URSI AP-RASC 2019, New Delhi, India,09 - 15 March 2019

EBG-Loaded Dielectric Resonator Antenna for Triple Band-Notch Characteristics

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Abstract

A novel configuration of ultra-wideband (UWB) antenna with triple band-notched characteristics is introduced in this article. The design consists of a modified U-shaped dielectric resonator placed at the edge of a rectangular radiating patch for achieving UWB performance. Two configurations of Archimedean spiral shaped EBG unit cells are then designed and implemented together to realize the triple notch characteristics. The antenna geometry is modeled on Rogers RO3003 (tm) substrate having an overall dimension of 25×30×0.762 mm^3. The proposed antenna covers the frequency range 2.4 GHz-10.65 GHz with VSWR ≤ 2 over the entire range except at the notch frequencies at 4.5 GHz, 5.1 GHz and 9.1 GHz, respectively. Standard behavior of radiation characteristic along with enhanced gain pattern is observed for the suggested antenna configuration. Simulation analysis manifests that the proposed antenna has the potential to avoid interferences from existing narrowband communication techniques and thus suitable for UWB communication systems.

1. Introduction

The deficiency of spectrum available for accommodating new services, with null effect to the existing ones, brought the use of ultra-wideband (UWB) communication system for unlicensed applications [1]. UWB technology has been widely used for its advance characteristics i.e. short range, high data rate with low energy level. In this context, design of UWB antenna plays a crucial role. This inspired the researchers to design wide variety of antenna geometries that can meet the criteria for implementation in UWB systems [2]. Dielectric resonator antennas (DRAs) are one class of antennas which are highly explored in present times for UWB applications. DRAs possess several attractive features, such as high impedance bandwidth, high radiation efficiency, lightweight, portable size, etc. [3]. In general, circular, rectangular, hemispherical are the conventional shapes of dielectric resonators (DRs) that are used for antenna applications. Besides these conventional shapes, some other modified shapes of dielectric resonators can be derived to achieve more design flexibility level [4]. However, each shape has its unique characteristics in terms of performance enhancement. Since UWB shares its spectrum with other narrow and wide-band wireless services, it is desirable to have notch characteristics in UWB antennas for avoiding interference with other existing radio communication systems [5]. In order to ensure notch in the UWB range (3.1-10.6 GHz), different techniques have been reported in the literature [6-8]. The use of slotted geometries on the radiating patch and/or in ground plane or adding an extra parasitic patch near to the radiating patch seem to be more common and effective [9]. These two techniques are easily capable of creating single notch. In comparison to this, ensuring dual notch is bit tricky. One proficient technique to obtain multiple notch characteristics is to use the electromagnetic band-gap (EBG) structure that produces a band-gap characteristic [10-11]. The concept of EBG is based on solid state physics and optical domain. However, it behaves as an artificial magnetic conductor (AMC) having the same electrical length properties as AMC. It can be noted that, the acquired notches are fixed at particular frequency [12-14]. Further adding re-configurable functionality to the notch frequency adds flexibility to UWB antenna [15].

Here, in this article, a multi band notched UWB DR-antenna is designed. The notch characteristics are obtained using uni-planar EBG structures. The proposed Archimedean spiral with inter-digital capacitance based EBG unit cells are utilized for generating triple notched characteristics at 4.5 GHz, 5.1 GHz and 9.1 GHz. The proposed EBG cells independently control the notch frequencies. The suggested design also offers compactness and flexibility in terms of controlling the notched band frequencies independently by changing the dimensions of the EBG unit cell. The proposed antenna geometry is modeled on Rogers RO3003 (tm) substrate having an overall dimension of 25×30×0.762 mm^3.

