On the Necessity of Cavity-type Coupling Mechanism for obtaining Circular Polarization with Microstrip Patch Antenna

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Abstract

A circularly polarized microstrip patch antenna (MPA) using electromagnetic (EM) coupled fed method is analyzed in view of the two types of coupling mechanisms *viz.* cavity and parasitic type, proposed earlier. The patch-ground plane distance is varied in order to achieve the fore-mentioned types of couplings. For each case of patch-ground plane distance, the offset position of feedline is optimized for perfect matching and the boresight axial ratio (AR) is observed. It is seen that CP operation is possible only for cavity-type coupling (smaller patch-ground plane distances). The simulated results for the boresight AR for the two types of coupling mechanisms are presented.

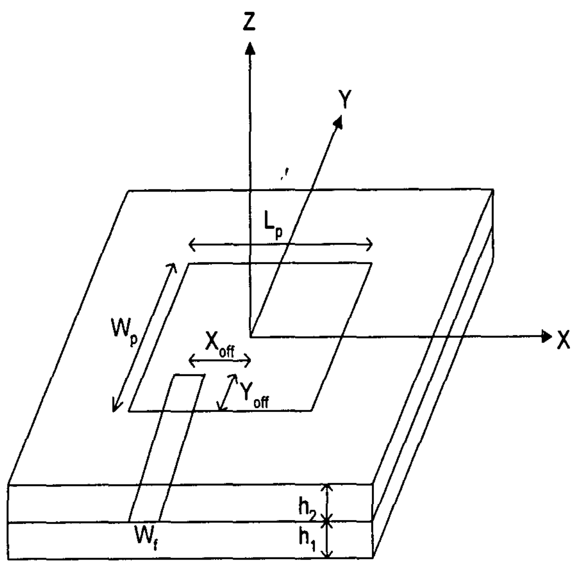
Introduction

A circularly polarized (CP) antenna with a low profile, small-size and light weight is required in mobile satellite communications. A microstrip antenna meets these requirements. The CP microstrip antennas are classified as single-fed type or dual-fed type depending on the number of feed points necessary to excite the circularly polarized waves. The single-fed type has the advantage of not requiring an external circular polarizer such as the 90° hybrid. The relationship between the optimum probe location and the frequency of the obtained circularly polarized has been clarified and good experimental results have been reported [1]. A microstrip antenna excited by an EM coupled microstrip line is suitable for constructing a low-profile, small-size and light weight antenna configuration [2]. This antenna has several well realized advantages like: i) reduction of unwanted radiation from discontinuities in the feed network, ii) wider antenna bandwidth and iii) ease of obtaining an impedance match between the patch and the microstrip line. It is reported [3-5] that for slot and EM (proximity) coupled patch antennas; there are two ways in which the fringing electromagnetic fields of the microstrip line are coupled to the patch antenna *viz.* cavity and parasitic. Cavity type of coupling dominates when the patch-ground plane distances are small and parasitic type of coupling dominates when the patch-ground plane distances are large. For CP operation with EM coupling, it is necessary to excite two orthogonally coupled modes, which are necessarily of cavity type. Hence, if once increases the upper substrate thickness in an EM coupled patch antenna, it would not be possible to excite CP waves. It is the purpose of this paper to justify this fact with the simulated results.

Antenna Structure

The physical dimensions of the antenna under study are as shown in fig. 1. The dielectric constant of the substrates ε_r is 2.6. The thickness of the lower substrate (h_1) is 1.6mm. The thickness of the upper substrate (h_2) is varied (increased) in steps of 1.6mm. The offset location of the feedline (x-offset and y-offset) is optimized for perfect matching for each value of h_2 The length of the patch antenna is L_p and the width is W_p. X_{off} is the offset length from the center of the rectangular patch to the center of the microstrip line and Y_{off} is the distance from the edge of the patch to the edge of the feedline. The characteristics impedance of the microstrip line is 50Ω. The aspect ratio L_p/W_p = (56 mm / 58 mm) is 0.966. The width of the microstrip feedline is 4 mm.

