A new compact design and comparative study of circular patch antenna with different conditions of operations

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Abstract – *A compact circular microstrip is presented. The presented configuration consists of a circular patch which has been given the probe feeding for the excitation. A comparative study of the behavior of the antenna is presented when the circular patch is simulated with the feed, then with a slot and finally with the shorting post. The substrate used is FR4 Epoxy and the antenna dimension is 20mm*20mm*1.8mm. The antenna proposed is well potential for C-band applications and hence mobile communication handsets where limited antenna size is a premium. But after the addition of the shorting post the antenna was found to suitable for X-band applications. From the given trends, valuable insight to the antenna behavior to the optimum design, namely, broad bandwidth, smile size and ease of manufacturing is given.*

Key Words: **Circular Microstrip patch antenna (CMPA), Probe feeding, Shorting Post, Cross shaped slot, FR4 Epoxy.**

1. INTRODUCTION

Micro strip patch antenna is robust, small size and can be easily fabricated [1] to achieve higher values of gain. Moreover, Micro strip Patch Antenna can be easily fabricated using printed technologies on a large scale and this reduces the cost of manufacturing [2]. They are relatively light weight and low profile antennas. Due to its better operational characteristics and small size, it is extensively used in mobile phones and satellites too. A micro strip antenna is basically designed to operate on a particular frequency based on its specifications. Micro strip Patch antenna (MPA) consists of a ground plane at a bottom layer, a substrate in the middle and a radiating patch at the top most. The relative permittivity and the substrate height determines the radiation characteristics and bandwidth of the antenna.

Not long ago a small micro strip patch antenna was proposed incorporating a single shorting pin, located in the close proximity to the coaxial feed point. [3]. The shorted patch gives a ground-laying advantage in the reduction in antenna real estate required as compared to the canonical microstrip patch antenna, but at the cost of reduction in impedence Bandwidth

and the gain of the antenna [3]. To enhance the impedence bandwidth of the antenna a concentric ring is placed about the shorted circular patch, although the concept of adding the parasitic ring to attain better Impedence bandwidth is not new [9]. Moreover as per the conventional demands, many researchers are paying a higher attention in reducing antenna size using different techniques, like, using a thicker substrate [4], using shorting plates/pins[5], or by cutting slots in the radiating patch [6], defected ground plane [7] and also by changing the dielectric constant of the substrate[8].

In [10]-[14], shorting posts have been used in different arrangements to reduce and overall size of the micro strip patch antenna. But as proved in [12], the maximum reduction in physical size of the antenna can be achieved when a single shorting post is used. This reduces the radius of the circular patch and hence reducing the overall size of the patch antenna, making the antenna very suited for handset terminals.

The substrate that has been used is the FR4 substrate with dielectric constant 4.4 and this has been chosen to study because of its low cost and convenient availability hence can be used for also, microstrip antenna array prototyping. There are also different feeding techniques that can be implemented for designing microstrip, antennas. We have here used the co-axial feeding technique which is mostly used for proper impedence matching at 50 ohms. Various parameters of the Microstrip circular patch antenna, design considerations and performances have been shown extensively.

2. MICROSTRIP PATCH ANTENNA

Microstrip patch antenna consists of a very small conducting patch built on a ground plane separated by a dielectric material of desired thickness, keeping in mind that the width of the substrate is directly proportional to the gain of the antenna. The patch is generally made up of some conducting material such as copper and can take any shape as chosen by the researcher. The radiating patch is usually photoetched on the dielectric substrate. The radiating patch, theoretically can be of any shape but conventionally the shape of a rectangle or a circle is preferred over the others, and these configurations are widely used and very common as well. However microstrip patch antennas have a problem of giving low bandwidth and also low value of gain.

The bandwidth hence can be increased by cutting slots and stacking configurations and gain can be enhanced by using different patch elements in an array, if that is made to achieve, maximum form.

