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A Compact Uniplanar Triple Band Asymmetric Coplanar Strip (ACS) Fed Monopole Antenna for Wireless Applications

Tanweer Ali, Reshma Roy, Apurva Singh, Om Prakash Kumar

***Abstract*: This research paper presents an ACS fed antenna that operates at three frequency band. The compact size of antenna is taken as $19 \times 10 \times 1.6\ mm^3$, and the substrate is made up of FR4 material with effective dielectric constant=4.4. In the proposed ACS fed antenna, both ground plane and radiating patch are on the same plane (i.e. monopole), thus making it more compact and cheap compared to patch antenna. The feedline is in the shape of inverted-L and the radiating patch has shape of meandered structure along with square shaped ground in the front plane. The proposed antenna operates at frequencies 5.6, 8.2 and 12.6 GHz, hence covering the WLAN and X-band applications. The gain corresponding to these operating frequencies are -0.11, -0.44 and 4.02 dB respectively. The antenna geometry and its evolution stages (including parametric analysis) are dealt to study the optimization process of given antenna.**

***Index Terms*: triple band; ACS fed ; radiating patch; monopole**

I. INTRODUCTION

The progress in wireless systems in today's time has increased the demand for various wireless applications. In order to meet the needs of the modern times, multiband antennas are of great interest [1-3]. Various designs of multiband microstrip patch antennas are proposed to achieve the wireless requirements [4]. Due to the complexity of the technique (occupies large space) ACS method is used which covers both compactness and multiband characteristics. The various advantages of ACS fed antennasmake it superior than other antennas. Various types of ACS fed antennas are proposed due to its simple structure and its ability to easily integrate with RF circuits. In [5] a triple-band antenna of size $28 \times 30\ mm^2$ at operating frequencies 1.8, 2.4 and 5.6 GHz is proposed. The antenna proposed in [6] has a size of $25 \times 17.5 \times 1.6 mm^3$ and operates at dual-band frequencies 2.45 and 5 GHz. In [7], a quad-band antenna is proposed whose operating frequencies are 2.5, 4.9, 5.5 and 5.7 GHz. The size of the antenna is$13.4 \times 22.7\ mm^2$. The work discussed in [8] depicts an antenna of size $21.6 \times 12\ mm^2$ at operating frequencies 2.4, 3.5, 4.4 and 5.5 GHz (quad band) thus covering WiMAX and WLAN applications. Similarly, dual band antenna is proposed in [9] of size $14.75 \times 26\ mm^3$operating at
frequencies of 2.48 and 3.6 GHz. In [10] a triple band antenna is proposed operating at frequencies 2.44, 5.3 and 8.2 GHz of size $22 \times 16.08 \times 1.6\ mm^3$. An antenna operating at 3.6 and 5.4 GHz is proposed in [11] of size $60 \times 36\ mm^2$. The triple band antenna that is proposed in [12] has a size of11.5×26 mm^2 with operating frequencies of 2.35, 3.5 and 5.2 GHz. Good impedance matching(S_{11}<-10dB) is achieved with coverage of WiMAX/WLAN ranges. In [13], a triple band antenna of size 12.5×18mm^2 operates at frequencies 2.45, 3.5 and 5.5 GHz.The antenna proposed in [14] is a triple band antenna of size $19.18 \times 22.64 \times 1.6\ mm^3$ with operating frequencies of 2, 3 and 5.2 GHz. A triple band antenna of size $14 \times 20.5 \times 1.6\ mm^3$ operating at frequencies 2.4, 3.5 and 5.5 GHz is presented in [15]. An antenna of size $14 \times 20\ mm^2$ with resonating at frequencies 2.35, 3.5 and 5.25 GHz is depicted in [16]. A triple band antenna is observed in [17] of size $12.5 \times 20\ mm^2$ operating at frequencies 2.5, 3.5 and 5.8 GHz. In [18], a triple band antenna of size $46 \times 26\ mm^2$ with resonant frequencies 5, 5.8 and 6.3 GHz is obtained. A dual band antenna is proposed in [19], operating at frequencies 2.6 and 5.6 GHz having a size of $10 \times 19\ mm^2$. However, in all these antennas X-bands are not covered along with WLAN or WiMAX bands.

