

Coupling Effects of Aperture Coupled Microstrip Antenna

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Abstract—The coupling mechanism mainly depends on the shape of aperture, patch and the feed line; it also affects the radiation properties. The paper analyses some of the different shapes of these elements on the aperture coupled microstrip antenna. One effective way to increase the impedance bandwidth is to change the patch shape, feed shape and the slot shape. The shape of coupling aperture has a great effect on the strength of coupling between the feed line and the patch. Mainly thin rectangular shape of the slot is used in an aperture coupled microstrip antenna. If a suitable combination of the shape of feed and slot is chosen and tuned perfectly, it gives an optimum impedance bandwidth with an improved radiation pattern.

Keywords—: -microstrip antennas, aperture, coupling

I. INTRODUCTION

Aperture coupling is an indirect method of feeding the patch. Aperture coupled microstrip antenna couples the patch antenna with microstrip line through an aperture [1]. The feed line creates an electric field in the aperture, which induces surface currents on the patch. The patch edges perpendicular to the feed line create fringing fields that radiate into free space.

The basic structure of the aperture coupled microstrip antenna is same as shown in fig(1) but the dimensional calculations are some how different and thus the proposed aperture coupled microstrip antenna is designed to miniature the size, to increase the front/back ratio and the bandwidth. Here only the coupling effects of the proposed antenna are discussed.

II. ANTENNA DESIGN

Proposed antenna design is fed by an open-circuit terminated microstrip line $0.42\lambda_g$ in length (see Fig2). The wavelength in dielectric is calculated with MATLAB at 5 GHz [2]. A slot in the ground plane is located above the feed line $\lambda_g/6$ (microstrip wavelength in dielectric) from the open termination.

Substrate is chosen RT/Duroid 5880 for the patch and microstrip feed line [3]. Patch length determines the resonant frequency of the patch. Here, the half-wavelength rectangular patch element is chosen. The aspect ratio affects the bandwidth of the patch. For high polarization purity, the value

of aspect ratio should be in the range from 0.750 to 1. In proposed design a value of 0.876 is chosen [4]-[5]. To obtain maximum magnetic coupling the position of the patch is placed at the center of the antenna. The feed line is at the right angle to the center of slot and the slot is etched in the centre of ground plane. Slot length affects the coupling level and back radiation. It should be $0.25\lambda_0$ and width of slot should be $0.1L_a$ [6]. For the patch substrate thickness $h_p \approx 0.09\lambda_0$ and the feedline substrate $h_f \approx 0.01\lambda_0$.

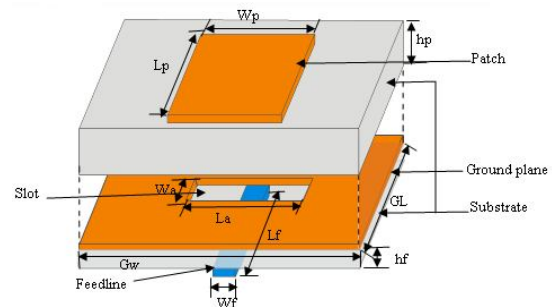


Figure 1: Aperture Coupled Microstrip Antenna

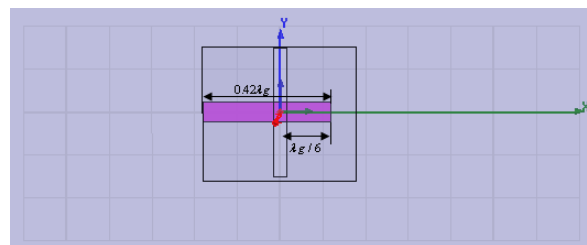


Figure 2: Representation of open circuit termination line.

This aperture is usually centered with respect to the patch where the patch has its maximum magnetic field. For maximum coupling it has been suggested that a rectangular slot parallel to the two radiating edges should be used. Two very similar coupling mechanisms take place, one between the feed line and the slot and another between the slot and the patch.

The first aperture coupled microstrip antenna was introduced in 1985 by D M Pozar [7].

It has many advantages such that it is used in monolithic phased arrays. No radiation from the feed network can interfere with the main radiation pattern. No direct connection is made to the antenna elements. The input impedance is easily controlled by the size and position of the aperture. Any excess reactance caused by the coupling aperture can be removed through the use of a tuning stub. Very low cross-polarization levels and it includes shielding of antenna from spurious feed radiation [1].