3. DESIGN PROCEDURE

The Circular patch has been presented with its radiation characteristics and then the same antenna is dealt with the cross shaped slot, this has been designed and presented in an iterative fashion. Everything has been shown in the figures below where the circular patch antenna designs have been shown both with and without the slot and also the addition of the shorting post. And the designed figures have been mentioned with the top view and the side view for better visual understanding of the design. The darker portion is that of the patch and the lighter portion is that of the slot when cut out. The configuration has been designed on a FR4 substrate of dimensions, 2 x 2 cm^2 and the dimension of the ground plane is same as that of the substrate. The relative permittivity of the substrate is 4.4, lost tangent of 0.0001 and thickness of 0.18 cm. Feeding technique used in the proposed antenna is coaxial feeding and the impedence is matched at 50 ohms.

The elementary geometry of the proposed circular patch is designed and simulated for C-band applications. And the shorting post makes it good for X-band applications.

Table -1: Antenna Parameters

Antenna design Parameters	Values
Substrate material	FR4
Substrate thickness 'h'	1.8mm
Length of Substrate 'L'	20mm
Width of Substrate 'w'	20mm
Dielectric constant	4.4
Dielectric loss tangent	0.02
Patch material	Copper
Patch radius	5mm
Radius of the Coaxial Probe	0.25mm
Position of the coaxial Probe	(x_p,y_p) (2,0)
Radius of the Shorting Post	0.25mm
Position of the Shorting Post	(x_s,y_s) (4.5,0)
Dimensions of slot_1	0.7mm,2mm
Position of the slot_1	(x,y) (-0.3,-1)
Dimensions of the slot_2	4mm,7mm
Position of the slot_2	(x,y) (-3,-0.5)

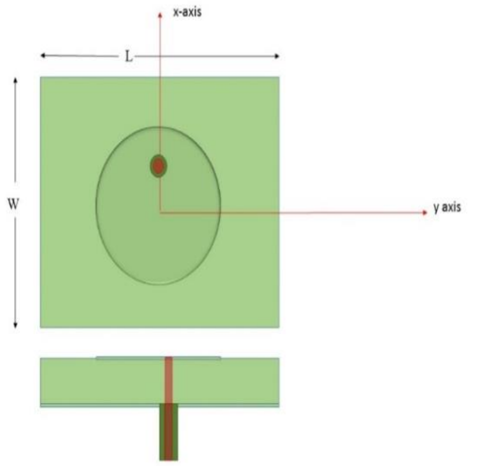

Fig -1: Only the Circular patch

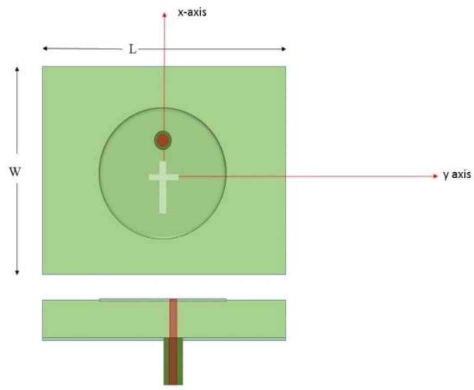

Fig -2: Patch with the Cross shaped slot

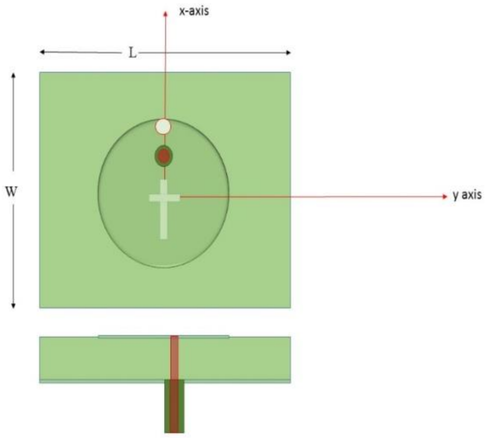

Fig -3: Patch with the Cross shaped slot and the shorting post.

