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COMPARATIVE STUDY OF TUNABLE MULTI FREQUENCY RECTANGULAR MICROSTRIP ANTENNA

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ABSTRACT

A comparative study on simulated and experimental results of rectangular microstrip antenna with open stub loading technique has been presented for tuning at various frequency bands. The open stub of equal length is located at different places on the radiating patch for multiple resonating frequencies without affecting linearly polarized broadside radiation characteristics. The proposed antenna gives frequency ratio of about 1.41 with maximum gain of 5.66 dB. The antenna is simple in design and fabrication. It may find applications in WLAN, Wi-MAX and SAR

KEYWORDS: Rectangular microstrip antenna, Open stub, tuning, WLAN, Wi-MAX and SAR

In microwave communication, microstrip antennas are widely used because they have advantages of low profile, light weight, ease of fabrication etc. (1-3). Conventional microstrip antennas are not suitable for wireless communications because of their disadvantages like narrow bandwidth, low gain and efficiency. Therefore, the main aim is to design antenna with small size, enhanced bandwidth, multiband and tunable characteristics. Because of various advantages of tunable antennas, they are used in modern wireless communication systems such as GSM, Bluetooth etc. capable of operating at two or more frequency bands (4). From the literature, it is found that tuning of frequency bands is achieved by integrating PIN/ varactor diode, cutting slots and placing stub on the patch (5-10). But the design of rectangular microstrip antenna with open stub placed on radiating edge of the conducting patch at different locations for tuning at different frequency bands is found to be rare in the literature.

ANTENNA DESIGN

The conventional rectangular microstrip antenna (CRMA) and open stub loaded rectangular microstrip antennas (OSRMA) are fabricated on low cost glass epoxy substrate material of area 5.3 x 9.82cm. The artwork of proposed antennas is prepared using the software AUTOCAD. The antennas are etched using photolithography process.

Figure 1 shows the top view geometry of CRMA, designed for 3.2 GHz. This antenna consists of a radiating patch of length L and width W. The antenna is excited through 50 Ω microstripline feed of length L_t and width W_t. The quarter wavelength matching transformer of length L_f and width W_f is used to match the impedance with radiating rectangular patch with microstripline feed. Below the substrate, a tight copper shield is used.

Figure 2(a) to 2(d) shows the top view geometries of OSRMA 1, OSRMA 2, OSRMA 3 and OSRMA 4, respectively. In Figure 2(a) and 2(b) vertically inverted open stubs S_1 and S_2 are inserted at the left side and right side parallel to the non radiating sides of the rectangular patch respectively. The distance between the open stub and edge of the patch is d_1 and the distance between open stub and centre axis of the patch is d_2.

In Figure 2(c) and 2(d) vertically inverted open stubs S_3 and S_4 are inserted at the left side and right side of the centre axis of the patch. The distance between open stub and edge of the patch is d_3 and the distance between open stub and centre axis of the patch is d_4. All the open stubs S_1 to S_4 are of same length L_s and width W_s and are extended up to 0.18cm on either side of the centre axis.

The designed parameters of proposed antennas are given in table 1. The proposed antennas are simulated using Ansoft HFSS EM 3D tool.

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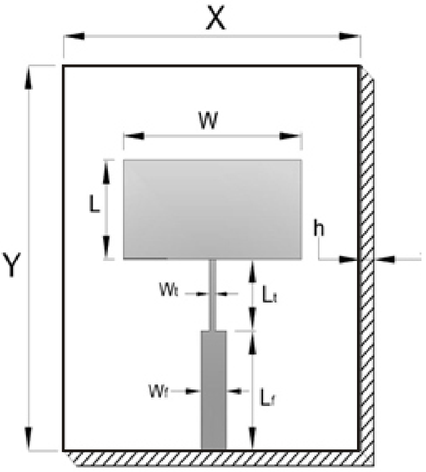

