ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

IJARCCE

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 5, May 2015

Circular Patch Antenna with Defected Ground and Parasitic Layer for Wide Bandwidth

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Abstract: This paper presents a modified circular Microstrip patch antenna fed by a coaxial probe. The proposed work makes use of parasitic layer and defected ground to improve the bandwidth of the antenna. IE3D version 12 is used to simulate the proposed work. Simulation result shows that the antenna resonates at 3.73 GHz and 5.07 GHz frequencies with improved bandwidth of 22.68 %. The antenna showed a huge increase in the bandwidth of 1.150 GHz for center frequency 5.07 GHz and 290 MHz bandwidth for center frequency 3.73 GHz.

Keywords: Microstrip patch antenna, Parasitic, Defected ground, Stacking

I. INTRODUCTION

Extensive studies and research work is being done in recent years in the field of microstrip patch antenna due to their attractive features like light weight, small size, ease of fabrication and low manufacturing cost [1]. Microstrip patch antenna has a wide range of applications in fields like Cellular Phones, Radar, Direct Broadcast Satellite, Global Positioning System (GPS), GSM, Wireless LANs etc [1].

However, these antennas have few drawbacks such as narrow bandwidth, low gain, excitation of surface waves and low power handling capability [2]. There are several techniques to overcome these drawbacks. Planar Multi-resonator, stacked Multi-resonator, compact shorted MSA (Microstrip Antenna) [2]. These techniques will improve the narrow impedance bandwidth of antenna. Surface mounted horn technique will improve the gain of antenna [5]. In this proposed antenna design, two layer stacking is implemented to improve the bandwidth. The parasitic layer is not directly fed instead electromagnetically coupled by the radiating patch which is directly fed by coaxial probe.

II. ANTENNA DESIGN

As mentioned earlier, the antenna design makes use of circular shaped patch. The reference antenna is designed to resonate at 5.8 GHz for which the radius of the patch is a = 6.83 mm for FR4 substrate having thickness h = 1.6mm, dielectric constant (ε_r) of 4.4, and loss tangent ($\tan\delta_m$) of 0.0245. The radius 'a' of circular patch is calculated by using the following equations [1].

$$a = \frac{F}{\left\{1+\frac{2h}{\pi F \varepsilon_r}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

Where,

$$F=\frac{8.791\times10^{9}}{f_r\sqrt{\varepsilon_r}} \quad \ldots\ldots\ldots\ldots \quad (2)$$

Where ε_r – Dielectric constant of substrate
h – Height of substrate
a – Radius of patch

First a basic circular patch antenna (without any modifications) is designed with probe feed at (x=3, y=0).

The simulation results showed that it resonates at 5.77 GHz with -21 dB of return loss and bandwidth of 5.34 % (309 MHz).
The circular patch is modified by inserting few slots in the patch as shown in figure 1.

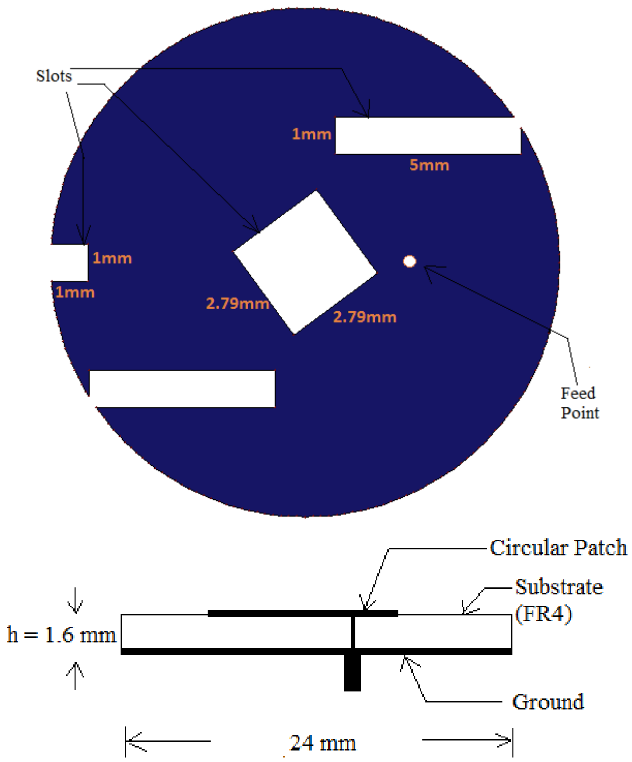

Figure 1: Modified circular patch with slots.

