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Designing of Hybrid Semi-Circle Coupled Slot Loaded Rectangular Microstrip Antennas for Wireless Applications

Rajeshwari Biradar[1], Boya Satyanarayana[1], Dr. S. N. Mulgi[1]

Department of P.G. Studies and Research in Applied Electronics, Gulbarga University, Gulbarga-585106, Karnataka, India[1]

ABSTRACT: In this paper a design of hybrid semi-circle coupled slot loaded rectangular microstrip antennas are presented for multiband operation. The proposed antennas are consisting a novel geometry of semi-circle radiating patch which is superimposed on conventional rectangular microstrip antenna (CRMSA) to form a hybrid model. The proposed antennas are excited through a simple 50-Ω microstripline feed using quarter wave impedance matching transformer. These antennas are operates between the frequencies from 1.87 to 6.50 GHz at different frequency bands and gives a highest virtual size reduction of 34.14% with broadside radiation characteristics. These antennas are useful for the applications such as WLAN, WiMax and Bluetooth. The important antenna parameters such as bandwidth, return loss, gain and radiation pattern are discussed and presented.

KEYWORDS: Microstrip antenna, Hybrid semi-circle, Gain, WLAN, WiMax, Bluetooth.

I. INTRODUCTION

Microstrip antennas (MSAs) offer many attractive features such as low-profile, light weight, planar, ease of fabrication, conformable to planar and non-planar surfaces etc. [1]. In the last four decades, the extensive technological work on MSAs have been developed for many wireless communication systems such as WLAN, Wi-Fi, sensors, satellite, broadcasting services, ultra-wideband (UWB), radio frequency identifications (RFIDs), reader devices, radars etc. [2]. Still extendable work has been going on MSAs for modern wireless communication systems capable to work for particular application such as portable, handheld devices, RFID handheld reader devices which provides a wireless networks. In the recent technological development the MSAs of smaller in physical size are very much preferable to integrate in the systems especially operating at the lower microwave frequency ranges.

Moreover in many applications such as land mobile telephony as well as in the field of WLANs [2] further requirement would be a multi-frequency operation. So the design of a printed antenna with intend to conform to multiple communications protocols, for example the IEEE 802.11b/g, in the band of 2.4 GHz and the IEEE 802.11a at 5.3 GHz and 5.8 GHz [4], would be a difficult task but at the same time a challenge for the designer. These requirements are made them to develop many techniques and are proposed in the literature. In this paper a simple technique has been proposed to construct the hybrid model comprising rectangular and semi-circular for multi-frequency operation without affecting the nature of broadside radiation characteristics of the antenna. The proposed geometries also provide large virtual size reduction of the antenna.

II. DESIGN OF ANTENNA CONFIGURATIONS

The configurations of the proposed antennas are designed using a commercial available low cost modified glass epoxy substrate material of area X × Y having a thickness h = 0.16 cm, with dielectric constant ε_r= 4.2. Figure 1 (a) shows the top view geometry of CRMSA. The antenna has been designed for the resonant frequency f_r of 3 GHz. This CRMSA consists of a radiating patch of dimensions width ‘W’ and length ‘L’. The antenna is excited through a simple 50 Ω microstripline feeding of length L_f and width W_f. The quarter wavelength matching transformer having length L_{tr} and

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width W_{tr} [4, 5] is used to match the impedance with radiating rectangular patch with the microstripline feed. Below the substrate a tight copper shielding is used.