Figure 1: Top view geometry of CRMA

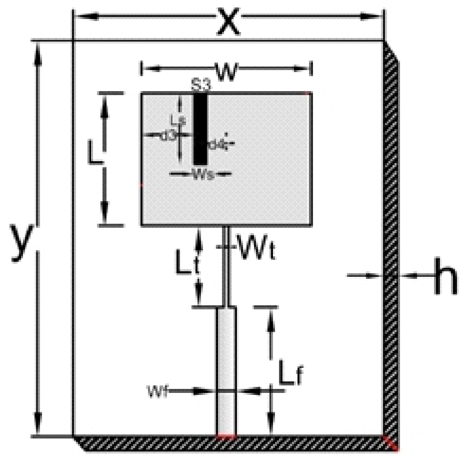

Figure 2(c): Geometry of OSRMA 3

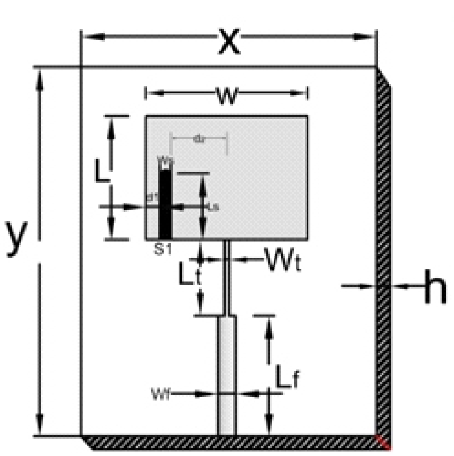

Figure 2 (a): Geometry of OSRMA 1

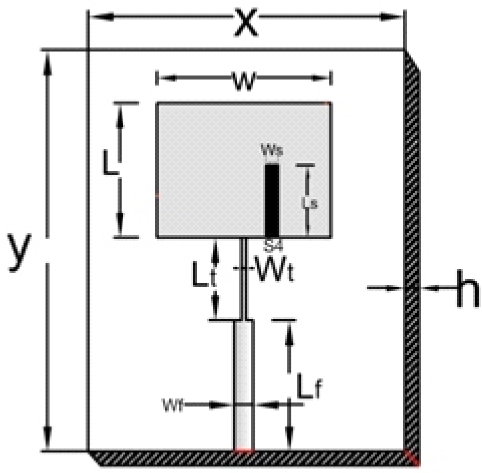

Figure 2(d): Geometry of OSRMA 4

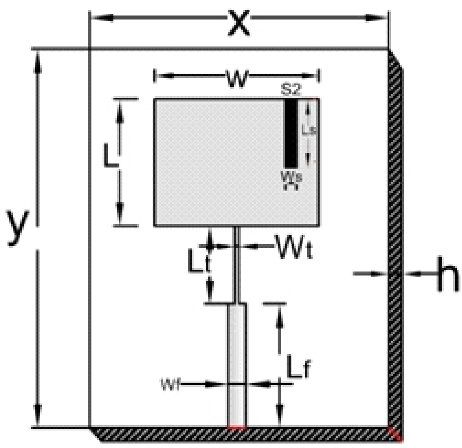

Figure 2 (b): Geometry of OSRMA 2

RESULTS AND DISCUSSION

Measurements were carried out for return loss, impedance bandwidth, resonant frequency and radiation pattern of antennas by using Vector Network Analyzer.

