

ACS Fed Triple Band Notched UWB Antenna for Diverse Wireless Applications

Om Prakash Kumar, Aman Singh, Rajat Sinha, Tanweer Ali

Abstract: In this manuscript a novel design of an asymmetric coplanar strip (ACS) fed UWB antenna with triple band notch facility is presented and discussed. The proposed antenna contains a combination of different radii of semi-circular patches in order to obtain ultrawideband (UWB) characteristics. The achieved UWB bandwidth ranges from 2.9 to 9.3 GHz. It's compact and simple designs make it very useful for application with respect to UWB communication systems. Furthermore, modifications are made in the proposed UWB antenna to achieve band notch characteristics in order to remove the electromagnetic interference from the adjacent frequency bands. From the radiating monopole a combination of semi-circular and quarter circular slots are etched out to obtain triple notch bands at 3.1–3.8 GHz (WiMAX), 5.3–5.8 GHz (WLAN) and 6.9–7.5 GHz (higher C-band).

Index Terms: asymmetric coplanar strip, ultrawideband, bandwidth, band notch.

I. INTRODUCTION

According to FCC, a signal is said to be ultrawideband (UWB) if the fractional bandwidth is greater than 20%, where fractional bandwidth is given as $2(fh - fl)/(fh + fl)$, where fh and fl are upper and lower $S_{11} < -10$ dB cut-off frequency. Alternatively, an UWB signal should have absolute bandwidth greater than 500 MHz [1]. Examples of UWB communication can be video streaming, MP3 file transfers, print files, movie transfers, disk backups, camera downloads etc. The range of communication is of a few meters.

Lot of work has been done to achieve ultrawideband characteristics. Some approaches include modifying the patch as decagonal shape [2], Volkswagen shape [3], modified circular shape [4] etc. Other ways to obtain UWB characteristics can be modifying the ground plane or adding slots in the patch. The antenna designed in [5] show W shaped ground plane and [6] shows U shaped slot. All the above antennas have impedance bandwidth greater than 100% with frequency between 2.3 to 12.8 GHz. However the demerit of most of the proposed structures is that they are large in size and have complex structures. To overcome the problem of size ACS fed UWB antenna is proposed which provides 50% reduction in size in comparison to microstrip and CPW fed antennas [7].

Today there are existing technologies whose applications

require their frequency bandwidth to be within the UWB frequency bandwidth which may later lead to interference and collision among signals which may lead to decline in efficiency of the systems [8]. This is the reason why various notching techniques are employed in UWB antennas to notch characteristics and various frequency ranges within their bandwidth. Literature [9-10] proposed ultrawideband antenna with dual notch characteristics while [11-12] eliminates three band ranges in the ultrawideband region.

In this manuscript UWB antenna design is introduced with a combination of semi-circular and quarter-circular patch with ACS feeding. The slits of width 0.3mm is utilized to obtain triple notch characteristics. The notch is obtained in the band range of 3.1–3.8 GHz (WiMAX), 5.3–5.8 GHz (WLAN) and 6.9–7.5 GHz (higher C-band).

II. ANTENNA CONFIGURATION AND DESIGN

Fig. 1, shows the actual design of the proposed UWB antenna with detailed dimension layout. The design is simulated on HFSS software. The substrate used is FR4 with dielectric constant being 4.4. The thickness of the substrate is 1.6 mm and the length and width of the antenna are 30 mm. The strip width is 3.8 mm and its gap between the ground-plane is 0.35mm. These dimensions are chosen so that they can correspond with the 50 Ω input impedance. The two semi-circular patches are of radius 12 and 9 mm respectively. These patches are very crucial because they help in achieving broad bandwidth which is necessary for UWB applications. The final UWB range obtained is from 2.9 to 9.3 GHz with a fractional bandwidth of 104%.