Fig 1: An EM coupled microstrip patch antenna.



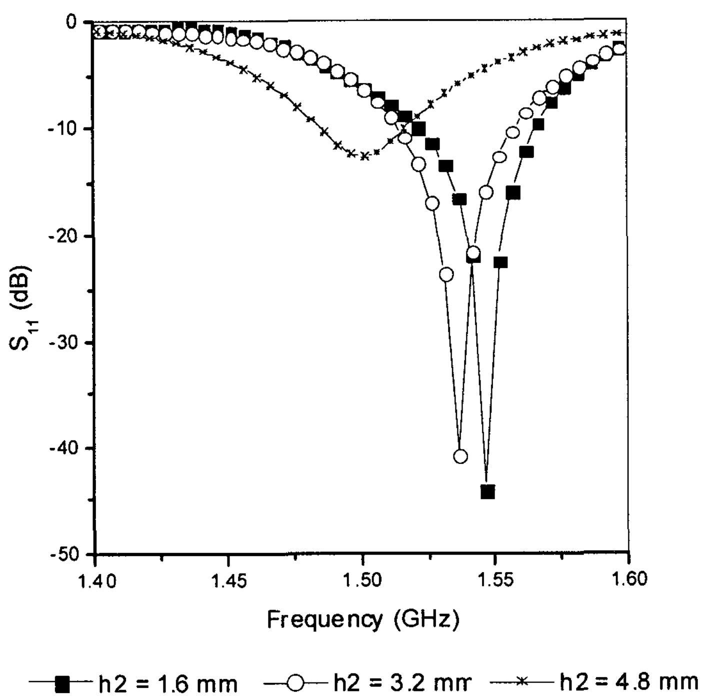
Results and Discussion

The structure described above is simulated using CST MWS. First, the offset position of the feed line is optimized for maximum coupling for various thicknesses of upper substrate. The offset positions for perfect match conditions for the three cases are listed in **table 1**. **Fig. 2** shows the return loss for the three cases. It must be noted that the offset position of the feedline for each case is different. **Fig. 3** shows the power patterns in the y – z plane.

Table 1: Optimum offset positions for maximum coupling for various thicknesses of the upper substrate

h_2 (mm)	X_{off} (mm)	Y_{off} (mm)	f_r (GHz)	S_{11} (dB)
1.6	14.4	9.4	1.5466	-43.65
3.2	20	27	1.5367	-40.1
4.8	20	26	1.502	-12.72

Fig.2: Variation of return loss (S_{11}) with frequency.



It is seen from table 1 that the Y_{off} in the case of higher h_2 values moves towards center of the patch. The resonant frequency decreases with increase in h_2 which is a consequence of better confinement of fields to the substrate region resulting in higher effective dielectric constant. The impedance matching deteriorates with increasing h_2 as is evident from the return loss. **Fig. 4** shows the variation of boresight axial ratio with frequency for the three cases. It is seen that with increase in thickness of the upper substrate the axial ratio increases. In other words, circularly polarized waves cannot be excited with increasing patch-ground plane distance. This in turn brings into light the two types of coupling mechanisms *viz.* cavity type (for smaller patch-ground plane distances) and parasitic type (for larger patch-ground plane distances) proposed by Cho *et al* [3, 4]. As is well known, for exciting circularly polarized waves two orthogonal modes should be excited with nearly the same frequency. In the case where patch is closer to the ground plane, cavity mode is excited and the well known cavity model can be applied to the resulting structure. For larger distances, cavity mode ceases to exist and cavity model cannot be applied. Since cavity mode is not excited, it is not possible to achieve CP operation with thicker substrates without any external perturbation. Therefore, cavity-type coupling is a necessity for CP operation with patch antennas. It would be interesting to see if even with higher substrate thickness, CP waves can be excited with the aid of some perturbation.

