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A Simple U-shaped Slot-loaded Hybrid Rectangular Microstrip Antenna for Hexa-band Operation

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***Abstract*—This paper presents a design and development of a simple hybrid semi-circle coupled rectangular microstrip antenna comprising U-slot on the radiating patch for hexa-band operation. The semi-circle patch is superimposed on conventional rectangular microstrip antenna (CRMSA) to form a hybrid model. The antennas are excited through a simple microstripline feed and designed on the low cost modified glass epoxy substrate material. The proposed antenna operates between 1.12 GHz to 9.63 GHz at a six different frequency bands and gives a virtual size reduction 57.71% when compared to conventional rectangular microstrip antenna with broadside radiation characteristics. This antenna is useful for the applications such as wireless CCTV, RFID, WLAN, IEEE 802.11a, WiMAX, Fourth Generation (4G) mobile communication system etc. The antenna parameters such as impedance bandwidth, return loss, radiation pattern and gain are discussed and presented.**

***Keywords*—microstrip antenna, hybrid semi-circle, U-slot, hexa-band.**

I. INTRODUCTION

Since for the past few decades, the microstrip antennas (MSAs) have attained a significant popularity and have become the major research topic in both theoretical and applied electromagnetics. The MSAs possess the attractive features like light weight, low profile, ease of installation, compatibility with other microwave and millimetre wave integrated circuits (MMICs), conformability to curved surface, low fabrication cost etc. [1]. It is the need of this modern communication era to select the suitable antenna integrability for specific application [2]. The MSA designers put forth their efforts to establish their methods and techniques to realize various wireless communication applications [3-4] using of different geometries like, triangular, square, annular ring etc. with comprising slot loading technique for achieving the multi-frequencies which is more useful for the modern wireless communication applications.

Moreover, in many applications such as land mobile telephony as well as in the field of wireless local area networks (WLAN) further requirement would be a multi-frequency operation [6]. So the designs of printed MSAs with intend to confirm to multiple communications protocols is very much useful [7-10]. In view of this, a simple technique has been proposed to in this paper to construct the hybrid model of rectangular microstrip antenna by superimposing the semi-circular patch on rectangular patch with U-shaped slot for hexa-band operation without much affecting the nature of broadside radiation characteristics of the antenna.

II. ANTENNA DESIGNING

The proposed antennas are designed and fabricated on low cost modified glass epoxy substrate material of dielectric constant $\varepsilon_r = 4.2$ with thickness h=0.16 cm and loss tangent of $\tan\delta = 0.02$. Figure 1 shows the top view geometry of CRMSA. This CRMSA consist of a radiating patch of width ‘W’ and length ‘L’ which is excited through a simple 50-Ω microstripline feed of dimensions L_f and W_f. To coupling the impedance between the radiating patch and the feed-line a quarter wavelength matching transformer of dimensions L_{tr} and W_{tr} is used. Under the substrate a tight copper shielding is used as a ground plane.

Figure 2 shows the top view geometry of semi-circle coupled hybrid microstrip antenna (SCHMSA). This antenna is constructed from the CRMSA which is shown in Fig. 1 by superimposing the semi-circular patch on the corresponding rectangular radiating patch. The dimension radius ‘a’ of the semi-circle is taken as half of the width of the rectangular patch (i.e. 1.55 cm).

The top view geometry of semi-circle coupled U-shaped slot hybrid microstrip antenna (SCUHMSA) is as shown in Fig. 3. In this antenna U-shaped slot is placed at the centre of the rectangular radiating patch. U_l and U_W are the length and width of vertical arms of U-slot and W_u and W_l are the length and width of the horizontal arm respectively. All dimensions of the U-shaped slot are taken in terms of free space wavelength λ_0 in cm corresponding to the designed frequency of f_r = 3 GHz. The length (U_l) and the width (U_w) of the horizontal arms is $\lambda_0/4$ and $\lambda_0/25$ (i.e. 2.5 cm and 0.4 cm) and the length (L_u) and width (W_u) of the vertical arm is $\lambda_0/5.26$ and $\lambda_0/25$ (i.e. 1.9 cm and 0.4 cm) respectively. The ground plane of Fig. 2 and Fig. 3 its remain same as that of Fig.1. The design parameters of the proposed antennas are listed in Table I.