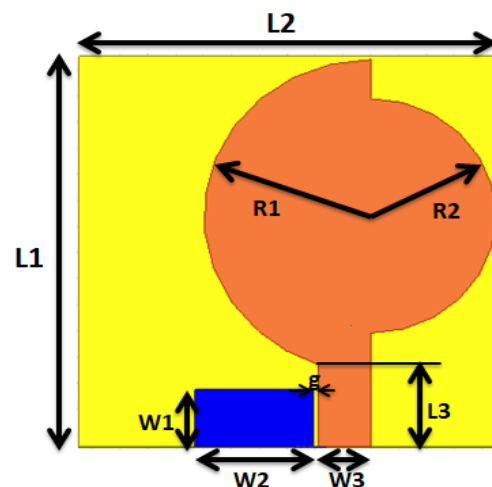


Fig. 1: Dimensions of the designed acs antenna (L1= 30mm, L2 = 30mm, L3= 6.3mm, W1 = 4.4mm, W2 = 8.5mm, W3 = 3.8mm, R1 = 12mm, R2 = 9mm, g = 0.35mm)

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Fig. 2, shows how the proposed antenna evolved from its prior stage and Fig. 3 shows their respective simulated return loss. The proposed UWB antenna design presented in Fig 2 configuration “A” is inspired by [9]. In the following designs a semicircular patch is added to increase the overall perimeter of the design to get a resonant frequency which takes a value of return loss as low as possible. In configuration “B” of Fig. 2, the value of R2 (as outlined in Fig. 1) is taken 3 mm but the obtained frequency range 3 to 5 GHz (Fig. 3) does not fall into the ultrawideband region. When R2 is increased to 6 mm (configuration “C”) the return loss is extremely close to the -10 dB line (Fig. 3) thus suffers from the drawback of less impedance matching. The final design configuration “D” (Fig 2) has the value of R2 as 9 mm which gives the best possible return loss ranging from 2.9 GHz to 9.3 GHz (Fig. 3). The overall design equation of the final UWB antenna is presented in equation 1-2.

$$f_L = \frac{300}{p\sqrt{\epsilon_{eff}}} \quad (1)$$

$$\varepsilon_{eff} = \frac{(\varepsilon_r + 1)}{2} \quad (2)$$

Where, p is the overall perimeter of the patch. The perimeter of the final design comes out to be 35 mm. The resonant frequency obtained from the design is 5.2 GHz

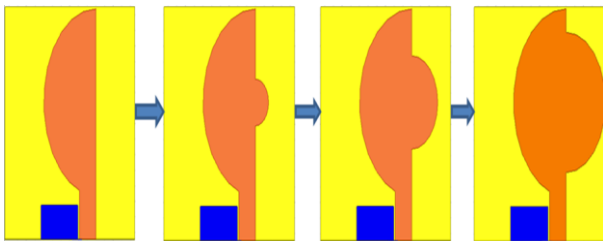


Fig. 2: Evolution of proposed ACS fed UWB antenna

The aforementioned designed UWB antenna suffers from the problem of electromagnetic interference from the adjacent frequency bands due to large bandwidth of operation. To remove the interference at the adjacent bands such as WiMAX, WLAN and higher C-band operations from the obtained UWB range, slots are etched out in the radiating patch of UWB antenna as outlined in Fig. 4. A semi-circular shaped arc of radius 10 mm and thickness 0.3 mm is cut from the patch to get the notch band in the Wi-MAX range. Then the dimensions of a combination of quarter circle of radius 5mm and thin strips in the range of 4.5 mm are cut and optimized to get the notch band in WLAN and higher C-band range. Fig. 5 shows how the ACS fed UWB antenna has evolved to exhibit notch characteristics and Fig. 6 gives the return loss of the corresponding stages of notch evolution. The notch frequency is achieved by the following equation 3.

$$f_{notch} = \frac{c}{2l_s \sqrt{\frac{\epsilon_r + 1}{2}}} \quad (3)$$

Where, c is the velocity of light, l_s is the slot length of slot, ϵ_r is the dielectric constant

