Effect of Proximity and Aperture Coupling on Multiband Operation of Corner Truncated Microstrip Antenna

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Abstract—The effect of proximity and aperture coupling on the resonance behavior of the corner truncated microstrip antenna is presented. With proximity coupling and H-slot in the ground plane the antenna resonates with two bands having bandwidths of 16.75% and 35.58%.When the same antenna is fed by aperture coupling, three bands occur with bandwidths of 44.3%, 4.75% and 53.43%. Further when the H-slot is replaced with a dumbbell slot all the three bands merge to give single band of 91.43% with a peak gain of 10.23dB while retaining the broadside radiation characteristics. The design concept is presented and experimental results discussed.

Keywords*: Bandwidth, gain, groundplane, multiple bands, return loss, proximity,aperture.*

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I. Introduction

Microstrip Antennas have gained much significance in communication systems.They are capable of multiband operations, low profile planar configuration making them easily conformal to host surface, light weight, low volume,low fabrication cost etc[1]. They can be easily integrated with microwave integrated circuits(MICs) and show the unique characteristcs of linear as well as circular polarization,They come in various shapes like rectanular, square, circular, triangular, elliptical and can be housed easily on moving vehicles. But these antannas have some drawbacks like narrow bandwitdh, low efficiency, low gain, extraneous radiation from feeds and junctions. To overcome these drawbacks researchers have worked by using parasitic elements[2], thicker substrate[3],proximity coupling[4], aperture coupling[5] etc. In this work the effect of proximity and aperture coupling with a slot in the ground plane is studied.

In the proximity coupling two substrates are used with the patch on top of the upper substrate and the microstripline feed on the top of the lower substrate.The microstripline feed lies between the upper substrate with the patch on it and the lower substrate with the ground plane at the bottom of it. This configuration reduces the cross polarization due to elimination of spurious radiation from feed geometry and possibility of two different dielectric media,one for the patch and the other for the feedline. But the disadvantage is that the proper alignment of the two substrates has to be taken care of and the overall thichness of the antenna increases. In the aperture-coupling , the field is coupled from the microstripline feed to the path through an electrically small aperture or a slot cut in the ground plane. The shape, size and location of the aperture decide the amount of coupling from the feed to the patch[3].In this paper antennas with corner-truncated patch fed by proximity and aperture coupling techniques have been presented. Further the shape of the aperture is varied in the aperture coupling and its effects on the performance is studied.

II. Antenna Configuration

The microstrip patch, the microstripline feed and the quarterwave transformer are designed using the equations equations available in the literature[6-7]. The artwork is sketched using the computer programme Auto-cad 2006 to achieve better accuracy.The antennas are fabricated using photolithography process on low cost substrate material of glass epoxy with thickness of h=3.2mm and the dielectric constant of ε_r=4.2.

Fig.1(a) shows the top view of the corner truncated square microstrip antenna with H-slot in the ground plane located at bottom of substrate 2 and the feed on top of substrate2 thus forming proximity coupling(PCSQMA).The patch of length and width L is etched on the top of substrate s1. The corners of the patch are truncated by taking $L_t=W_t=\lambda_0/15$ corresponding to the design frequency of 9.4GHz, where λ_0 is the free space wavelength in cm. The mirostripline feed is etched on top of substrate s_2 which is shown in figure.1(b) with its tip lying below the centre point of the upper radiating truncated square patch placed on the top of the substrate s_1 as shown in fig.1(a).The length and feed of microstripline feed are L_f and W_f respectively. The H-coupling slot is placed exactly below the centre of the truncated square patch on the bottom of substrate as shown in fig.1(c). The length and width of middle arm and length and width of side arms of H-coupling slots are L_m, W_m and L_s ,W_s respectively. The thickness of the substrate h, ε_r and dimensions of the substrate s_1 and s_2 remain same .Since the substrate s_2 is placed below s_1 and the feedline lies between the two substrates, the proximity coupling takes place. Further the same antenna is fed through aperture coupling and the antenna is named as corner truncated square microstrip antenna with H-slot on the ground plane fed by aperture coupling(ACSQMA).The top geometry of ACSQMA remains same as that of Fig.1(a). The H-coupling slot on the ground plane is now placed on top of the substrate s_2. The microstripline feed shown in Fig.1(b) is etched on the bottom surface of s_2.

Since the H-coupling slot is placed between the two substrates, it acts as the aperture and thus forming the aperture coupling feed. The H-slot is placed exactly below the truncated patch on top of s_1.The microstripline feed is placed such that its tip lies exactly below the centre of the patch thereby enabling the feed from microstripline through the H-coupling aperture.

Further the antenna is modified by replacing the H-coupling slot with a octagonal dumbbell slot(D-slot). It is named as OACSQMA. The D-slot is constructed on top of s_2 shown in Fig.2. The diameter of each D-slot is d.The distance bêtween the two dumbbells is connected by the microstripline of length L_m and width W_m . The design parameters of the antennas are given in table 1.

