Compact sectoral UWB antenna with WLAN (5.2/5.8 GHz) and WiMAX (5.5 GHz) filtering characteristics

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Abstract

This paper presents a compact circular sectored microstrip antenna embedded with two symmetric circular slots and a sectoral ground plane embedded with an open-ended rectangular slot for enhancement of bandwidth and its applicability for UWB communications. The proposed structure exhibits Fractional Bandwidth(FBW) of 157.38 % (2.38 GHz –19.96 GHz) using Rogers RT Duroid 5880as a substrate for lower surface wave loss and attaining broader bandwidth producing notch band centered at around 5.30 GHz (4.26 GHz – 6.34 GHz) which effectively filters out WLAN(5.2/5.8 GHz) and WiMAX(5.5 GHz) bands. The gain of the antenna ranges from 5.34 – 5.73dBi throughout the resonant frequency band and the results obtained from measurement have good accordance with simulated solutions in terms of return loss, gain, polarization and far field patterns.

1 Introduction

Due to the development of various wireless standards in the telecommunication standards there has been increment in the requirement of wideband and multiband antennas. The Federal Communication Commission (FCC) assimilated the use of 3.1-10.6 GHz frequency band for use in UWB applications in 2002[1]. Researchers, till now have designed several UWB antennas because of their capabilities. As a result, these wideband and UWB structures are common now a day because of its multifunctional capability. The Microstrip Antennas (MSAs) were normally used for a particular tuned frequency providing maximum power transmit or receive in that particular resonant frequency. Various UWB antennas have been presented in [2-9], which allows covering various narrow frequency bands like WLAN (5.1-5.9 GHz), WiMAX (3.25-3.75 GHz), HIPERLAN/2 IEEE 802.11a (5.15-5.35 GHz/5.47-5.725 GHz) and Multichannel Video and Data Distribution Service (MVDDS) (12.2-12.7 GHz).

Due to various advantages of compact size of antennas it has been a challenge to the researchers in designing miniaturized antennas and hence compactness plays a significant role in terms of antenna design. The dielectric (Ɛr) is preferred to be larger in most of the cases in order to achieve UWB characteristics. But as a result of larger Ɛr various demerits are to be suffered in the terms of greater size of the antenna, increase in weight, surface wave loss, extraneous radiations and dielectric loss which leads to use of less value of Ɛr. By increasing or decreasing the thickness of substrate the total effectiveness of an antenna can be enhanced. While, by using a thin substrate the desired characteristics were achieved. Various efficient antenna structures have been proposed in articles [2-6]. Mukhejee et al.[7] designed a T-shaped slotted antenna accompanied with inverted U-slot resonator inside feed line and symmetrical pair of slits in ground plane while in [8] dual notch is achieved by introducing Complementary Split Ring Resonator(CSRR) in the hexagonal patch. In [9], U – shaped slot in the staircase shaped patch is used to achieve notching feature, whereas in [10] U shaped parasitic strips on either side of the feed line and C-shaped stub is etched in the patch to achieve dual notch. Lee et al.[11] designed a tapered slot antenna with Archimidean spiral slot to attain notch band characteristics. However, compactness is still an existing issue for all these antenna structures.

The proposed structure provides various useful factors especially regarding dimensions, dielectric constant, substrate height (h), which provides better results in respect of Gain, Return Loss, VSWR, Polarization and Radiation Patterns. Also, an efficient UWB antenna is designed by introducing unique techniques that will reject the bands that will interfere with the UWB frequency. The proposed structure improves the bandwidth ratio and FBW by embedding two symmetric circular slots in the patch and an open-ended rectangular slot in the ground substrate.

2 Antenna Design steps

In order to design the proposed structure at first a rectangular shaped antenna is taken having dimensions40 × 40 mm^2 in which a circular sector of radius "a" is embedded in the patch and a circular sector of radius "b" in the ground structure as Defected Ground Structures (DGS) as shown in Figure 1 (a) to achieve wideband characteristics from 2.65 GHz – 6.32 GHz (3.67 GHz). In the next step two symmetrical circular slots are embedded in the patch of radius (r1=r2= 5.00 mm). The distance (d) is the centre to centre distance of the two circles. The radius of the circles plays an important part in enlarged bandwidth and compactness. Finally, the proposed structure is achieved by embedding an open -ended rectangular slot in the ground plane. RT Duroid 5880 substrate having thickness of 0.787mm, dielectric constant (Ɛr) of 2.2 and loss tangent (tan δ) = 0.002 is used for the structure.