Figure 1(b) shows the top view geometry of semi-circle coupled hybrid microstrip antenna (SHMSA). The semi-circle patch is superimposed on the corresponding rectangular radiating patch. The radius of the semi-circle is taken as half of the widths of the rectangular patch i.e. 1.55 cm. Figure 1(c) and 1 (d) shows the top view geometries of semi-circle coupled vertical rectangular slot loaded hybrid microstrip antenna (SVHMSA-1) and (SVHMSA-2) respectively. In Fig. 1(c) and Fig. 1(d) the rectangular slots are vertically inserted at the right side and left side parallel to the non-radiating sides of the rectangular patch respectively. The dimensions of the rectangular slots are taken in terms of free space wavelength (λ_0) corresponding to the designed frequency of f_r . The length of slots is L_{S1} and L_{S2} which are equal to $\lambda_0/5$ i.e. 2 cm. The width of slots is W_{S1} and W_{S2} which are equal to $\lambda_0/25$ i.e. 0.4 cm. The artworks of these antennas are outlined using AutoCAD computer software to achieve better accuracy. The designed parameters of the proposed antennas are given in Table I. The proposed antennas are analysed using 3D EM simulation tool Ansys HFSS and the antenna models are shown in Fig. 2.

TABLE I
DESIGNED PARAMETERS OF THE PROPOSED ANTENNAS

Antenna parameters	Dimensions in cm
X	5.6
Y	10.4
W	3.1
L	2.4
L_f	2.1
W_f	0.37
W_{tr}	0.07
L_{tr}	1.85
a	1.55
L_{S1} and L_{S2}	$\lambda_0/25$
W_{S1} and W_{S2}	$\lambda_0/5$

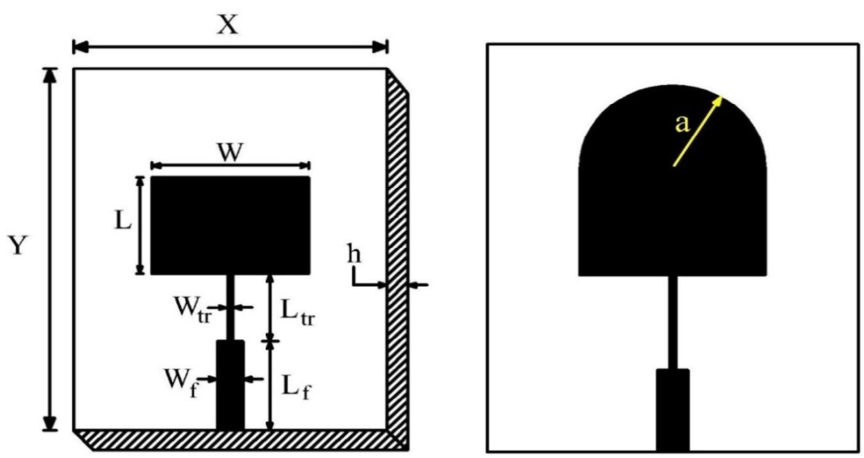

Fig. 1(a)Fig. 1(b)

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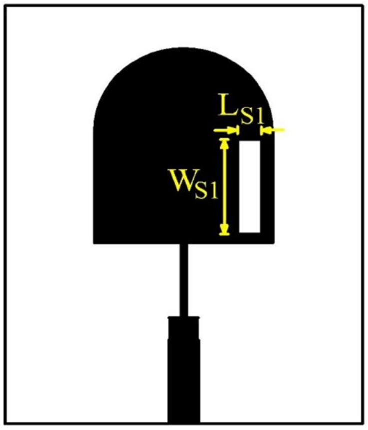

Fig. 1(c)

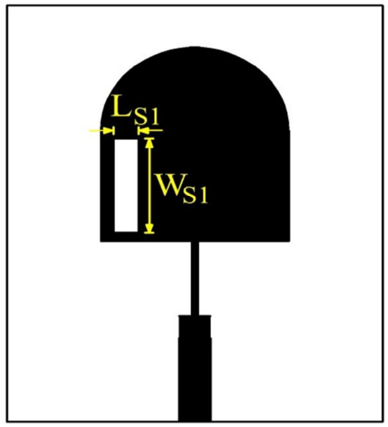

Fig. 1(d)