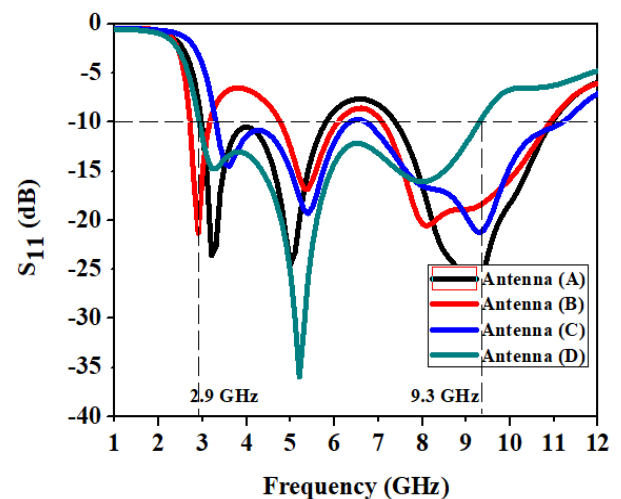


Fig. 3: Return loss of corresponding designs in evolution

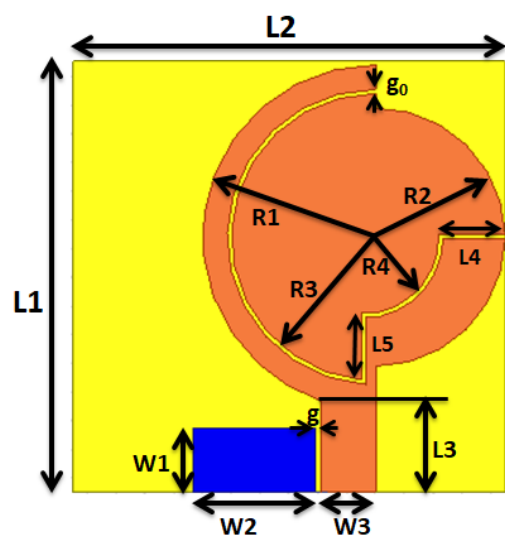


Fig. 4: ACS antenna design with notch characteristics (L1= 30mm, L2= 30mm, L3= 6.3mm, W1= 4.4mm, W2= 8.5mm, W3= 3.8mm, R1= 12mm, R2= 9mm, R3= 10mm, R4= 5mm, L4= 4.7mm, L5= 4.5mm, g= 0.35mm, g₀=0.3mm)