2. Antenna Configuration

The geometry of the proposed dielectric resonator based UWB antenna with optimized dimensions and loaded with EBG structures for triple-band notched characteristics is presented in Figure 1. The antenna geometry is designed on 0.762 mm thick Rogers RO3003 (tm) substrate ($\varepsilon_r = 3$, $tan\ \delta = 0.0013$) having an overall size of 25×30 mm^2 (W × L). The geometry consists of a rectangular radiating patch, a pair of Archimedean spiral EBG unit cells mounted on the substrate sheet and a partial ground plane in opposite side of the substrate. By etching three slots (slot #1, slot #2, and slot #3) in ground plane and in addition by placing a DR at the edge of the radiating patch, a suitable impedance bandwidth covering the UWB region has been realized.

For a good understanding of the design process, a step-wise procedure is followed as described in Figure 2. These structures are termed as Antenna #1, Antenna #2, Antenna #3, Antenna #4, Antenna #5, and Antenna #6, respectively. Antenna #1 consists of a rectangular patch and partial ground only. It does not manifest any satisfactory result. Three slots (Slot #1, Slot #2, and Slot #3) are then incorporated in the ground plane to form Antenna #2. Antenna #3 is the UWB antenna without any notch when DRA is placed in the edge of the radiating patch and Antenna #6 is the proposed EBG loaded UWB DR-antenna with triple notch characteristics. In between, Antenna #4 and Antenna #5 are designed individually, as dual and single band-notched antennas for rejecting interfering frequencies in the UWB region. These six antennas are designed, simulated and optimized using ansoft HFSS software.

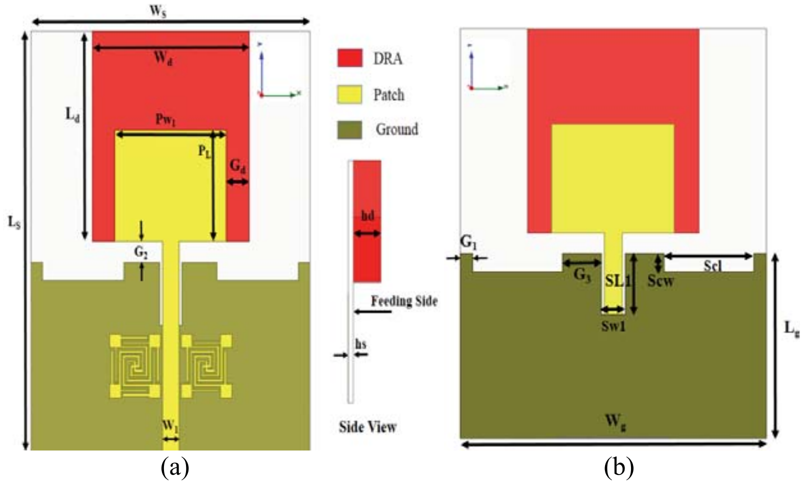


Figure 1. Geometry of the proposed antenna (a) Top view (b) Bottom view.

Table 1. Different Antenna Parameters

Parameters	Values(mm)	Parameters	Values(mm)	Parameters	Values(mm)
Ls	30	W_g	11.5	G_3	3.172
W_S	25	G_d	2	SL_1	4.5
H_S	0.762	G_2	1.5	Sw_1	2
Pw1	10	W_d	14	Scw	1.3
P_L	8	L_d	15	Sc_l	7.3
W_1	1.5	H_d	5.08		
L_g	13.5	G_1	1.028		

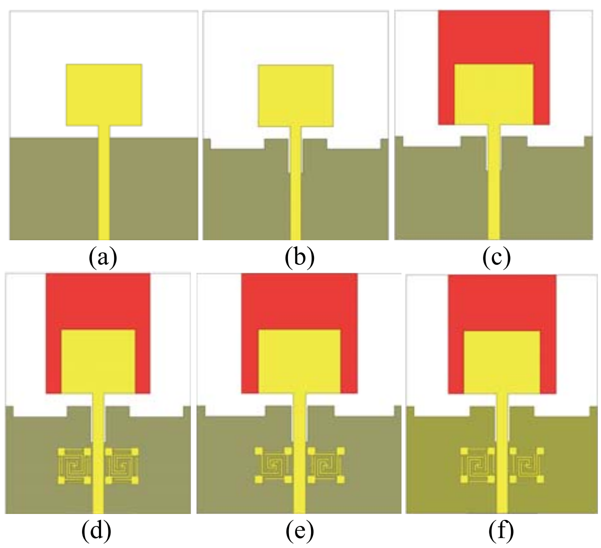


Figure 2. Step-by-step design procedure: (a) Antenna #1, (b) Antenna #2, (c) Antenna #3, (d) Antenna #4, (e) Antenna#5, (f) Antenna#6.