Fig. 1 Top view geometries of CRMSA, SCCHMSA, SVHMSA-1 and SVHMSA-2

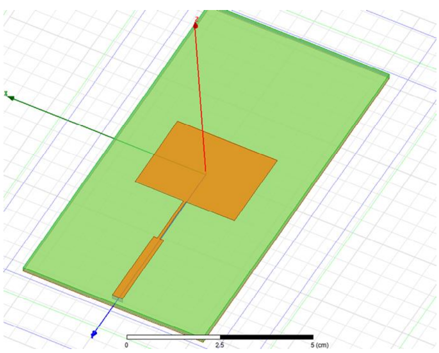

Fig. 2(a)

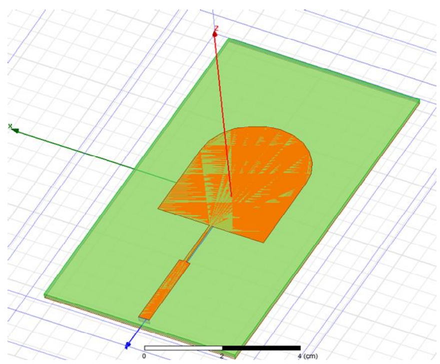

Fig. 2(b)

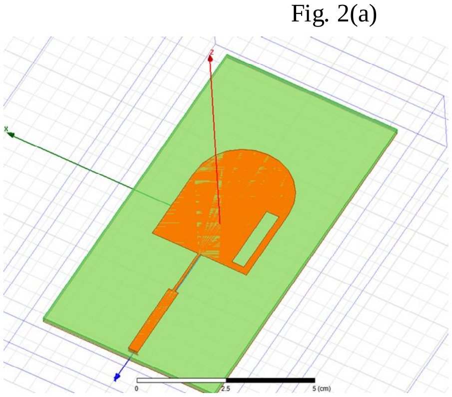

Fig. 2(c)

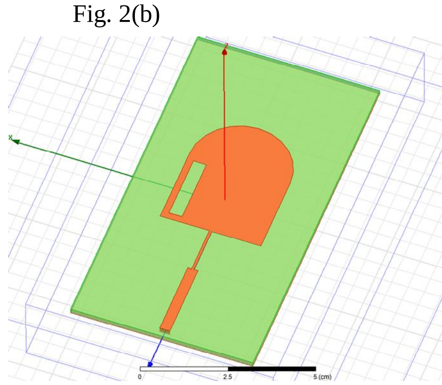

Fig. 2(d)

Fig. 2 Simulated Ansys HFSS models of CRMSA, SCCHMSA, SVHMSA-1 and SVHMSA-2

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III. RESULTS AND DISCUSSIONS

The designed antennas are simulated using Ansys HFSS electromagnetic (EM) 3-D tool. For all these antennas the bandwidth over return loss less than -10 dB is determined. The variations of return loss versus frequency of these antennas are shown in Fig. 3(a) to Fig. 3(d). From these figures the impedance bandwidth is calculated using the equation,

$$BW = \left[\frac{f_H - f_L}{f_C}\right] \times 100\ \% \qquad (1)$$

where, f_L and f_H are the lower and upper cut-off frequencies of the bands respectively when its return loss reaches -10 dB and f_C is the centre frequency between f_H and f_L. From these figures, it is clear that, the antennas operate between the frequencies 1.87 to 6.50 GHz which covers WLAN, WiMax, Bluetooth and Wi-Fi frequency ranges.

The impedance bandwidth of CRMSA is determined from Fig. 3(a) using equation (1) and it is found to be BW_1 = 2.42 % (2.85 GHz-2.92 GHz). From this figure it is clear that, the antenna resonates at 2.885 GHz (i.e. m_1) which is close to the designed frequency 3 GHz. This validates the design concept of CRMSA.

