Design and Development of Quad Band Rectangular Microstrip Antenna with Ominidirectional Radiation Characteristics

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Abstract:
This paper presents the design and development of slotted rectangular microstrip antenna for quad band operation and ominidirectional radiation characteristics. The quad bands are achieved between 4.81 to 16 GHz. The magnitude of operating bandwidth has been enhanced to a maximum value of 3.29, 17.22, 36.44 and 43.33% by varying the width of vertical slots on the patch. This enhancement does not affect the nature of ominidirectional radiation characteristics. The proposed antenna is simple in its geometry and has been constructed from conventional rectangular microstrip antenna by placing vertical slots on the patch and a ground plane of height equal to the length of microstripline on the top and bottom surface of the substrate. Experimental results are in close agreement with the simulated results. The proposed antenna may find application in microwave communication system**.**

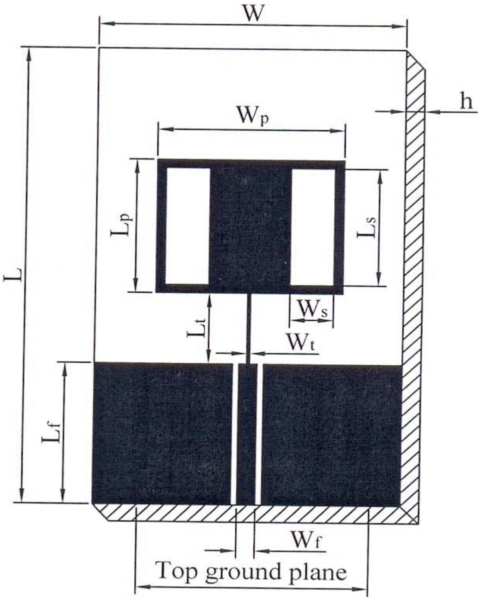
Keywords: Bandwidth, Microstrip antenna, Ominidirectional and Slot

1. Introduction

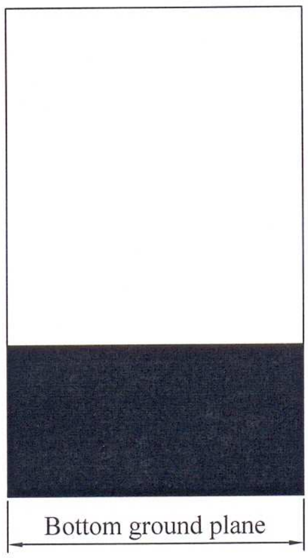
Microstrip antennas (MSAs) are finding increasing applications in microwave communication systems because of their diversified uses such as low profile, light weight, planar configurations, easy to fabricate and low cost [1]. The MSA operating at more than one band of frequencies is quite useful because each band can be used independently for transmit receive applications. Number of investigations have been reported in the literature for the realization of dual, triple and multi band operation of microstip antenna [3-9]. But design of quad band operation realized from conventional rectangular microstrip antenna with ominidirectional radiation characteristics is an additional advantage of the device. Further the construction of quad band slotted rectangular microstrip antenna (QSRMSA) does not alter its size when compared to the size of conventional rectangular microstrip antenna (CRMA) designed for the same resonant frequency.

2. Description of antenna geometry

The art work of the proposed antenna is sketched by using computer software Auto-CAD to achieve better accuracy and is fabricated on low cost FR4-epoxy substrate material of thickness $h = 1.6$ mm and permittivity $\varepsilon_r = 4.4$ using photolithography process. Figure 1(a) shows the top view geometry of QSRMSA. The bottom view geometry of this antenna is as shown in Fig. 1(b). In Fig. 1(a) the selected area A of the substrate is $L \times W$ cm. On the top surface of the substrate a ground plane of height which is equal to the length of microstripline feed L_f is used. A gap of 1 mm is used between the top ground plane and microstripline feed. On the bottom of the substrate a continuous copper layer of height L_f is used below the microstripline which is bottom ground plane. The QSRMSA is designed for 3 GHz using the equations available for the design of conventional rectangular microstrip antenna in the literature [2]. The length and width of the rectangular patch are L_p and W_p respectively. The feed arrangement consists of quarter wave transformer of length L_t and width W_t which is connected as a matching network between the patch and the microstripline feed of length L_f and width W_f. A Semi miniature-A (SMA) connector is used at the tip of the microstripline feed for feeding the microwave power.