III. EFFECT OF THE DIFFERENT RECTANGULAR SHAPES OF THE ELEMENTS OF ACMA

A. Coupling Aperture (Slot):

Since the patch is normally cantered over the aperture, magnetic polarization of the slot is the dominant mechanism for coupling, which depends on the shape and size of the coupling aperture. Hence, it is desirable to use a shape that has maximum coupling for a given size. The size of coupling slot is generally smaller than the patch. This allows the antenna to be impedance-matched with a smaller aperture. Smaller aperture areas result in lower back radiation levels, leading to less spurious radiation in the back region and improved efficiency [8].

A thin rectangular aperture gives much stronger coupling. The coupling can be increased by using longer or wider rectangular apertures. For a simple rectangular slot, the transverse electric field must vanish at the end of the aperture.

As the electrical length of the slot increases, coupling increases which increase the resonant input impedance as shown in figure (3b). The same concept applies for the aperture width also.

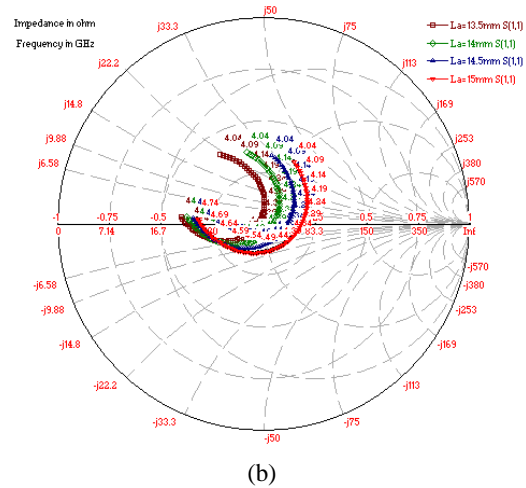


Figure3: (a) Different length of the coupling slots (b) Impedance loci for the different aperture length. (a)La=13.5mm, (b) La=14mm, (c) La=14.5mm (d), La=15mm.

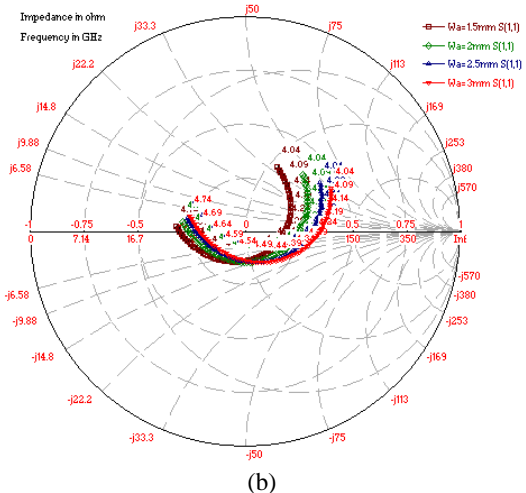
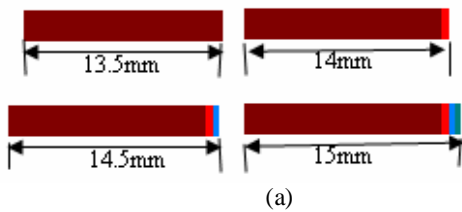
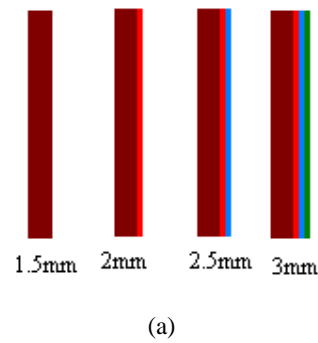


Figure4: (a) Different width of the coupling slots (b) Impedance loci for the different aperture width. (a)Wa=1.5mm, (b) Wa=2mm, (c) Wa=2.5mm (d), Wa=3mm.

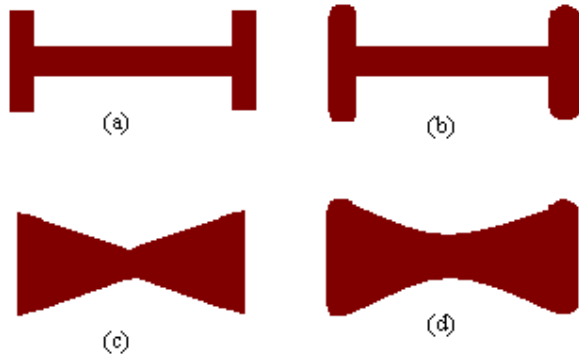


Figure5: Different shapes of slot (a) H-shape, (b) Dog bone-shape, (c) Bowtie-shape, (d) Hourglass-shape.

By adding a slot at the end of the rectangular aperture (i.e., the ‘H’-shaped aperture), the field becomes nearly uniform along the aperture and hence the coupling increases [9],[15].

