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Coupling Effect on Microstrip Patch Antenna, Consisting of Dollar Shape

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Abstract* - A microstrip patch antenna consisting of a dollar shape, and the effect of coupling on various parameters are presented. The coupling is done using another shape of copper material placed near the design. This coupling is sometimeused for bandwidth enhancement, and sometimes because of application purpose. We will first design dollar shape, then couple it with a design consisting of hash key (#) shape, later we will see the effect of this on antenna parameters. The whole structure will be designed and simulated using CST Microwave Studio.

I. INTRODUCTION

Microstrip Patch antennas are very much popular Due to its advantages such as low weight and volume, low costs, low configuration. The antenna is "a means for radiating or receiving radio waves" according to IEEE Standard Definitions of terms for Antennas (IEEE Std 145–1983) [1]. The microstrip patch antenna is extremely well-matched for applications such as cellular phones, missile systems, and satellite communications systems [2-6]. Recent demand is to improve the antenna performance, especially the input impedance and VSWR. One can also improve antenna performance either by using Defected Ground Structures [7], or by using the mutual coupling phenomenon [8-9]. This coupling sometime is possible sometime due to other radiating element placed nearby the antenna, which affects the electromagnetic radiation pattern directly or indirectly. While in some cases, coupling is done to limit the radiation pattern as well as directivity, which usually happen in array configuration. Usually when we power up the microstrip patch antenna with some source, charge distribution will occur on patch as well as ground surface. Which further leads to the flow of current and generation of electromagnetic field. So this electromagnetic field distribution is usually effected due to the presence of other radiating or non-radiating elements.

In this work we will design a microstrip patch antenna consisting of dollar shape. Firstly, we will make a dollar shape with some specified dimensions for the frequency of operation in S Band (2-4 GHz). Then we will couple it by placing a design consisting of shape as that of hash key (#) with some definite length and width, while height is as that of the patch, and see the changes in its various parameters, such as frequency of operation, return loss, VSWR (Voltage Standing Wave Ratio) and radiation pattern and also in its load impedance. CST software is used for simulation work.

II. ANTENNA DESIGN

The Microstrip antenna is designed for the frequency of operation in S-Band. The basic structure of microstrip patch antenna consisting of $-shape with and without coupling is shown below.

As we can see in Fig. 1 and 2 that feed location for both the antennas is same (using co-axial probe shown with a black dot), the only change is in the coupling from outer side. We just covered the outer area of the antenna with a design consisting of shape as that of hash key (#).This antenna is designed on a substrate (FR-4 with dielectric constant 4.3) of dimensions 20 x 20 mm2 with a height of 1.6 mm.

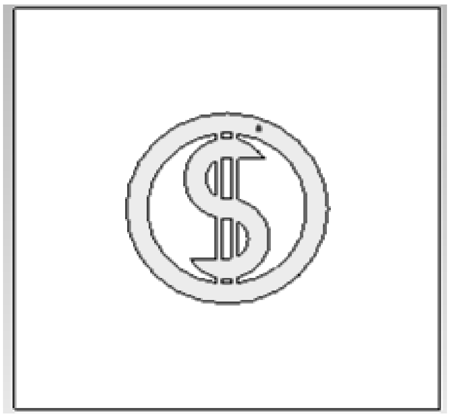


Fig. 1 Dollar shaped Microstrip patch Antenna (without Coupling)

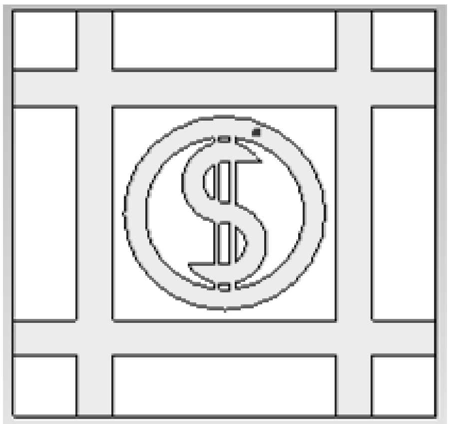


Fig. 2 Dollar shaped Microstrip patch Antenna (without Coupling)

The conducting patch aswell as ground surface is made of copper material, with thickness of 0.06 mm. Usually ground surface is of infinite area, but due to not possibility of the same, we will keep dimensions limited as same as that of the substrate. All the simulation results as explained below are obtained with the help of CST studio.

III. RESULTS AND DISCUSSION

A) Return Loss and Bandwidth

The scattering parameters as obtained from simulated results from co-axial port are shown inFig. 3 (a) and (b)for microstrip patch antenna consisting of dollar shape with and without coupling.

The return loss and frequency data are shown in table 1 below, which shows that when we couple the microstrip patch antenna from the outer side, the frequency of operation is same as that of without coupling i.e. 3.235 GHz. But now the antenna is working in dual frequency mode, i.e. at 3.235 GHz and 3.995 GHz while keeping the same feed location, which is beneficial in application purpose.