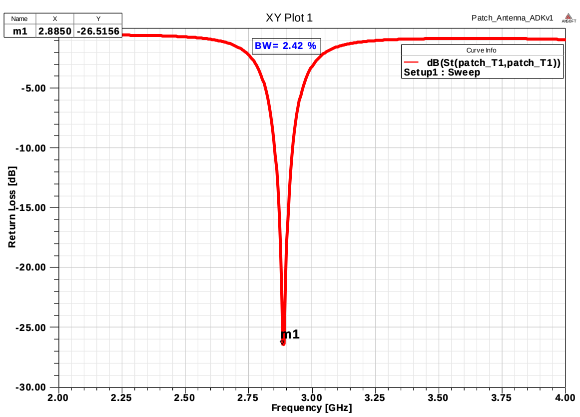

Fig. 3(a)

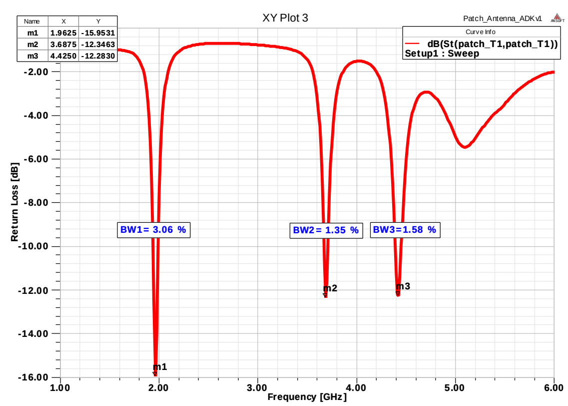

Fig. 3(b)

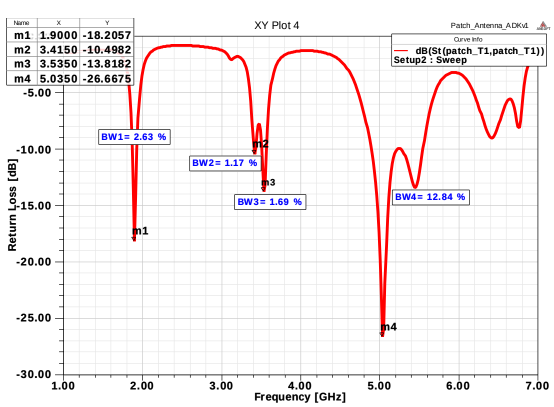

Fig. 3(c)

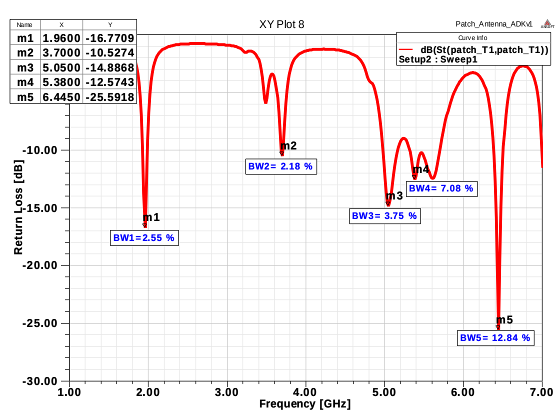

Fig. 3(d)

Fig. 3 Variation of return loss versus frequency of CRMSA, SCCHMSA, SVHMSA-1 and SVHMSA-2

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The variation of return loss versus frequency of SCCHMSA is as shown in Fig. 3(b). From this figure it is clear that, the antenna resonates for three frequency modes at m_1, m_2 and m_3 with corresponding impedance bandwidth of BW_1= 3.06% (1.93 GHz- 1.99 GHz), BW_2= 1.35% (3.66 GHz- 3.71 GHz) and BW_3= 1.58% (4.38 GHz- 4.45 GHz). Hence, from Fig. 3(h) it is clear thatby constructing SCCHMSA realized from CRMSA gives three frequency modes.

