DESIGN AND ANALYSIS OF A COMPACT ELLIPTICALDUAL BAND-NOTCHED UWB ANTENNAUSING ESCSRRS

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Abstract

In this paper, a compact elliptical shaped patch ultra-wideband (UWB) antenna for dual band-notched characteristics is presented. The antenna is consists of an elliptical shaped patch, a 50 Ω microstrip feed line, half elliptical square slot modified ground plane, and two elliptical single complementary split ring resonators (ESCSRRs) of different dimensions. The proposed antenna exhibits impedance bandwidth 2.82-12 GHz for UWB applications. The dual band-notched characteristics are created at 3.27-3.76 GHz and 4.1-4.6 GHz by cutting two ESCSRRs of different dimensions in the elliptical patch near to feed line for rejecting 3.5 GHz WiMAX band and 4.4 GHz C-band, respectively. Overall two bands are notched using two notched elements and all notches are controllable through circumference of the individual ESCSRR. The reduced peak realized gain – 5.3 dBi for 3.5 GHz WiMAX and – 3.2 dBi for 4.4 GHz C-band is obtained in the notched region. Results show good UWB characteristics, realized gain and omnidirectional radiation patterns over the UWB band with size of 24 mm × 34 mm.

Keywords—*Elliptical antenna; ESCSRRs; UWB antenna, WiMAX; C-Band*

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1. INTRODUCTION

In 2002, the Federal Communications Commission (FCC) allocated an unlicensed band 3.1-10.6 GHz for ultra-wideband (UWB) for indoor/hand-held applications. Very low power of -41.3 dBm/MHz pulses is emitted by an UWB system. For the UWB wireless transmission, the UWB antenna is desirable which having characteristics of compact size, planar, low profile, low cost, easy to integrate with other circuits and omnidirectional radiation pattern[1]-[2].In the UWB band, there are some narrow bands also exists and need to address and eliminate these narrow bands from UWB range. Therefore, the demand of UWB antenna with band-notched characteristics is increasing. Initially, notching of two narrow bands simultaneously especially 3.5 GHz worldwide interoperability for microwave access (WiMAX) band (3.4-3.69 GHz) and C-band (4.2-4.6 GHz) is desirable. Then, stable realized gain with good band-notched characteristics and omnidirectional radiation patterns is desired. Therefore, various simple shapes like rectangular, circular, elliptical UWB and slot antennas with and without single/dual band-notched functions are reported and demonstrated in the literature [3]-[16].The planar circular and elliptical UWB antenna [3]-[5], circular and elliptical slot UWB antenna [6]-[7], band-notched circular slot UWB antenna using inverted C-shaped parasitic stub [8], heart-shaped UWB antenna using U-shaped slot for band-notched UWB applications [9], band-notched semi-elliptic slot UWB antenna [10], dual band-notched UWB antenna [11], dual band-notched UWB antenna using defected ground structure (DGS) and split-ring resonator (SRR) [12], dual band-notched compact UWB antenna [13], a CPW-fed dual band-notched hexagonal open slot antenna [14], dual band-notched UWB antenna using complementary SRR [15], and electromagnetically coupled elliptical UWB antenna using parasitic element [16] are reported and presented.

In this paper, a compact elliptical shaped patch UWB antenna for dual band-notched characteristics is proposed. The UWB band is achieved by using elliptical shaped patch, 50 Ω microstrip feed line and half elliptical square slot modified ground plane and dual band-notched characteristics are obtained by cutting two ESCSRRs in the elliptical shaped patch which placed near to feed line of different dimensions. The notching element dimensions can be varied and desired notched bandwidth and centre notch frequency controlled through the circumference of individual ESCSRR. The rest of the paper is organized as follows: Section II describes geometry of proposed elliptical patch antenna with two ESCSRRs. Section III discusses the step wise simulation results of dual band-notched elliptical UWB antenna and section IV presents conclusion.

2. PROPOSED ANTENNA DESIGN

The geometry of a compact elliptical UWB antenna with dual band-notched characteristics front view, back view, and two ESCSRRs is shown in Fig. 1 with its physical parameters. The proposed antenna is printed on the FR-4 dielectric substrate of dielectric constant of 4.3, thickness of 1.6 mm and loss tangent of 0.025.The elliptical patch with major axis length 24 mm and minor axis length 18 mm is fed through a 50 Ω microstip feed line of width 3 mm on FR-4 dielectric substrate material with two elliptical single complementary split-ring resonators (ESCSRRs) of different dimensions on one side and shown Fig. 1 (a). On the other side of dielectric substrate a half elliptical shaped modified ground plane and a square notch element on the upper edge of ground plane is printed as shown in Fig. 1 (b).The gap between elliptical shaped patch and modified ground plane provides impedance matching circuit. The S-parameter can also be improved by introducing a notching square slot on upper edge of half elliptical modified ground plane. By cutting two ESCSRRs of different dimensions from elliptical shaped patch near to feed line for rejecting 3.5 GHz WiMAX band and C-band. The antenna is simulated on the CST Microwave Studio software [17] and optimized dimensions of proposed antenna with dual band-notched characteristics are listed in Table 1.