4. RESULTS AND DISCUSSIONS

4.1 Return Loss (S11)

The antenna have been designed and the circular patch for the C-Band application seems to resonate at a frequency 7.80 Ghz and seems to give better loss characteristics at -20.6898. Increased negative value of return loss implies good impedence matching with respect to the reference impedence of 50Ω. After the addition of the cross shaped slot in the patch there seems to be a decrement in the value of the resonating frequency and we get a return loss value at 7.6 Ghz and the value equals to -19.9190 and the impedence is matched at the same 50Ω. After the addition of the pin in the slotted structure, the antenna shows itself to be working in the X- band and the return loss comes out to be at the frequency of 9.3 GHz and the value is -16.3561.

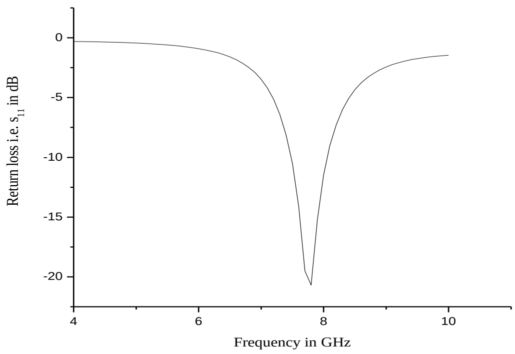

Fig -1(a): Return Loss

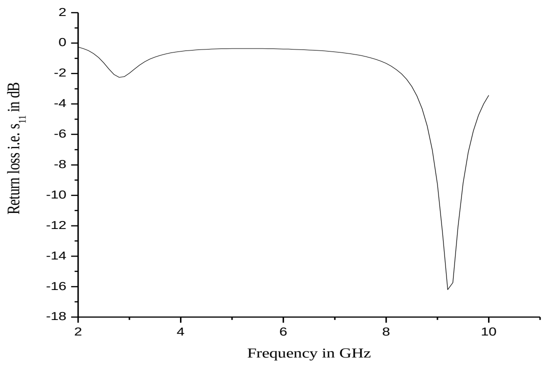

Fig -2(a): Return Loss

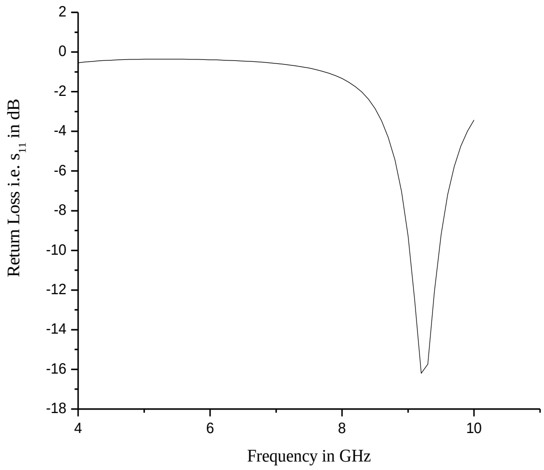

Fig -3(a): Return Loss

4.2 VSWR

When we look at the value of the VSWR, we observe that at the frequency of 7.80 Ghz, the circular patch gives a value <2 which corresponds to 1.60. Moreover the addition of the cross shaped slot gave the value of VSWR equal to 1.75 which is also <2, at the resonating frequency of 7.60 GHz. When the shorting post is added to this slotted structure we see that the VSWR value comes a bit >2 and the value is, 2.4 at the frequency 9.30 GHz.