3. Proposed EBG Structure

The proposed EBG unit cells, EBG #1 and EBG #2, are shown in Figure 3. The dimensions of the EBG structure is as follows: m = 4.54 mm, k= 1 mm, b = 0.17 mm, and a = 0.15 mm.

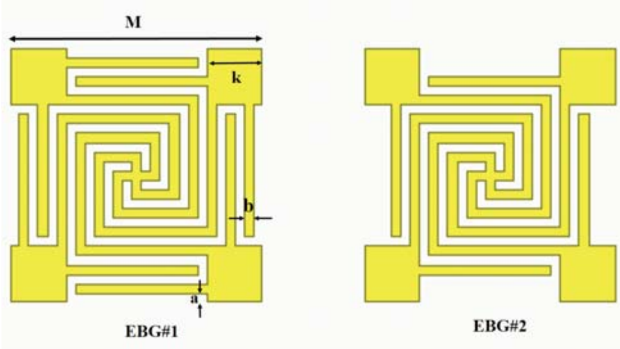
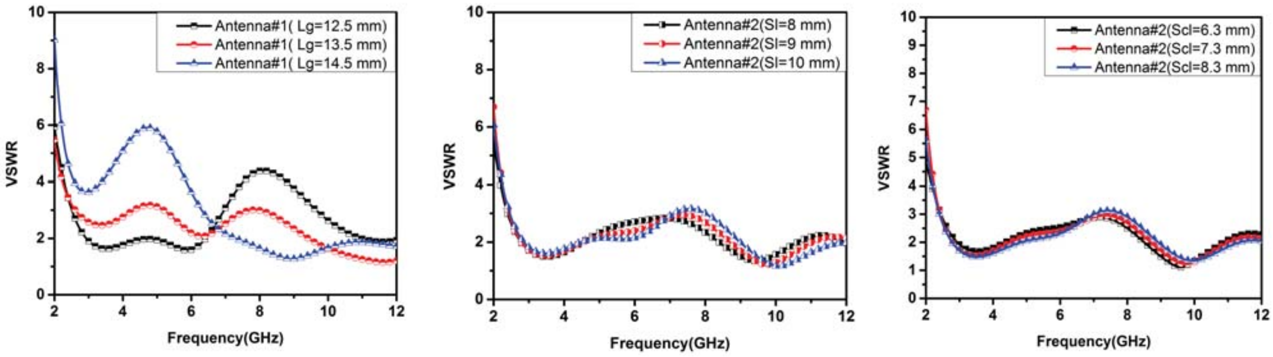


Figure 3. Proposed EBG structures.