(a) Top view geometry of QSRMSA



(b) Bottom view geometry of QSRMSA

Fig. 1 Geometry of QSRMSA when W_s = 6.1 mm

In Fig.1 (a) the vertical rectangular slots are placed on the patch. These slots treated as wide slots as their width is comparable to the length. The wide slots are selected because they are more effective in enhancing the bandwidth when compared to narrow slots. The length and width of vertical rectangular slots are L_s and W_s respectively. Both the slots are kept at a distance of 1.5 mm from the non resonating edges (L_p) of the patch. The design parameter of the proposed antenna is given in Table 1.

TABLE 1 Design Parameters of Proposed Antenna

L_p = 23.4 mm	W_p = 30.4 mm
L_f = 24.8 mm	W_f = 3.0 mm
L_t = 12.4 mm	W_t = 0.5 mm
L = 80.0 mm	W = 50.0 mm
Ls = 20.4mm	Ws = 6.1 mm

3. Experimental results

For the QSRMSA, the bandwidth over return loss less than -10 dB is simulated using HFSS simulating software and then tested experimentally on the Vector Network Analyzer (Rohde & Schwarz, Germany make ZVK model 1127.8651). The variation of return loss frequency of QSRMSA is as shown in Fig. 2. From this graph the experimental bandwidth (BW) is calculated using the equations,

$$BW = \left[\frac{f_2 - f_1}{f_C} \right] \times 100\ \%$$

were, f_1 and f_2 are the lower and upper cut of frequencies of the band respectively when its return loss reaches – 10 dB and f_c is the center frequency of the operating band. From this figure, it is found that, the antenna operates between 4.81 to 16 GHz.

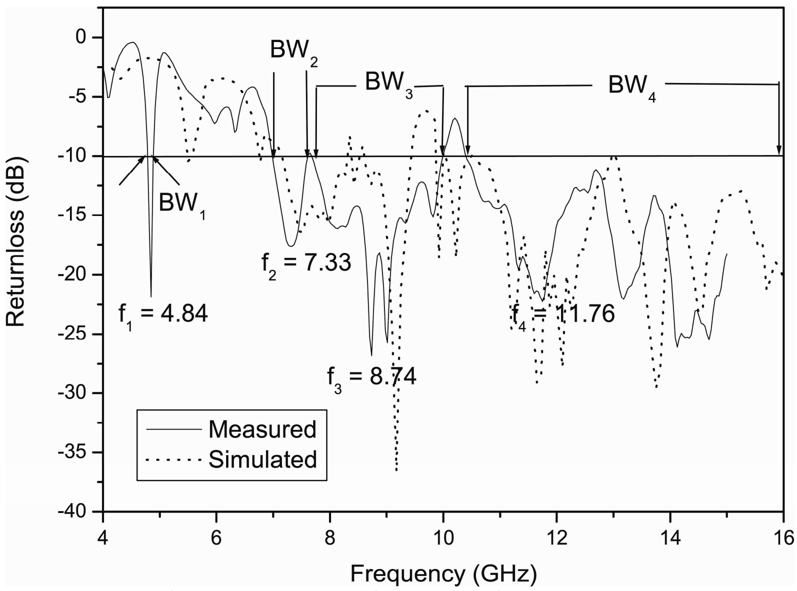


Fig. 2 Variation of return loss versus frequency of QSRMSA when W_s = 6.1 mm

In Fig. 2 it is seen that, the antenna gives four resonant frequency modes. The resonant frequency mode at f_1=4.84 GHz is due to the fundamental resonant frequency of the patch and others modes at f_2 = 7.33 GHz, f_3 = 8.74 GHz and f_4 = 11.76 GHz are due to the novel geometry of QSRMSA. The magnitude of experimental -10 dB bandwidth measured at BW_1 to BW_4 are 60 MHz (4.78-4.84 GHz) 1.24 %, 580 MHz (6.97-7.55 GHz) 7.98 %, 2.27 GHz (7.67-9.94 GHz) 25.78 % and 5.59 GHz (10.41-16 GHz) 42.33% respectively. Since the QSRMSA has been designed for 3 GHz. The fundamental resonant frequency mode (4.84 GHz) shifts from 3 GHz to 4.84 GHz. This shift of resonant mode towards higher frequency side is due to the coupling effect of microstripline feed and top ground plane. Simulated results of QSRMSA are also shown in Fig. 2.