The designed prototype is fed by a co-axial probe of 50 Ω impedance with the help of an SMA connector of radius 0.5 mm. The feed point is optimized to match the input impedance over the entire UWB range. Table.1 shows all the dimensions of the parameters starting from Antenna 1-3.

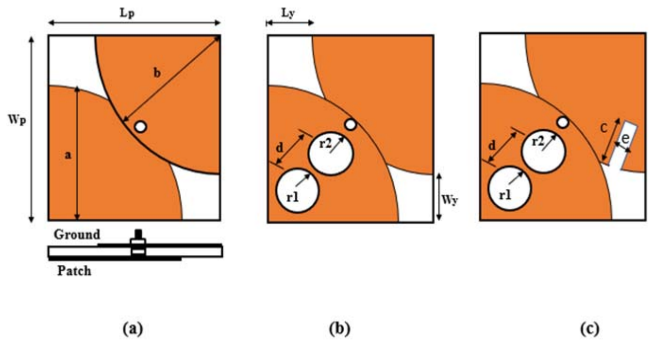

Figure 1. (a) Reference antenna (Antenna 1), (b) Antenna 2, (c) Antenna 3 (Proposed prototype).

Table 1. Parametric Dimensions

Parameters	Value (mm)
W_p	40
L_p	40
L_y	5.35
Wy	5.35
a	25
b	34.65
d	14.30
r1	5.00
r2	5.00
C	6.413
e	1.847

3 Results and analysis

Various results regarding the proposed antenna is discussed here. The S-parameters v/s frequency plots of all antennas: (Antenna 1-3) is shown in Figure2. It can be seen from Figure 2 that -10 dB bandwidth of Antenna 2 ranges from 2.5-20.25 GHz producing a bandwidth ratio of 8.1: 1(Bandwidth ratio of upper frequency level and lower frequency level) having FBW of 156.04 % (2.5 - 20.25 GHz) which indicates that it is UWB characteristics. The impedance bandwidth enhances as a result of extra modes being excited with the help of these circular slots.

Table 2. Frequency response characteristics of Ant.1-3

Type	**Resn. Freq bands (GHz)**	**Notch Bands**	**Notch Band Freqs (GHz)**	**-10 dB BW (GHz)**	**FBW (%)**	**Max Peak Gain (dBi)**
Ant1	(2.65-6.32), (13.74-15.19) and (19.05-20.33)	✓	(6.33-13.73), (15.2-19.04)	6.40	153.87	5.34
Ant2	2.5-20.25	×	N.A.	17.75	156.04	6.1
Ant3	(2.38-4.25, 6.35-19.96)	✓	(4.26-6.34)	15.48	157.38	5.73

Note: Fractional Bandwidth is calculated neglecting the notched bands under the condition of S_{11}≤10dB.

$$d = 2a - 2(r1 + r2) - \frac{\pi}{2}(r1 + r2) \quad (1)$$

From Eq.1, it is found that the value of d =14.30 mm (r1, r2=5.0 mm). Similarly a relation can be obtained for fu and fl with respect to d where fl is the lower resonant frequency level and fu is the upper resonant frequency level from Equation 2 and 3 respectively. By changing the value of'd', the bandwidth of final antenna can also be changed accordingly and the frequency range can be fixed to maintain a particular value of'd'.

$$f_l \cong \frac{c(r1+r2)}{2a\sqrt{\varepsilon_r}} \times \frac{\pi^2}{d} \quad (2)$$

and

$$f_u \cong \frac{c(r1+r2)}{2a\sqrt{\frac{(\varepsilon_r+1)}{2}}} \times \left(\frac{d}{\pi}\right) \qquad (3)$$