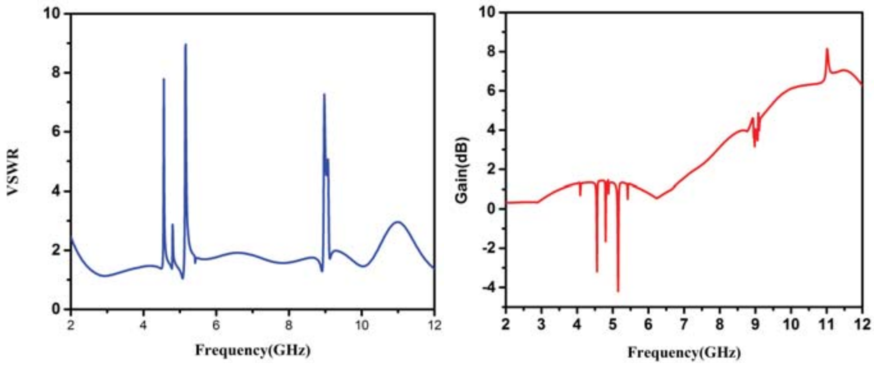
4. Simulated Result and Discussion

In Figure 2, different types of antennas (Antenna #1-to-Antenna #6) are designed and depicted. In this section, performance analysis of the different stages of antenna has been reported. Antenna #1 is a conventional antenna with partial ground plane. The voltage standing wave ratio (VSWR) value of Antenna #1 at different values of the design parameter Lg = 12.5 mm, 13.5 mm and 14.5 mm, is plotted in Figure 4(a). It is concluded that Lg = 13.5 mm provides good performance characteristics. By introducing three different slots at the edge of the ground plane in Antenna #2 and by varying the dimensions of the slots, different parametric results have been obtained, which is shown in Figure 4(b) and 4(c), respectively. In Antenna #3, DR is mounted on the upper side of the radiating patch for further improvement of the antenna performance and for obtaining impedance matching over a wide frequency range. The other design parameters are maintained same as Antenna #2. The suggested antenna produces an impedance bandwidth ranging from 2.4 GHz to 10.65 GHz without any notch, as displayed in Figure 6(a).



(a) (b) (c)

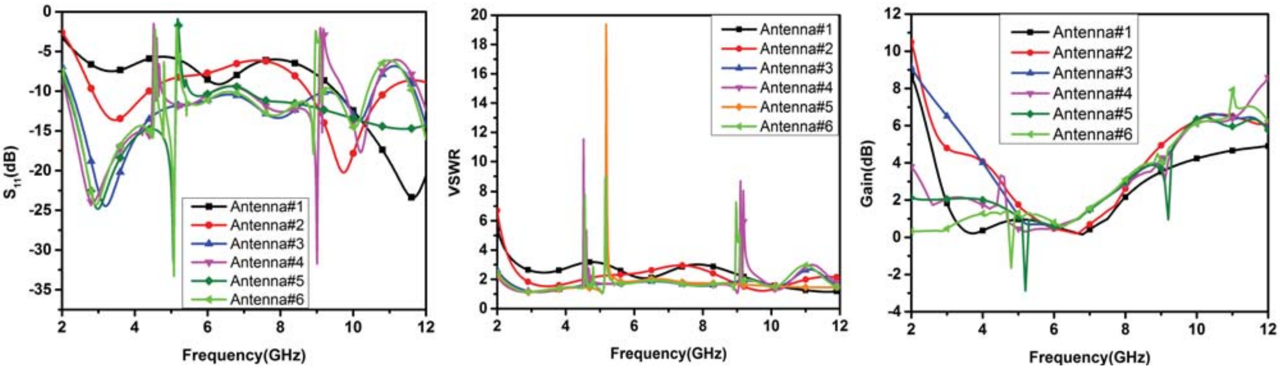
Figure 4. Simulated VSWR with different parameter (a) Lg (b) Sl (c) Scl.



(a) (b)

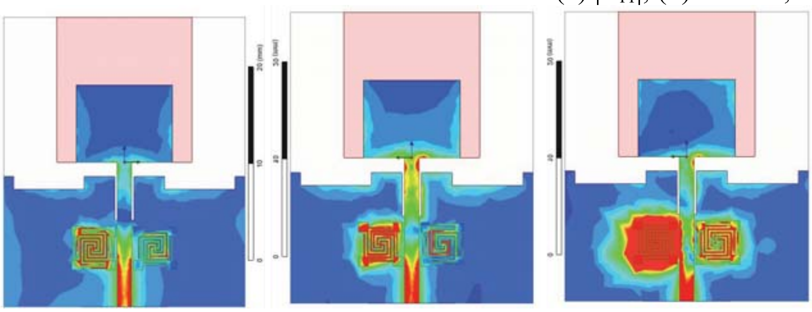
Figure 5. (a) Simulated VSWR vs. frequency (b) Simulated Gain vs. Frequency of proposed antenna.