In this paper, a compact meandered shaped radiating patch is printed in the front plane of the antenna with triple operating frequencies. This technique is used to feed this multiband antenna of size$19 \times 10 \times 1.6$ mm^3. The design comprises of L and meandered parts that act asradiating elements and produces operating frequencies at 5.6 (WLAN), 8.2 and 12.6 GHz (X-band). The performance of the triple band ACS fed antenna are studied by return loss (S_{11}) for all the evolution stages, radiation patterns and peak gain. The antenna exhibited stable and acceptable performances at the targeted frequencies.

II. ACS FED ANTENNA DESIGN

A. Design Equation

The initial dimensions for a monopole antenna with resonant frequency (f_r) is calculated as

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$$L = \frac{\lambda_g}{4} = \frac{C}{2f_r\sqrt{\varepsilon_{eff}}}$$

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

Where L= Length and ε_{eff}= 4.4. The equations mentioned beloware used for the calculation of impedance matching:

$$Z_0 = \frac{60\pi}{\sqrt{\varepsilon_{eff}}}\frac{K(k)}{K(k')}$$

$$\frac{K(k)}{K(k^1)} = \begin{cases} \dfrac{\pi}{ln\frac{2(1+\sqrt{k^1})}{(1-\sqrt{k^1})}} & , 0 \le k \le \dfrac{1}{\sqrt{2}} \\ \dfrac{1}{\pi ln\frac{2(1+\sqrt{k})}{(1-k)}} & , \dfrac{1}{\sqrt{2}} \le k \le 1 \end{cases}$$

where ε_r =dielectric constant of the material, k=a/b (Length of major axis/Length of Minor axis).

B.Design Evolution

The evolution steps of the above mentioned antenna is seen in Fig. 1. It is a one sided antenna with both radiating patch and ground plane in the same side. This structure is evolved multiple times to achieve the desired antenna configuration. The first step is shown in configuration"A1" of Fig. 1. It is a basic structure with square shaped ground and an inverted-L shaped feed line. It is further optimized to "A2" because of the failure to get any bands in configuration "A1" as illustrated in Fig. 2.In step 2, a wide band is achieved with frequency 6.1GHz (Fig. 2) but with negative gain(-0.91dB).Similarly "A2" is kept on optimizing until desired output is achieved. Hence this process goes on till configuration A9 where results are better in comparison to prior stages. In the proposed configuration "A9", three bands are achieved i.e. 5.6, 8.2 and 12.6 GHz respectively, as presented in Fig. 2. Thus configuration "A9" (proposed antenna) easily covers WLAN and X-band operations. The S_{11} plot of all the evolution stages (till "A9") is demonstrated in Fig.2.

