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# Design of Aperture Coupled Micro-Strip Patch Antenna for Wireless Communication Applications at 10Ghz (X BAND)

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***Abstract:*** In this paper, a simple aperture coupled microstrip antenna at a frequency of 10GHz is presented. Here, substrates with different thickness, one using 0.762mm and second with 0.508mm, are considered. [1] In this, various parameters have been varied for the optimization of antenna design using 3D electromagnetic simulator. This antenna is useful for wireless communication.

***Keywords:*** Micro-strip patch antenna, slot, Aperture coupling, VSWR, return loss, bandwidth, radiation pattern, gain, directivity.

## 1. INTRODUCTION

A microstrip antenna is basically a low profile antenna with a number of advantages over other antennas like small in size, light weight, inexpensive to fabricate. A microstrip antenna with aperture coupled feeding technique is used here as it is one of the most important method for exciting microstrip antenna and its analysis has been shown here. In ACMPA, the radiating element (patch) and feed line are separated by conductive layer (ground) between them.[2] The two are electromagnetically coupled through an aperture on the ground. The antenna can be optimized for a desired performance in terms of gain, bandwidth and VSWR by varying its parameters (L, W, slot dimensions)

## 2. DESIGN AND ANALYSIS OF ACMPA

In ACMPA as, there are two dielectric substrates, one above the ground and second beneath the ground. A patch is printed over the low dielectric constant substrate above the ground and the feed is printed beneath the high dielectric constant substrate below the ground. Patch and feed line are electromagnetically coupled through an aperture made on the ground. As it can see from the Figure 1, there are two dielectric slabs with height $h_1$ and $h_2$. There is a feed line on the lower substrate and patch on the upper substrate; slot is cut on the ground. For maximum coupling, slot is centered below the patch and also feed line should be at right angle to the slot. [3] Such a design can be well explained with the help of following diagram:

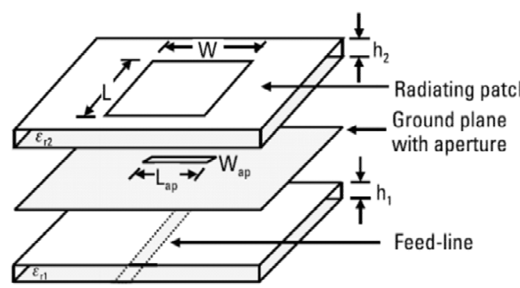


**Figure 1: Design of ACMPA**

### 2.1. Design of Microstrip Patch Antenna

The design of the antenna is done using the following considerations as mentioned in the equations given below. Mostly the length (L) and width (W) of the patch can be calculated using the parameters like height of the substrate ($h_2$) below the patch and the dielectric constant ($\varepsilon_{r2}$) and the resonant frequency ($f_r$) which are given. The formulas for calculating length ($L$) and width ($W$) are:

$$W = \frac{1}{2fr\sqrt{(\mu o \varepsilon o)}}\sqrt{\frac{2}{\varepsilon r+1}} = \frac{Vo}{2fr}\sqrt{\left(\frac{2}{\varepsilon r+1}\right)} \tag{1}$$

$$L = \frac{1}{2fr\sqrt{(\varepsilon rff)}\sqrt{(\varepsilon o \mu o)}} - 2\Delta L \tag{2}$$

Where $Vo$ is the speed of light. If the height of the substrate is not given then it can be calculated using resonant frequency and the dielectric constant of the substrate. [4] The formula is:

$$h \le \frac{0.3\,Vo}{2\pi fr\sqrt{\varepsilon r}} \tag{3}$$

### 2.2. Design of the Microstrip Feed Line

Usually 50&Ω microstrip line is used to feed the radiating patch. Feed line width decides the characteristic impedance of the feed line, so chosen to get the required impedance. Also for maximum coupling, the feed line must be placed perpendicular to the center of the slot.

### 2.3. Design of the Aperture

The amount of the coupling between the patch and feed line is determined by the aperture, so aperture has a very important role in the microstrip antenna with aperture coupled feeding. Mostly the length of the aperture (Lap) and the stub length are considered and width of the aperture ($W_{ap}$) is small usually 1mm is considered.

### 2.4. Design of the stub

Stub length is considered as the length after the feed line. It is used to tune the excess reactance of the aperture. The optimization is done using 3D electromagnetic simulator and the variations of the stub lengths are optimized.

## 3. PARAMETRIC STUDY AND OPTIMIZATION

Now the influence of various parameters on ACMPA will be studied.