Now in order to develop band-notch characteristics within the UWB frequency range, EBG structures are placed near the feed line of the antenna. In Antenna #4, unit cell EBG #1 is introduced on both sides of the feed line, which results in generating two notches at frequency 4.5 GHz, and 9.1 GHz, respectively. Now, the second unit cell structure, EBG #2 is embedded on both side of the feed line of Antenna #3 geometry, which then gives Antenna #5. The Proposed antenna produces a single notch at frequency 5.1 GHz. Finally, both the structures EBG #1 and EBG #2 are combined together and placed near the feed line in order to develop the configuration of Antenna #6. The resultant configuration realizes triple band notched behavior in the frequency band of interest. A comparison is made between the $|S_{11}|$-, VSWR, and gain-performance of all the six antennas, revealed in Figure 2, which is displayed in Figure 6(a), 6(b), and 6(c), respectively. The surface current distribution of Antenna #6 is further investigated to realize the appearance of triple band notch performance, as shown in Figure 7. In Figure 8, radiation patterns of the proposed antenna at 3.20 GHz, 8.10 GHz, and 10.0 GHz, is displayed.



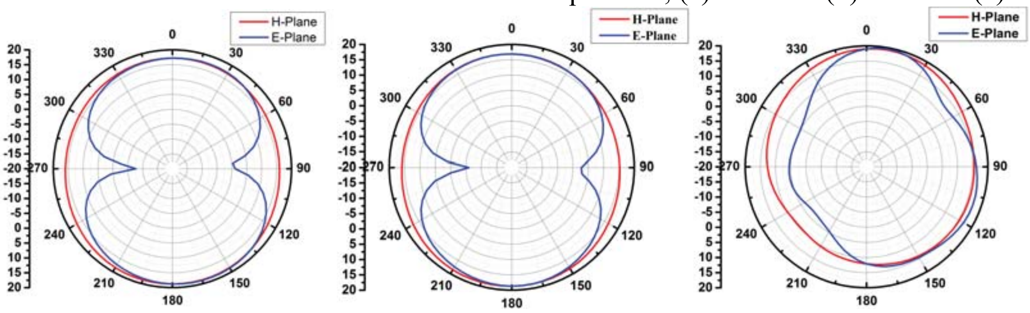
(a) (b) (c)

Figure 6. Simulated results of Antenna #1 to Antenna #6 (a) $|S_{11}|$, (b) VSWR, and (c) Gain.



(a) (b) (c)

Figure 7. Current distribution of Antenna #6 at different frequencies, (a) 4.5 GHz (b) 5.1 GHz (c) 9.1 GHz.



(a) (b) (c)

Figure 8. Simulated radiation patterns of Antenna #6: (a) 3.20 GHz, (b) 8.10 GHz, (c) 10.0 GHz.

5. Conclusion

A triple band-notched UWB dielectric resonator antenna (DRA) is designed and discussed. The suggested antenna has produced an impedance bandwidth ranging from 2.4 GHz to 10.65 GHz. EBG structures are implemented to obtain stopband characteristics to block certain UWB interfering frequency bands. Three notched frequencies are obtained at 4.5 GHz, 5.1 GHz and 9.1 GHz to avoid potential interferences from INSAT, WLAN, and Radio allocation applications, respectively.

Acknowledgement

This work was supported by Science and Engineering Research Board (SERB), Department of Science and Technology (DST), Govt. of India (GoI) under research grant No. SB/S3/EECE/093/2016.

References

[1] K. H. R. Zheng, H. O. Chua and L. W. Li, "Analysis and design of UWB monopole-dielectric resonator antenna," 2010 IEEE International Conference on Ultra-Wideband, Nanjing, 2010, pp. 1-4. doi: 10.1109/ICUWB.2010.5614241.

[2] O. M. H. Ahmed, A. R. Sebak and T. A. Denidni, "Compact UWB printed Monopole loaded with dielectric resonator antenna," in Electronics Letters, vol. 47, no. 1, pp. 7-8, January 6 2011. doi: 10.1049/el.2010.7337.