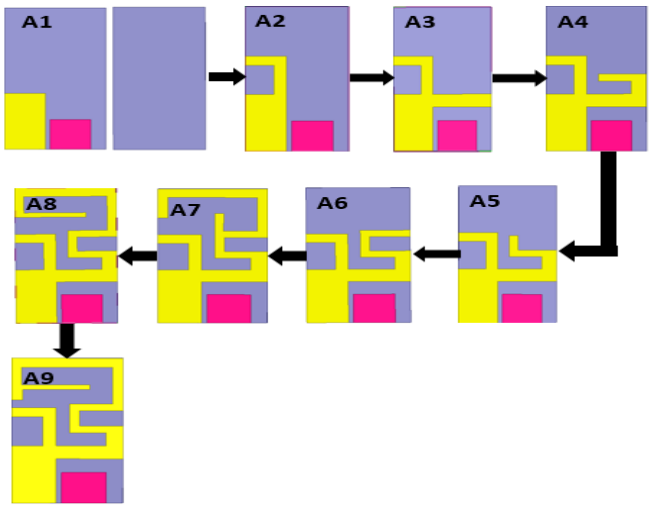


Fig.1 : Evolution stages of ACS fed antenna

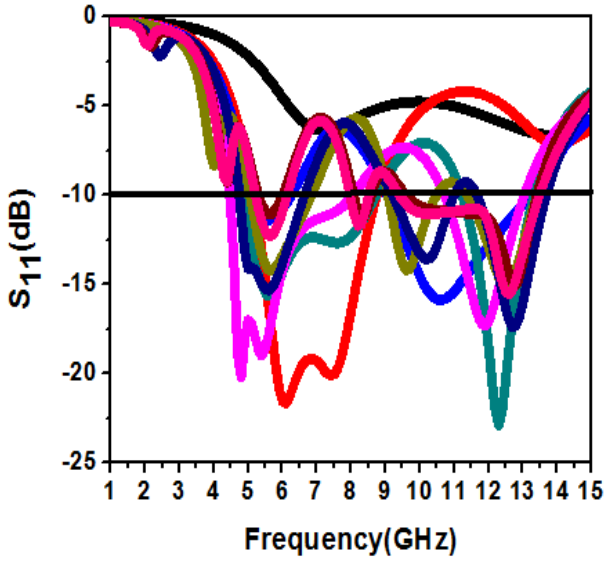
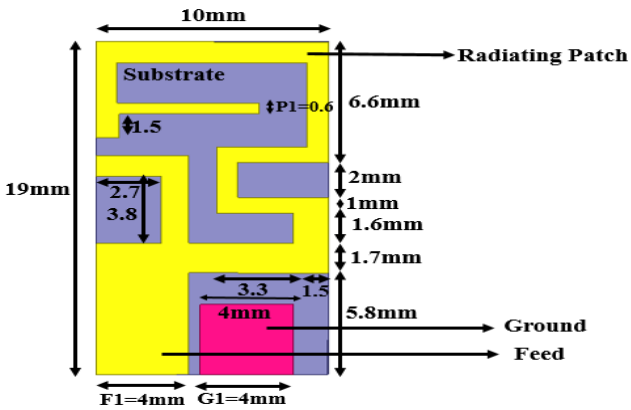


Fig. 2: Evolution stage S_{11} results

The final design of the antenna is outlined in Fig 3.The antenna consists of meandered shaped patch with square shaped ground in the same side (front part). The antenna is fed using rectangular ACS feed line to achieve an impedance matching of 50 ohm.



(a)

(b)

Fig. 3: Proposed "A9" configuration (a) front view and (b) back view

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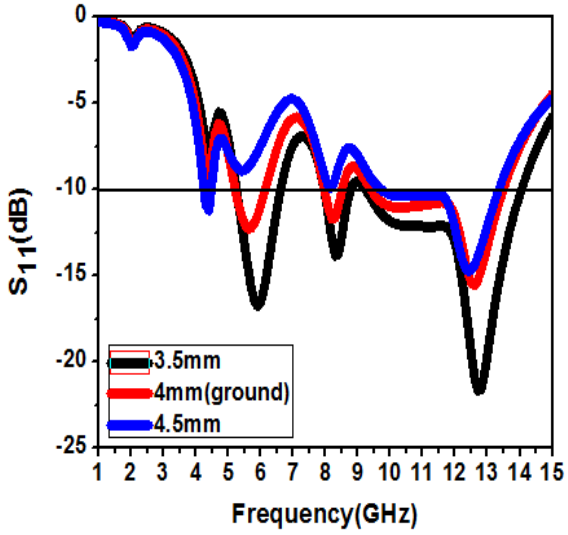
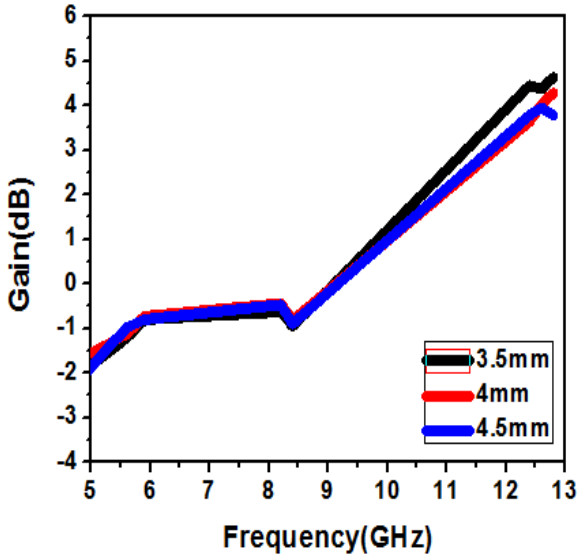
C. Parametric Analysis

The operational characteristics is observed by doing parametric analysis where the antenna dimensions have been optimized by keeping one dimension constant and varying the other dimension. The first analysis includes the optimization of the ground plane. Its width is first decreased by 0.5mm and then increased by 0.5mm. S_{11} and gain plots are depicted in Fig. 4. Similarly, feed width and the rectangular strip length (part of meandered shaped radiating patch) is altered to observe the variations in the performance of the antenna shown in Fig. 5, 6 respectively. From the plots we can easily conclude that the performance at ground width=3.5mm, feed line width=3.5mm and strip length=0.6mm, is best and hence is considered for the proposed structure.