Other nonlinear shaped apertures ‘U’ and ‘L’ could also be used, but the ‘H’- or dog bone-shaped aperture yields better coupling. A bowtie or butterfly shaped aperture, also gives more coupling and higher resonant impedance as compared the rectangular aperture. An hourglass shaped aperture uses the features of both the dog bone- and the bowtie-shaped apertures without any sharp edges and hence give maximum coupling.

The top substrate contains radiating element. Lower permittivity gives wider impedance bandwidth and reduced surface wave excitation and a thicker substrate results in wider bandwidth, but less coupling for a given aperture size.

B. Radiating element (Patch):

The length of the patch radiator determines the resonant frequency of the antenna and the width of the antenna affects the resonant resistance of the antenna as shown in the figure (6) and (7) [1],[10].

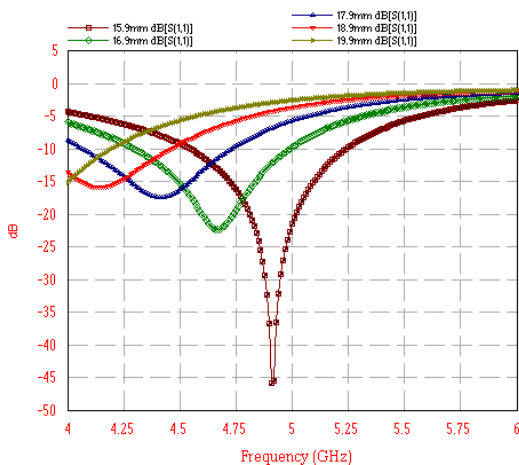


Figure6: Representation of the resonant frequency for different length of patch.

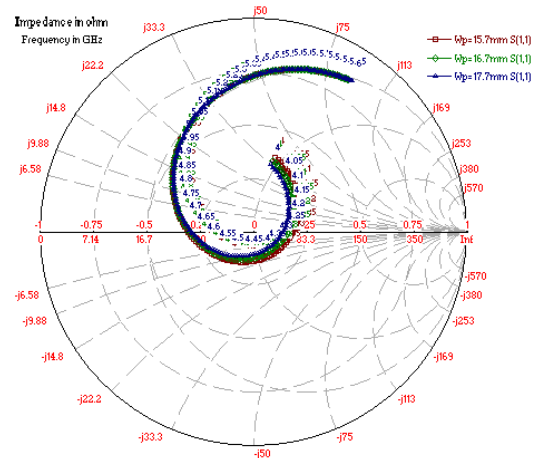


Figure7: Impedance loci for different patch width.

Patch substrate has a significant effect on the input impedance [11]. As the dielectric constant increases, the field is less spread out and the electrical length of the aperture increases, which increases coupling. The increase in coupling results in an increase in the resonant input resistance. The input impedance loci shifts toward the left side of the Smith chart as the thickness of the substrates increases and the coupling decreases. This reduction in coupling can be compensated for by increasing the length or width of the aperture.

The shape of the patch is the main parameter which affects the bandwidth of the antenna. It also affects its electrical characteristics such as polarization and gain. It is very difficult to make a general rule instead we are discussing here some of the patch [12].

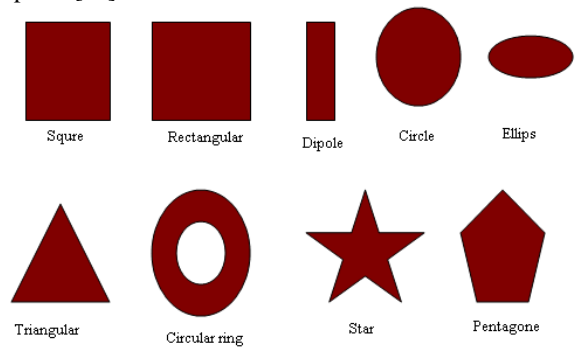


Figure8: Different shapes of patch

If the patch shape is like the square or the circle shown in fig (8), the bandwidth is the same and proportional to its size. The deviations start when the shape changes significantly and becomes a narrow or wide rectangle. If the radiation edge

becomes narrow, the radiation loss decreases and the antenna Q increases, reducing the bandwidth. The opposite is true for a patch with a wide radiating edge.

More noticeable effects are found when the central part of the patch is removed to make a ring. Historically, annular ring (or square ring) antennas were considered to be wideband [13]. This is true, however, only for the second mode of the patch, when it operates in the TM₁₂ mode. For the first mode, the patch operates in the TM₁₁ mode similar to a circular disk, and the antenna is a hybrid of a solid patch and a printed loop. For this mode the antenna bandwidth decreases rapidly as more central conductor is removed, making it a thinner ring.