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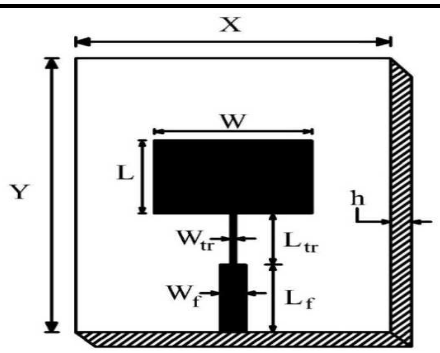

Fig.1 Top view geometry of CRMSA

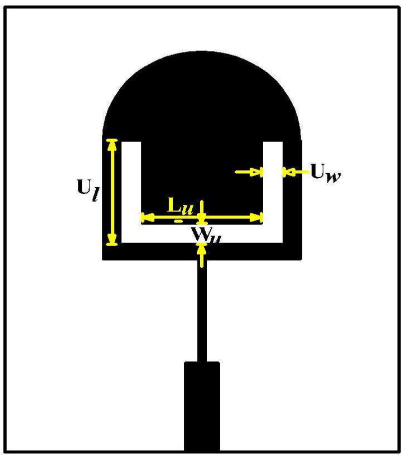

Fig.2 Top view geometry of SCHMSA

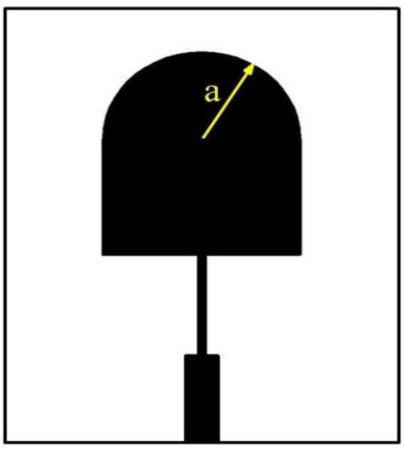

Fig. 3 Top view geometry of SCUHMSA

TABLE I
DESIGN PARAMETERS OF 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
U_l *and* U_w	2.5 and 0.4
L_u *and* W_u	1.9 and 0.4

III. RESULTS AND DISCUSSIONS

The designed antennas are simulated using electromagnetic (EM) Ansoft HFSS software. For all these antennas the impedance bandwidth over return loss less than –10 dB is determined. The variation of return loss versus frequency of CRMSA is as shown in the Fig. 4 which is designed for the resonant frequency 3 GHz. The impedance bandwidth is calculated using the equation,

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

where, f_H and f_L are the upper and lower cut-off frequencies of the resonating band respectively when its return loss reaches to –10 dB and f_c is a centre frequency between f_L and f_H. From Fig. 4 it is clear that, the antenna is resonanting at 2.855 GHz with the impedance bandwidth is found to be BW= 2.42% (2.85 GHz – 2.92 GHz) which is close to the designed frequency 3 GHz which validates the design concept of CRMSA.

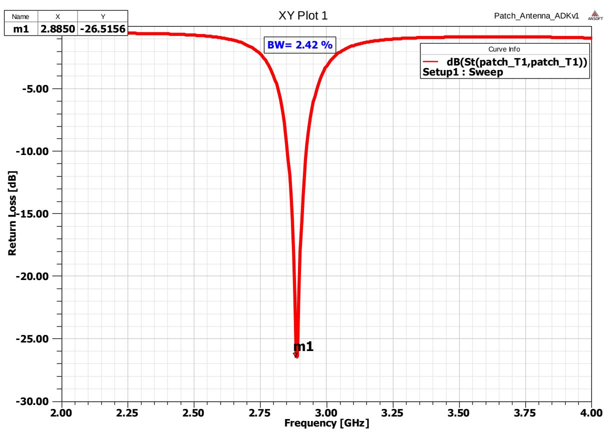

Fig. 4 Variation of return loss versus frequency of CRMSA

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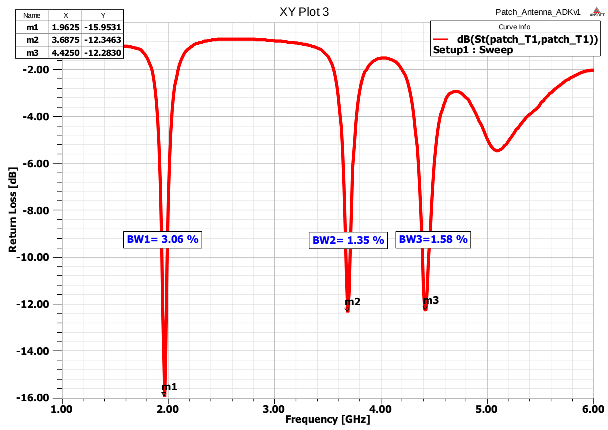