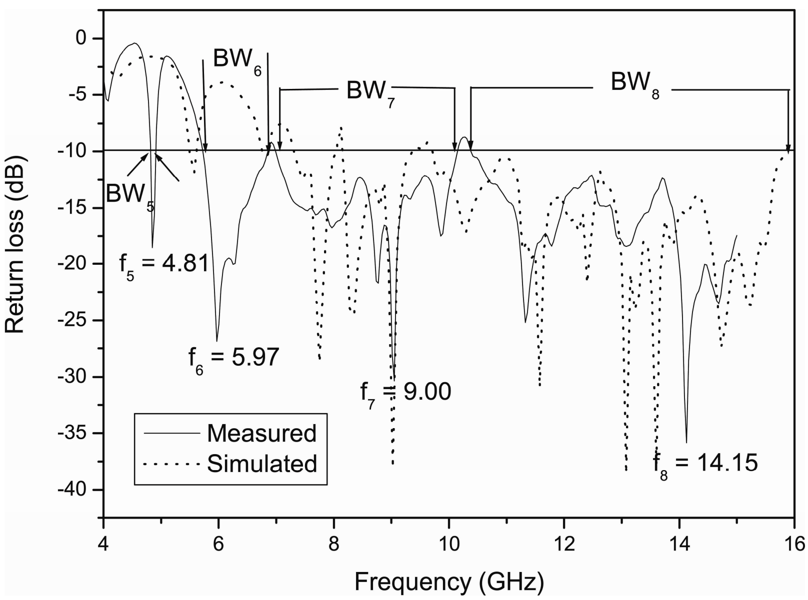


Fig. 3 Variation of return loss versus frequency of QSRMSA when W_s = 7.1 mm

Figure 3 shows the variation of return loss verses frequency of QSRMSA when W_s = 7.1 mm. It is clear from this figure that, the antenna again operates for four resonant frequency modes retaining the fundamental resonant mode at f_5 = 4.81 GHz and other modes at f_6 = 5.9 GHz, f_7 = 9.00 GHz and f_8 = 14.15 GHz. The magnitude of experimental bandwidth measured at BW_5 to BW_8 are 160 MHz (4.78-4.94 GHz) 3.29 %, 1.08 GHz (5.73-6.81 GHz) 17.22 %, 3.12 GHz (7-

10.12 GHz) 36.44 % and 5.59 GHz (10.41- 16 GHz) 43.33 % respectively. By comparing Fig. 2 and 3 it is clear that BW_5, BW6 and BW_7 increases in their magnitude respectively by 3.29 %, 17.22 % and 36.44 % when compared to BW_1, BW_2 and BW_3 by changing the width W_s to 7.1 mm in QSRMSA.This enhancement of bandwidth does not affect much the fundamental resonant frequency mode f_5 of QSRMSA when compared to f_1.The experimental and simulated results shown in Fig. 3 are in close agreement with each other.

The co-polar and cross-polar radiation pattern of QSRMSA is measured in its operating bands when W_s =. 7.1 mm. The typical radiation patterns measured at 5.97 GHz and 11.32 GHz are as shown in Fig. 4 and 5 respectively. The patterns are ominidirectional in nature

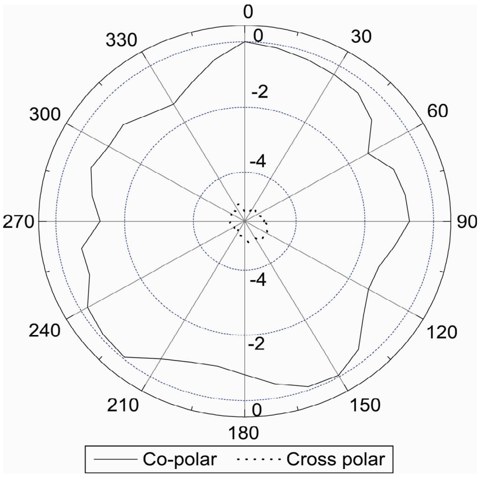


Fig. 4 Radiation pattern of QSRMSA measured at 5.97 GHz.

