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A Novel Design of Square Microstrip Antenna for Dual Band Operation

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Abstract: A novel design of square microstrip antenna is designed for dual band operation. The dual band is achieved by inserting right angle equal arm inverted slot on the patch. The impedance bandwidth of each operating band is found to be 1.85% and 2.57% respectively. These bands are enhanced to 15.60% and 44.94% by increasing the thickness of the substrate from 1.6 to 3.2 mm and placing right angle equal arm inverted slot in the ground plane. Further, the secondary band is enhanced to 63.15% by loading parasitic strip around the patch. This enhancement does not affect broadside radiation characteristics. Details of the antenna design are given and experimental results are discussed. The proposed antennas may find applications in radar communication systems.

Keywords: Square microstrip antenna, Dual band, Slot, Thickness, Parasitic strip.

1. INTRODUCTION

The microstrip antenna (MSA) consist a very thin metallic strip or patch over a substrate. The thickness of the substrate is very small as compared to the free space wavelength l_0. The substrate is placed only a small fraction of free space wavelength above the ground plane. On the substrate a conducting patch of required geometry is designed. In practice, different dielectric substrates are used in the design of microstrip antenna. Since, the dielectric constant for the thick substrate is at the lower end which provides better antenna parameters hence the thick substrate are most desirable. On the other hand, the dielectric constants are higher for the thin substrates and they are less efficient and relatively less raggedness. In view of this a thicker substrate has been selected in designing the proposed antennas.

MSAs are of various shapes and have several advantages, such as lightweight, low volume, planar configuration, low fabrication cost, low scattering cross-section, etc. However, the main disadvantage is their narrow bandwidth and low gain [2]. Many methods have been presented in the literature to increase bandwidth. These methods include use of slot loading [3], aperture coupled [4], parasitic elements [5] etc. Further, dual band antennas have gained wide attention in many communication systems because each operating band can be used independently for transmit/receive applications and hence they avoid the use of two separate antennas. Many researches have applied various techniques to get dual band operation [6-8]. But in this presentation a simple concept has been used to achieve the dual band operation by loading slot on the square patch. The enhancement of each operating band is achieved by changing the thickness of the patch and by placing slot in the ground plane and using parasitic strip around the patch. This kind of study on square microstrip patch is found to be rare in the literature.

2. DESIGN AND EXPERIMENTAL RESULTS

The artwork of proposed antennas is designed by using the equations available for the design of square microstrip antenna [1, 9] and is sketched using computer software Auto CAD–2006 to achieve better accuracy. The antennas are fabricated using photolithography process on low cost glass epoxy substrate material of thickness h = 0.16 cm, 0.32 cm and with a dielectric constant $\varepsilon_r = 4.2$.

Figure 1 shows the geometry of right angle equal arm inverted slot loaded square microstrip antenna (RSSMA) designed by using substrate of thickness 0.16 cm. The length and width of RSSMA is L. The right angle equal arm inverted slot is placed on the square patch with a distance of 1mm from L. The dimensions of slots are taken in terms of λ_o, where λ_o is the free space wavelength in cm. The length L_h and L_v are taken as $\lambda_o/6$. The width of the slot is 1mm. The antenna is fed by using microstripline feeding. This feeding has been selected because it is simple in design and can be simultaneously fabricated along with the antenna element. A quarter wave transformer of dimensions L_t, W_t is used for better impedance matching between microstripline feed of dimension L_f and W_f of the square microstrip patch. At the tip of microstripline feed a 50Ω coaxial SMA connector is used for feeding the microwave power. The hatched part indicates the right angle equal arm inverted slot on the square patch.

Further, the antenna is designed by changing thickness of substrate from h = 0.16 to 0.32 cm and by placing top right angle equal arm inverted slot shown in Figure 1 in the ground plane. When the thickness changes the dimension of square patch remains same [9]. However, the dimensions of feed arrangement shown in Figure 1 changes [1], the new values of length and width of quaterwave transformer and feedline are L't, W't, L'_f and W'_f respectively. This antenna is named as right angle equal arm inverted slot loaded square microstrip antenna with double thickness (RSSMAD). The bottom view geometry of RSSMAD is as shown in Figure 2.

