DESIGN AND DEVELOPMENT OF APERTURE COUPLED RECTANGULAR MICROSTRIP ANTENNA FOR WIDE BAND OPERATION

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Abstract

This paper presents the experimental investigations carried out for obtaining wide band operation of rectangular microstrip antenna by using aperture coupled feeding technique. By incorporating U-slots with stubs on the radiating element, antenna resonates for single wideband with an impedance bandwidth of 45.61%. The antenna has two resonant peaks f_1 and f_2 which occurs at 12.1 GHz and 14.38 GHz with minimum return loss of −32.46 dB and −46.12 dB respectively. The lower resonant frequency f_1 is closer to the fundamental resonance of the rectangular patch. The second resonant frequency f_2 is due to current along the edges of U-slots and stubs of aperture coupled U-slot and stub rectangular microstrip antenna (AUSRMSA). This technique also enhances the gain to 9.96 dB which is 1.89 times more than the gain of conventional rectangular microstrip antenna (CRMA). The enhancement of impedance bandwidth and gain does not affect the nature of broadside radiation characteristics. The design concepts of antennas are presented and experimental results are discussed.

Keywords: *Microstrip, wide band, Aperture coupled, Slots.*

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1. INTRODUCTION

In the current communication systems, the use and significance of microstrip antennas (MSAs) has become widespread due to their attractive features such as light weight, low volume, ease in fabrication and low cost [1]. However, the major limitations associated with MSAs are narrow impedance bandwidth and low gain. The conventional MSAs have typical impedance bandwidth nearly 2 to 5% [1-2], which restricts their many useful applications. Therefore, much work has been devoted to increasing the impedance bandwidth of microstrip antennas, such as adding an impedance matching network, stacked patches, using parasitic patches, slots or by using additional resonators [3–9] and gain [10-12**]**. In this presentation wide band antenna is realized by using aperture coupled feeding technique. Further the proposed antenna is also capable for the enhancement of gain and reduction of cross polar power level by placing U-slot & stubs on the patch and by feeding it through aperture coupled technique. The enhancement of bandwidth, gain and reduction of cross-polar power level does not affect the nature of broadside radiation characteristics.

2. DESCRIPTION OF THE ANTENNA GEOMETRY

The art work of proposed antennas are developed using computer software AutoCAD and are fabricated on low cost glass epoxy substrate material of thickness h=1.6 mm and permittivity ε_r=4.2. The CRMA has been designed using the equations available in the literature [1]. Figure 1 show the geometry of CRMA, which is designed for the resonant frequency of 9.4 GHz. The antenna is fed by using microstripline feeding. This feeding has been preferred because of its simplicity and it can be simultaneously fabricated along with the antenna element. Figure 1 consists of a radiating patch of length L and width W, quarter wave transformer of length L_t and width W_t used between the patch and 50 Ω microstripline feed of length L_f and width W_f. At the tip of microstripline feed, a 50 Ω coaxial SMA connector is used for feeding the microwave power.

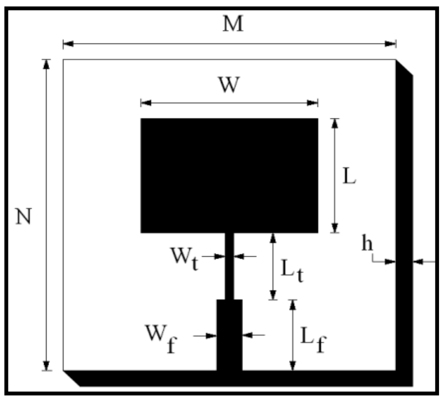

Fig 1 Geometry of CRMA

Figure 2 shows the geometry of AUSRMSA. The radiating element is etched on the top surface of substrate S_1 as shown in Fig. 2 (a). The two open circuited stubs of length L_T and width W_T are placed at a distance D_1 on the radiating element. The dimensions of L_T and W_T are taken as $\lambda_0/6.30$ and $\lambda_0/63.83$ respectively. The distance D_1 is chosen as $\lambda_0/63.83$ from the non-radiating edges of the rectangular patch. The U-slot is placed at the centre of the patch, which is symmetrical to its centre axis along the width. The distance between the vertical arms of the U-slot and open circuit stub D_2 is $\lambda_0/16.38$. The length and width of the U-slot are same as that of the open circuit stubs. The distance between the inner sides of the U slots U_a is taken as $\lambda_0/10.64$. The copper layer on the bottom surface of S_1 is removed. The H-coupling aperture is etched on top surface of substrate S_2 which is the ground plane as shown in Fig. 2 (b). The length L_1 of vertical arm in H-slot is $\lambda_0/10.64$ and width W_2 is $\lambda_0/63.83$. The length and width of horizontal arm namely L_2 and W_1 of this slot are $\lambda_0/15.95$ and $\lambda_0/63.83$ respectively as shown in Fig. 3.