The variation of return loss versus frequency of SVHMSA-1 and SVHMSA-2 are as shown in Fig. 3(c) and Fig. 3(d) respectively. From Fig. 3(c) it is seen that, the antenna resonates for four frequency modes at m_1, m_2, m_3 and m_4 with corresponding impedance bandwidth of BW_1 = 2.63% (1.87 GHz- 1.92 GHz), BW_2 = 1.17% (3.40 GHz- 3.43 GHz), BW_3 = 1.69% (3.50 GHz- 3.56 GHz) and BW_4 = 12.84% (4.88 GHz- 5.55 GHz). The first band BW_1shown in Fig. 3(c) shifts towards the lower frequency side due to loading a vertical slot on the rectangular radiating patch at the right side parallel to the non-radiating side of the patch. This shifting of frequency gives the useful property of virtual size reduction which is equal to 34.14 % when compared to the resonant frequency of CTMSA shown in Fig 3(a). It is also clear from Fig. 3 (c) that, the highest impedance bandwidth is achieved at frequency mode m_4 i.e. BW_4 = 12.84%

In Fig. 3(d) the variation of return loss versus frequency of SVHMSA-2 is illustrated. This antenna resonates for five frequency modes at m_1, m_2, m_3, m_4 and m_5 with corresponding impedance bandwidth of BW_1 = 2.55% (1.93 GHz- 1.98 GHz), BW_2 = 2.18% (3.64 GHz- 3.72 GHz), BW_3 = 3.75% (4.97 GHz- 5.16 GHz), BW_4 = 7.08% (5.31 GHz- 5.70 GHz) and BW_5 = 12.84% (4.88 GHz- 5.55 GHz). Hence it is clear from Fig. 3(d) that, the operating bands of SVHMSA-1 can be increased from four to five by placing the vertical slot on the patch towards the left side parallel to the non-radiating edge of the patch.

The simulated 2D and 3D gain of CRMSA is as shown in Fig. 4 measured at frequency 2.885 GHz. The maximum gain of CRMSA is found to be 3.09 dB which is evident from 2D gain total variation of Fig. 4.

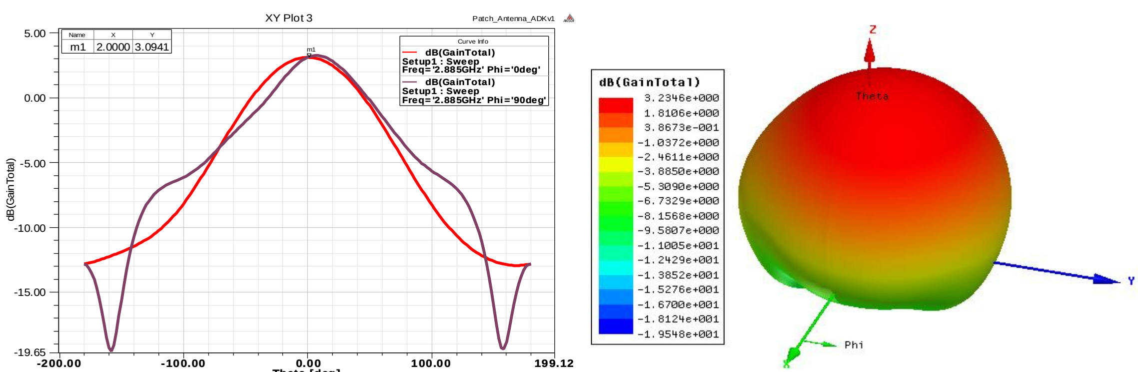

Fig. 4 2D and 3D gain totals of CRMSA measured at 2.885 GHz

The E and H plane radiation patterns of the proposed antennas for Phi at 0^0 and 90^0 and Theta at 0^0 and 90^0 is as shown in Fig. 5(a) to Fig. 5(d). From these figures it is clear that, the obtained radiation patterns are broadside and linearly polarized.