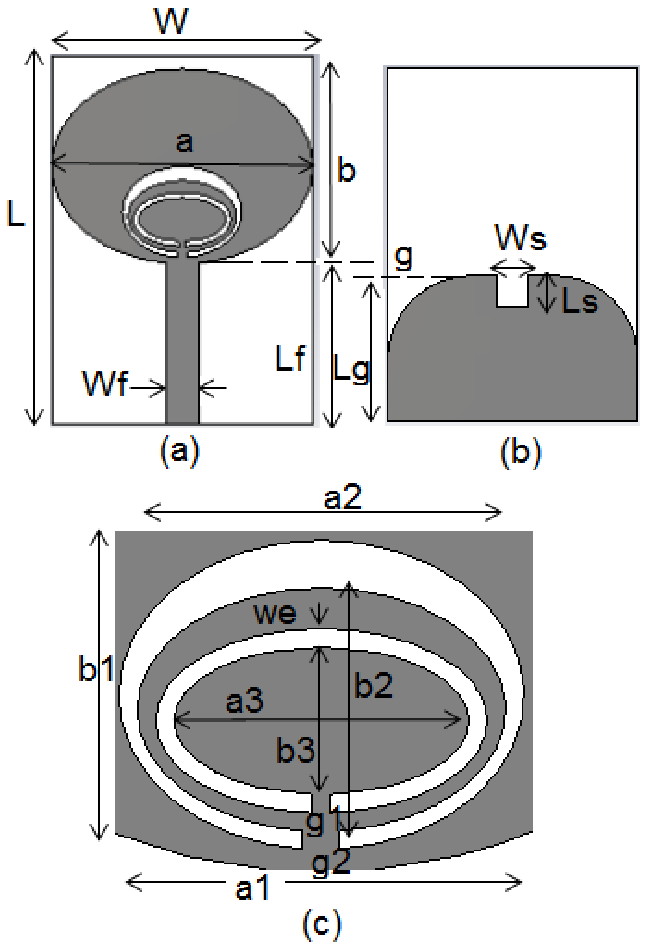

Fig. 1: Geometry of the proposed elliptical dual band-notched UWB antenna with physical parameters (a) front view, (b) back view, and (c) ESCSRRS

Table 1: Proposed elliptical dual band-notched uwb antenna parameters

Parameters	*L*	*W*	*Lf*	*Wf*	*a*	*b*
Dimensions (mm)	34	24	15	3	24	18
Parameters	*Ls*	*Ws*	*Lg*	*a1*	*a2*	*a3*
Dimensions (mm)	3	3	14	11	10	8
Parameters	*b1*	*b2*	*b3*	*We*	*g1=g*	*g2*
Dimensions (mm)	8.4	6.6	4	0.5	1	2

3. RESULTS AND DISCUSSION

3.1 Compact Elliptical UWB Antenna

In Fig. 2 (a) and (b), the front and back view of the compact elliptical shaped patch antenna is shown. The simulated S-parameter (S11) against frequency of the compact elliptical UWB antenna is shown in Fig. 3. The simulated impedance bandwidth 3-13 GHz is observed. This characteristic indicates that it is useful for UWB applications. The S-parameters value for elliptical UWB antenna observed at 3.4 GHz is -19.15 dB, at 5.66 GHz is -32.38 dB, at 8.5 GHz is -33.7 dB, at 9.8 GHz is -29.4 dB, and at 11.65 GHz is -22.65 dB. The voltage standing wave ratio is less than 2 observed in the whole UWB frequency range as shown in Fig. 4.The simulated realized gain against frequency of the compact elliptical UWB antenna is shown in Fig. 5. The realized gain variation of this antenna is 1 dBi to 4dBi in the UWB band. The 5.5 dBi peak antenna gain is observed at 11.9 GHz and overall good gain is observed. Fig. 6 shows the simulated 3D radiation patterns of the compact elliptical UWB antenna at four resonant frequencies 3.4 GHz, 5.66 GHz, 8.5 GHz and 9.8 GHz in UWB range.