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
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In [3], a diamond shaped slot is placed at the center of circle. In this work a tilted square is placed at center. The modified circular patch (figure 1) has two rectangular slots and two square slots: one at circumference and other at the center [6-8]. The rectangular slot has length = 5mm and width = 1mm. The square slot placed at circumference has 1mm of length and the other placed at center has 2.79mm of length. These modifications gave multiband frequency which resonates at 4.36 GHz and 5.7 GHz. However it did not show much improvement in the bandwidth but gave multiband resonance.

To improve the bandwidth, we have implemented two layer stacking technique. The stacking of layers' technique is explained in [2]. In this technique, one more circular patch (with similar modifications shown in figure 1) is used as parasitic layer which is suspended in air medium above the radiating patch with 10mm air spacing between them as shown in figure 2. This parasitic layer is also supported by FR4 substrate. Along with modified radiating and parasitic patch, ground is also defected by inserting a circular hole of 5mm radius as shown in figure 3.

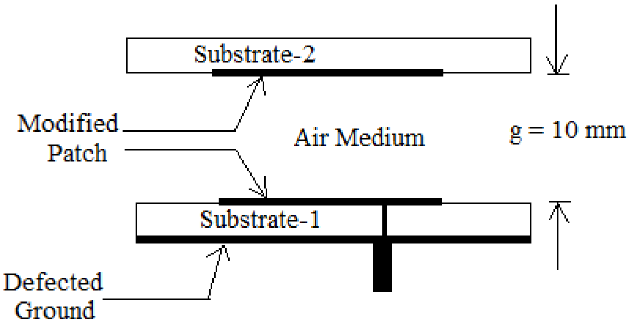
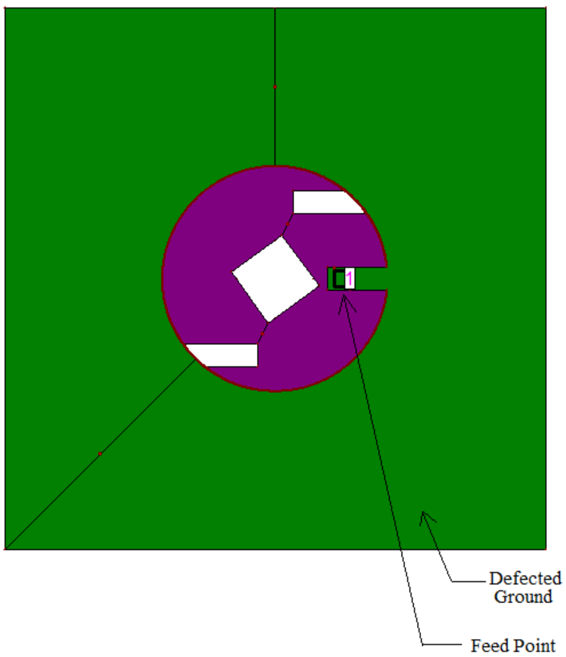


Figure 2: Parasitic layer placed above radiating patch.



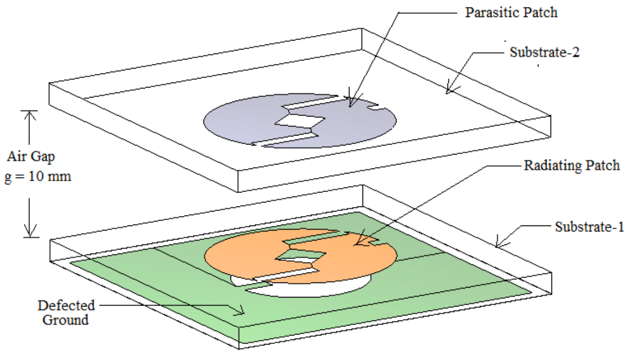


Figure 3: Final design of proposed antenna with defected ground and parasitic layer (2D and 3D view).

III. SIMULATION AND RESULTS

The simulation results were done for different values of g (air gap between radiating and parasitic patch).

Simulation results showed values for parameters like bandwidth, gain, directivity and antenna efficiency.

Table I shows simulation results for basic circular patch antenna (circular patch without defect and without parasitic layer) and for circular patch with parasitic layer (circular patch without defect).