Fig.5 Variation of return loss versus frequency of SCHMSA

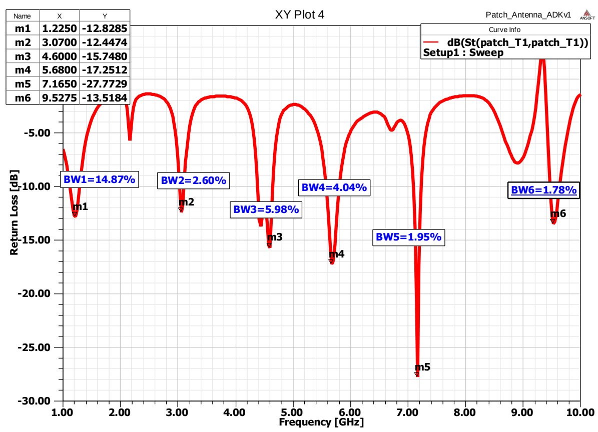

Fig. 6 Variation of return loss versus frequency of SCUHCMSA

The variation of return loss versus frequency of SCHMSA is as shown in Fig. 4. It is seen from this figure that, the antenna resonates for triple frequency modes m_1, m_2, and m_3 with 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) respectively. Hence, from this plot it is observed that, by the construction of this antenna which is realized from the CRMSA gives a triple frequency operation.

Fig. 6 shows the variation of return loss versus frequency of SCUHMSA. This antenna resonates for six frequency modes at m_1, m_2, m_3, m_4, m_5 and m_6 with impedance bandwidth of BW_1=14.87% (1.30 GHz -1.12 GHz), BW_2=2.60% (3.11 GHz-3.03 GHz), BW_3=5.98% (4.65 GHz – 4.38 GHz), BW_4=4.04% (5.80 GHz–5.57 GHz), BW_5=1.95% (7.22 GHz – 7.08 GHz) and BW_6=1.78% (9.63 GHz – 9.46 GHz) respectively. It is also observed in this figure that, the highest impedance bandwidth is achieved at frequency mode m_1 i.e BW_1 = 14.87% and is shifted towards the lower frequency side of the frequency spectrum which gives the virtual size reduction of 57.71% when compared to the resonant frequency of CRMSA.

The typical E and H-plane radiation patterns of the CRMSA, SCHMSA and SCUHMSA is shown in Fig. 7 to Fig. 9 which are measured at the resonant frequency of 2.885 GHz, 1.96 GHz and 1.22 GHz respectively. All the antennas give the broadside radiation characteristics. The simulated 3D gain of CRMSA and SCUHMSA is as shown in Fig. 10 and 11 respectively which are measured at frequency 2.885 GHz and 1.22 GHz. The maximum gain of CRMSA is found to be 3.23 dB.

The E and H field current distributions of the CRMSA and SCUHMSA is as shown in Fig. 12 to Fig. 13 which are observed at resonant frequencies 2.885 GHz and 1.25 GHz. It is evident from these figures that the maximum current distribution observed at the middle of the radiating patch which shows that, the proposed antenna will effectively radiates at the corresponding resonant frequencies.