Where, the value of f_l and f_u are more or less similar to that of the simulated results. While, Antenna 3 has '-10dB' bandwidth ranging from (2.38- 4.25 GHz and 6.35-19.96 GHz, having a notch from 4.26- 6.34 GHz, which covers the desired bands (5.2/5.8/5.5 GHz). The notch is centered at 5.30 GHz (4.26 – 6.34 GHz) and can be calculated from the given formula

$$f_{notch} \approx \frac{1.5c}{4(2C+e)\sqrt{\varepsilon_{reff}}} \qquad (4)$$

Where,

f_{notch} = centre frequency of the notched band.
c = velocity of light
C = length of the open ended rectangular slot in the ground
e = width of the open ended rectangular slot in the ground.
ε_{reff} = Effective di-electric constant.

Where,

$$\varepsilon_{reff} = \left(\frac{\varepsilon_r+1}{2}\right) + \left(\frac{\varepsilon_r-1}{2}\right)\left(1+\frac{12h}{W}\right)^{-\frac{1}{2}} \qquad (5)$$

The surface current flow pattern of Antenna 3 is shown in Figure 3, where 3(a) and (b) represents current distribution pattern at pass band frequencies of 3.2 GHz and 3.5 GHz respectively whereas 3(c) and 3(d) represents current flow at 5.2 GHz and 5.5 GHz respectively. The gain of Antenna 3 in comparison to Antenna 2 is plotted in Figure 4. It can be clearly observed that the gain falls below the 0 dB line in case of Antenna 3. The measured co-pol. and cross pol. far-field patterns of proposed antenna at 3.20 GHz, 3.50 GHz, 5.20 GHz and 5.50 GHz are shown in Figure5.

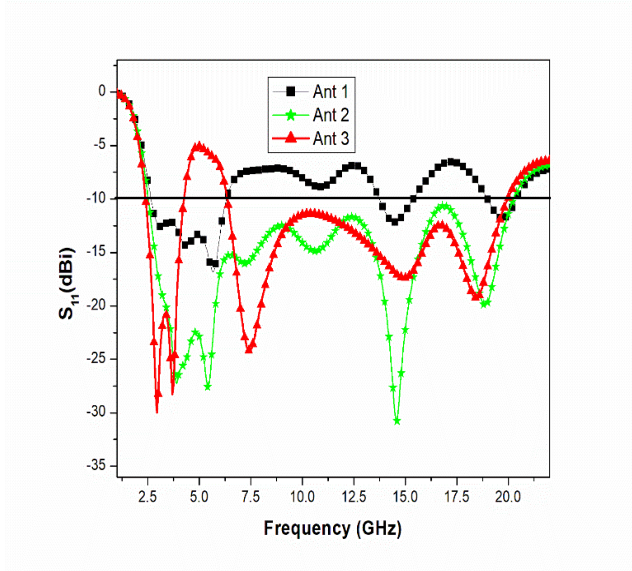

Figure 2: Comparison of S_{11} v/s Frequency plot for all antennas

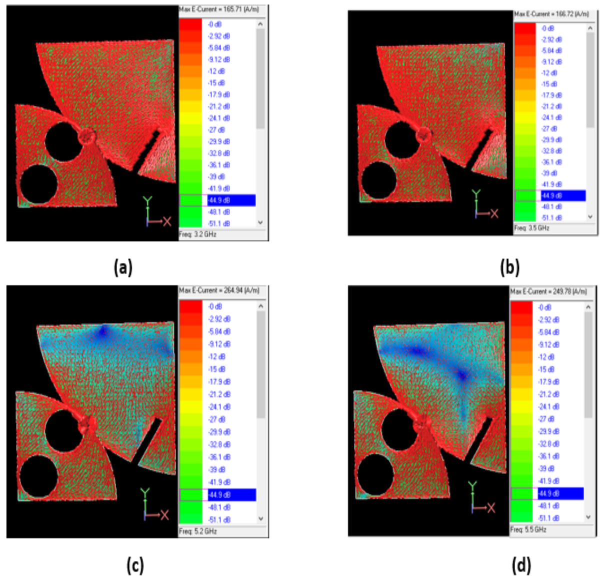

Figure 3: Current distribution pattern of proposed antenna (Antenna 3) at (a) 3.2 GHz (b) 3.5 GHz (c) 5.2 GHz and (d) 5.5 GHz

The proposed antenna is fabricated as depicted in Figure. 6 and the results are analyzed using Rohde and Schwarz (ZVA-40) VNA. The calculated results have good agreement with the simulated ones as shown in Figure.7. Table 3 depicts the comparison of the final antenna with the state of art antennas. Although the proposed antenna has greater patch area than some others yet it create some advantages in terms of Gain, Fractional Bandwidth (FBW %), Radiation patterns and notch band range.