TABLE I
SIMULATION RESULTS FOR CIRCULAR PATCH WITH AND WITHOUT PARASITIC LAYER (G=10MM)

	Circular patch without parasitic layer	**Circular patch with parasitic layer**
f_r (GHz)	5.77	5.96
Return loss (dB)	-21	-29
Bandwidth (MHz)	308	370
Efficiency (%)	46.78	55
Gain (dBi)	3.78	4.94
Directivity (dBi)	7.1	7.53

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TABLE II
SIMULATION RESULTS FOR PROPOSED ANTENNA DESIGN WITH DEFECTED CIRCULAR PATCH AND DEFECTED GROUND WITH PARASITIC LAYER FOR DIFFERENT VALUES OF G.

Antenna Parameters/ Air gap (g)	6mm		8mm		10mm		11mm		12mm	
	f_{r1}	f_{r2}	f_{r1}	f_{r2}	f_{r1}	f_{r2}	f_{r1}	f_{r2}	f_{r1}	f_{r2}
f_r (GHz)	3.63	4.8	3.67	4.8	**3.73**	**5.07**	3.63	5.08	3.76	5.08
Return loss (dB)	-14.57	-25.6	-11.5	-12.6	**-18.35**	**-20.7**	-12.1	-25.3	-12.7	-31
Bandwidth (MHz)	200	630	132	440	**290**	**1150**	220	760	227	692
Efficiency (%)	36.5	52.6	36.65	51.16	**44.3**	**60.85**	41	62	45.4	62.3
Gain (dBi)	2.3	4.78	2.22	4.57	**3.14**	**5.02**	2.67	4.87	3.07	4.66
Directivity (dBi)	6.64	7.57	6.7	7.5	**6.67**	**7.17**	6.47	6.95	6.5	6.7

Now the simulation is done for antenna design shown in figure 3. Table II shows simulation results for proposed antenna design for different values of g. Simulation result shows that as the air gap between radiating and parasitic patch increases, the bandwidth increases. For air gap of 10 mm the antenna is optimized i.e. if the gap is further increased beyond 10 mm the bandwidth starts decreasing.

For g = 10mm (highlighted text in Table II), there is extremely high bandwidth of 1150 MHz i.e. 22.68 % for center frequency of 5.07 GHz and 290 MHz for center frequency 3.73 GHz. Antenna efficiency is also increased to 60.85 % in comparison to basic circular patch antenna.

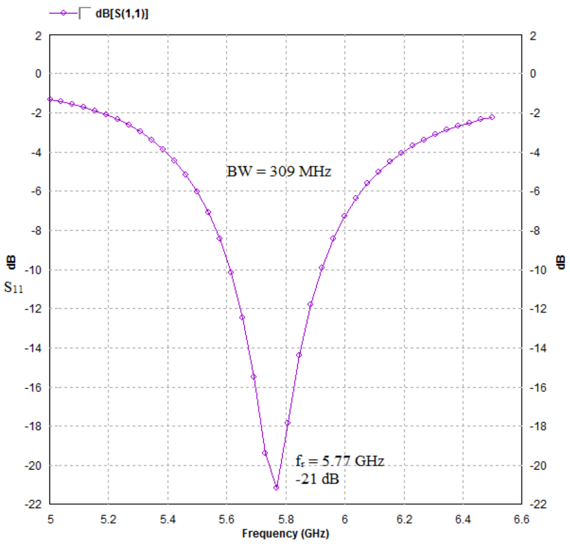

Figure 4: Simulated reflection co-efficient for basic circular patch antenna (without parasitic layer).

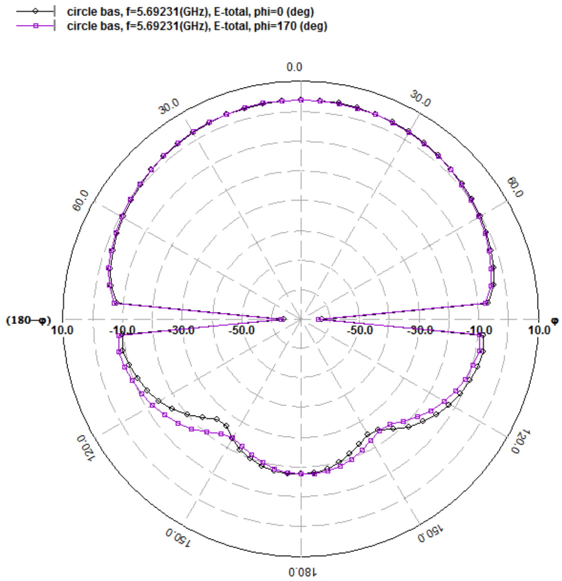

Figure 5: Radiation pattern of basic circular patch antenna at 5.77 GHz (without any modifications).