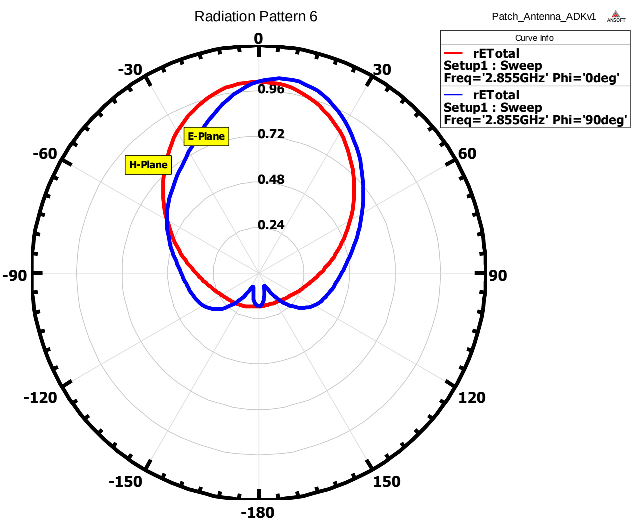

Fig. 7 E and H-plane radiation pattern of CRMSA measured at 2.885 GHz

Fig. 8 Typical E and H-plane radiation pattern of SCHMSA measured at 1.96 GHz

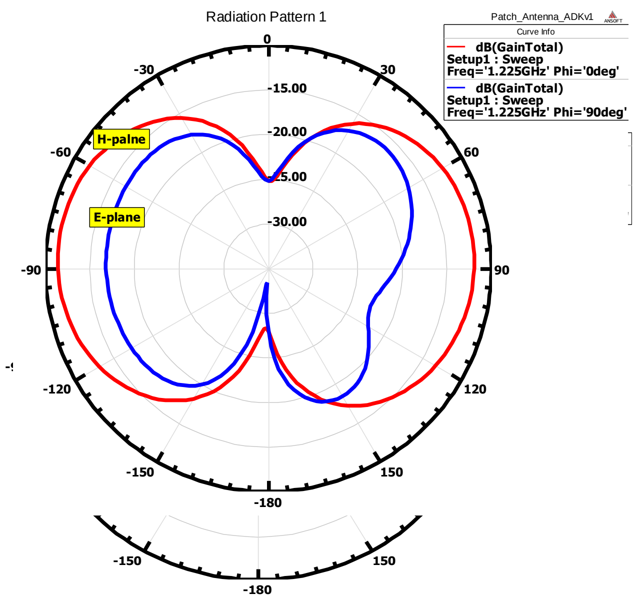

Fig. 9 Typical E and H-plane radiation pattern of SCUHMSA measured at 1.22 GHz

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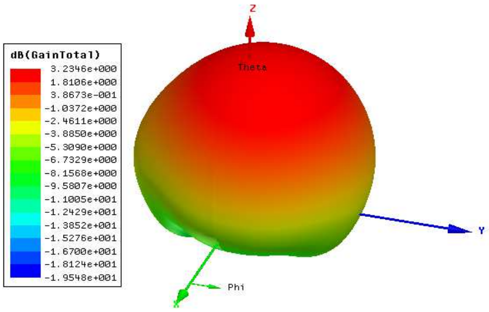

Fig. 10 3D gain total of CRMSA measured at 2.885 GHz

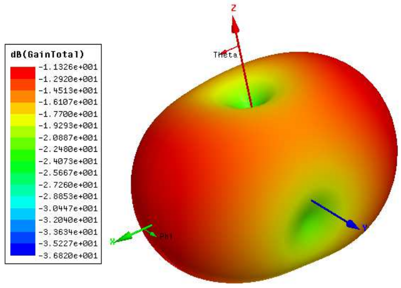

Fig. 11 3D gain total of SCUHMSA measured at 1.22 GHz

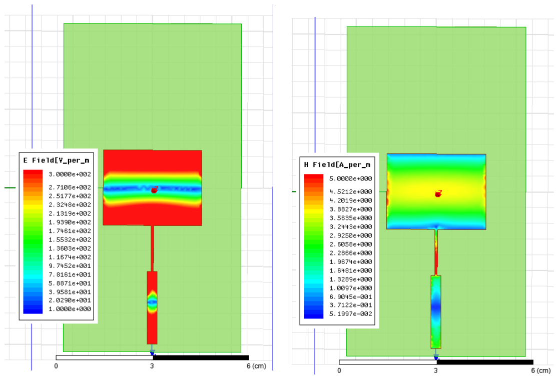

Fig. 12 E and H field charge distribution of CRMSA, respectively.

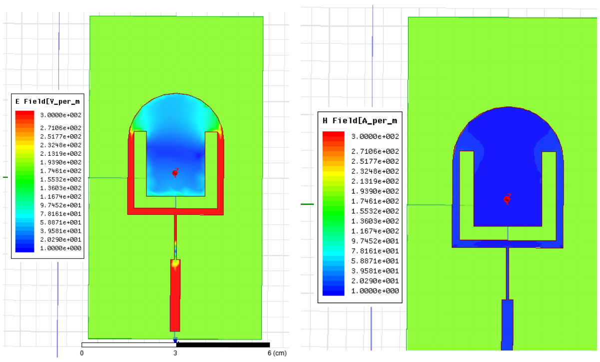

Fig. 13 E and H field charge distribution of SCUHMSA, respectively.

IV. CONCLUSIONS

A novel U-shaped slot loaded semi-circle hybrid rectangular microstrip antenna is presented. The antenna is laminated on low cost modified glass epoxy substrate material and is excited by a simple microstripline feed. The proposed antenna operates for hexa-frequency bands which covers frequency range from 1.12 GHz to 9.63 GHz. The first impedance bandwidth gives a highest of 14.87 % and gives virtual size reduction of 57.17 %. The radiation pattern of all the antennas are found to be broadside and linearly polarized. These antennas may find applications in CCTV, RFID application, WLAN IEEE 802.11a, WiMAX, and fourth generation (4G) mobile communication system.

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