### 3.1. Varying the Slot Length

Coupling level is primarily decided by the slot length. There are two types of slots i.e. resonant and non-resonant type based on the length of the slot. If the slot length is comparable to the half of the wavelength of the antenna, it is called resonant slot. If the smaller length slots are used, it is non-resonant slot. As the slot length is decreased, input resistance also decreases. But there can also be decrease in the coupling between patch and feed line. The plot of return loss against frequency for various slot lengths has been plotted.

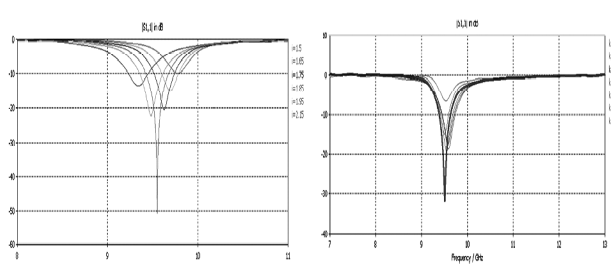

**Figure 2 (a&b): It can be Seen that Return Loss is Maximum for Aperture Length = 3.7 mm**

| Slot Length | 1.5 | 1.65 | 1.75 | 1.85 | 1.95 | 2.15 |
|---|---|---|---|---|---|---|
| Return Loss | -10 | -15 | -20.5 | -50 | -22.3 | -13 |

### 3.2. Varying the Stub Length

The open stub length can be adjusted to get the required reactance and also the slot length can be used to obtain the required resistive part of impedance. Typically stub length is of the length of 0.5 times the guided wavelength. Shorter stubs move the impedance circle downwards towards the capacitive part of the smithchart. The plot of return loss against frequency for various stub lengths has been plotted.

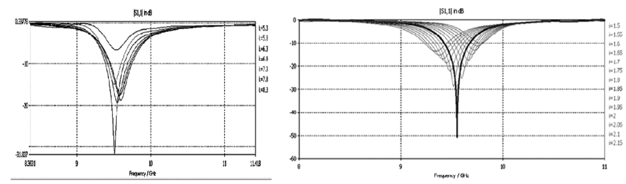

**Figure 3(a&b): It can be Seen that Maximum Return Loss is Obtained Using Stub Length = 6.3mm**

| *Stub Length* | *Return Loss* | *Stub Length* | *Return Loss* |
|---|---|---|---|
| 5.3 | -6.5 | 7.3 | -17 |
| 5.8 | -15 | 7.8 | -16 |
| 6.3 | -32 | 8.3 | -18 |
| 6.8 | -19 | | |

### 3.3. Varying the Dielectric Constant Value of the Substrate

It affects the bandwidth of the antenna directly. Also low permittivity of the dielectric substrate, wider the bandwidth and lesser surface wave excitation. High permittivity of the substrate is used for feed network and lower permittivity is used for antenna substrate. As the dielectric constant and thickness are varied in these analysis the feed line width and stub length are modified to maintain a characterstic impedance of 50&Ω and s atub length of $\lambda_g$ /4. The plot of return loss against frequency for various values of dielectric substrate has been plotted.

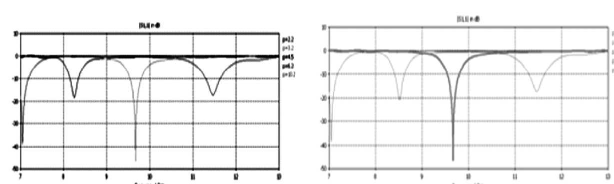

**Figure 4(a&b): The Return Loss is Maximum with Dielectric Constant = 3.2**

| *Dielectric Constant* | *Return Loss* |
|---|---|
| 2.2 | -17 |
| 3.2 | -46 |
| 4.5 | -16 |
| 6.2 | -39 |
| 10.2 | 0 |

## 4. VALUES OF THE DESIGN PARAMETERS

For final designing of the ACMPA with accurate parameters, the values of the parameters are given below: [1] and Figure 5 shows the design.

| | |
|---|---|
| Dielectric constant (εr) (both of the substrate have same values) | 3.2 |
| Thickness of the substrate above the ground (h2) | 0.762mm |
| Thickness of the substrate below the ground (h1) | 0.508mm |
| Length of the patch (Lp) | 7.5mm |
| Width of the patch (Wp) | 7.5mm |
| Width of the aperture (Wap) | 1mm |
| Length of the aperture (Lap) | 3.7mm |
| Width of the feed line (Wf) | 1.224mm |
| Length of the stub (Lfs) | 6.3mm |

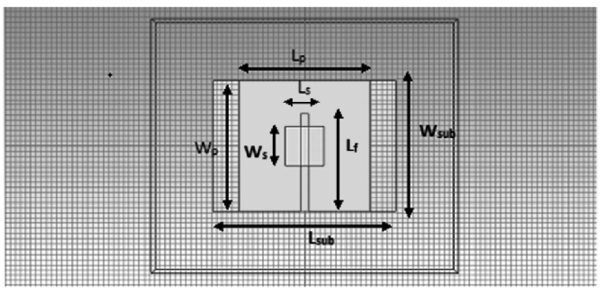


**Figure 5: Antenna Design**

The results are shown below in Figure 6, 7, 8, 9 and 10.