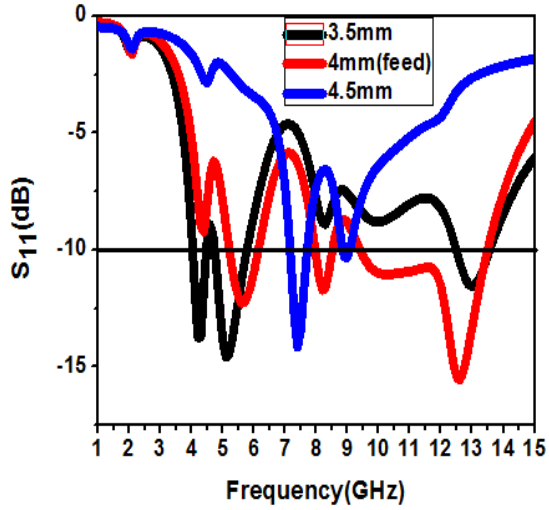


(a)



(b)

Fig.4: Parametric variations of G1 for (a) S_{11} and (b) Gain



(a)

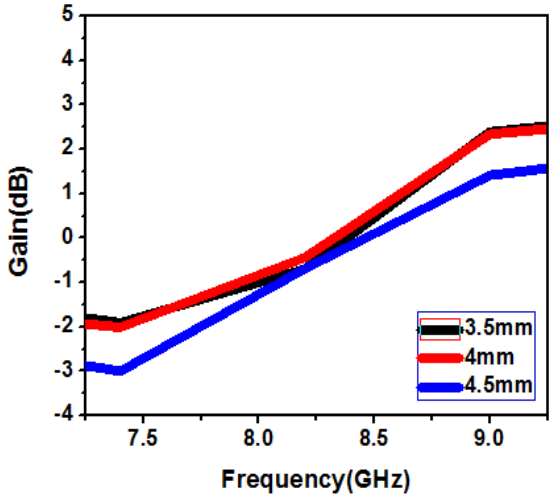


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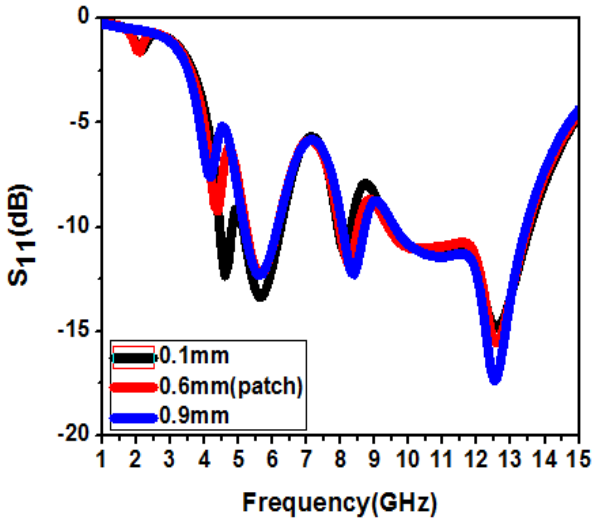
Fig.5:Variations of F1 for (a) S_{11} and (b) Gain



(a)

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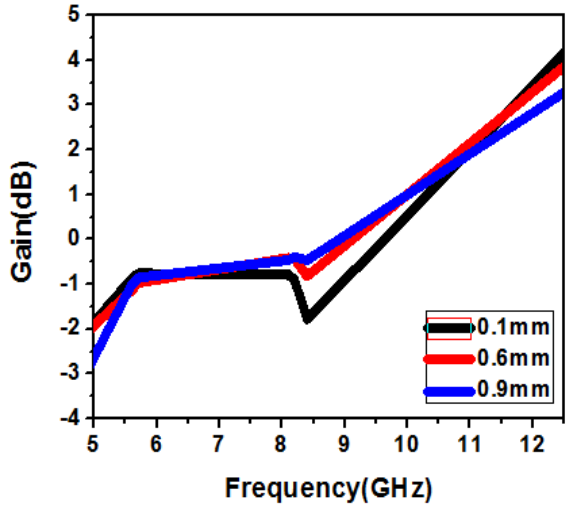