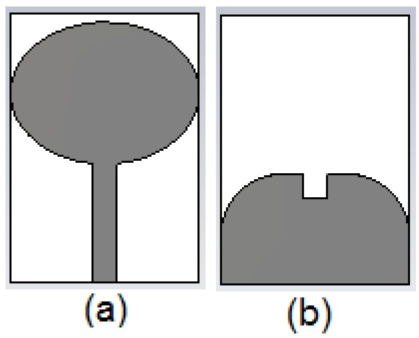

Fig. 2: Structure of elliptical UWB antenna (a) front view, (b) back view

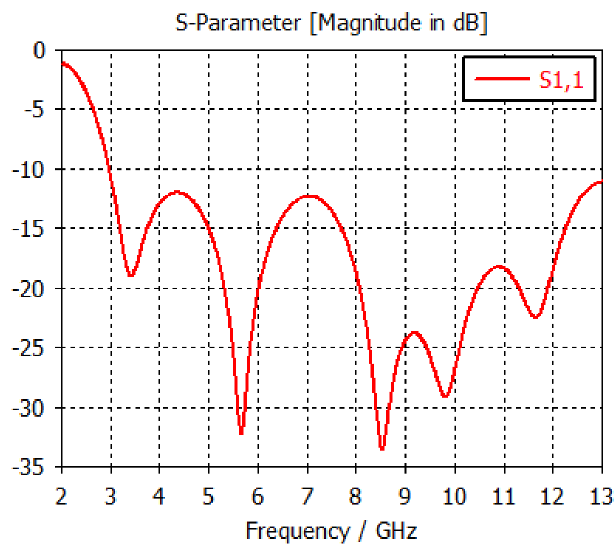

Fig. 3: S-parameter (dB) of the proposed compact elliptical UWB antenna

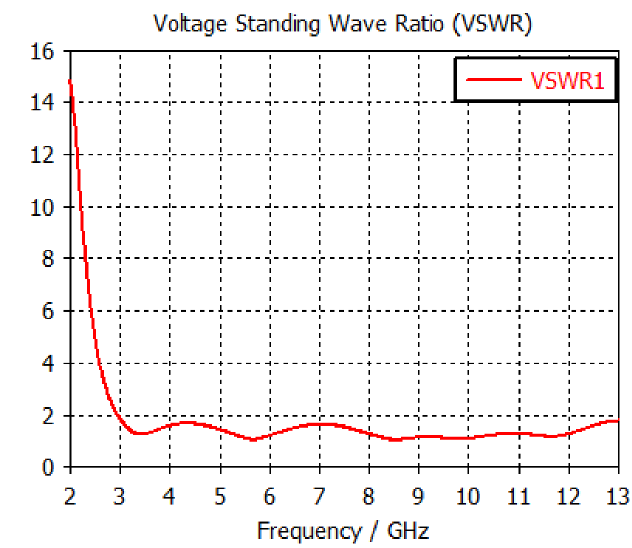

Fig. 4: VSWR of the proposed compact elliptical UWB antenna

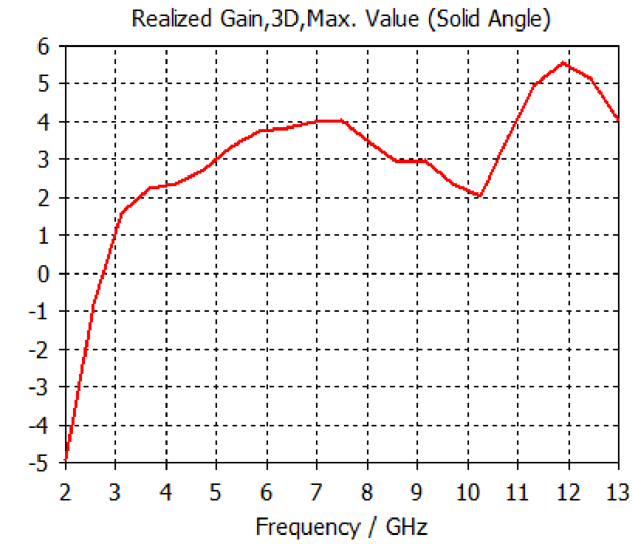

Fig. 5: Realized gainof the proposed compact elliptical UWB antenna

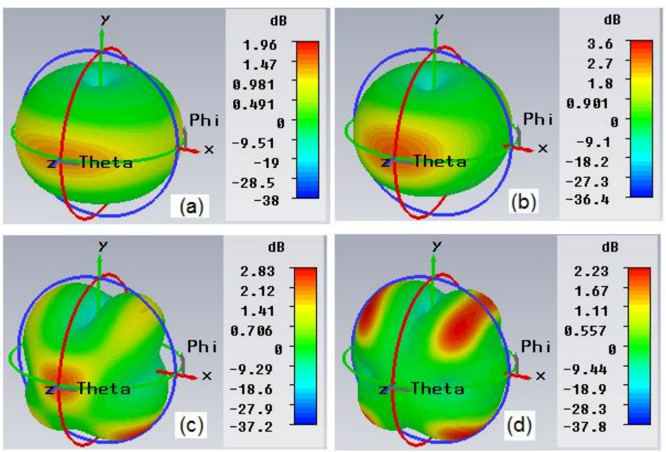

Fig. 6: 3D radiation patternof the proposed compact elliptical UWB antennaat (a) 3.4 GHz, (b) 5.66 GHz, (c) 8.5 GHz, and (d) 9.8 GHz

The radiation pattern shows omnidirectional at lower two (3.4 GHz and 5.66 GHz) and nearly omnidirectional at upper two (8.5 GHz and 9.8 GHz) resonant frequencies. The realized gain at 3.4 GHz is 1.96 dBi, 5.66 GHz is 3.6 dBi, 8.5 GHz is 2.83 dBi, and 9.8 GHz is 2.23 dBi observed as shown in Fig. 6. The above exhibit characteristics of antenna make it suitable for UWB applications.

3.2 Compact Elliptical UWB Antenna with Single ESCSRR

In Fig.7 (a) and (b), the front and back view of the compact elliptical UWB antenna with single ESCSRR is shown. The single ESCSRR create band-notched at 3.5 GHz WiMAX band (3.4-3.69 GHz) when it is placing near to feed line.The dimensions of single ESCSRR are mentioned in Table I. To obtain optimized results in the 3.5 GHz WiMAX band, the parametric study is performed by varying some parameters. The single ESCSRR have five parameters: *a1*, *b1*, *a2*,*b2*, and*g2* (as shown in Fig. 1). The parametric analysis is observed when one parameter is varying and other parameters are kept constant. Here, three parameters *b1*, *a2* and *g2* of single ESCSRR are discussed. Firstly, the effect of varying *b1* on S-parameter is shown in Fig. 8. It is observed that when *b1* changes from 6.4 mm to 10.4 mm with gap of 2 mm, the notch bandwidth of 3.5 GHz WiMAX band changes and shift towards to lower edge frequency side. It is also observed that notched centre frequency of 3.5 GHz WiMAX band shift towards lower side as outer minor axis length*b1* increases. The similar effect is analysed when *a1* changes and same response is observed. Secondly, the effect of varying *a2* on S-parameter is shown in Fig. 9. It is observed that when *a2* changes from 6 mm to 10 mm with gap of 2 mm, the notch bandwidth of 3.5 GHz WiMAX band changes and shift towards to lower edge frequency side. It is also observed that notched centre frequency of 3.5 GHz WiMAX band shift towards lower side as inner major axis length *a2* increases. Lastly, the third parameter which has the impact on the notch bandwidth is gap *g2* of ESCSRR. When gap *g2* increases from 0.5 mm to 1.5 mm with a variation of 0.5 mm, the centre notch frequency and notched bandwidth of 3.5 GHz WiMAX band shift towards upper frequency side because circumference of ESCSRR reduced as gap *g2*increases. Therefore, we can consider the optimized value of *b1*, *a2*, and *g2* is to be 8.4 mm, 8 mm, and 1 mm, respectively.

The simulated impedance bandwidth of the proposed elliptical UWB antenna with single ESCSRR is 2.84-12 GHz and single notched band from 3.35-3.76 GHz obtained for rejecting 3.5 GHz WiMAX band as shown comparison of S11 with and without band-notched in Fig. 11.The comparison of VSWR against frequency of the proposed elliptical UWB antenna with and without band-notched is shown in Fig. 12 and VSWR is less than 2 observed in the UWB frequency range except the 3.5 GHz notched band. In the 3.5 GHz notched region, the VSWR value 6.6 is observed.