The variation of return loss versus frequency of CRMA is as shown in Figure 3. From this figure, it is observed that CRMA resonates at 2.98 GHz of frequency which is close to the designed frequency of 3.2 GHz. The experimental impedance bandwidth over return loss less than -10 dB is calculated using the equation,

$$\text{Impedance bandwidth } (\%) = f = \frac{f_H - f_\ell}{f_r} \times 100\% \quad ....(1)$$

Table 1: Design parameters of CRMA and OSRMA

CRMA Antenna parameters	Dimensions in cm	OSRMA Antenna parameters	Dimensions in cm
W	2.91	Ls	1.3
L	2.24	Ws	0.2
W_f	0.317	d 1	0.255
L_f	2.183	d 2	1
W_t	0.078	d 3	0.855
L_t	1.372	d 4	0.4

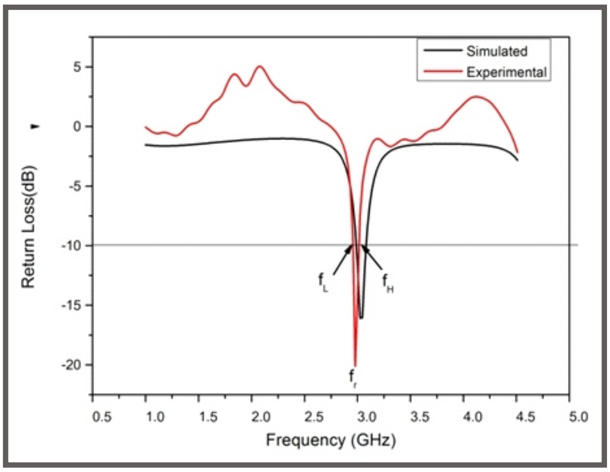

Figure 3 : Variation of return loss and frequency of CRMA

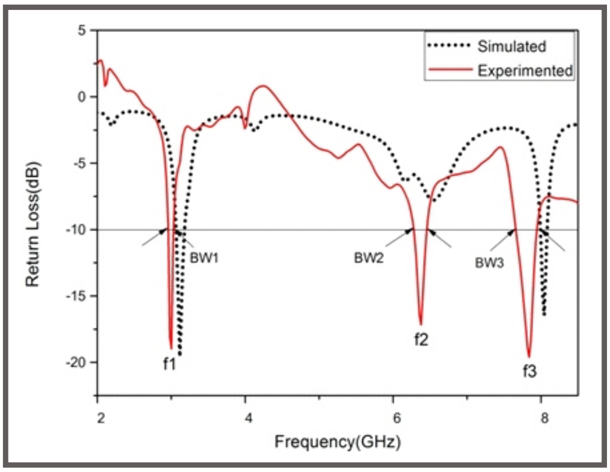

Figure 4: Variation of return loss and frequency of OSRMA-1

where f_H and f_L are upper and lower cutoff frequencies respectively, when its return loss reaches 10 dB and fr is the centre frequency between f_H and f_L. The impedance bandwidth of CRMA is found to be 2.34%. The simulated result is also shown in Figure 3.

Figure 4 shows the variation of return loss versus frequency of OSRMA -1. It is seen from this figure that, the antenna operates for three frequency bands BW_1 (3.04 - 2.94GHz) =3.33% , BW_2 (6.46 6.27GHz) = 2.98% and BW_3 (7.96 7.65GHz) = 3.94% for the resonating frequencies of f_1, f_2 and f_3 respectively. These frequency bands are due to independent resonance of the patch and open stub S_1 of OSRMA 1. The BW_1 is considered as primary band because its resonating frequency f_1 is close to fr of CRMA. The BW_2 is considered as first secondary band and BW_3 is considered as second secondary band. Further, it is seen from Figure 4 that, the simulated result of OSRMA 1 is also shown, which is observed that simulated result shows only two frequency bands whereas experimental result shows three frequency bands hence experimental result is better than simulated result.