(b)

Fig.6:Variations of P1 for (a) S_{11} and (b) Gain

III. RESULTS

The proposed structure of triple band ACS fed antenna has a total dimension of $19 \times 10 \times 1.6\ mm^3$ at lower resonance of 5.6 GHz. This antenna (i.e. proposed configuration "A9") operates at three bands, two being narrow bands and one being wideband, of about 100 MHz, 500 MHz and 4100 MHz, respectively as presented in Fig. 7.On the other hand, all the three resonating bands show good impedance matching (S_{11}<-10dB). The proposed triple band ACS fed antenna can work for WLAN (5.6 GHz) and X-band (8.2 and 12.6 GHz) implementations. Table 1 shows the detailed simulated results.

Table 1: Results of triple band ACS fed antenna

Freq.(GHz)	S_{11}(dB)	-10 dB impedance B.W (GHz)	Gain	Application
5.6	-12.25	5.2-6.2	-0.11	WLAN
8.2	-11.72	5.4-5.9	-0.44	X-Band
12.6	-15.54	9.4-13.5	4.02	X-Band

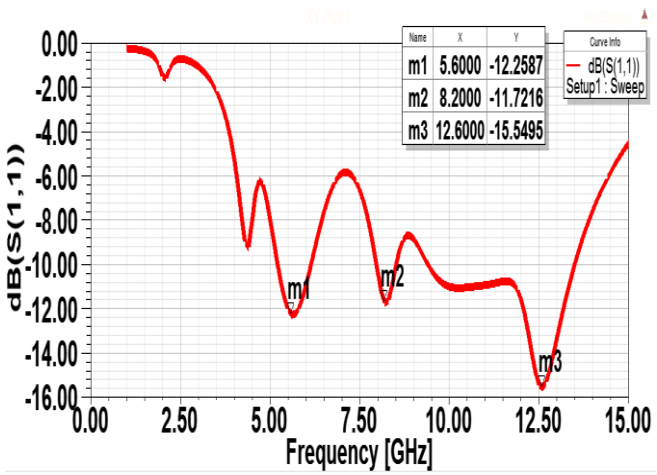
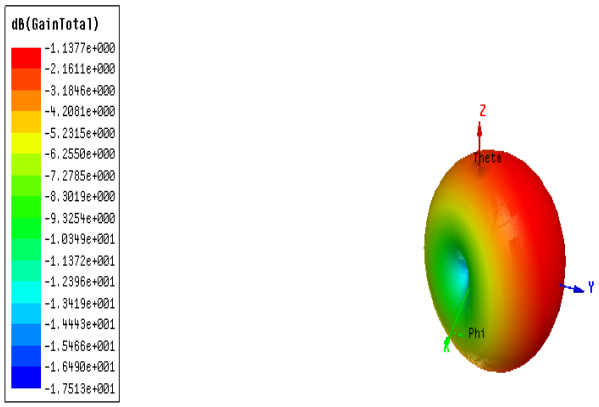


Fig. 7: S11 versus frequency of dual band antenna

The gain obtained at 5.6 GHz is -0.11 dB, at 8.2GHz is -0.44dB and at 12.6 GHz is 4.02 dB as outlined in the Fig. 8 (a), (b) and (c), respectively.

The radiation pattern for the threeoperating frequencies are depicted in the Fig. 9. The antenna has bi-directional radiation pattern and omnidirectional pattern in E ($\varphi = 0°$) and H-plane ($\varphi = 90°$) respectively.



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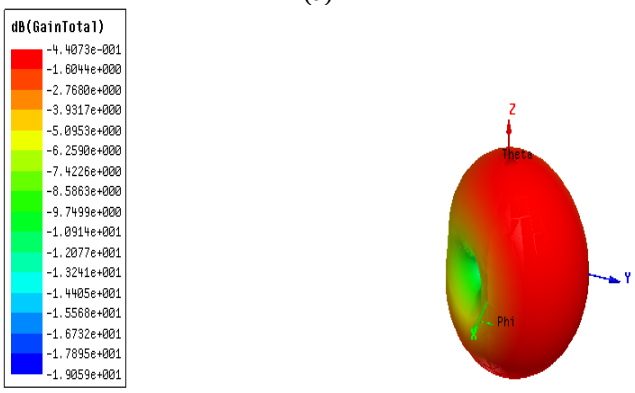