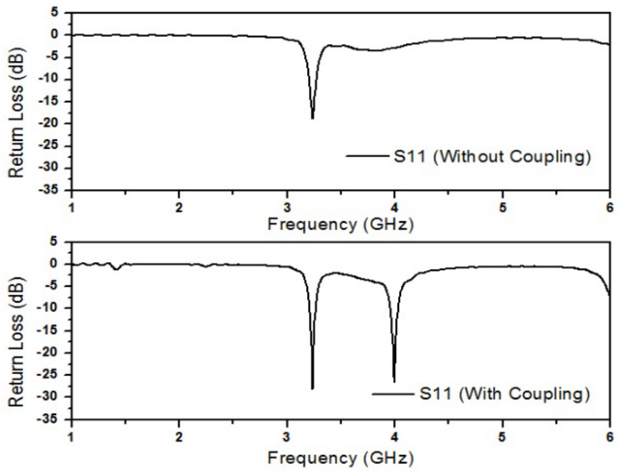


Fig. 3. Return Loss parameters for Microstrip patch antenna with and without coupling).

Because we need not to supply extra power for dual frequency operation. It is clearly visible from table 1 that return loss is changed with huge amount for same frequency of operation. Bandwidth is also calculated for both antennas using formula [10]. Which shows that bandwidth is little bit reduced from previous values.

TABLE 1 RETURN LOSS VALUE AS OBTAINED FROM MICROSTRIP PATCH ANTENNAS

Parameters	Antenna Configuration		
	Without Coupling	With Coupling	
Frequency (GHz)	3.235	3.235	3.995
Return Loss (dB)	-18.783	-25.892	-26.570
Bandwidth (%)	2.030	1.737	1.81

$$\square\square = \frac{\square_{\square}}{\square_{\square}} \quad (1)$$

$$\square\square(\%) = \left\{\frac{\square_{\square}-\square_{\square}}{\square_{\square}}\right\} * 100 \quad (2)$$

Where,

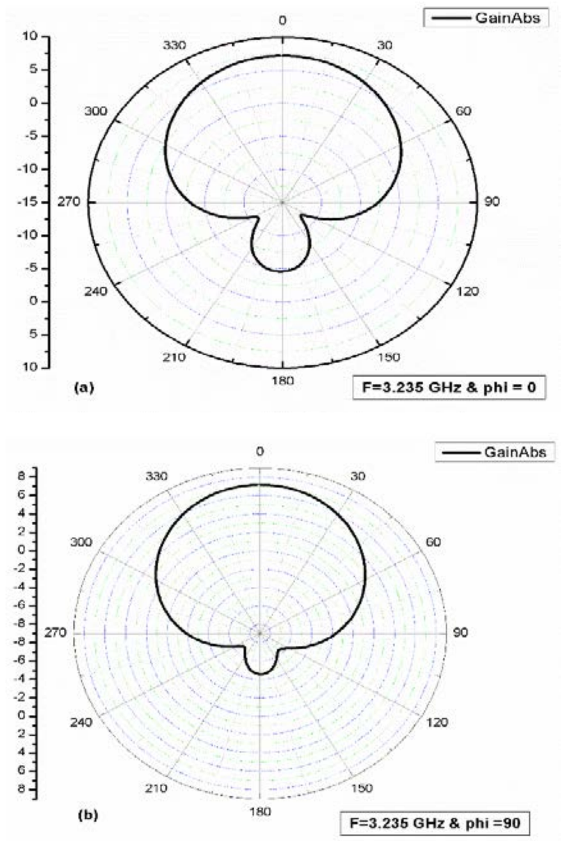
f_H = The Upper Frequency,

f_L = The Lower Frequency,

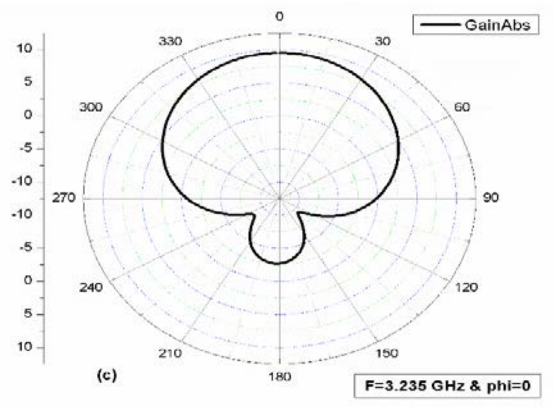
f_C= The Centre Frequency.

B) Radiation Pattern

The Polar plot for both antennas is shown belowin Fig. 4 and 5, which shows that gain is same for both configuration, i.e 6.3 dBi and angular width is changed from 95.7 deg to 95.8 deg with main lobe direction in 0.0 deg for both antennas.It is visible that coupling is no affecting the total radiation pattern at-all. The far field pattern for extra frequency is shown in Fig. 6. Which is having gain of 5.9 dBi with main lobe direction at 3.9 deg.