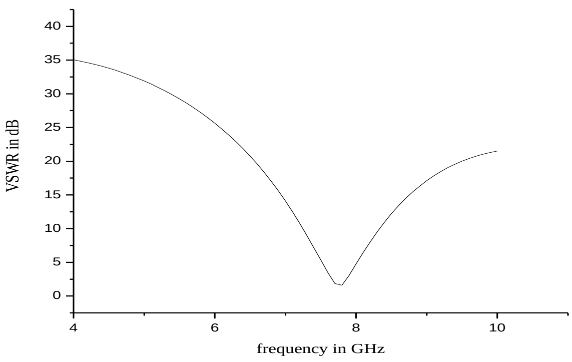

Fig -1(b): VSWR

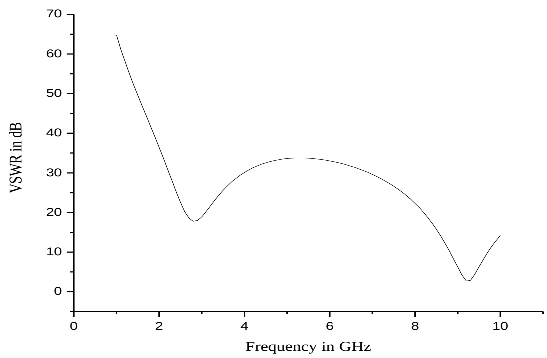

Fig -2(b): VSWR

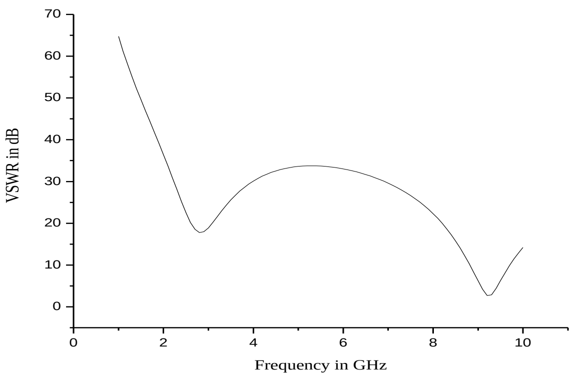

Fig -3(b): VSWR

4.3 Gain

We see a pattern in the gain where at 7.8 GHz the antenna gave the gain equals to 3.8892 dB and this shows the power radiated in a particular direction. When we added the cross shaped slot the gain was 3.6696 dB. But after we added the shorting post in the slotted structure the antenna shows itself to be working in the X-Band and the gain seems to come at a frequency of 9.30 GHz and the gain improves to 4.3320 dB.