The radiation occurs due the fringing field between the periphery of the patch and the ground plane. Thus the different shapes of the patch impacts different calculations.

C. Feed line:

Feed substrate dielectric constant should be in the range of 2 to 10. A thinner feed substrate results in less spurious radiation from feed lines, but higher loss. A compromise of 0.01λ to 0.02λ is usually good [14].

Feed line width decides the characteristic impedance of the feed line. For maximum coupling the feed line must be placed perpendicular to the centre of the slot. Skewing the feed from the slot will reduce the coupling.

The purpose of the feed line is to carry energy from a connector to the actual antenna and so to launch guided waves only. An electrically thin substrate with large permittivity is therefore suitable. Another fact that influenced the selection of the feed substrate is the width of the feed line. The characteristic impedance of a microstrip line depends only on the normalized line width W/H , and not on the absolute value of W . This implies that for a smaller substrate height a corresponding smaller line width has to be used to obtain the same characteristic impedance.

The width of the feedline $W_f=2.34$ mm for the characteristics impedance $Z_0=50\ \Omega$. The aperture length and width are taken as $W_a=0.1L_a$ mm, $L_a = 15$ mm, respectively. For various values of the stub length L_s , the simulated return loss and input impedance loci in the frequency range of 4.04 GHz to 4.75GHz are shown in fig (9) and (10). As the stub length optimized for the stub length $L_s=9.94$ mm to 17.94 mm, the input impedance loci moves in the clockwise direction.

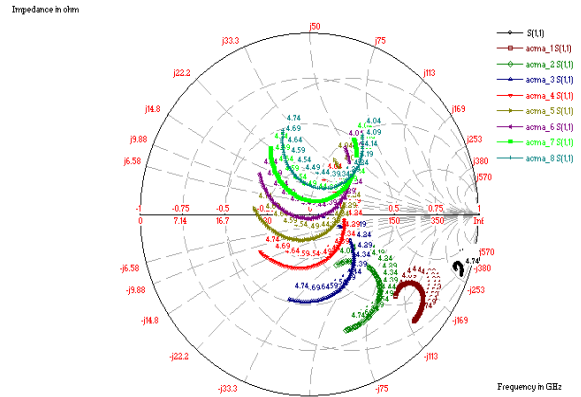


Figure9: Input impedance loci of ACMA for different values of stub length L_s .

If the input impedance at a single frequency is plotted for various stub lengths, the locus approximately follows a constant resistance contour (i.e., the stub provides only the reactance to the input impedance loci). The impedance Z_s provided by the open-ended stub with characteristic impedance Z_0 and length L_s is given by:

$$Z_s = jZ_0 / \tan(\beta L_s)$$

Thus, the length of the stub can be varied to achieve a reactance compensation for matching purposes in the antenna design [15].

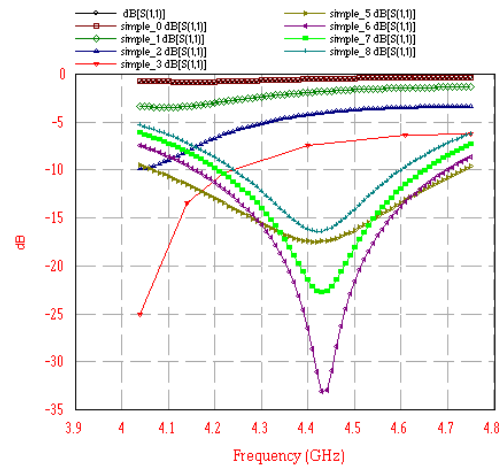


Figure10: Representation of the resonant frequency for different stub length.

As the stub length increases return loss minimizes and at stub length $L_s = \lambda_g / 6$ return loss is minimum but after $L_s = \lambda_g / 6$ return loss starts to maximize as shown in figure (10). $L_s = \lambda_g / 6$ is the stub length at which the

proposed ACMA works properly with best radiation and return loss performance.

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Different shapes of the feed line:



Figure11: Different shapes of feed (a) Rectangular (b) Tee(c) Tuning fork

When the Tee shape feed line is used, it can extend the bandwidth in proportion to the slot width [16]

U shape feed line also increases the impedance bandwidth and the gain of the antenna [17].

IV. CONCLUSION:

This paper has presented the overview of the coupling effects of the different rectangular shapes of the elements of aperture and patch on the aperture coupled microstrip antenna.

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