From simulation results we also observe that there is a difference between radiation patterns of the basic circular patch antenna (figure 5) and proposed antenna design (figure 7).The back lobe of basic antenna is very large.It is reduced in the proposed antenna. However, small amount of back lobe is still present. The gain is improved from 3.78 dBi of basic antenna to 5.02 dBi of proposed antenna. Also efficiency of proposed antenna is improved from 46.78 % to 60.85%. However, there is not much difference between the directivity of basic antenna and final antenna design.

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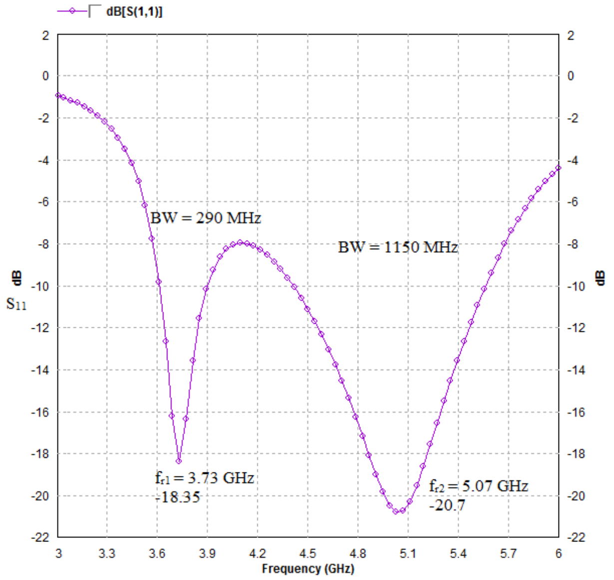

Figure 6: Simulated reflection co-efficient for proposed antenna design shown in figure 3.

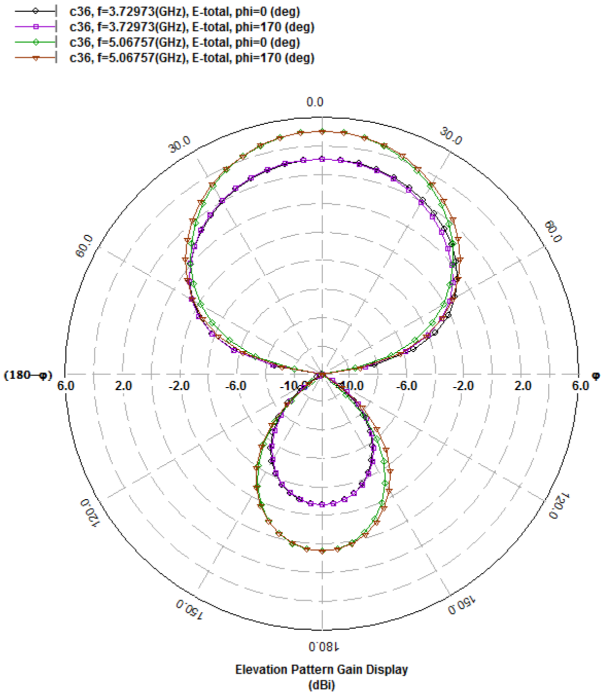

Figure 7: Radiation patterns of proposed antenna design at 3.73 GHz and 5.07 GHz.

IV. Conclusion

This paper presented a method to increase the bandwidth of circular patch antenna. Stacking of layer method improved the bandwidth drastically. The slots in the circular patch made the antenna design to resonate at two frequencies: 3.73 GHz and 5.07 GHz. The bandwidth for center frequency 5.07 GHz is 1150 MHz which is 22.68 %. And also the dual band frequency shifted to 3.73 GHz in the spectrum which reduces the size of antenna to 59.2 %. Further changes can be made to the design to suppress the back lobe which may even increase the gain of antenna.

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