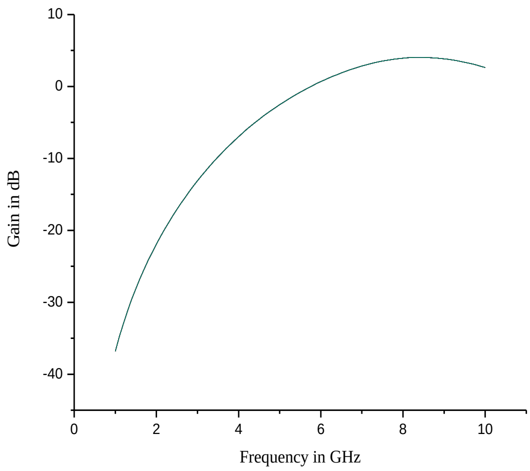

Fig -1(c): Gain

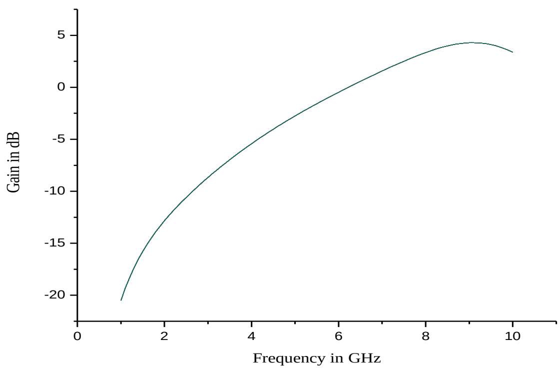

Fig -2(c): Gain

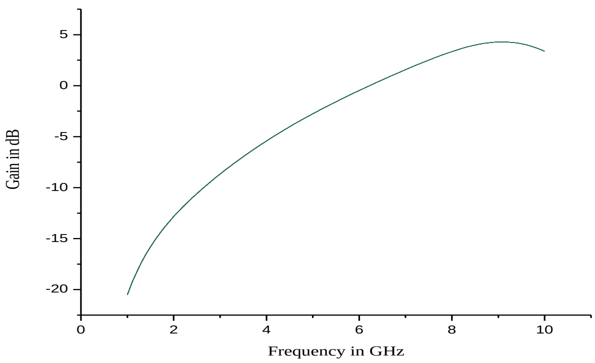

Fig -3(c): Gain

4.4 Directivity

Directivity of the circular patch came out to be equal to 4.8 when just the circular patch was simulated and after the addition of the cross shaped slot the directivity was observed to be equal to 4.7. After the addition of the shorting post, the directivity improves to 5.4211.

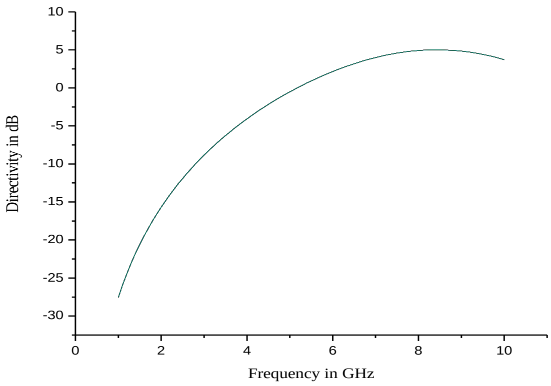

Fig -1(d): Directivity

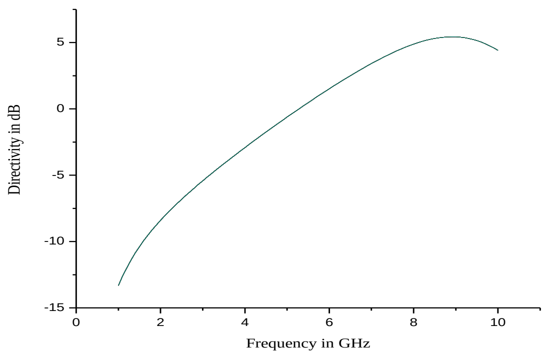

Fig -2(d): Directivity

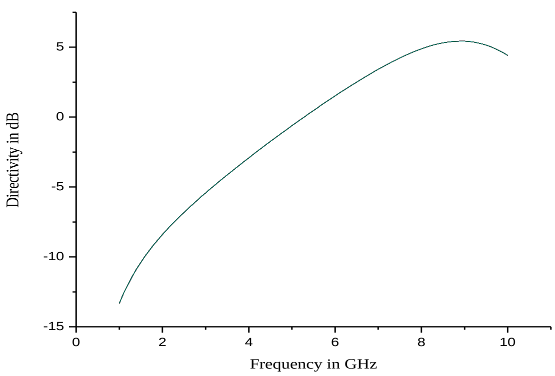

Fig -3(d): Directivity

4.5 Radiation Pattern

Radiation Pattern given is the 2D graph that explains the reception and transmission of radiation of the antenna, here is given the radiation patterns of the circular patch in three different given conditions.