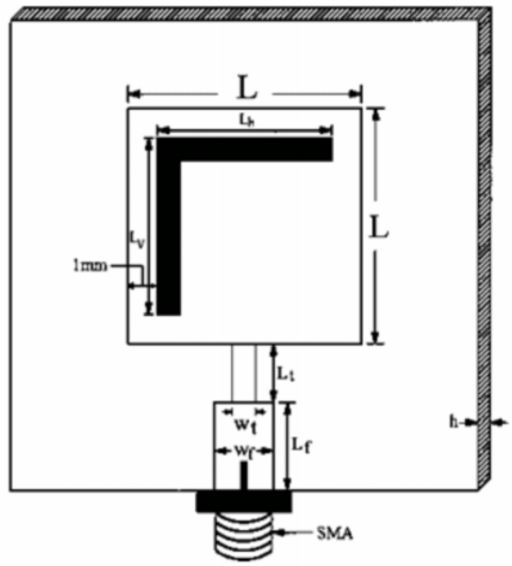

Figure 1: Geometry of RSSMA

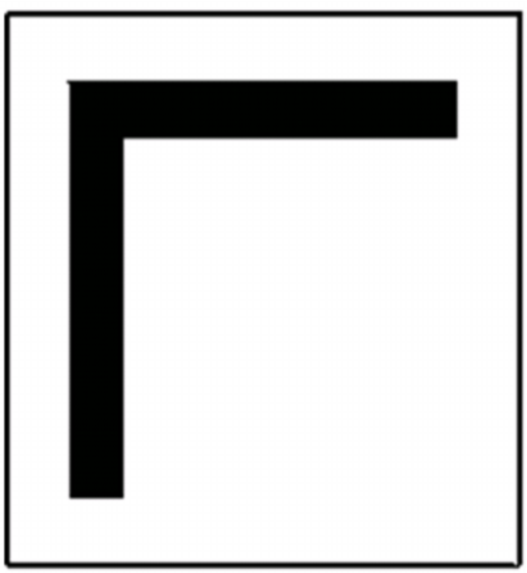

Figure 1: Geometry of RSSMA

Figure 3 shows the geometry of right angle equal arm inverted slot loaded square microstrip antenna with parasitic strip (RSSMAP). This antenna is constructed from RSSMAD by placing parasitic strip around the square patch and by removing the slot used on the ground plane of RSSMAD. The length L2 and width W2 of parasitic element is λo/3 and λo/32 respectively. The gap G between the edges of the square parasitic strip from the quaterwave transformer is 1mm. The feed arrangement of this antenna remains same as that of RSSMAD. The design parameters of the proposed antennas are given in Table 1.

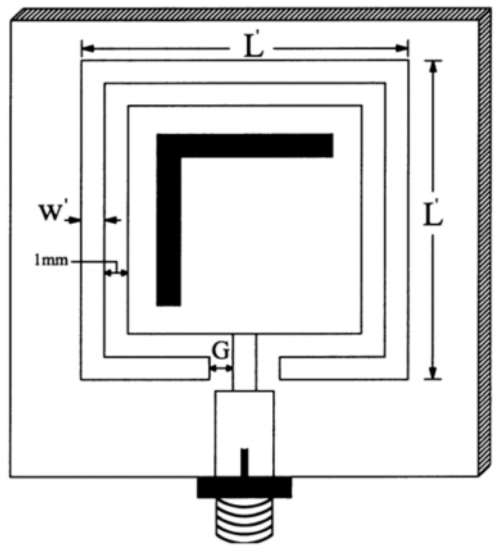

Figure 3: Geometry of RSSMAP

Table 1
Design Parameters of Proposed Antennas in mm

h = 1.6, 3.2	L = 7.6
L_h = 5.3	L_v = 5.3
W_f = 3.1	L_f = 4.1
L_t = 4.2	W_t = 0.5
L't = 4.1	W't = 1.0
L'_f = 4.0	W'_f = 6.3
L' = 11.6	W2 = 1.0
G = 1.0	