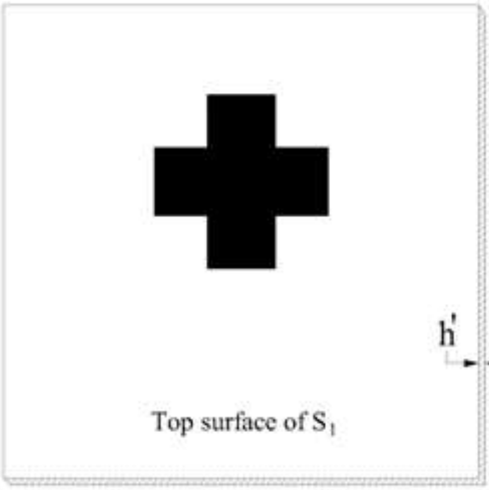

Fig.1(a) Top View of the corner truncated square radiating element

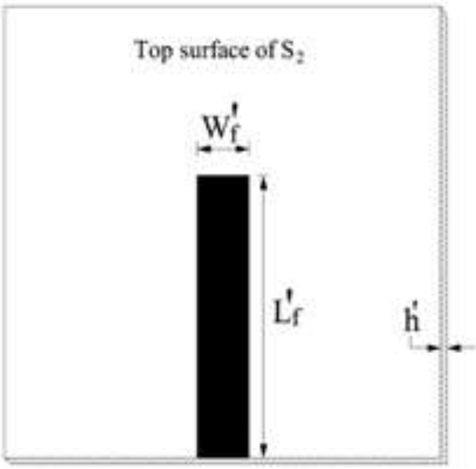

Fig.1(b) Microstripline Fee

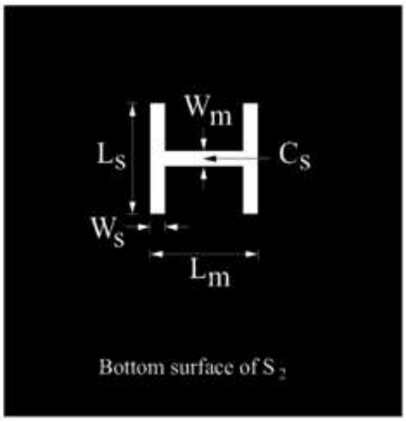

Fig.1(c) H-coupling slot on the ground plane

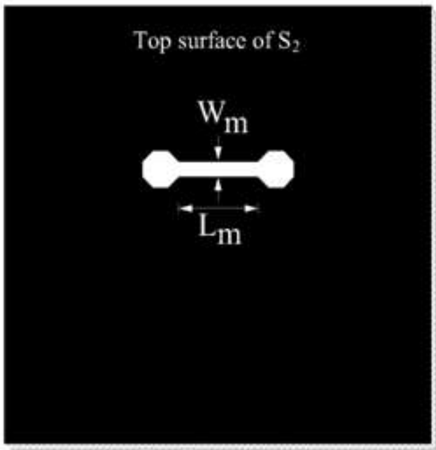

Fig.2. Dumbbell-shaped coupling slot on top surface S_2 of OACSQMA

TABLE 1

Design parameters of the Antennas

Antenna Parameters	Dimension in cm
h	3.2
L	7.6
W_t	2.0
L_t	2.0
W_f	1.0
L_f	6.1
W_m	1.0
L_m	4.0
W_s	1.0
L_s	5.3
d	1.2

III. EXPERIMENTAL RESULTS

The return loss as a function of the frequency for the proposed antennas is measured on Vector Network Analyzer.The variation of return loss versus frequency of PCSQMA is as shown in Fig.(3). From this figure it is seen that, the antenna resonates for two bands of frequencies BW_1 and BW_2. The magnitudes of the bands are found to be 16.75% and 35.58% respectively. The bandwidth is determined by using the following equation,

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

Where f_2 and f_1 are the lower and upper cut-off frequencies of the band respectively when the return loss goes less below -10db and f_c is the centre frequency between f_1 and f_2. The shift in the resonant frequency from f_c from the designed value of 9.4GHz to 14GHz is due to the effect of truncation of the corners and the proximity coupling. Two bands are obtained due to the fundamental resonance of the patch and the addition of the H-slot in the ground plane. The corner truncated square patch can be regarded as the proximate director, which guides most of the radiation from the slot towards the patch because the electromagnetic coupling takes place between the patch and the feeding mechanism. The reflection of the input power effectively decreases, which improves impedance matching and hence the antenna resonates repeatedly. When the patch is fed by aperture coupling, that is the H-slot is placed on top of the substrate s_2,the antenna resonates with three bands having bandwidths BW_3, BW_4 and BW_5 of 44.30%, 4.75% and 53.43% respectively. The variation of return loss with frequency of this antenna is shown in Fig.(4). Three bands appear due to the H-coupling aperture, which gives rise additional resonance[8]. By changing the shape of the slot to that of a dumbbell(D-slot) the antenna is called OACSQMA whose variation of return loss with frequency is shown in Fig.(5). The antenna resonates with a single band BW_6 but with a bandwidth of 91.43%. This band results due to the merging of all three bands of ACSQMA due to the effect of D-slot. The coupling D-slot can be either resonant or non-resonant. If it is resonant the current along the edges of the slot introduces an additional resonance ,which adds to the fundamental resonance of the radiating element. The resultant effect of this resonance causes merging of bands[8] thereby enhancing the bandwidth.