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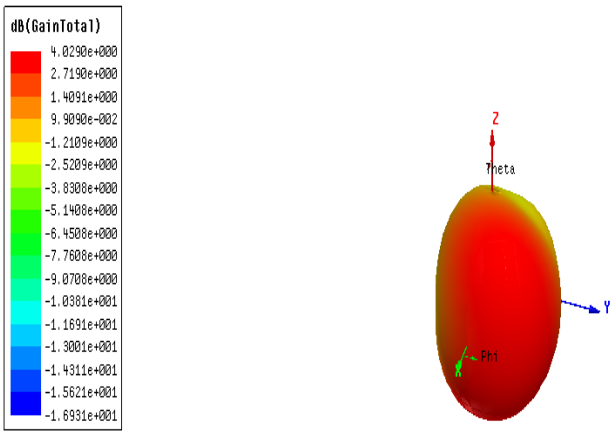

(c)

Fig. 8: Gain at (a) 5.6, (b) 8.2 and, (c) 12.6GHz

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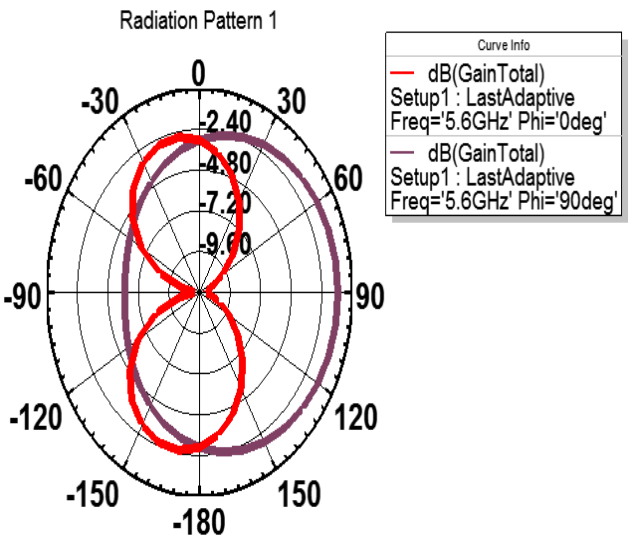
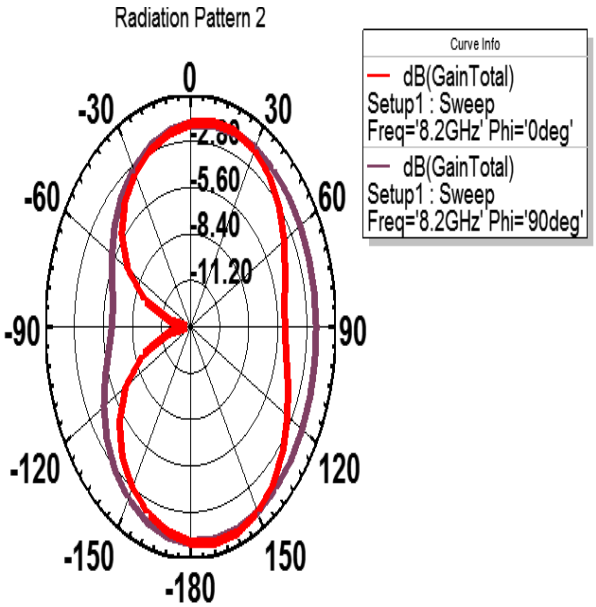


(a)



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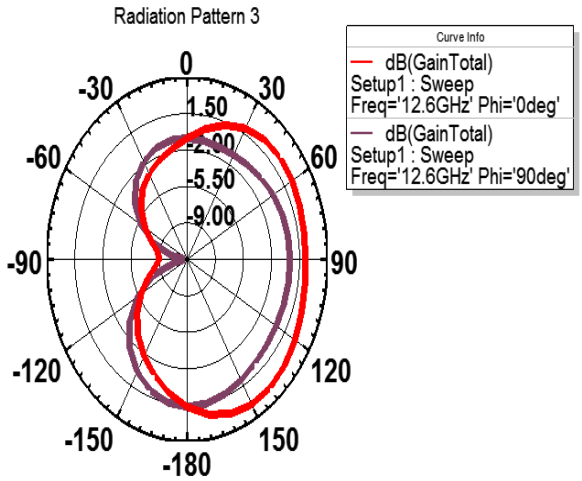


(c)

Fig. 9: Radiation patterns at (a) 5.6, (b) 8.2 and, (c) 12.6 GHz.