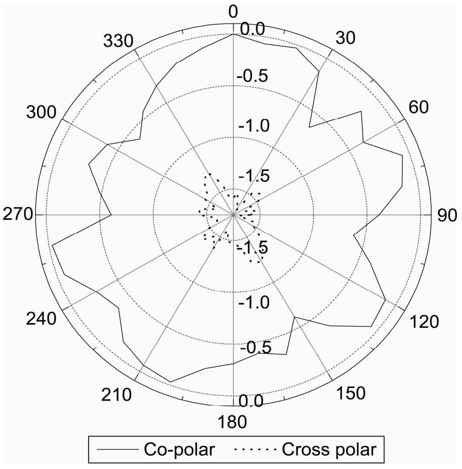


Fig. 5 Radiation pattern of QSRMSA measured at 11.32 GHz

The gain of the proposed antenna is measured by absolute gain method [1] using the formula

$$(G)dB = 10\ \log\left(\frac{P_r}{P_t}\right) - (G_t)dB\ -\ 20\log\left(\frac{\lambda_0}{4\pi R}\right)dB$$

where, P_t is the power transmitted by pyramidal horn antenna, P_r the power received by antenna under test (AUT), G_t the gain of the pyramidal horn antenna and R the distance between transmitting antenna and AUT. The variation of experimental gain versus frequency of QSRMSA when W_s = 7.1 mm is as shown in Fig. 6. It is seen that, the antenna shows maximum gain of 14.95 dB at 4.85 GHz.

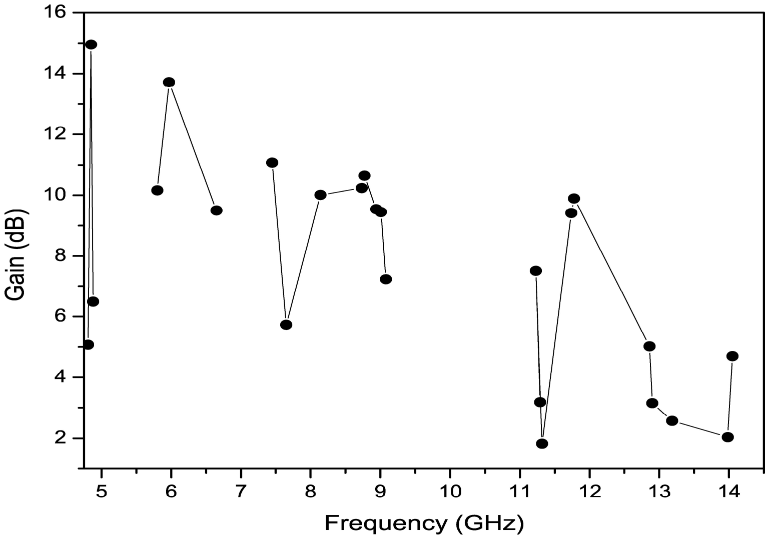


Fig. 6 Variation of gains versus frequency of QSRMSA when W_s = 7.1 mm

4. Conclusion

From the detailed experimental study it is concluded that, the QSRMSA constructed from CRMA is quite capable in producing quad band operation. The antenna operates between 4.81 to 16 GHz of frequency and gives ominidirectional radiation characteristics at each operating band. The magnitude of operating bandwidth has been enhanced to a maximum value of 3.29, 17.22, 36.44 and 43.33% by varying the width of vertical slots on the patch. The enhancement of bandwidth does not affect the nature of ominidirectional radiation characteristics. The simulated and experimental return loss results of QSRMSA are in close agreement with each other. The proposed antenna is simple in its design and fabrication. The antenna is fabricated using low cost FR4 substrate material. With these features the antenna may find any applications in microwave communication system.

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