The gain of the antennas is measured by absolute gain method[9]. The power transmitted 'P_t' by pyramidal horn antenna and power received 'P_t' by antenna under test(AUT) are measured independently. Using the data thus obtained , the gain(G) of AUT is calculated by using the equation,

$$(G)\text{dB} = 10log\left[\frac{pr}{pt}\right] \text{-}(G_t)\ \text{dB-}20\log\left[\frac{\lambda o}{4\pi R}\right]\ \text{dB} \quad \text{--------(2)}$$

Where, G_t is the gain of the gain of the pyramidal horn antenna and R is the distance between the transmitting antenna and the AUT. Using the equation (2), the maximum gain of their operating bands BW_2, BW_5 and BW_6 are found to be 9.99dB, 10.13dB and 10.23dB respectively. Hence it is clear that OACSQMA gives highest gain when compared to the other two antennas.

Figures 6-8 show the typical co-polar and cross-polar radiation patterns of PCSQMA, ACSQMA and OACSQMA respectively measured in their operating bands. From these figures it is clear that, the patterns are symmetric, broad sided and linearly polarized. Further , it is seen that the cross-polar power levels are -24 dB down when compared with their respective co-polar power levels in all the three cases, which is useful in array design of the antennas.

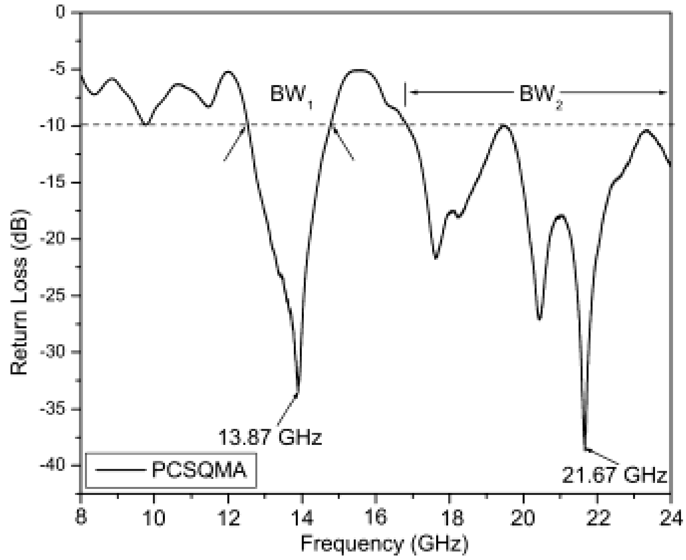

Fig.3. Variation of Return loss versus frequency of PCSQMA

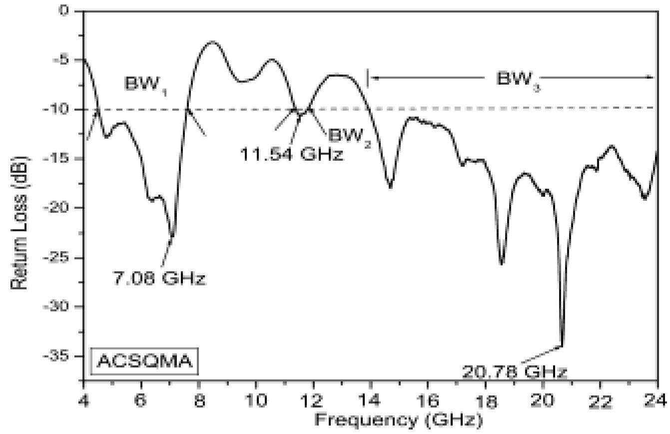