It can be seen that the optimum boresight axial ratio is not obtained at the resonance for each of the three cases as is evidenced from fig. 2 and fig. 4. One important thing is noted during the simulations: the optimum axial ratio for any of the three cases is not achieved at boresight but rather at values of θ ranging 60° - 75°.

Fig. 3: y-z plane power patterns for the three cases of upper substrate thickness.

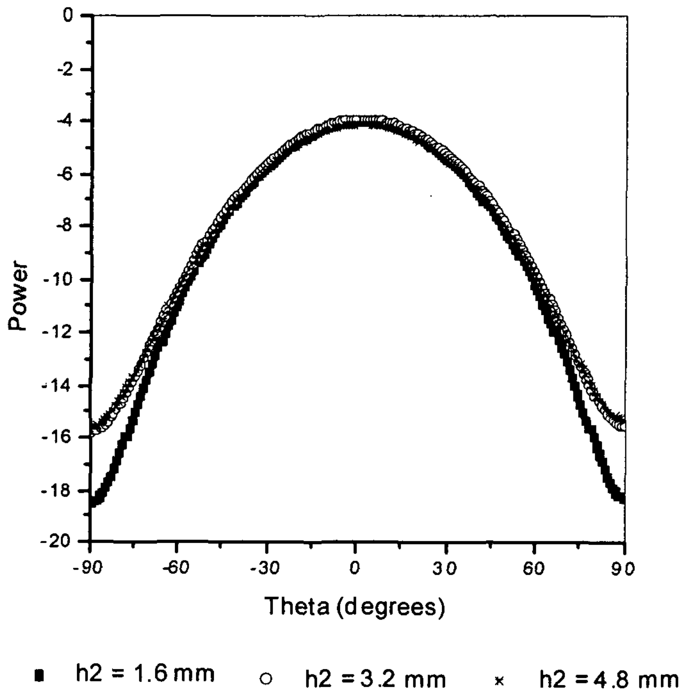
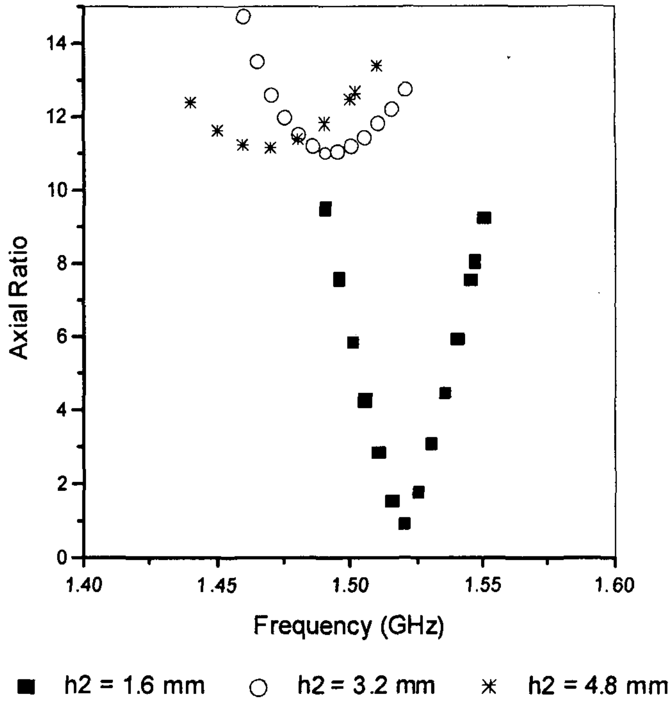


Fig.4: Variation of boresight axial ratio with frequency.



Conclusions

A circularly polarized microstrip patch antenna (MPA) using EM coupling is analyzed in view of the two types of coupling mechanisms. It is shown that CP operation is not possible when the antenna is parasitically coupled to the feed line. Cavity-type coupling mechanism is a necessity for obtaining CP operation with MPA.

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