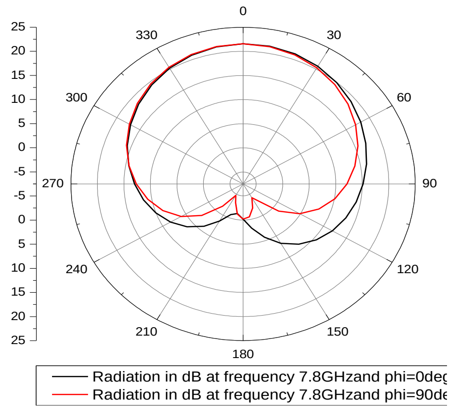

Fig -1(e): Radiation Pattern

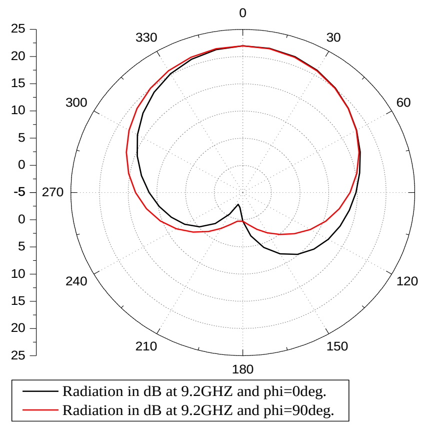

Fig -2(e): Radiation Pattern

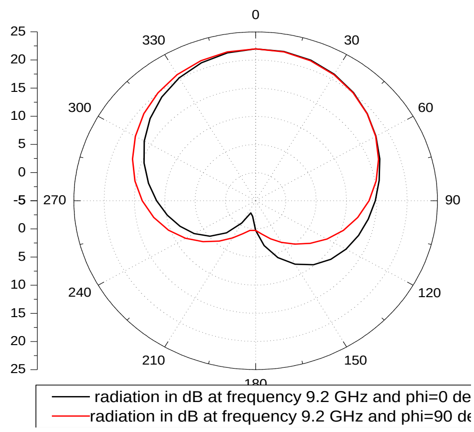

Fig -3(e): Radiation Patten

Conditions	Only Patch	With the Slot	With the slot and Pin
Resonant Frequency	7.80 GHz	7.60 GHz	9.30 GHz
S11 Parameter	-20.6898	-19.9190	-16.3561
VSWR	1.60	1.75	2.4
Gain	3.8892	3.6696	4.3320
Directivity	4.8	4.7	5.4

4.6 3D Polar Plot

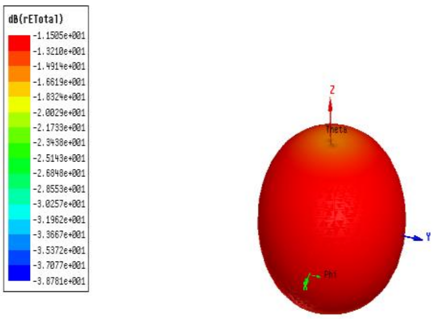

Fig -1(f): 3D Polar Plot

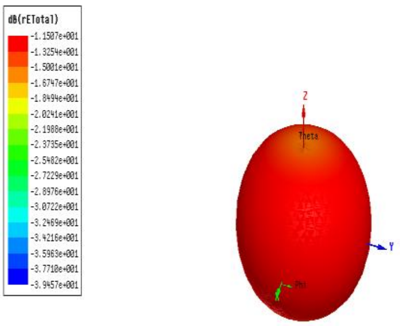

Fig -2(f): 3D Polar Plot

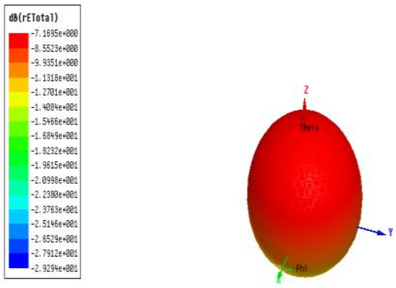

Fig -3(f): 3D Polar Plot

Table -2: Results

5. CONCLUSIONS

The model of the circular patch have been studied in three different conditions and the results have been mentioned separately. For further studies on this circular patch, different substrate with different dielectric constants can be used to enhance the results. We can also vary the height of the substrate to achieve better gain of the circular shaped microstrip patch antenna.

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