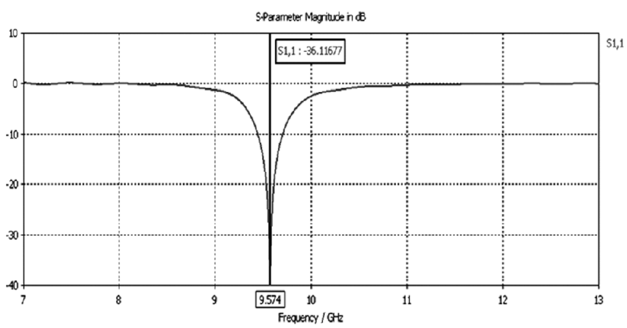


**Figure 6: Plot of Return Loss Against Frequency**

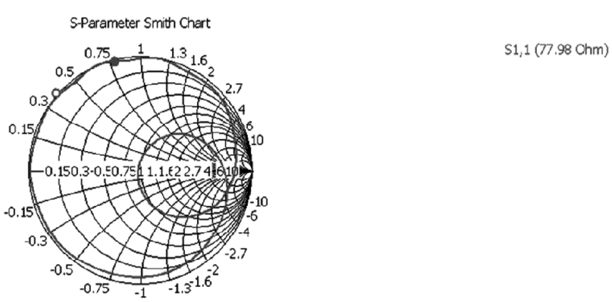


**Figure 7: Impedance Measured Using Smith Chart**

- Directivity at a frequency of 10GHz is 7.354dBi, radiation pattern obtained is omnidirectional with main lobe directed at an angle of 5.0 degree, having angular beamwidth of 81.4 degree. The magnitude of the main lobe is 7.4dBi

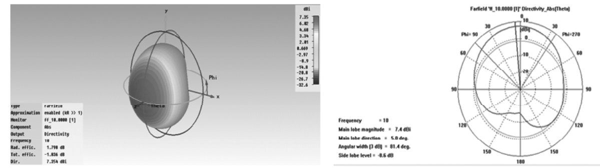

**Figure 8(a & b): Directivity**

- Gain at a frequency of 10GHz is 9.152dB, radiation pattern obtained is omnidirectional with main lobe directed at an angle of 5.0 degree, having angular beamwidth of 81.4 degree. The magnitude of the main lobe is 9.2dB.

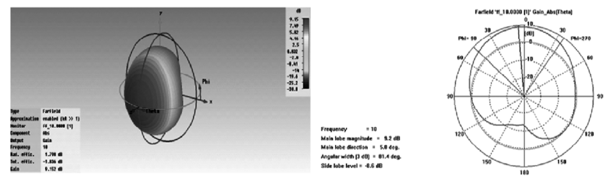

**Figure 9(a &b): Gain of Antenna**

- *VSWR:* When a transmitter is connected to an antenna by a feed line, the impedance of the antenna and feed line must match exactly for maximum energy transfer from the feed line to the antenna to be possible. When an antenna and feed line do not have matching impedances, some of the electrical ener gy cannot be transferred from the feed line to the antenna. Energy not transferred to the antenna is reflected back towards the transmitter. It is the interactio n of these reflected waves with forward waves which causes standing wave patterns.

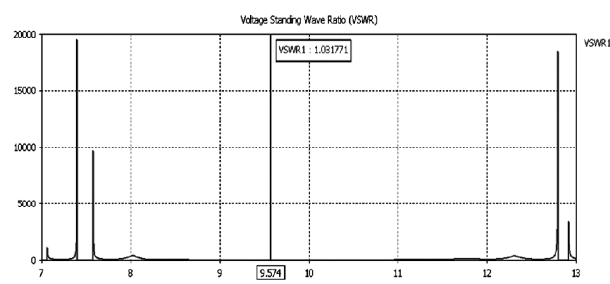


**Figure 10: VSWR**

## 5. CONCLUSIONS AND FUTURE SCOPE

A rectangular microstrip patch antenna having return loss of -37db and bandwidth of 200 MHz, is coupled to the feed line through a rectangular aperture in the ground has been optimized. Also the parametric analysis is performed to the see effect of the stub length, slot length and dielectric constant on the return loss. It cab be designed using IC fabrication and can be tested using Network Analyser.

Due to small and compact size of antenna operating on X-band, has many applications in Space communication, Space communication, Amateur radio, Traffic lights and motion detectors.

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