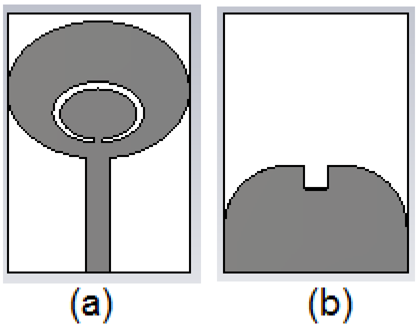

Fig. 7: Structure of theproposed elliptical UWB antenna with single ESCSRR (a) front view, (b) back view

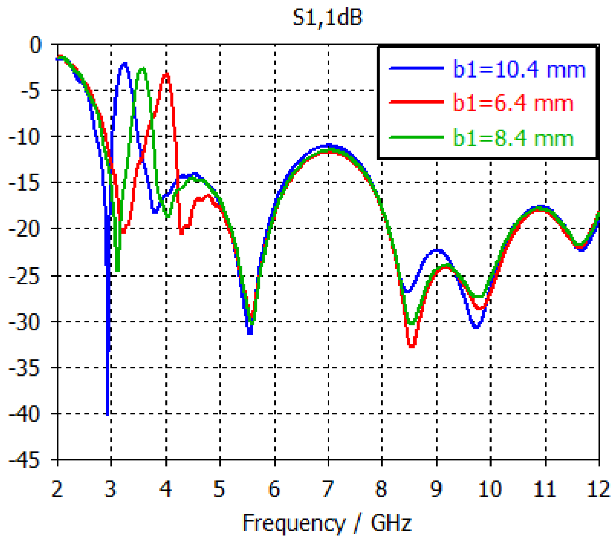

Fig. 8: S11 (dB) of the proposed elliptical UWB antenna with band-notched by varying values of*b1*

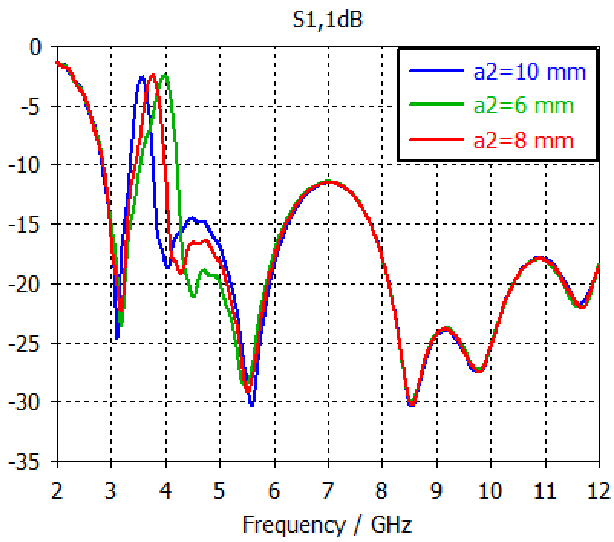

Fig. 9: S11 (dB) of the proposed elliptical UWB antenna with band-notched by varying values of *a2*

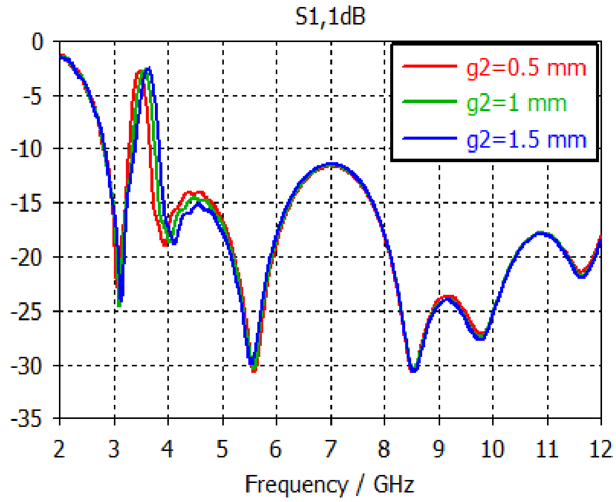

Fig. 10: S11 (dB) of the proposed elliptical UWB antenna with band-notched by varying values of *g2*

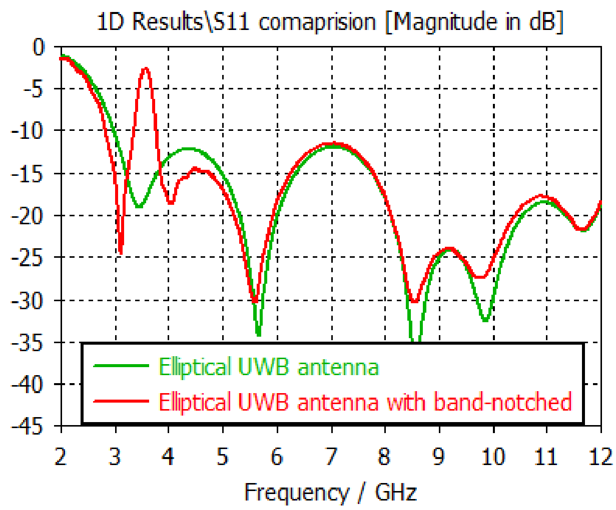

Fig. 11: S11comparison of the proposed elliptical UWB antenna with and without band-notched

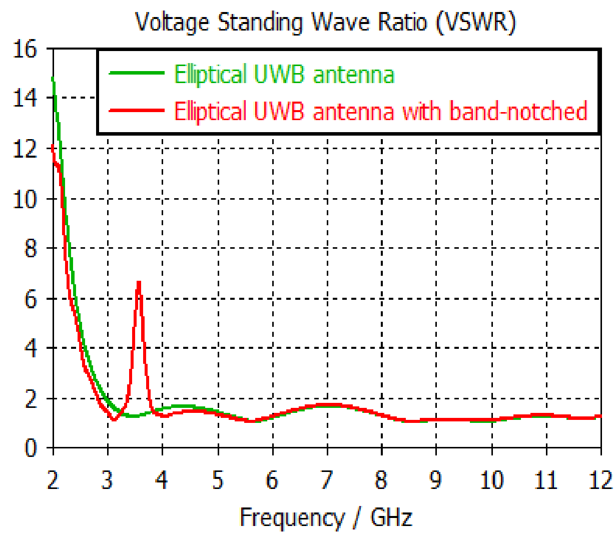

Fig. 12: VSWR comparison of the proposed elliptical UWB antenna with and without band-notched

The surface current distribution of the proposed elliptical UWB antenna with single ESCSRR at notch centre frequency 3.56 GHz is shown in Fig. 13. It can be observed that the mainly surface current is concentrated on the ESCSRR notching element in opposite direction. It means that the antenna does not radiate and notched band created at about 3.56 GHz. This concept is also verified with the realized gain curve as shown in Fig. 14. In the notched region, the realized gain is -5.4 dBi observed at 3.56 GHz frequency. From Fig. 14, it is also observed that in the UWB band similar realized gain obtained as elliptical UWB antenna except notch region. Therefore, we can say that by cutting a single ESCSRR in the elliptical patch the antenna characteristics will not hinder except the notched region. The 3D radiation pattern of the proposed elliptical UWB antenna with band-notched is shown in Fig. 15 and nearly omnidirectional pattern is obtained.