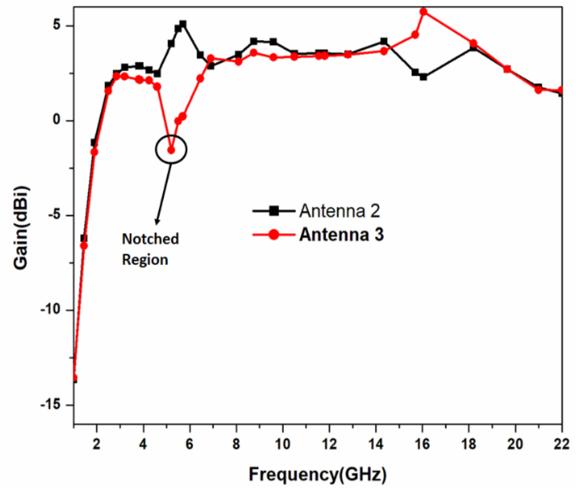

Figure 4: Gain v/s Frequency graph of Ant. 2 and Ant. 3.

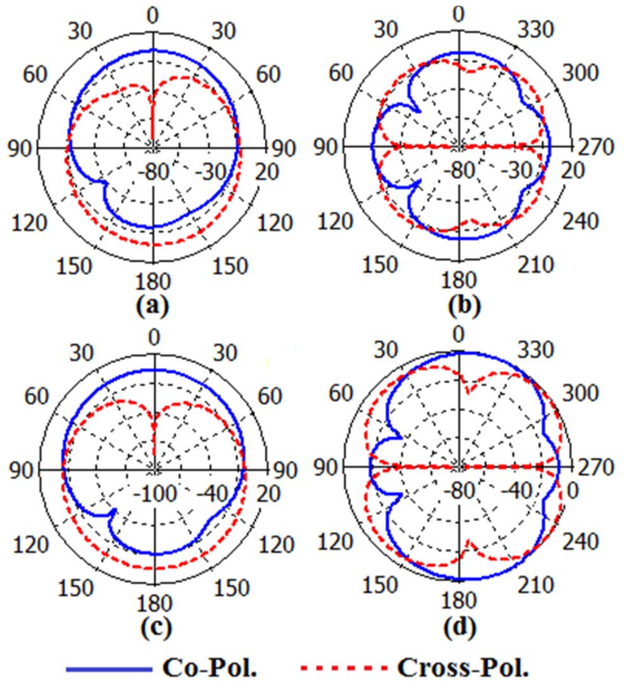

Figure 5: Measured Co-pol. and Cross-pol. radiation patterns at (a) 3.20 GHz, (b) 3.50 GHz, (c) 5.20 GHz and (d) 5.50 GHz.