The effect produced by an electric charge that exerts a force on charged objects is the E and H-field. Distribution of charges on the patch indicates the radiation by the antenna. The charge distribution on the patch of all proposed antennas i.e. CRMSA, SCCHMSA, SVHMSA-1 and SVHMSA-2 are shown in the Fig. 6(a) to Fig. 6(h) respectively.

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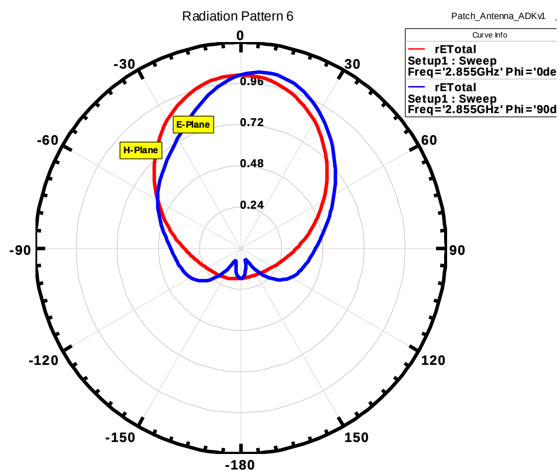

Fig. 5(a)

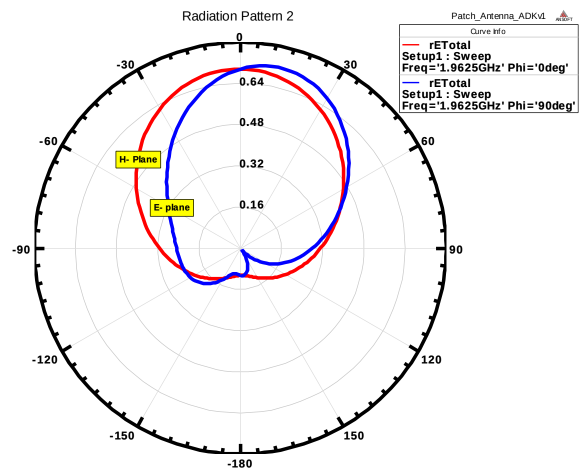

Fig. 5(b)

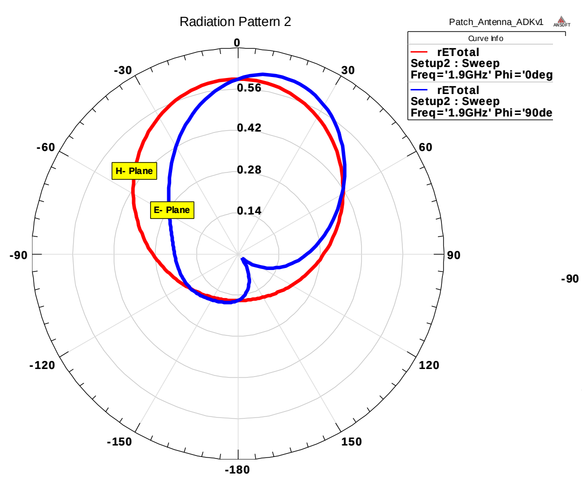

Fig. 5(c)

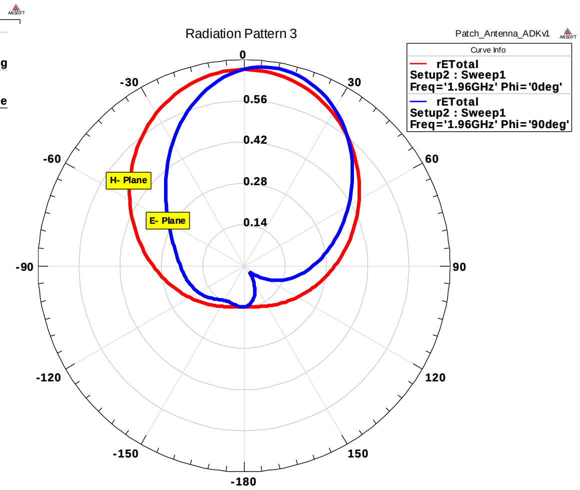

Fig. 5(d)

Fig. 5 Typical E and H-plane radiation patterns of CCMSA, SCCHMSA, SVHMSA-1 and SVHMSA-2 measured at 2.885 GHz, 1.96 GHz, 1.90 GHz and 1.96 GHz respectively.