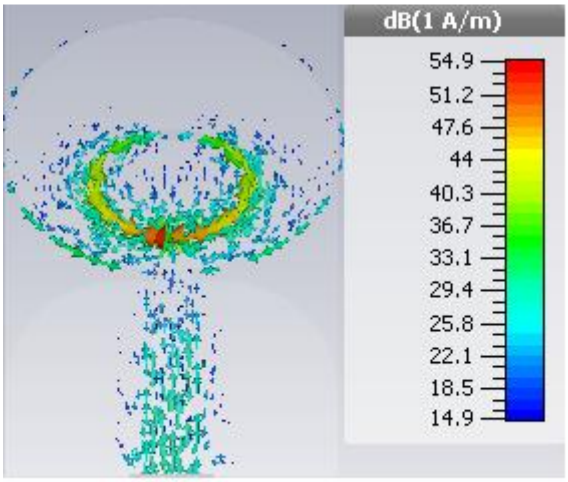

Fig. 13: Surface current distributions of the proposed elliptical UWB antenna with single ESCSRR at 3.56 GHz

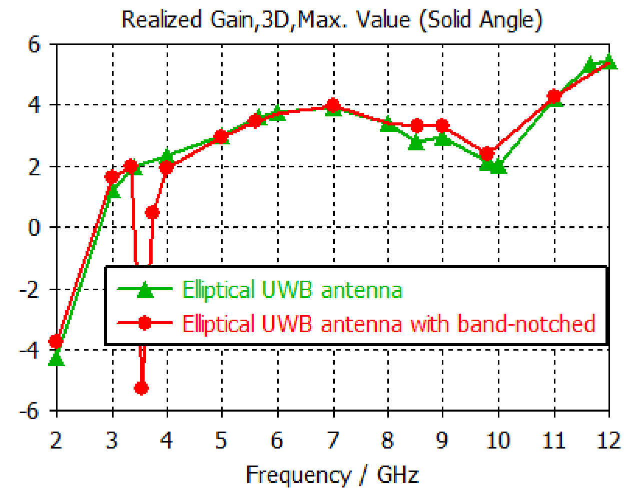

Fig. 14: Realized gain comparison of the proposed elliptical UWB antenna with and without band-notched

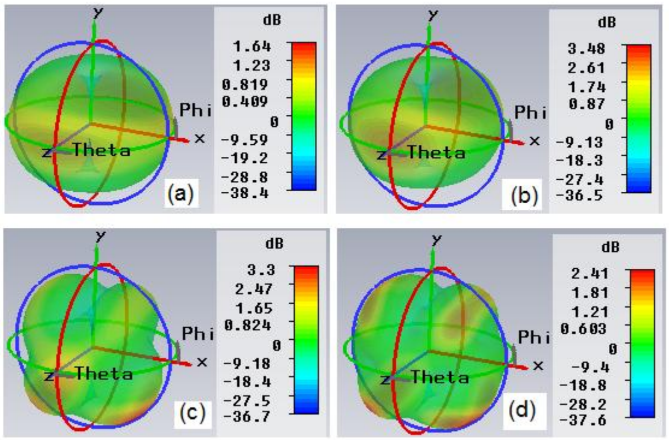

Fig. 15: 3D radiation pattern of the proposed elliptical UWB antenna with band-notched at (a) 3.1 GHz, (b) 5.6 GHz, (c) 8.5 GHz, and (d) 9.8 GHz

3.3 Compact Elliptical UWB Antenna with Two ESCSRRs

In Fig. 16 (a) and (b), the front and back view of the compact elliptical UWB antenna with two ESCSRRs is shown. The two ESCSRRs creates band-notches for 3.5 GHz WiMAX band (3.4-3.69 GHz) and C-band (4.2-4.6 GHz) when both are placing near to feed line. The second ESCSRR is placed inside the first ESCSRR. The dimensions of elliptical UWB antenna and ESCSRRs are mentioned in Table I. To obtain optimized results in the 3.5 GHz WiMAX and C-band, the parametric study is performed by varying some parameters of second ESCSRR only because first ESCSRR parameter is also discussed in the elliptical UWB antenna with band-notched characteristics section. The second ESCSRR have four parameters: *a3*, *b3*, *we*, and*g1* (as shown in Fig. 1).

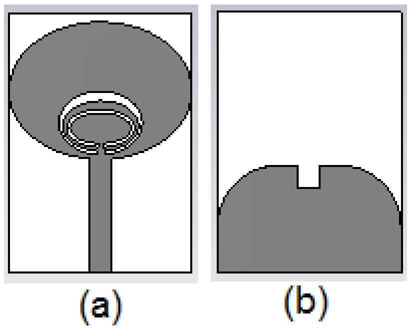

Fig. 16: Structure of the proposed elliptical UWB antenna with two ESCSRRs (a) front view, (b) back view

The parametric analysis is also analysed for *a3* and *g1*of second ESCSRR when one parameter is varying and other parameters are kept constant. Firstly, the effect of varying inner major axis length *a3* on S-parameter is shown in Fig. 17. It is observed that when *a3* changes from 6 mm to 8 mm with gap of 1 mm, the notch bandwidth of 4.4 GHz C-band changes and shift towards to lower edge frequency side. It is also observed that notched centre frequency of 4.4 GHz C-band shift towards lower side as inner major axis length *a3*of second ESCSRR increases. It can also be observed that 3.5 GHz WiMAX notched band remains unchanged. Similarly, the effect of varying gap *g1* on S-parameter is shown in Fig. 18. It is observed that when *g1* changes from 0.5 mm to 1.5 mm with variation of 0.5 mm, the notch bandwidth of 4.4 GHz C-band changes and shift towards to upper edge frequency side. It is also observed that notched band of 4.4 GHz C-band shift towards upper side as gap of second ESCSRR*g1* increases because circumference of second ESCSRR reduced as gap *g1*of second ESCSRR increases. It can also be observed that 3.5 GHz WiMAX band remains unchanged and C-band is optimized by varying gap *g1*. Therefore, we can consider the optimized value of *a3* and*g1* is to be 8 mm and 0.5 mm, respectively.