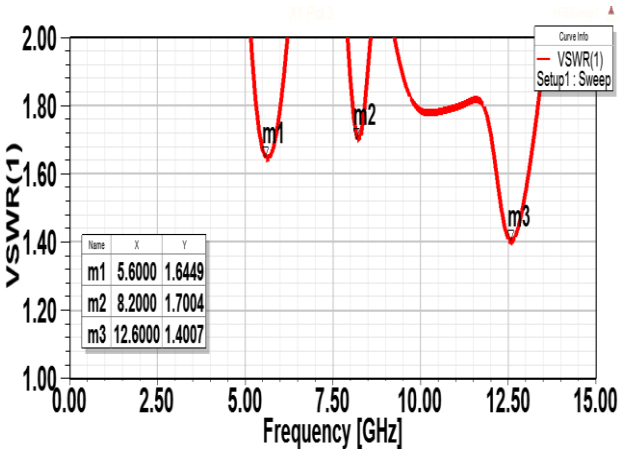


Fig. 10: VSWR versus frequency

The input impedance of the antenna is presented in Fig. 11. The triple band ACS fed antenna has an input impedance of (31.9+j8.8) Ω at 5.6 GHz, (84+j7.25) Ω at 8.2 GHz and (64.9+j12.2)Ω at 12.6 GHz, respectively. [Note Y1 represents Input Impedance].

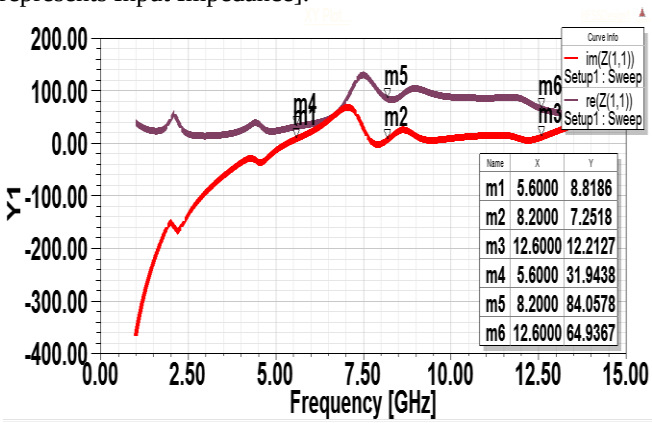
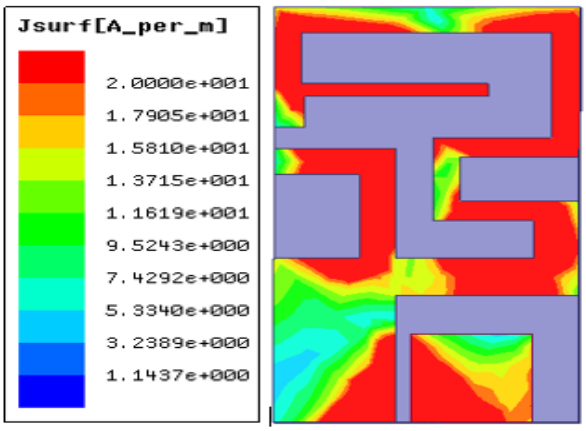


Fig. 12: Input impedance of the proposed triple band configuration

The current distribution of triple band antenna is presented in Fig.13. At 5.6 GHz, the meandered shaped radiating patch is more active as dense red color current is more in that area, as compared to current at 8.2 and 12.6GHz.



(a)

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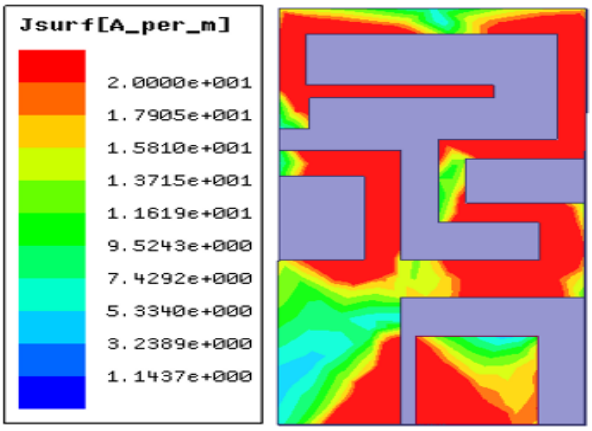