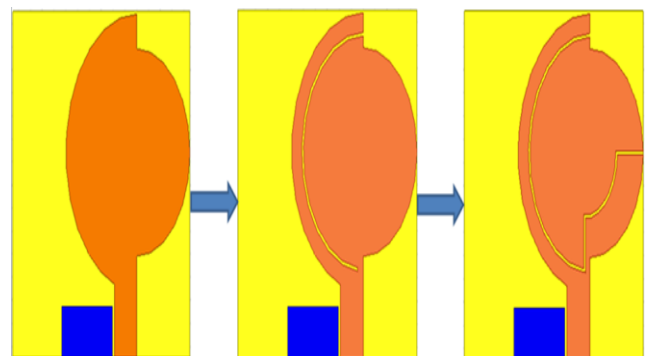


Fig. 5: Evolution of ACS fed UWB antenna to obtain notch characteristics

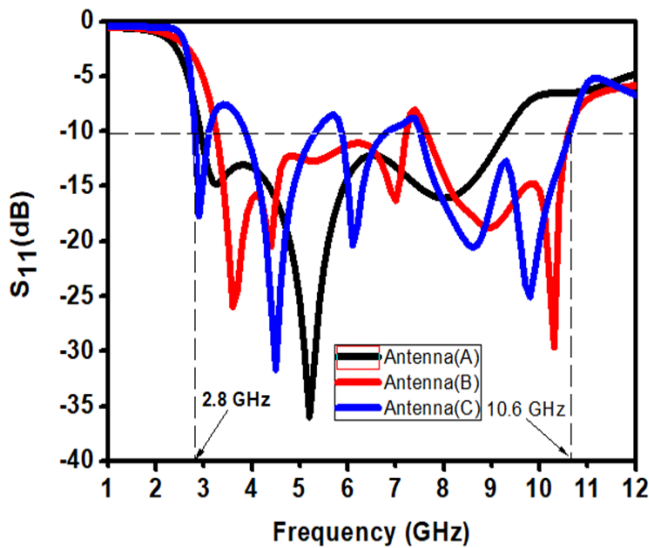


Fig. 6: Return Loss at different stages of evolution

III. PARAMETRIC INVESTIGATIONS

To finalize the design dimension of the UWB and proposed notch antenna its parametric investigations are performed and are outlined in Fig. 7 and 8. Firstly, the width of ground plane (W_2) of UWB antenna is changed from 8 to 9 mm in steps of 0.5 mm to observe its effect on the overall impedance matching performance of the antenna as presented in Fig. 7. As for both 8 and 9 mm it can be clearly observed that the impedance matching is not proper as some values of return loss goes above the -10 dB line, while 8.5 mm width gives the acceptable UWB range. Similarly, Fig. 8 shows the parametric investigation of the proposed notch antenna when the value of R_3 changes from 9.5 to 10.5 mm in steps of 0.5 mm with the value of R_4 being fixed at 5 mm. It can be easily concluded from the Fig. 8, that when the value of R_3 is 9.5 and 10.5 mm, dual notch characteristics is being displayed. But the proposed antenna had triple notch characteristics, which is obtained only when the value of R_3 becomes 10 mm. The final optimized dimensions of the UWB notch antenna are outlined in Fig. 4.

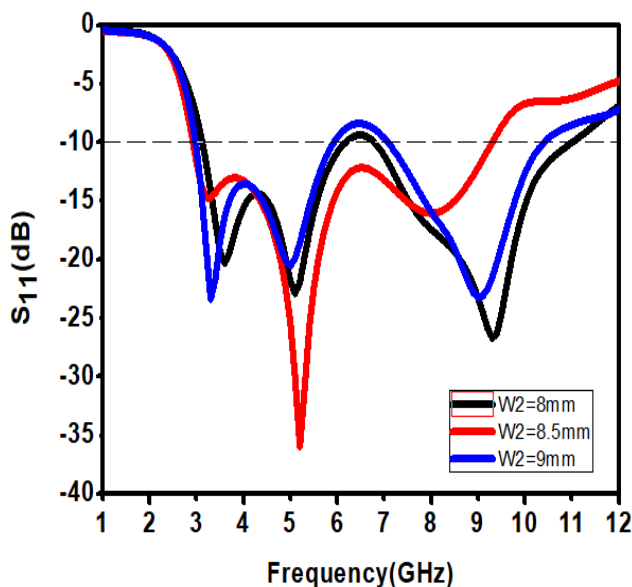


Fig. 7: Simulated S_{11} of the antenna when W_2 changes

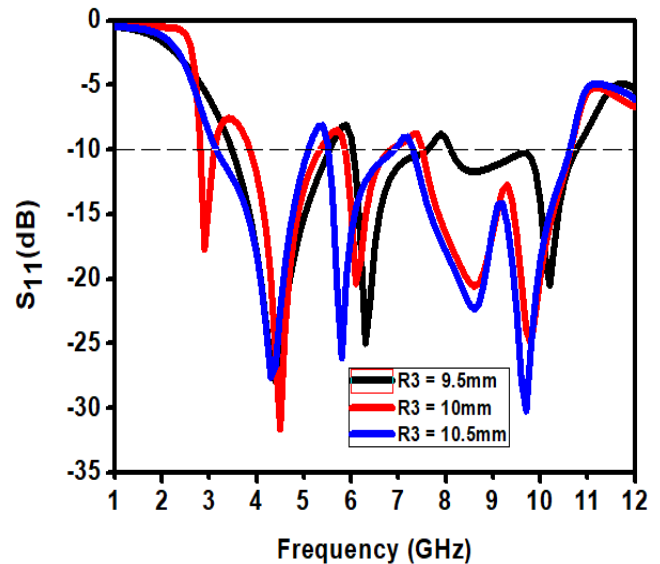


Fig. 8: Simulated S_{11} of the ACS fed UWB antenna with notch characteristics when R_3 changes with R_4 being fixed at 5 mm.

IV. RESULTS AND DISCUSSIONS

The Fig. 9 outlines the S_{11} results of the UWB antenna which exhibits ultrawideband characteristic from 2.9 to 9.3 GHz with the fractional bandwidth being 104 %. The resonant frequency is obtained at 5.2 GHz. Fig. 10 shows the variation of peak gain with respect to the frequencies. At resonant frequency of 5.2 GHz, maximum peak gain of 9.5 dB is obtained.