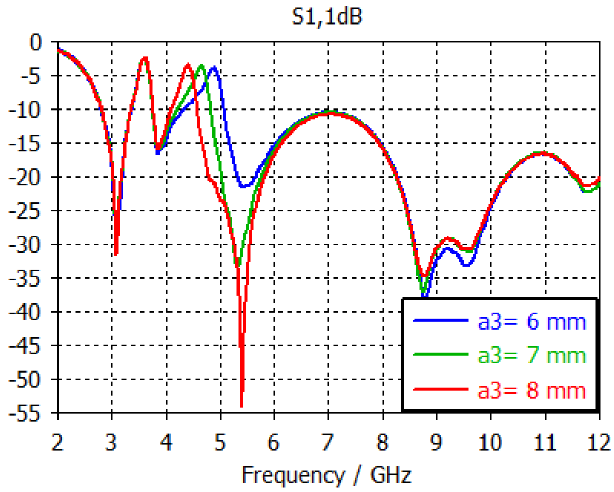

Fig. 17: S11 (dB) of the proposed elliptical UWB antenna with two band-notches by varying values of *a3*

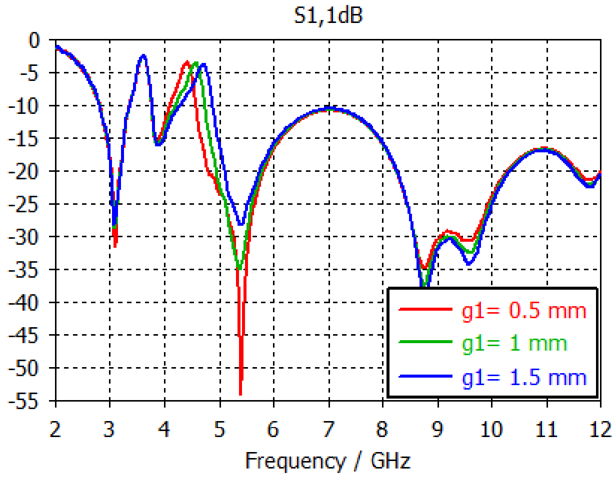

Fig. 18: S11 (dB) of the proposed elliptical UWB antenna with two band-notches by varying values of *g1*

The simulated impedance bandwidth of the proposed elliptical UWB antenna with two ESCSRRs is 2.82-12 GHz and dual notched bands 3.27-3.76 GHz, 4.1-4.6 GHz obtained for rejecting 3.5 GHz WiMAX band and 4.4 GHz C-band, respectively as comparison of S11 shown in Fig. 19.The comparison of VSWRs against frequency of the proposed elliptical UWB antenna with (single/dual) and without band-notches is shown in Fig. 20 and VSWR is less than 2 observed over UWB frequency range except the 3.5 GHz WiMAX and 4.4 GHz C-band notched region. In the 3.5 GHz WiMAX notched region, the VSWR value is 7 and in the 4.4 GHz C-band notched region, the VSWR is 4.9 observed.

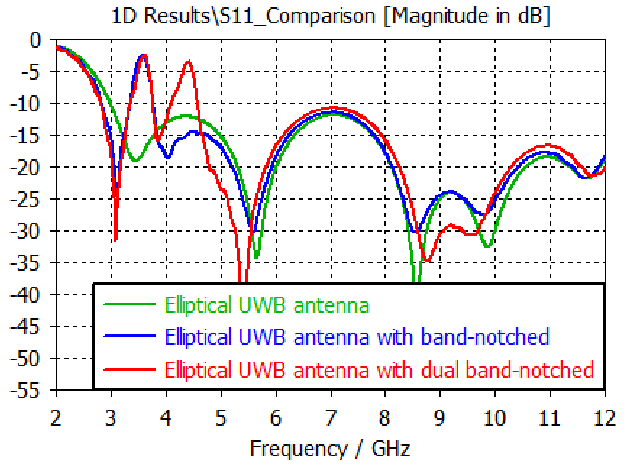

Fig. 19: S11(dB) comparison of the proposed elliptical UWB antenna with (single/dual) and without band-notches

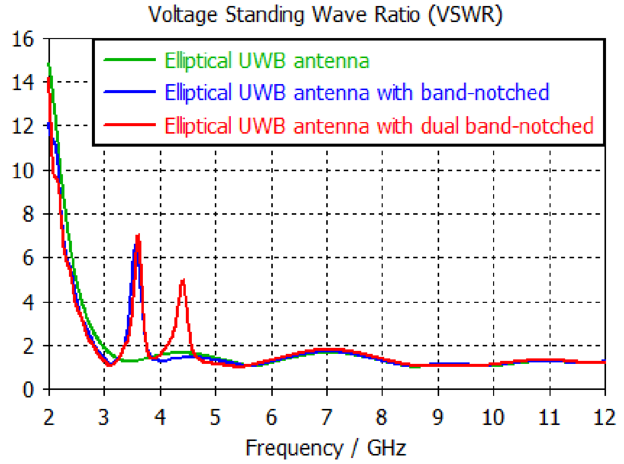

Fig. 20: VSWR comparison of the proposed elliptical UWB antenna with (single/dual) and without band-notches