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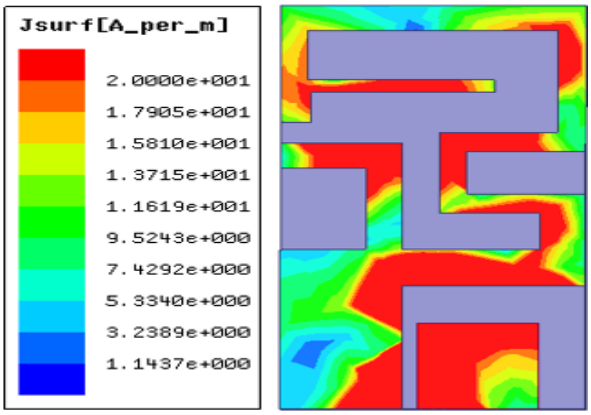

(c)

Fig. 13: Current distribution at (a) 5.6, (b) 8.2, and (c) 12.6 GHz

IV. CONCLUSION

Hence an ACS fed antenna has been designed and analyzed. The antenna operates in three frequencies, the resonant frequencies being 5.6 (WLAN), 8.2 (X-Band) and 12.6 (X-Band) with impedance bandwidth of 6.67%, 3.33% and 27.33% respectively. The patch dimensions are modified which affects the impedance matching of the antennas which has been depicted in the parametric analysis. The compact nature, simple configuration and stable radiation performances makes ACS fed antennas a very competitive candidate for the above mentioned applications.

A comparative analysis is done between the obtained antenna and the similar type of existing in literature and is presented in Table 2.

Table 3: Comparative analysis of the proposed dual and quad band antenna with similar type in the literature

Ref.	Size(mm^2)	No. of bands	Operating Frequencies (GHz)	Operating Bandwidth (GHz)	Applications
[5]	28 × 30	3	1.8/2.4/5.6	1.61-1.9 /2.2-2.6 /5.2-5.8	GPS/WLAN
[6]	25 × 17.5	2	2.45/5	2.30-2.55/4.06-6.65	Bluetooth/WLAN
[7]	13.4 × 22.7	4	2.5/4.9/5.5/5.7	2.5-2.69/4.94-4.99/5.15-5.35/5.28-5.85	WiMAX/WLAN
[8]	21.6 × 12	4	2.4/3.5/4.4/5.5	2.3-2.4/3.3-3.45/4.2-4.7/5.45-5.7	WiMAX/WLAN
[9]	14.75 × 26	2	2.48/3.6	2.38-3.95/3.3-4.2	WiMAX/WLAN
[10]	22 × 16.08	3	2.44/5.30/8.2	2.3-2.53/5.18-5.85/8-8.53	WiMAX /WLAN
[11]	60 × 36	2	3.6/5.4	(3.4-3.8/5.15-5.6	WLAN/WiMAX
[12]	11.5 × 26	3	2.35/3.5/5.2	2.28-2.46/3.33-3.6/(5.05-5.4	WLAN/WiMAX
[13]	12.5 × 18	3	2.45/3.5/5.5	2.41-2.55/3.45-3.65/4.6-6.5	WLAN/ WiMAX
[14]	19.1 × 22.6	3	2/3/5.2	1.86-1.91/2.89-2.98/4.96-6.78	WLAN/WiMAX
[15]	14 × 20.5	3	2.4/3.5/5.5	2.3-2.5/3.4-3.6/4.25-6.85	WLAN/WiMAX
[16]	14 × 20	3	2.35/3.5/5.25	2.3-2.4/3.4-3.55/4.15-6.6	WLAN/ WiMAX
[17]	12.5 × 20	3	2.5/3.5/5.8	2.45-2.6/3.4-3.7/4.5-6.3	WLAN/ WiMAX
[18]	46 × 26	3	5/5.8/6.3	4.75-5.25/5.76-5.83/6.27-6.33	WLAN/ WiMAX
[19]	10 × 19	2	2.6/5.6	2.5-2.7/4.6-6.1	WLAN/ WiMAX
Prop.	**19 × 10**	**3**	**5.6/8.2/12.6**	**5.2-6.2/7.52-8.6/9.4-13.5**	**WLAN/X-Band**

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