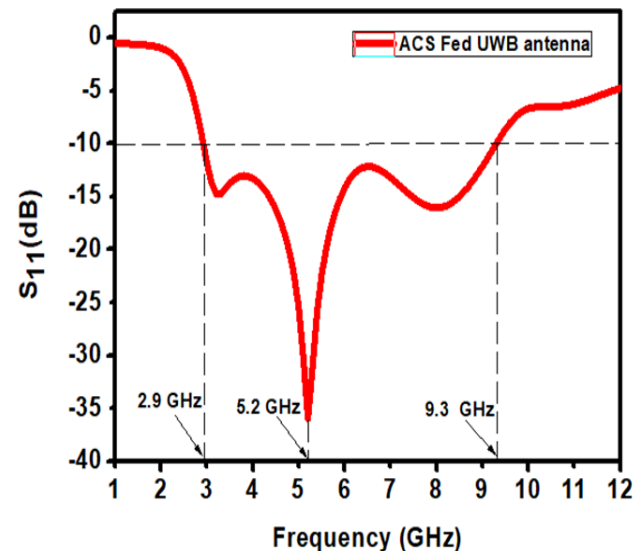


Fig. 9: Return Loss of ACS fed UWB antenna

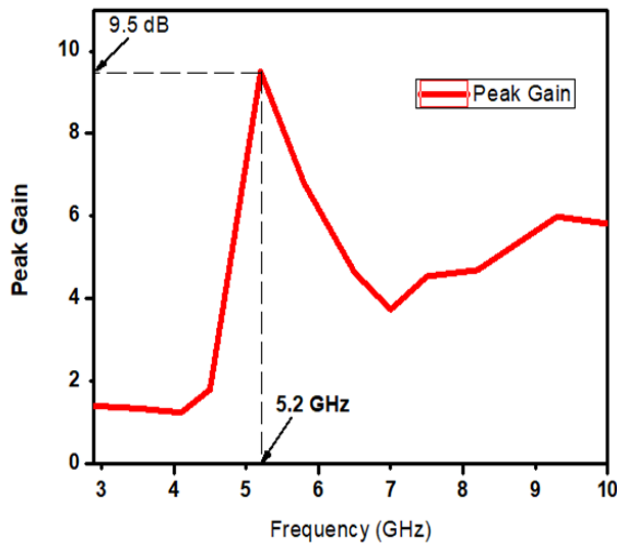


Fig. 10: Peak Gain (dB) of ACS Fed UWB antenna

Fig. 11, shows the return loss of the proposed ACS fed UWB antenna with notch characteristics. The frequency notching is obtained at Wi-MAX (3.1 - 3.8 GHz), WLAN (5.3 - 5.7 GHz) and higher C-band (6.9 - 7.5 GHz) operations.

The current distribution at the obtained notch frequencies of 3.4, 5.7 and 7.4 GHz are outlined in Fig. 12. The Figs suggest that there are strong current distributions at the edges of the slots cut to provide notch characteristics. It can be clearly observed that the current distribution along the slots are in reverse directions, therefore the radiating field emitted by them gets cancelled to a large extent. Thus, the slots seem to be quite useful in obtaining the required band notch frequencies.