The surface current distribution of the proposed elliptical UWB antenna with dual band-notches at 3.56 GHz and 4.4 GHz is shown in Fig. 21 (a) and (b), respectively. From Fig. 21 (a), it can be observed that the mainly surface current is concentrated on the outer ESCSRR notching element and current is in opposite direction. It means that antenna does not radiate and notched band created at around 3.56 GHz for WiMAX band. Similarly, from Fig. 21 (b) it can be observed that mainly surface current is concentrated on the inner ESCSRR notching element and current is in opposite direction. It means that antenna does not radiate and notched band is created around at 4.4 GHz for C-band. Therefore, it may be concluded that 3.5 GHz WiMAX and 4.4 GHz C-band notches created by individual ESCSRRs. This concept is also verified with the realized gain comparison curve as shown in Fig. 22 with and without band-notches. In the 3.5 GHz WiMAX notched region, the peak realized gain is -

5.3dBi observed at 3.56 GHz frequency. Similarly, in the 4.4 GHz C-band notched region the peak realized gain is -3.2 dBi at 4.4 GHz observed. From Fig. 22, it is also observed that in the UWB band good realized gain obtained and gain remains unchanged in the UWB range when cutting second ESCSRR in the elliptical shaped patch. Therefore, we can say that by cutting two ESCSRRs in the elliptical patch near to feed line the antenna characteristics will not hinder except the notched region. The 3D radiation pattern of the proposed elliptical UWB antenna with dual band-notches is shown in Fig. 23. It can be observed omnidirectional pattern at lower frequencies (3.1 GHz and 5.4 GHz) and nearly omnidirectional pattern at upper frequencies (8.77 GHz and 9.6 GHz). Fig. 24 (a) to (d) shows the E-plane and H-plane radiation patterns at four resonant frequencies 3.1 GHz, 5.4 GHz, 8.77 GHz and 9.6 GHz, respectively. In the E-plane dipole-like (bi-directional) radiation pattern is observed at all frequencies. The omnidirectional radiation pattern at lower two resonant frequencies (3.1 GHz and 5.4 GHz) and nearly omnidirectional at upper two resonant frequencies (8.77 GHz and 9.6 GHz) is observed in the H-plane.

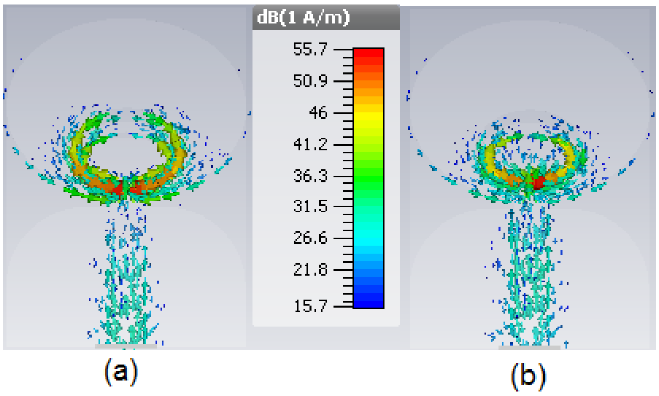

Fig. 21: Surface current distributions of the proposed elliptical UWB antenna with dual band-notches at (a) 3.56 GHz, and (b) 4.4 GHz

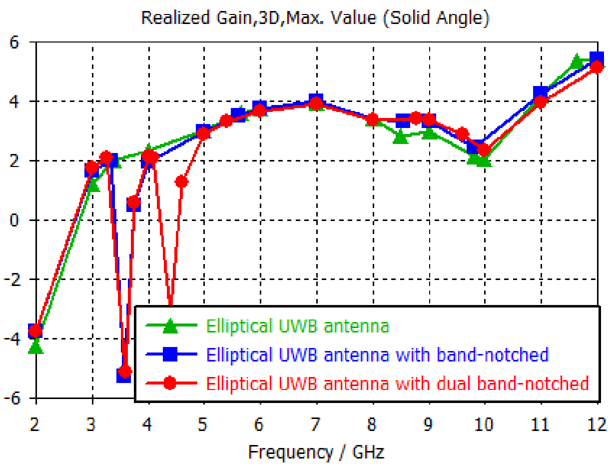

Fig. 22: Realized gain comparison of the proposed elliptical UWB antenna with (single/dual) and without band-notches

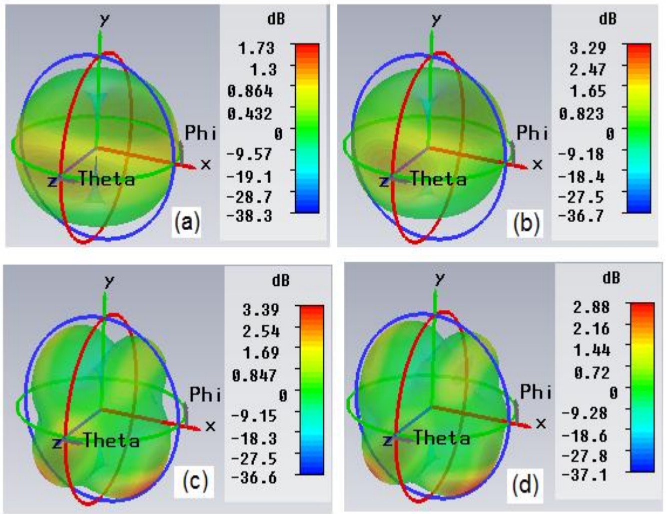

Fig. 23: 3D radiation pattern of the proposed elliptical UWB antenna with dual band-notches at (a) 3.1 GHz, (b) 5.4 GHz, (c) 8.77 GHz, and (d) 9.6 GHz

