in the Fig.11. At a passband frequency of 4.5 GHz i.e. outside the notched band, the distribution of the surface current is uniform shown in Fig.11.(a). whereas in Fig. 11 (b-c), have observed stronger current distributions concentrated near the edges of CSRR slot and EBGat the center frequency of the first notched band 3.5 GHz, and the second notched band 5.5 GHz, respectively.

These clearly show the positive effects of the slots upon obtaining the band notched characteristics.



(a) (b) (c)

Fig. 11. Current density distribution over patch (a) 4.5 GHz, (b) 3.5 GHz, (c) 5.5 GHz

III. RESULTS AND DISCUSSIONS

Simulated and measured results of proposed antenna for return loss and VSWR have been shown in Fig.12 & 13. The antenna with CSRR slot and EBG successfully exhibits dual notched bands of 3.3 - 3.6 GHz, maintaining broadband performance from 3.1 to 12.24 GHz (includes UWB frequency band) with VSWR less than 2. The simulated radiation patterns at 3.5, 5.5 and 7.5 GHz have been shown in Fig.14. (a to c),respectively. At the passband frequencies out of the notched bands 7.5 GHz, the antenna displays good omnidirectional radiation patterns in the H-plane and dipole like radiation patterns in E- plane as shown in Fig.14.(c). Meanwhile, at notched band frequencies (3.5 and 5.5 GHz) the antenna displays distorted and unstable radiation patterns as shown in Fig.14. (a) & (b). The calculated realized peak gain and radiation efficiency of the proposed antenna is shown in Fig.15.

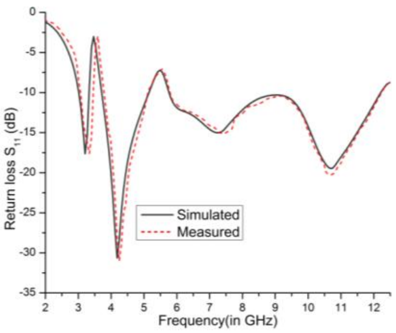


Fig. 12. Measured Return loss S_{11} Vs frequency

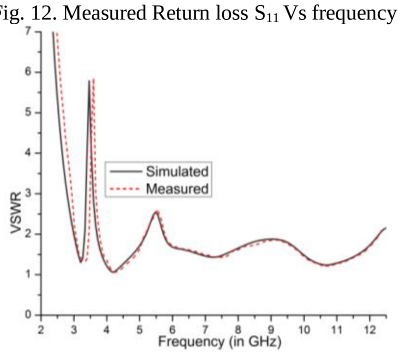


Fig. 13. Measured VSWR Vs frequency

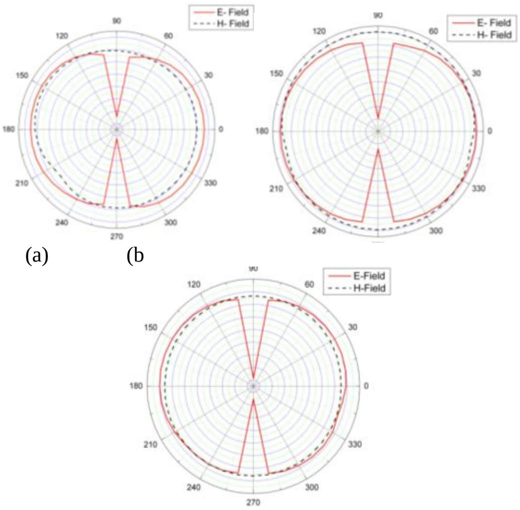


Fig.14.Simulated E-H field pattern of proposed antenna (a) 3.5 GHz (b) 5.5 GHz (c) 7.5 GHz

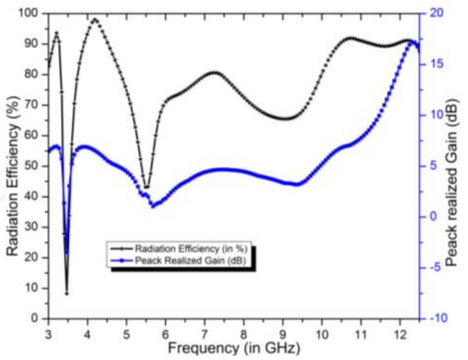


Fig. 15. Simulated Radiation Efficiency and Peack Realized GainVs frequency graph of proposed antenna

IV. CONCLUSION

A compact dual band notched UWB antenna has been presented in this paper. This antenna has simple structure and compact size of 30x 30 mm ^{2}, which is easy to be integrated in miniature devices. Proposed antenna covers frequency band from 3 to 12.24 GHz, where simulated results are good in agreement with measured results. To prevent interferences with WLAN and WiMAX, two band rejection structures have been successfully designed to produce sharp rejection. Results & analysis of this antenna indicates that it is applicable in miniature devices, simple design & compact size as added advantage.

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