Fig. 4. Variation of return loss versus frequency of ACSQMA by

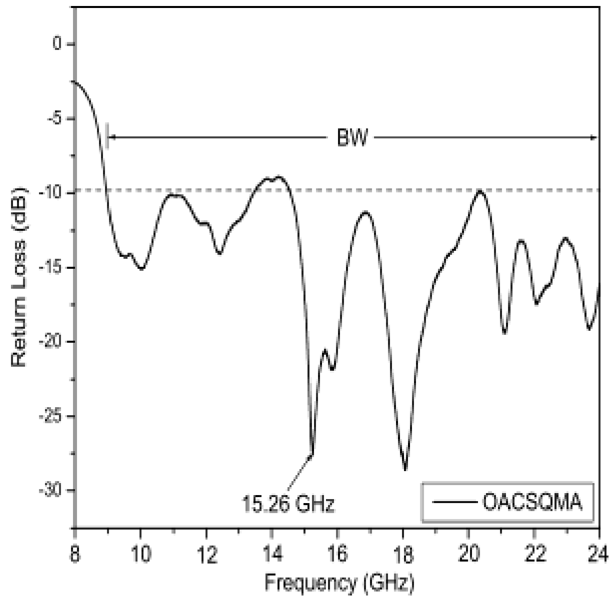

Fig.5. Variation of Return loss versus frequency of OACSQMA

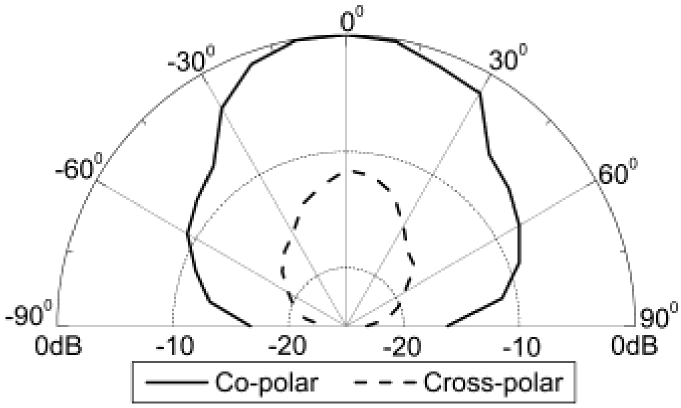

Fig.6. Radiation pattern of PCSQMA measured at 13.87GHz

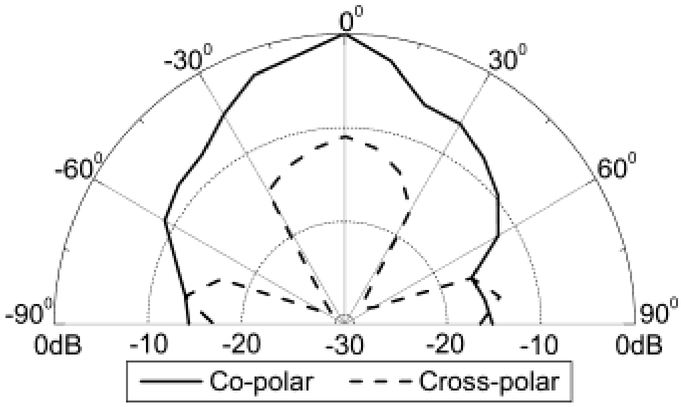

Fig.7. Radiation pattern of ACSQMA measured at 7.08 GHz

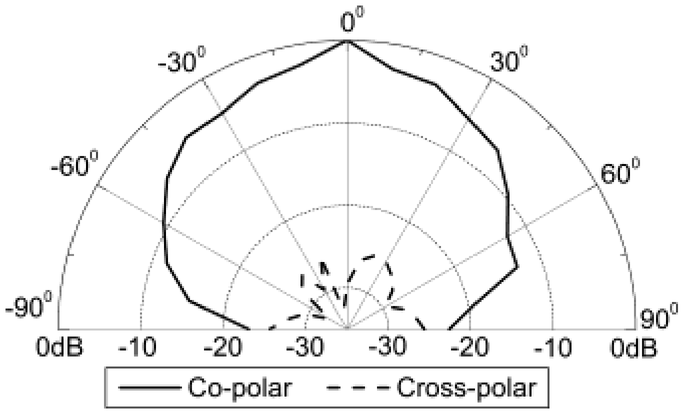

Fig.8. Radiation pattern of OACSQMA measured at 15.26GHz

IV. CONCLUSIONS

From the study performed, it can be concluded that the PCSQMA with the corner truncation and proximity coupling resonates with two bands. The upper operating band with bandwidth of 35.58% and gain of 9.99dB are greater than the bandwidth of 21% and gain of 8dB found in the literature[4].Three bands occur when the antenna is fed with aperture coupling. Further when the H-slot is replaced by D-slot the three bands merge into a single band with highest bandwidth of 91.43% and 10.23dB of peak gain while retaining the nature of broadside radiation characteristics and cross-polar level of -24dB down with respect to co-polar level. The radiation characteristics of the antenna are not affected by the improvement in the bandwidth and gain.Moreover these antennas are simple in their design and fabrication and use low cost substrate material. They may find applications in the microwave systems operating in the range of 4-24GHz.

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