(a) Radiating element of AUSRMSA (b) Coupling slot on the ground plane (c) Microstrip line feed etched on the top surface of S_1

Fig. 2 Geometry of AUSRMSA

In the aperture coupled feed configuration, the field is coupled from the microstripline feed to the radiating patch through an electrically small aperture or slot cut in the ground plane as shown in Fig. 2 (b). The coupling aperture is usually centered under the patch, leading to lower cross-polarization due to symmetry of the configuration. The shape, size and location of the aperture decide the amount of power to be coupled from the feed line to the patch. The expanded geometry of the coupling H-slot is as shown in Fig. 3. This aperture has been preferred because it is more effective in coupling the power to the patch etched on the top surface of S_1 when compared to any other aperture [13]. The length of each vertical arm in H-slot is L_1 and width W_2. The length and width of horizontal arm of this slot are L_2 and W_1 respectively as shown in Fig. 3. Table1 and Table 2 show the design parameters of the proposed antennas in mm.

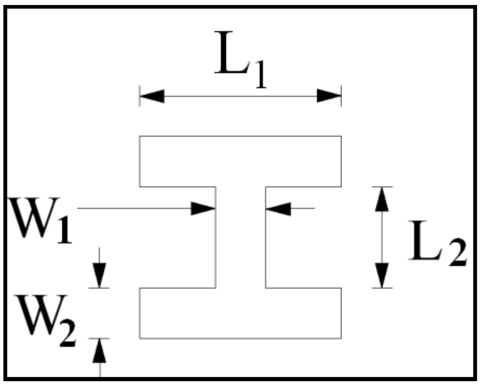

Fig. 3 Expanded geometry of H-coupling slot

Table 1 Design parameters of CRMA

Antenna Parameters	L	W	L_t	W_t	L_f	W_f	h	N	M
Dimensions (mm)	7.10	9.89	4.18	0.48	4.10	2.50	16	25	25

Table 2: Design Parameters of Adusrmsa

Antenna Parameters	L'_f	W'_f	L_1	L_2	W_1& W_2	L_T	W_T	U_a	D_1	D_2
Dimensions (mm)	13.00	2.50	3.00	2.00	0.50	7.06	0.5	2.99	0.50	1.95

3. EXPERIMENTAL RESULTS

The CRMA is designed and fabricated for 9.4 GHz of frequency which is standard or test frequency of X-band. The impedance bandwidth over return loss less than −10 dB is measured from 8 to 12 GHz of frequencies. The variation of return loss versus frequency of CRMA is as shown in Fig. 4.

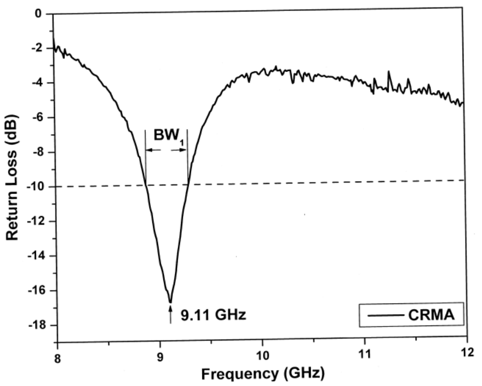

Fig 4 Variation of return loss versus frequency of CRMA

From this figure, it is seen that the antenna resonates at 9.11 GHz of frequency with minimum return loss of −16.79 dB. The impedance bandwidth (BW_1) of CRMA is calculated by using equation (1) and is found to be 4.40 %.

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

Where, f_H and f_L are the upper and lower cut-off frequency of the band respectively when its return loss becomes -10dB and f_c is the centre frequency between f_H and f_L. The variation of return loss versus frequency of AUSRMSA of Fig. 2 is as shown in Fig. 5. From this figure, it is seen that, the antenna resonates for single band BW. The impedance bandwidth of BW is found to be 45.61 %. From the Fig. 5, it is observed that, two resonant peaks f_1 and f_2 occurs at 12.1 GHz and 14.38 GHz respectively with minimum return loss of −32.46 dB and −46.12 dB respectively. The use of U-slots with stubs in this antenna resonates very close to the patch resonance.