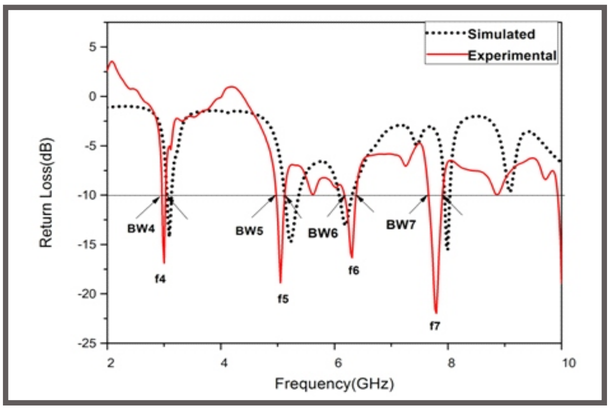

Figure 5: Variation of Return loss Vs frequency of OSRMA-2

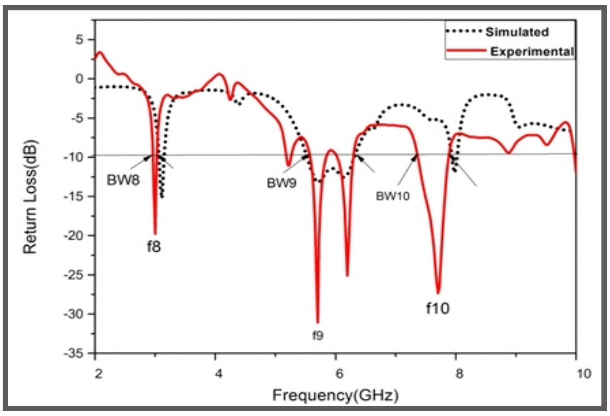

Figure 6: Variation of return loss Vs frequency of OSRMA-3

Figure 5 shows the variation of return loss versus frequency of OSRMA 2. It is seen from this figure that the antenna operates for four frequency bands BW_4, BW_5, BW_6 and BW_7 for the resonating frequencies of f_4, f_5, f_6 and f_7 respectively. The magnitude of impedance band widths are BW_4 (3.04 2.94GHz) = 3.33%, BW_5 (5.11 4.97GHz) = 2.76%, BW_6 (6.37 6.17GHz) = 3.17% and BW_7 (7.96 7.65GHz) = 4.24%. It is clear from this figure that, the resonating frequencies f_5 and f_6 are shifted left side of f_2 where as f_7 is nearly close to f_3 without change in primary band resonating frequency f_1. This shift in the resonating frequencies is due to change in the location of open stub S_2 of an antenna OSRMA 2 compared to the location of open stub S_1 of an antenna OSRMA 1. Further it seen from Figure 5 that, the simulated result of OSRMA 2 is in good agreement with the experimental results.

Figure 6 shows the variation of return loss versus frequency of OSRMA 3. It is seen from this figure that the antenna operates for three frequency bands BW_8, BW_9 and BW_{10} for the resonating frequencies of f_8, f_9 and f_{10} respectively. The magnitude of impedance band widths are BW_8 (3.04-2.94GHz) = 3.33%, BW_9 (5.85-5.56GHz)= 5.08% and BW_{10} (7.86-7.35GHz) = 6.61%. These frequency bands are due to independent resonance of the patch and open stub S_3 of OSRMA-3. The BW8 is considered as primary band because its resonating frequency f_8 is close to fr of CRMA. The BW_9 is considered as first secondary band and BW_{10} is considered as second secondary band. Further it seen from Figure 6 that, the simulated result of OSRMA 3 is in good agreement with the experimental results.