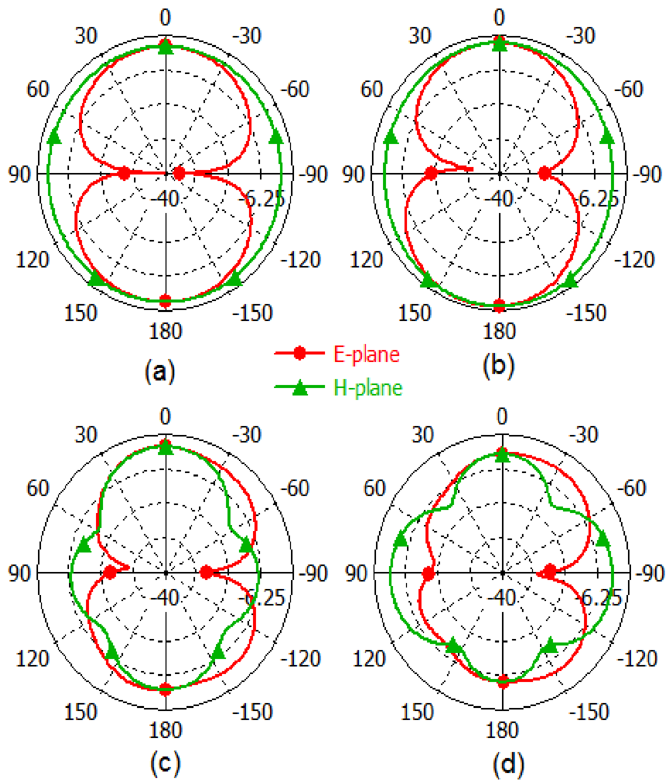

Fig. 24: E-plane and H-plane radiation pattern of the proposed elliptical UWB antenna with dual band-notches at (a) 3.1 GHz, (b) 5.4 GHz, (c) 8.77 GHz, and (d) 9.6 GHz

4. CONCLUSION

A compact elliptical shaped patch dual band-notched UWB antenna loading of two ESCSRRs are proposed. By introducing two ESCSRRs in the elliptical patch, dual band-notches are obtained for rejecting 3.5 GHz WiMAX band and 4.4 GHz C-band. The proposed antenna provides impedance bandwidth 2.82-12 GHz with dual band-notches3.27-3.76 GHz and 4.1-4.6 GHz. The surface current distributions are used to analyse the impact of two

ESCSRRs in achieving band-notches. The reduced gains in the dual notched region and omnidirectional radiation pattern of the proposed antenna have been presented. The characteristics of the proposed antenna show that it is useful of UWB applications except the 3.5 GHz WiMAX and 4.4 GHz C-band applications.

REFERENCES

[1] New Public Safety Applications and Broadband Internet Access among Uses Envisioned by FCC Authorization of Ultra-Wideband Technology-FCC News Release 2002.

[2] Oppermann, M. Hamalainen, and J. Iinatti, *UWB Theory and Applications*, New York: Wiley, 2004.

[3] J. Liang, C. C. Chiau, X. Chen, and C. G. Parini, "Study of a printed circular disc monopole antenna for UWB systems," *IEEE Transactions on Antennas and Propagation*, vol. 53, no. 11, 3500–3504, 2005.

[4] C. Y. Huang and W. C. Hsia, "Planar elliptical antenna for ultra-wideband communications," *Electronics Letters*, vol. 41, no. 6, 296–297, 2005.

[5] K. P. Ray and Y. Ranga, "Ultrawide band printed elliptical antennas," IEEE Trans. Antennas Propag., vol. 55, no. 4, pp. 1189-1192, 2007.

[6] E. S. Angelopoulos, A. Z. Anastopoulos, D.I. Kaklamani, A. A. Alexandridis, F. Lazarakis, and K. Dangakis, "Circular and elliptical CPW-fed slot and microstrip-fed antennas for ultrawide band applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 5, no. 1, pp. 294-297, 2006.

[7] P. Li, J. Liang, and X. Chen, "Study of printed elliptical/circular slot antennas for ultrawideband applications," *IEEE Trans. Antennas Propag.*, vol. 54, no. 6, pp. 1670-1675, 2006.

[8] C. Y. Huang, S. A. Huang, and C. F. Yang, "Band-notched ultra-wideband circular slot antenna with inverted C-shaped parasitic strip," *Electronics Letters*, vol. 44, no. 15, pp. 891-892, Jul. 2008.

[9] J. Shen, J.Wang, and C. Li, "Heart-shaped band-notched UWB antenna with U-shaped slots," 2016 *Progress In Electromagnetic Research Symposium, Shanghai*, pp. 2792-2797, Aug. 2016.

[10] M. Gopikrishna, D. D. Krishna, and C. K. Aanandan, "Band notched semi-elliptic slot antenna for UWB systems," *Proceedings of the 38th European Microwave Conference, Amsterdam*, pp. 889-892, Oct. 2008.

[11] J. Kazim, A. Bibi, M. Rauf, M. Tariq, and Owasis, "A compact planar dual band-notched monopole antenna for UWB application," *Microw. Opt. Technol. Lett.*, vol. 56, no. 5, pp. 1095-1097, 2014.

[12] M.M.Sharma, A.Kumar, S.Yadav, andY.Ranga, "Anultra-widebandprintedmonopoleantenna with dual band-notched characteristics using DGS and SRR," *Procedia Technology*, vol. 6, pp. 778-783, 2012.

[13] Q.-X. Chu and Y.-Y. Yang, "A compact ultrawideband antenna with 3.4/5.5 GHz dual band-notched characteristics," *IEEE Trans. Antennas Propag.*, vol. 56, no. 12, pp. 3637-3644, 2012.

[14] T. Mandal and S. Das, "Design and analysis of a coplanar waveguide fed ultrawideband hexagonal open slot antenna with WLAN and WiMAX band rejection," *Microw. Opt. Technol. Lett.*, vol. 56, no. 2, pp. 434–443, Feb. 2014.

[15] M. M. Sharma, J. K. Deegwal, M. C. Govil, and A. Kumar, "Compact printed ultra-wideband antenna with two notched stop bands for WiMAX and WLAN," *International Journal of Applied Electromagnetics and Mechanics*, vol. 47, no.2, pp.523-532, 2015.

[16] N. Fatolahzadeh and Y. Zehforoosh, "Electromagnetically coupled elliptical antenna for UWB and WLAN/WiMAX systems," *Microw. Opt. Technol. Lett.*, vol. 59, no. 6, pp. 1321–1326, June 2017.

[17] CST Microwave Studio, User's Manual, 2013, www.cst.com.