Normalized Load Impedance (both real and imaginary values) as obtained from simulated results are shown in table 2. In addition to that corresponding VSWR values are also shown below for the corresponding frequency of operations.



C) Normalized Load Impedance and Voltage Standing Wave Ratio (VSWR)

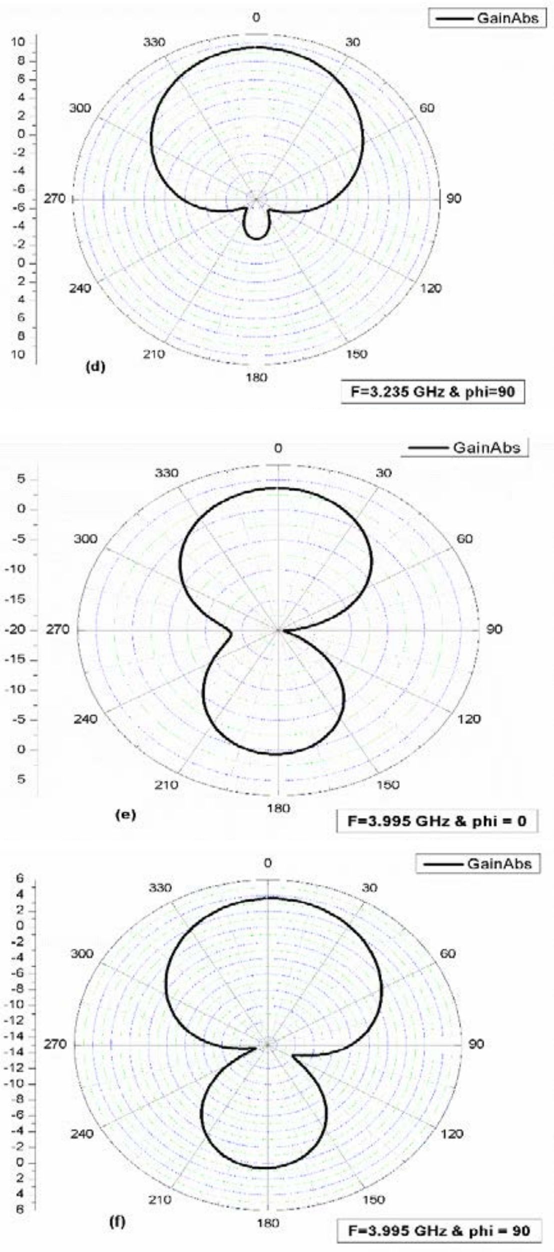


Figure 3.7 Far Field pattern for Microstrip Patch Antenna (a) & (b) are for without coupling, (c), (d), (e) and (f) are for with coupling.

Table 2 shows that Reactive fragment of load impedance is inductive in nature in all cases. The above values can also be calculated with the help of reflection coefficient from following formulas [11].

Reflection Coefficient $|\Gamma|=\left|\frac{Z_L-Z_0}{Z_L+Z_0}\right|$ (3)

VSWR $= \frac{1+|\Gamma|}{1-|\Gamma|}$ (4)

Return Loss (RL) = -20 log $|\Gamma|$ dB (5)

Where

ZL = Load Impedance

Z0= Source Impedance (50 ohm)

TABLE 2 NORMALIZED LOAD IMPEDANCE AS WELL AS VSWR VALUES AS OBTAINED FROM SIMULATED DATA

<table>
<tr><th colspan="2" rowspan="2">Parameters</th><th colspan="3">Antenna Configuration</th></tr>
<tr><th>Without Coupling</th><th colspan="2">With Coupling</th></tr>
<tr><td colspan="2">Frequency (GHz)</td><td>3.235</td><td>3.235</td><td>3.995</td></tr>
<tr><td rowspan="2">Normalized Load Impedance</td><td>Real (resistive part)</td><td>1.102</td><td>1.028</td><td>1.077</td></tr>
<tr><td>Imaginary (inductive or capacitive part, i.e. ±jX)</td><td>+0.220 j</td><td>+0.074 j</td><td>+0.058j</td></tr>
<tr><td colspan="2">VSWR</td><td>1.259:1</td><td>1.082:1</td><td>1.098:1</td></tr>
</table>

We are getting VSWR values close to 1, however, it should be less than 3, which shows that reflected power is only up to 1.23 % in case of without coupling and rest 98.77% power is transmitted. While in case of coupling reflected power is maximum upto 0.184 % and transmitted power is almost 100%.

IV. CONCLUSION

A microstrip patch antenna consisting of dollar shape has been designed and also the effect of coupling has been studied successfully. The designed antenna is working in at 3.235 GHz.It is observed that if we couple this antenna with other shape, then the antenna is operating in dual frequency mode, with enhanced return loss value and VSWR. The normalized load impedance is also approached to 1. At lastit is concluded that this design is application specific, with almost 100% transmitted power.

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