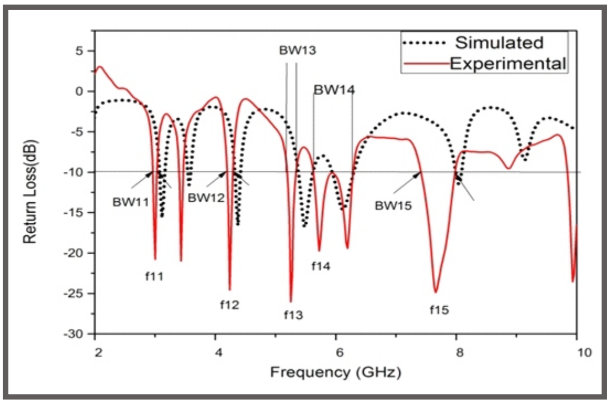

Figure 7: Variation of Return loss Vs frequency of OSRMA-4

Figure 7 shows the variation of return loss versus frequency of OSRMA-4. It is seen from this figure that the antenna operates for penta bands BW_{11}, BW_{12}, BW_{13}, BW_{14} and BW_{15} for the resonating frequencies of f_{11}, f_{12}, f_{13}, f_{14} and f15 respectively. The magnitude of impedance band widths are BW_{11}(3.04-2.94GHz) = 3.33%, BW_{12} (4.32-4.20GHz)= 2.83%, BW_{13} (5.35-5.20GHz)=2.86%, BW_{14}(6.29-5.64GHz) = 11.36% and BW_{15} (7.96 -7.43GHz) = 6.92%. It is clear from this figure that, the resonating frequencies f_{12} and f_{13} are shifted left side of f_9 where as f_{14} is close to f_9 with bandwidth twice as that of BW_9 without change in primary band resonating frequency f_8. This shift in the resonating frequencies and increase in bandwidth is due to change in the location of open stub S_4 of an antenna OSRMA S4 compared to the location of open stub S_3 of an antenna OSRMA -3. Further it seen from Figure 7 that, the simulated result of OSRMA-4 is in good agreement with the experimental results.

The frequency ratio's of the antennas OSRMA-1, OSRMA-2, OSRMA-3 and OSRMA-4 are 2.12, 1.69, 1.9 and 1.41 respectively. The antenna OSRMA 4 has the minimum frequency ratio i.e., 1.41 which indicates flexibility of tuning and gives overall BW = 27.3%.