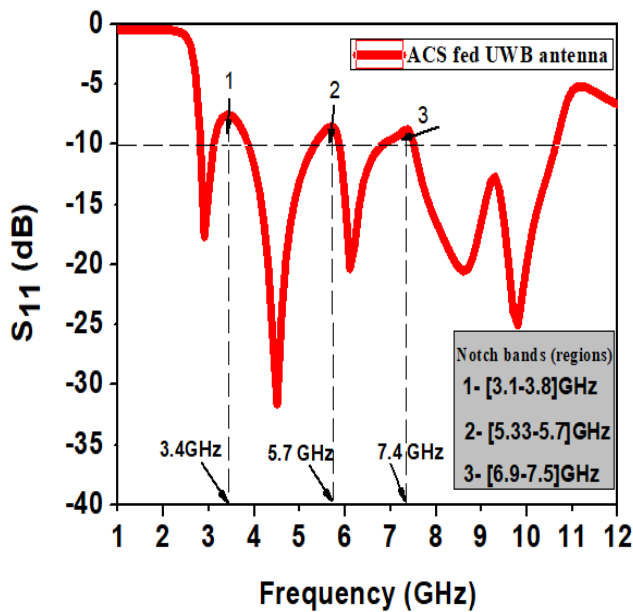
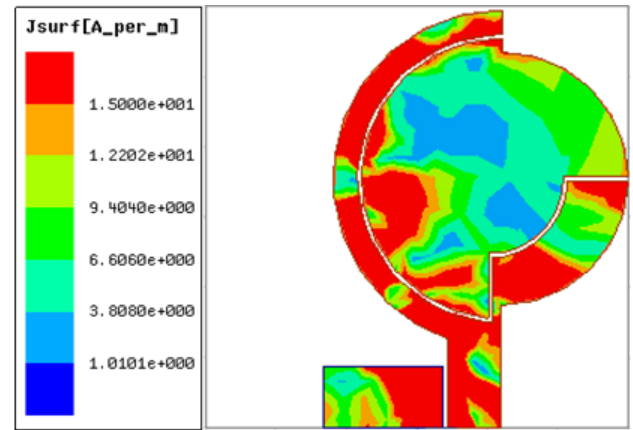
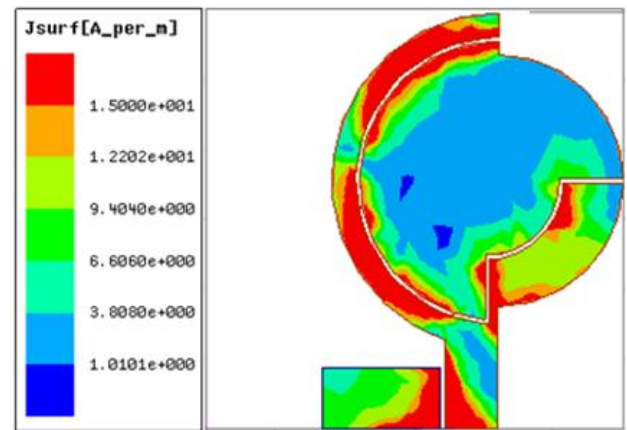


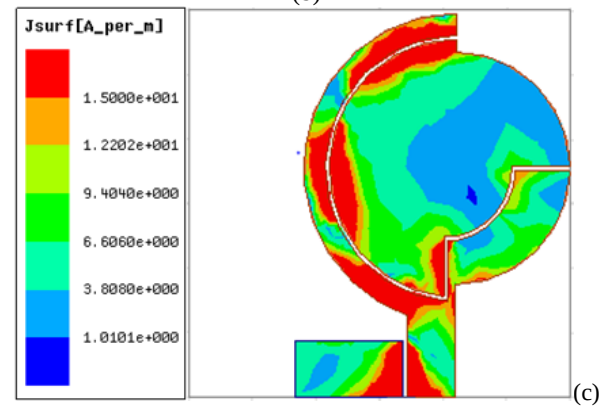
Fig. 11: Return Loss of ACS fed UWB antenna with notch characteristics



(a)



(b)



(c)

Fig. 12: Current Distribution of the proposed antenna at notch frequencies (a) 3.4 (b) 5.7 (c) 7.4 GHz

The radiation plot of the antenna at operating frequencies of (2.9 GHz, 4.5 GHz, 6.1 GHz, 9.8 GHz for $\phi = 0^\circ$ (H-plane) and $\phi = 90^\circ$ (E-plane) is outlined in Fig. 13. The antenna exhibits omnidirectional response in H-plane and bi-directional response in E-plane.