The bandwidth over return loss less than -10 dB for the proposed antennas is measured on Vector Network Analyzer (Rohde & Schwarz, Germany make ZVK model 1127.8651). The variation of return loss versus frequency of RSSMA is as shown in Figure 4. From this figure it is seen that, the antenna resonates for two bands of frequencies BW_1 and BW_2. The magnitude of each operating band is found to be 1.85% and 2.57% respectively which is determined by using the equation (1),

$$BW_1(\%) = \left[\frac{f_2 - f_1}{f_c}\right] \times 100 \qquad (1)$$

where, f_1 and f_2 are the lower and upper cut-off frequencies of the band respectively, when its return loss becomes -10 dB and f_c is the centre frequency between f_1 and f_2. The obtained dual bands are due to the independent resonance of the patch and right angle inverted slot on the patch [11].

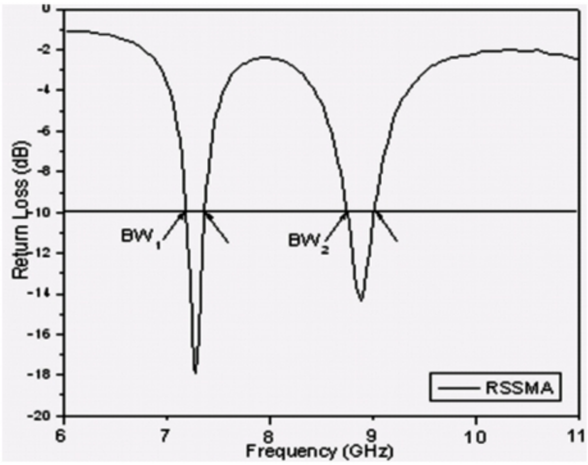

Figure 4: Variation of Return Loss versus Frequency of RSSMA

The variation of the return loss versus frequency of RSSMAD is as shown in Figure 5. From this figure it is seen that, the antenna resonates for two band of frequencies BW_3 and BW_4 with a corresponding impedance bandwidth of 15.60% and 44.94% respectively. The magnitude of BW_3 and BW_4 are quite large when compared to BW_1 and BW_2. This enhancement in the impedance bandwidth is mainly due to effect of changing thickness of substrate from 0.16 to 0.32 cm [9] and by using right angle inverted slot in the ground plane, The slot can be either resonant or non-resonant, if it is resonant current along the edges introduce an additional resonance, which add fundamental resonance of the radiating patch [10].