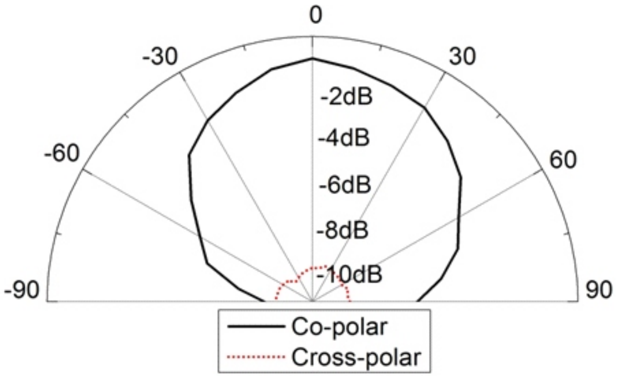

Figure 8: Radiation pattern of CRMA at 3.2 GHz

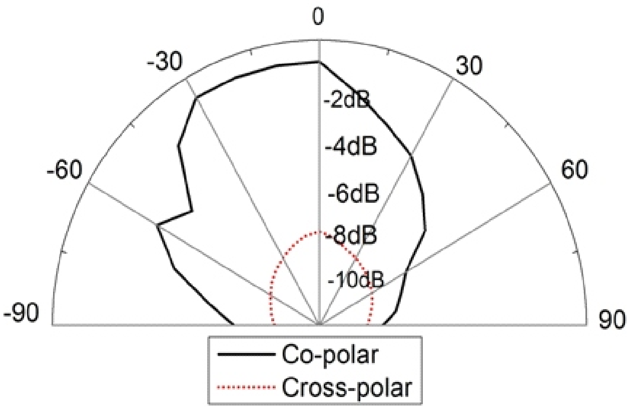

Figure 9(a): Radiation pattern of OSRMA 1 at 3 GHz

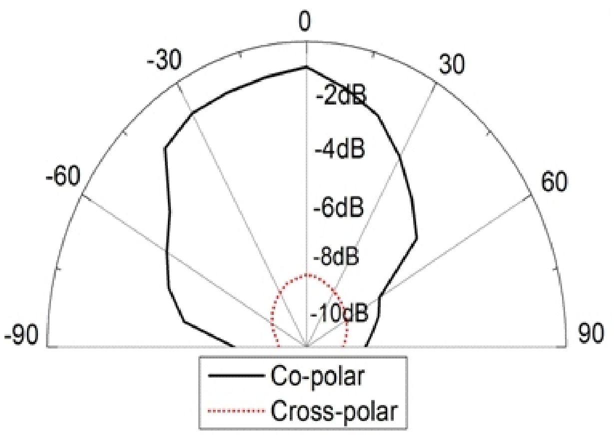

Figure 9(b): Radiation pattern of OSRMA 2 at 3GHz

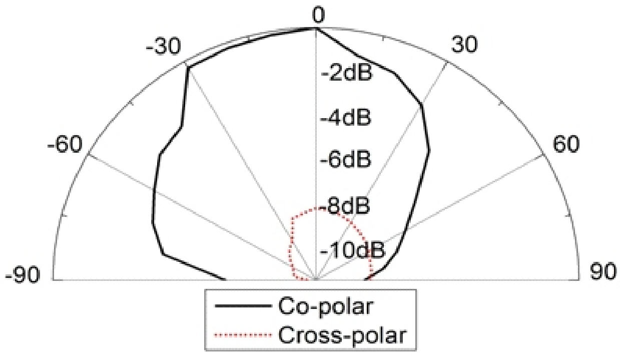

Figure 9(c): Radiation pattern of OSRMA 3 at 3 GHz

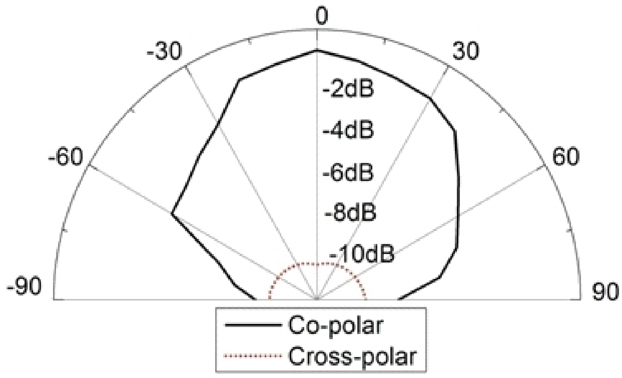

Figure 9(d): Radiation pattern of OSRMA 4 at 3GHz

Figure 8 shows the radiation pattern of CRMA at 3.2 GHz, and Figure 9 (a) to (d) shows radiation patterns of OSRMA 1, OSRMA 2, OSRMA 3 and OSRMA 4 measured at frequency 3 GHz which are broadside and linearly polarized.

The gain of CRMA and OSRMA is calculated using absolute gain method given by the formula,

$$(G)dB = 10\log\left(\frac{Pr}{Pt}\right) - (G_t)dB - 20log\left(\frac{\lambda_0}{4\pi R}\right)dB \quad \text{............ (2)}$$

where G_t is the gain of the pyramidal horn antenna and R is the distance between the transmitted antenna and the antenna under test (AUT). The power received by AUT, "P_r", and the power transmitted by standard pyramidal horn antenna "P_t" are measured independently. The gain measured for CRMA and OSRMA is found to be 5.75 dB and 5.66 dB respectively, which is nearly same to that of conventional antenna.

CONCLUSION

The proposed antennas can be made to operate at different frequency bands between 3 to 7.86 GHz by loading open stub on the radiating patch. The multiband frequencies are obtained due to tuning of the middle band with maximum gain of 5.66 dB. The tuning technique does not affect the primary band, last band and also broadside radiation characteristics. The bandwidth of the second secondary band is gradually increased from 3.94 GHz to 6.92 GHz without much change in its resonating frequency. The minimum frequency ratio is obtained by OSRMA- 4 which gives flexibility for tuning with overall bandwidth of about 27.3%. These antennas may find applications in Wi MAX, WLAN and SAR.

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