[3] M. Abedian, S. K. A. Rahim and M. Khalily, "Two-Segment Compact Dielectric Resonator Antenna for UWB Application," in IEEE Antennas and Wireless Propagation Letters, vol. 11, pp. 1533-1536, 2012. doi: 10.1109/LAWP.2012.2232639.

[4] K. S. Ryu and A. A. Kishk, "UWB dielectric resonator antenna mounted on a vertical ground plane edge," 2009 IEEE Antennas and Propagation Society International Symposium, Charleston, SC, 2009, pp. 1-4.doi: 10.1109/APS.2009.5171978.

[5] M. J. Almalkawi and V. K. Devabhaktuni, "Quad band-notched UWB antenna compatible with WiMAX/INSAT/lower-upper WLAN applications," in Electronics Letters, vol. 47, no. 19, pp. 1062-1063, September 15 2011. doi: 10.1049/el.2011.1862.

[6] J. Banerjee et al., "A compact printed UWB monopole antenna with triple band notch characteristics," 2018 3rd International Conference on Microwave and Photonics (ICMAP), Dhanbad, India, 2018, pp. 1-2.doi: 10.1109/ICMAP.2018.8354590.

[7] H. A. Majid, M. K. A. Rahim, M. R. Hamid, N. A. Murad, A. Samsuri and O. Ayop, "Reconfigurable band notch UWB antenna using EBG structure," 2014 IEEE Asia-Pacific Conference on Applied Electromagnetics (APACE), Johor Bahru, 2014, pp. 268-270. doi: 10.1109/APACE.2014.7043798

[8] N. Jaglan, S. D. Gupta, S. Srivastava and B. K. Kanaujia, "Satellite downlink communication band notched UWB antenna using uniplanar EBG structure," 2016 International Conference on Signal Processing and Communication (ICSC), Noida, 2016, pp. 89-94.doi: 10.1109/ICSPCom.2016.7980554.

[9] T. A. Denidni and Z. Weng, "Hybrid ultrawideband dielectric resonator antenna and band-notched designs," in IET Microwaves, Antennas & Propagation, vol. 5, no. 4, pp. 450-458, March 21 2011. doi: 10.1049/iet-map.2009.0425.

[10] B. Ghosh, Y. M. M. Antar, A. Petosa and A. Ittipiboon, "CPW-fed DRA," 2004 10th International Symposium on Antenna Technology and Applied Electromagnetics and URSI Conference, Ottawa, Canada, 2004, pp. 1-4. doi: 10.1109/ANTEM.2004.7860617.

[11] P. de Maagt, R. Gonzalo, J. Vardaxoglou and J. M. Baracco, "Review of electromagnetic-bandgap technology and applications," in URSI Radio Science Bulletin, vol. 2004, no. 309, pp. 11-25, June 2004. doi:10.23919/URSIRSB.2004.7909613.

[12] E. El-Deen, S. H. Zainud-Deen, H. A. Sharshar and M. A. Binyamin, "The effect of the ground plane shape on the characteristics of rectangular dielectric resonator antennas," 2006 IEEE Antennas and Propagation Society International Symposium, Albuquerque, NM, 2006, pp. 3013-3016. 11 doi: 10.1109/APS.2006.1711242.

[13] M. A. Abdelaal and A. A. Kishk, "Dielectric resonator antenna gain improvement using electromagnetic band gap surface for radar applications," 2016 17th International Symposium on Antenna Technology and Applied Electromagnetics (ANTEM), Montreal, QC, 2016, pp. 1-2 doi: 10.1109/ANTEM.2016.7550188.

[14] Nikitha Prem E. K and R. Karthikeyan, "Triple band notch UWB antenna array with EBG structure," 2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), Chennai, 2016, pp.1869-1873. doi: 10.1109/WiSPNET.2016.7566466.

[15] K. S. Ryu and A. A. Kishk, "UWB Dielectric Resonator Antenna Having Consistent Omnidirectional Pattern and Low Cross-Polarization Characteristics," in IEEE Transactions on Antennas and Propagation, vol. 59, no. 4, pp. 1403-1408, April 2011. doi: 10.1109/TAP.2011.2109676.