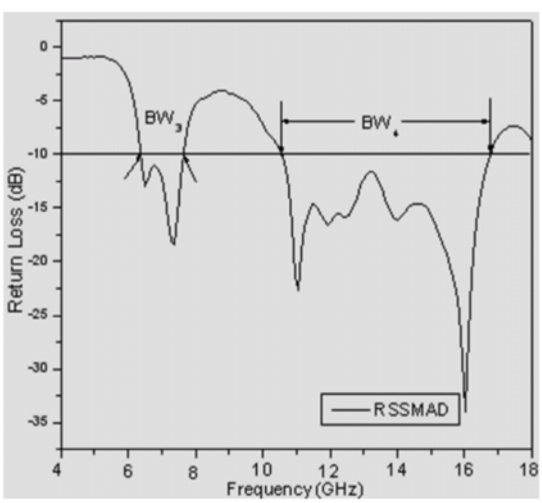

Figure 5: Variation of Return Loss versus Frequency of RSSMAD

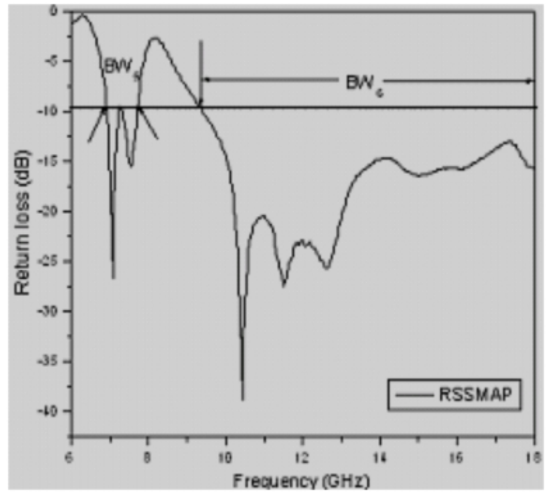

Figure 6: Variation of Return Loss versus Frequency of RSSMAP

The variation of the return loss versus frequency of RSSMAP is as shown in Figure 6. From this figure it is clear that, the antenna resonates for two bands of frequencies BW_5 and BW_6 with a corresponding bandwidth of 10.65% and 63.15% respectively. It is clearly seen from this figure that, by using parasitic strip around the patch, the BW_6 increases from 44.94% to 63.14% and BW_5 decreases from 15.60% to 10.65% when compared with BW_4 and BW_3 of Figure 5 respectively [11]. Further, from Figure 4-6 it is clear that, the resonant frequency of primary band of RSSMA, RSSMAD, and RSSMAP is remained constant at 7.50 GHz. However, the magnitude of secondary band is enhanced from 2.57% to 63.15%. The gain of the proposed antennas is measured in their operating bands BW_2, BW_4 and BW_6 are found to be 5.14 dB, 9.69 dB and 9.78 dB respectively. Hence, RSSMAP gives highest gain when compared to the gain of RSSMA and RSSMAP in their secondary bands. Figure 7 and 8 shows the co-polar and cross-polar radiation pattern of RSSMAD measured at 11.05 GHz and RSSMAP measured at 10.44 GHz respectively. From these figures it is clear that, the pattern are broadsided and linearly polarized. Hence it is seen that, the RSSMAD and RSSMAP gives broadside radiation pattern in spite of enhancement in the bandwidth and gain.

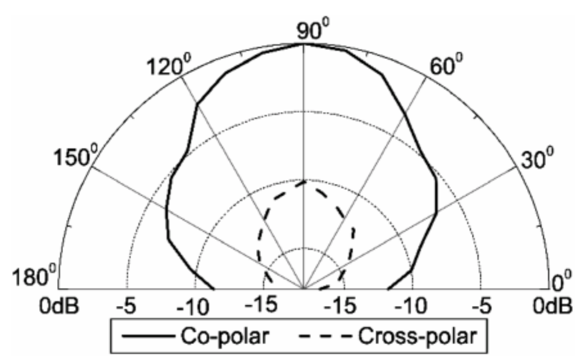

Figure 7: Radiation Pattern of RSSMAD Measured at 11.05 GHz

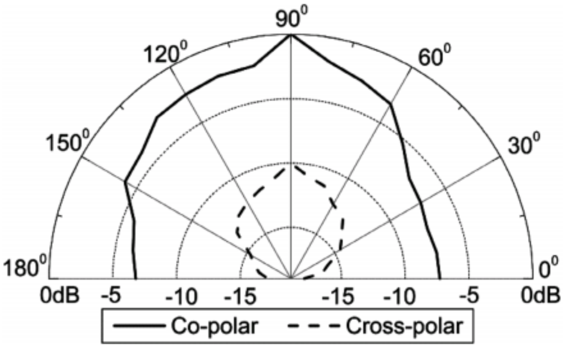

Figure 8: Radiation Pattern of RSSMAP Measured at 10.44 GHz

4. CONCLUSION

From the detail experimental study it is concluded that, the novel design of right angle inverted slot loaded square microstrip antenna, i.e. (RSSMA) is quite capable in producing dual band operation. The magnitude of each operating bandwidth in dual band operation can be enhances to 15.60% and 44.94% by changing the thickness of the substrate and by placing right angle equal arm inverted slot in the ground plane. Further, the upper operating band can be enhanced to 63.12% by incorporating parasitic strip around the square patch. This enhancement does not change the resonant frequency of primary band and nature of broadside radiation characteristics. The proposed antennas are simple in their design and fabrication and they use low cost substrate material. These antennas may find applications in radar communication systems.

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