

# Effect of the Different Shapes: Aperture Coupled Microstrip Slot Antenna

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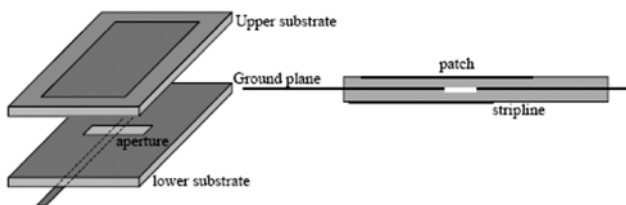
**Abstract:** The paper reviews the effect of the different shapes on the aperture coupled microstrip slot antenna. Aperture coupled microstrip slot antenna couples the patch antenna with microstripline through an aperture. One effective way to increase the impedance band-width is to change the patch 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 aperture coupled Microstrip slot 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.

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## 1. INTRODUCTION

Aperture coupling is an indirect method of feeding the resonant patch. Aperture coupled microstrip slot antenna couples the patch antenna with microstripline through an aperture or the energy of the stripline is coupled via the opening (slot) in the ground plane, and excites the patch. 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 [1].



**Figure 1:** Aperture Coupled Microstrip Slot Antenna

The geometry of an aperture coupled microstrip antenna is shown in Fig. 1. It consists of two substrates bonded together, with a ground plane in between [2]. The radiating patch is printed on the top (antenna) substrate; while a microstrip feed line is printed on the bottom (feed) substrate. A small nonresonant aperture in the ground plane couples the patch to the feed line. The bandwidth is essentially that of the patch antenna itself, and is not affected by the aperture coupling mechanism.

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.

### Radiating Element (Patch Substrate)

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.

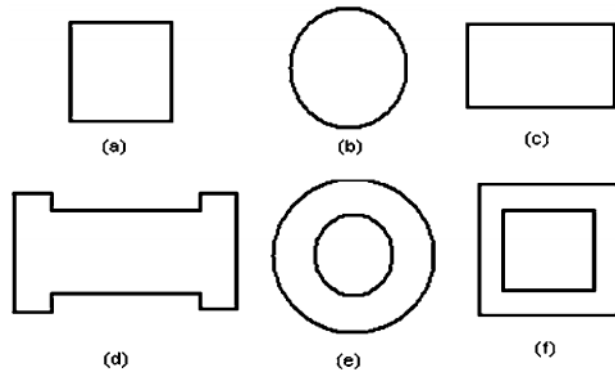
The length of the patch radiator determines the resonant frequency of the antenna and the width of the antenna affects the resonant resistance of the antenna [3]. To obtain maximum coupling, the patch should be placed at the center.

Patch substrate has a significant effect on the input impedance [4]. 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. As the thickness of the substrates increases, the coupling decreases, and hence the input impedance loci shifts toward the left side of the Smith chart. 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 [5]. It is very difficult to make a general rule instead we are discussing here some of the patch shapes.

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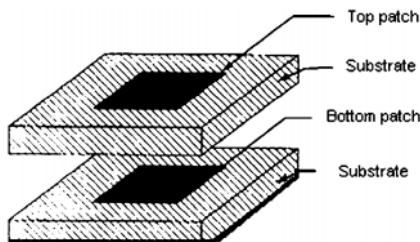
**Figure 2:** Different Shapes of Patch

If the patch shape is like the square or the circle shown in fig (a) and fig (b), 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 as shown in fig(c). The opposite is true for a patch with a wide radiating edge as in (d).

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 [6].

This is true, however, only for the second mode of the patch, when it operates in the TM<sub>12</sub> mode. For the first mode, the patch operates in the TM<sub>11</sub> 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.

A more effective means of designing wideband microstrip antennas is by using coupled resonators [7], which can yield bandwidths in excess of 50 percent. The patch antenna need not be very special, but must be able to couple to another patch or to resonant elements. Resonant elements that are commonly used are a near resonant slot in the ground plane, a resonant slot on the patch itself, or a near resonant feed probe like a bent monopole.



**Figure 3:** Stack Configuration of the Patch

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.

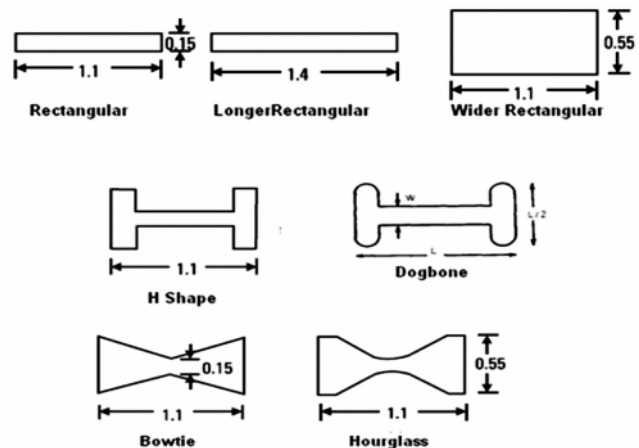
**Coupling Aperture**

The Slot length affects the coupling level and the back radiation level. The slot should be made no larger than is required for impedance matching. The ratio of slot length to width is typically 1/10.

For maximum coupling, the patch should be centered over the slot. The feed line is positioned at right angle to the center of the slot.

Since the patch is normally centered 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. 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.



**Figure 4:** Different Shapes of Slot

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].

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.

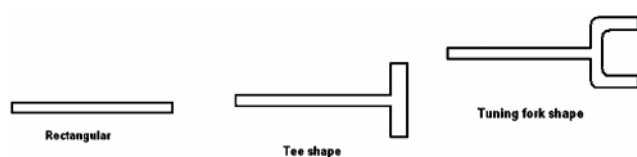
### Microstrip Feed Line

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  $0.01 \lambda$  to  $0.02 \lambda$  is usually good.

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.

### Shape of the Feed Line



**Figure 5:** Different Shapes of Feed Line

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.

When the Tee shape feed line is used, it can extend the bandwidth in proportion to the slot width [10].

U shape feed line also increases the impedance bandwidth and the gain of the antenna [11].

### Dimension of the Ground Plane

The dimension of the ground plane must be chosen enough large to replace entirely the infinite ground plane [12]. In practice these dimensions are in order of some wavelengths. Finite ground plane gives rise to diffraction of radiation from the edges of the ground plane resulting in changes in radiation pattern, radiation conductance, and resonance frequency.

The experimental investigations on the resonant frequency of a rectangular patch as a function of the size of the ground plane show that the influence on the resonance

frequency is negligible if the ground plane size exceeds the patch sizes with about  $\lambda/2$  from all sides.

A theoretical study shows that the influence on the radiation pattern can be neglected if the size of the ground plane exceeds two-wave length.

### CONCLUSION

This paper has presented the overview of the effects of the shapes of the patch, slot and the feed line on the aperture coupled microstrip slot antenna.

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