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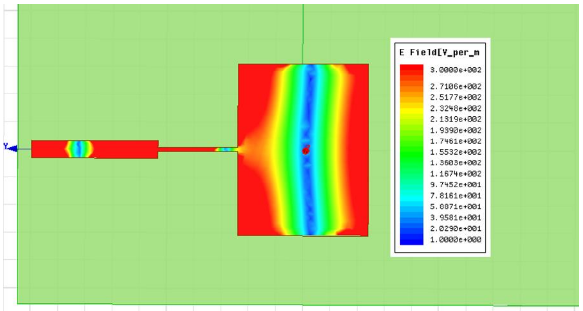

Fig. 6(a).

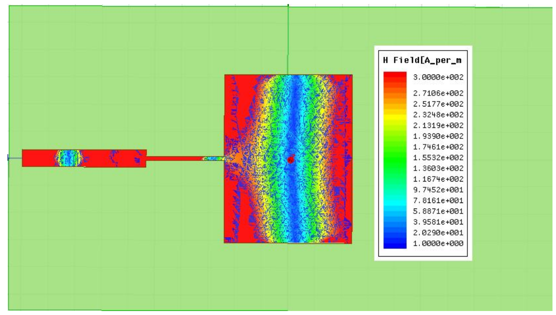

Fig. 6(b).

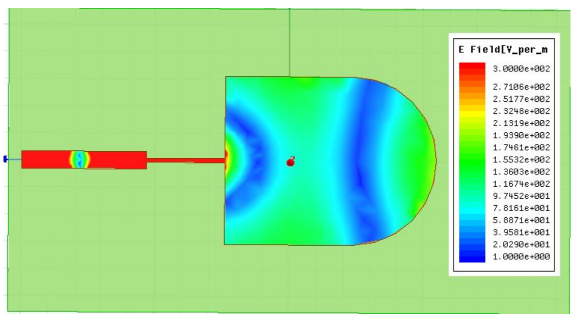

Fig. 6(c).

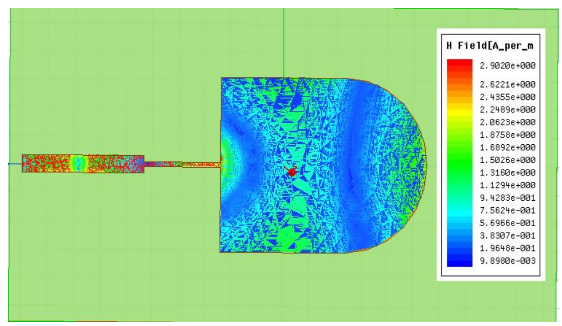

Fig. 6(d)

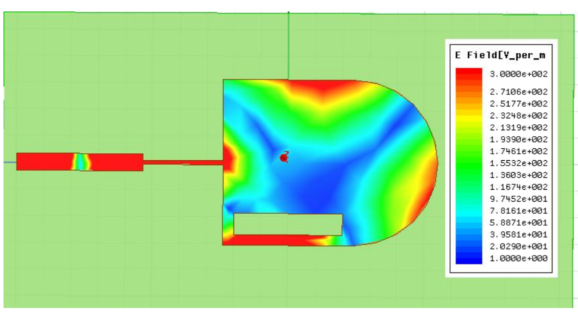

Fig. 6(e).