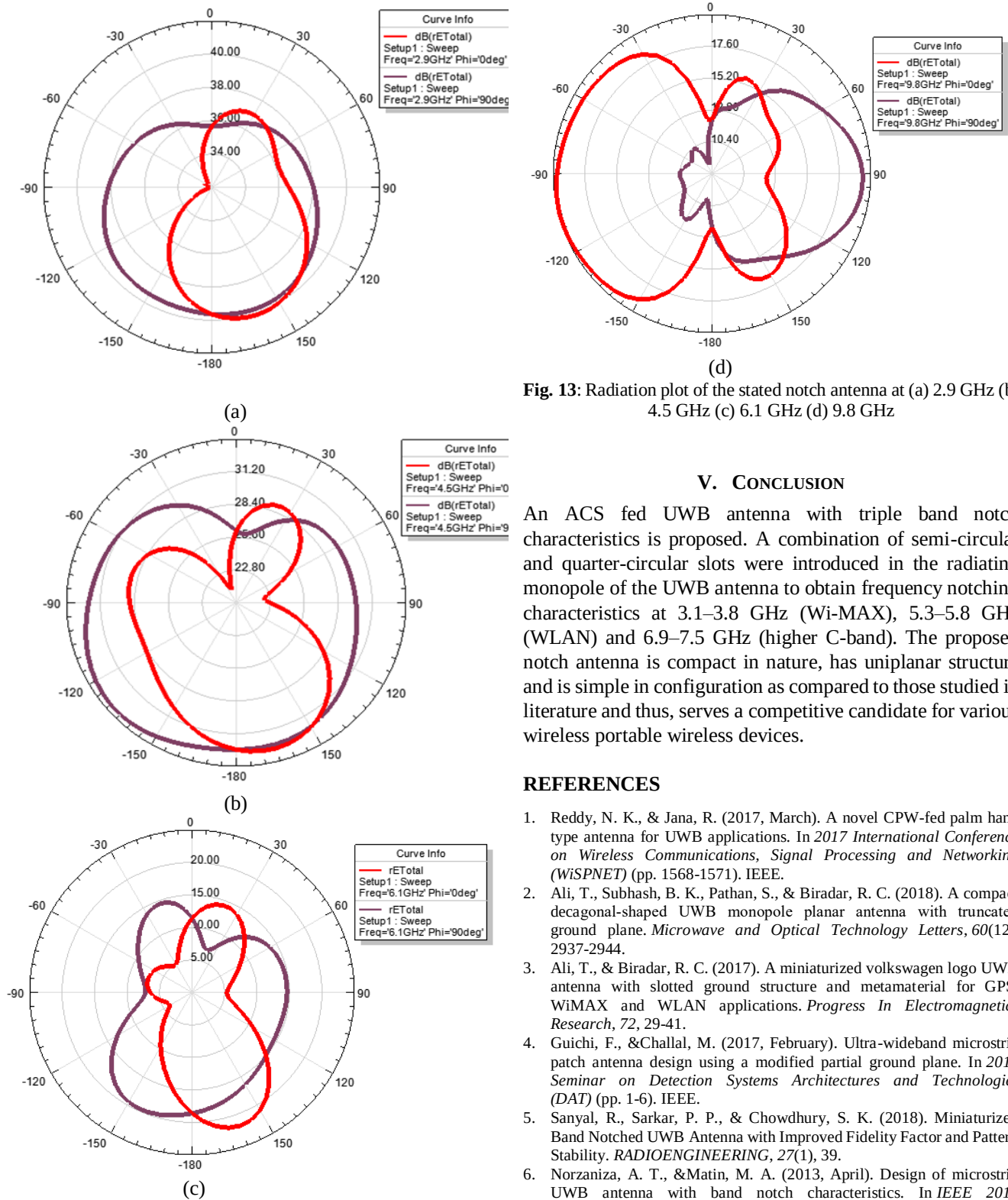


Fig. 13: Radiation plot of the stated notch antenna at (a) 2.9 GHz (b) 4.5 GHz (c) 6.1 GHz (d) 9.8 GHz

V. CONCLUSION

An ACS fed UWB antenna with triple band notch characteristics is proposed. A combination of semi-circular and quarter-circular slots were introduced in the radiating monopole of the UWB antenna to obtain frequency notching characteristics at 3.1–3.8 GHz (Wi-MAX), 5.3–5.8 GHz (WLAN) and 6.9–7.5 GHz (higher C-band). The proposed notch antenna is compact in nature, has uniplanar structure and is simple in configuration as compared to those studied in literature and thus, serves a competitive candidate for various wireless portable wireless devices.

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