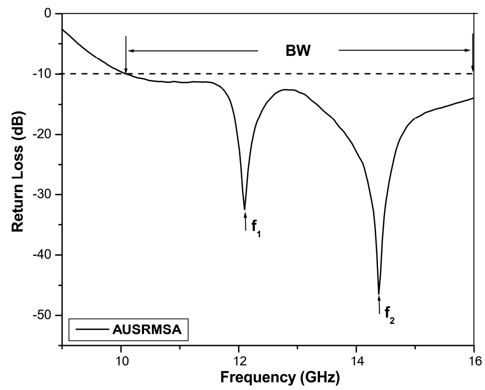

Fig 5 Variation of return loss versus frequency of AUSRMSA

The co-polar and cross-polar radiation patterns of CRMA are measured in its operating band. The typical radiation patterns measured at 9.11 GHz are as shown in Fig. 6. From this figure, it is seen that, the pattern is broadsided and linearly polarized. The half power beam width (HPBW) measured from Fig.6 is found to be 76^0. The cross-polar power level is −10.14 dB down compared to co-polar power level. The cross polar power level usually -10 dB down or below with respect to co-polar power level normally indicates the broadside nature of radiation. The gain of CRMA is found to be 5.26 dB.

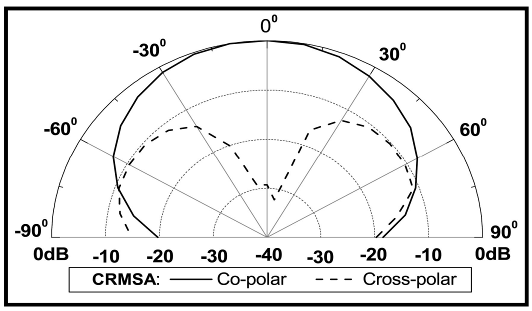

Fig 6 Co-polar and cross polar radiation patterns of CRMA measured at 9.11 GHz.

The co-polar and cross-polar radiation pattern of AUSRMSA is measured in its operating band BW. A typical radiation pattern measured at 12.1 GHz is as shown in Fig. 7. From this figure, it is seen that, the pattern is broadsided and linearly polarized. The HPBW measured from Fig 7 is found to be 94.84°. The gain of AUSRMSA is found to be 9.96 dB which is 1.89 times more than the gain of CRMSA.

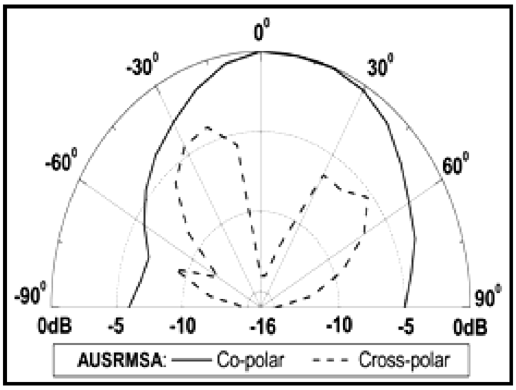

Fig 7 Co-polar and cross polar radiation patterns of AUSRMSA measured at 12.1 GHz.

The variation of input impedance of AUSRMSA is measured on VNA which is as shown in Fig. 8. In this figure the multiple loci appears around the centre of the Smith chart. This validates its wide band nature.

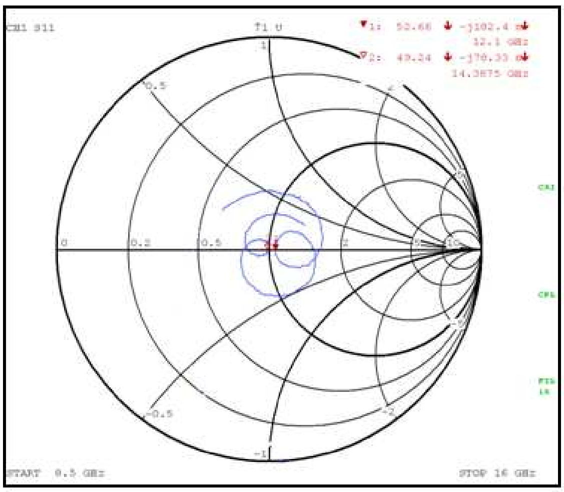

Fig 8 Variation of input impedance of AUSRMSA

The minimum input impedance of this antenna is 49.24−j78.33 Ω found from Smith chart which is very close to the characteristic impedance of 50 Ω. This shows excellent impedance matching.

CONCLUSIONS

From the detailed experimental study it is concluded that the use of aperture coupled technique is effective in enhancing the impedance bandwidth of CRMA. The impedance bandwidth of BW of AUSRMSA is found to be 45.61 %. This technique also enhances the gain to 9.96 dB which is 1.89 times more than the gain of CRMA. The enhancement of impedance bandwidth, gain and reduction of cross-polar power level does not affect the nature of broadside radiation characteristics**.** The proposed antennas are simple in design and fabrication and they use low cost substrate material. The wideband broadside nature of radiation of AUSRMSA may find applications in radar communication systems operating from X to Ku-band of frequencies.

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