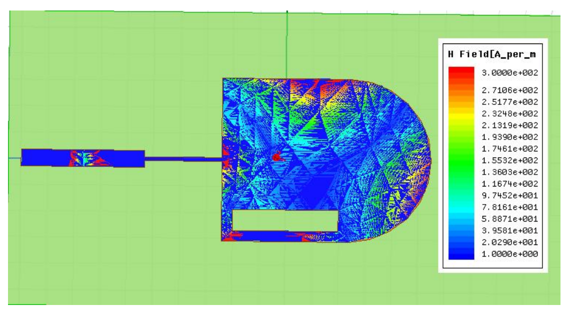

Fig. 6(f).

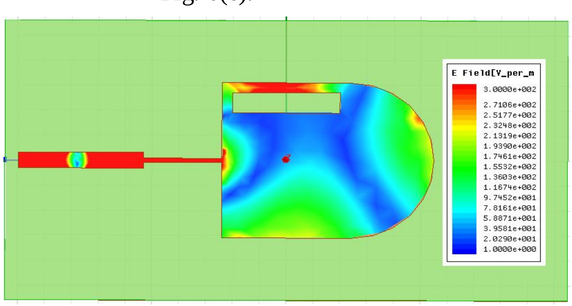

Fig. 6(g).

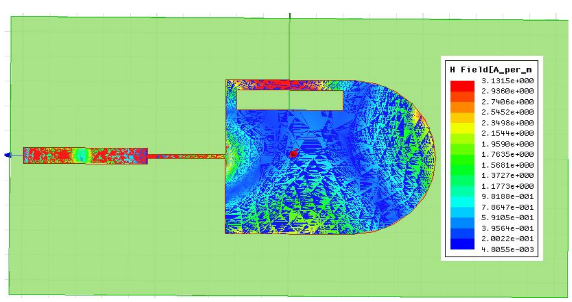

Fig. 6(h).

Fig. 6 E and H field charge distribution of CRMSA, SCCHMSA, SVHMSA-1 and SVHMSA-2 respectively.

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IV. CONCLUSION

From the detailed study it is concluded that, the novel geometries of hybrid semi-circle coupled slot loaded rectangular microstrip antennas derived from CRMSA are effective for producing multi-band operation without affecting the nature of broadside radiation characteristics. The proposed antennas resonates for triple, quad and penta frequency bands which covers frequency range from 1.87 GHz to 6.50 GHz. The antenna SVHMSA-1 gives a highest impedance bandwidth of 12.84 % and gives virtual size reduction which is equal to 34.14 %. The radiation patterns of all the antennas are found to be broadside and linearly polarized. The proposed antennas are simple in their design, compact and they use low cost substrate material. These antennas may find applications in WLAN, Wi-fi, WiMAx and Bluetooth and other wireless applications.

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BIOGRAPHY

Rajeshwari Biradar received her M.Sc. degree in Department of Applied Electronics, from Gulbarga University, Gulbarga in the year 2002 and M. Phil degree from Vinayak Mission University, from Salem in the year 2007. Presently she is pursuing for Ph. D degree under the guidance of Dr. S. N. Mulgi, Professor in the Department of P. G. Studies and Research in Applied Electronics, Gulbarga University, Gulbarga. Her fields of interest include Microwave Electronics.

Boya Satyanarayana received his M.Sc and M.Phil degrees in Applied Electronics from the Department of Applied Electronics, Gulbarga University, Gulbarga in the year 2011 and 2013 respectively. Presently he is pursuing Ph.D degree under the guidance of Dr. S. N. Mulgi, Professor in the Department of P. G. Studies and Research in Applied Electronics, Gulbarga University, Gulbarga.

Dr. S. N. Mulgi received his M.Sc, M.Phil and Ph.D degrees in Applied Electronics, from Gulbarga University Gulbarga in the year 1986, 1989 and 2004 respectively. He is working as a Professor in Department of P. G. Studies and Research in Applied Electronics, Gulbarga University, Gulbarga. He is an active researcher in the field of Microwave Electronics. He has published more than seventy five reputed peer reviewed International Journals and more than 30 in National Journals. He has presented several papers in International and National Conferences.