Figure 6: Fabricated Prototype (a) Front View , (b) Rear View

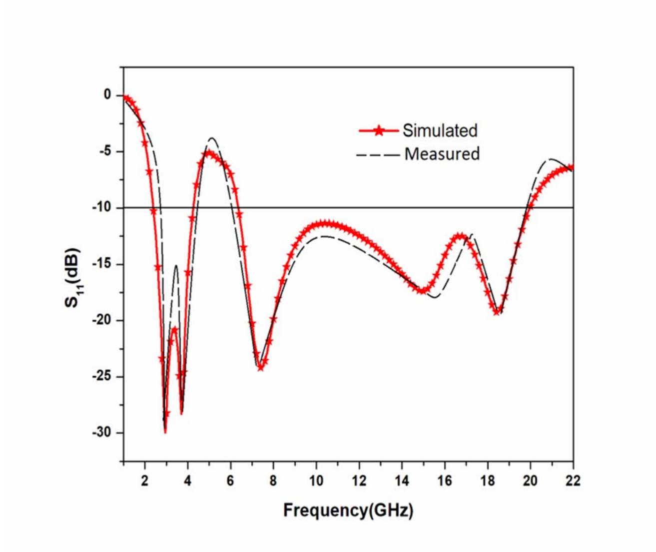

Figure 7: Simulated versus measured results

Table 3. Comparison of various antennas with respect to our designed prototype

Ref	Dimension (mm^2)	Resonant Bands (GHz)	Notch Bands (GHz)	FBW %	Max Gain (dBi)
[7]	35×36	2.52-10.68	(3.3-3.7) (5.15-5.825)	123.6	7.1
[8]	30×35	2.7-16.9	(3.3-3.7) (4.6-5.9)	144.89	2.0
[9]	40×30	2.68-17.50	(3.3-3.7) (5.2-5.825)	136	3.69
[10]	32×38	3-20	(3.5-5.3)	147.83	4.0
[11]	50×50	2.4-11.2	(4.6-6.2)	129.41	5.1
This work	**40×40**	**2.38-19.96**	**(4.26-6.34)**	**157.38**	**5.73**

4 Conclusions

In this paper a compact circular sectored microstrip antenna has been presented. The proposed structure exhibits fractional bandwidth of 157.38 % (2.38 GHz – 19.96 GHz). Effective filtering of the WLAN (5.2/5.8 GHz) and WiMAX (5.5 GHz) bands have been performed. The compact structure of the proposed antenna makes it suitable for UWB communications with notch band characteristics.

5 References

1. FCC and D. FCC, 1st report and order on ultra-wideband technology, FCC, Washington, DC (2002).

2. A. Dastranj and H. Abiri, Bandwidth enhancement of printed e-shaped slot antennas fed by CPW and microstrip line, IEEE Transactions on Antennas and Propagation 58(4) (2010) 1402-1407.

3. A. K. Gautam, A. Bisht, and B. K. Kanaujia. "A wideband antenna with defected ground plane for WLAN/WiMAX applications." AEU-International Journal of Electronics and Communications 70.3 (2016): 354-358.

4. S. Nikolaou, and M. A. Babar Abbasi. "Design and development of a compact UWB monopole antenna with easily-controllable return loss., " IEEE Transactions on Antennas and Propagation 65.4 (2017): 2063-2067.

5. M. Gupta, and V. Mathur. "Wheel shaped modified fractal antenna realization for wireless communications." AEU-International Journal of Electronics and Communications 79 (2017): 257-266.

6. B. Roy, et al. "Wideband Snowflake slot antenna using Koch iteration technique for wireless and C-band applications." AEU-International Journal of Electronics and Communications 70.10 (2016): 1467-1472.

7. B. Mukherjee et al., Coplanar waveguide fed ultra-wide band printed slot antenna with dual band-notch characteristics, 2017 8th Annual Industrial Automation and Electromechanical Engineering Conference (IEMECON), Bangkok, 2017, pp. 314-317.

8. Zeng, H. Zhang, Y. Zhang and H. Zhao, "Compact Band-Notched UWB Antenna Based on CSRR for WiMAX/WLAN Applications," *2018 International Conference on Microwave and Millimeter Wave Technology (ICMMT)*, Chengdu, 2018.

9. N. Waheed *et al.*, "Ultra-Wideband antenna with WLAN and WiMAX band-notch characteristic," *2017 International Conference on Communication, Computing and Digital Systems (C-CODE)*, Islamabad, 2017, pp. 101-106.

10. A. S. Eltrass, N. A. Elborae and H. M. Elkamchouchi, "A New Compact Wide-Band Antenna Design for Satellite Communications with Dual Band-Notches for WiMAX and WLAN Using Particle Swarm Optimization," *2018 IEEE Conference on Antenna Measurements & Applications (CAMA)*, Vasteras, 2018, pp. 1-4.

11. D. Lee, H. Yang and Y. Cho, "Tapered Slot Antenna With Band-Notched Function for Ultrawideband Radios," in *IEEE Antennas and Wireless Propagation Letters*, vol. 11, pp. 682-685, 2012.