

Applying Partial-Ground Technique to Enhance Bandwidth of a UWB Circular Microstrip Patch Antenna

Abhishek Viswanathan, Rajasi Desai

Abstract— The design of a Circular Patch Microstrip antenna, etched on an FR4 PCB, operating over a wide bandwidth for various applications in the range 1 GHz - 8GHz, with a partial ground plane has been presented in this paper. The design was optimized to obtain the most suitable configuration in terms of desired values of VSWR, S11 and Gain. The simulation was performed using the software Ansoft HFSS 13.0.0, a software that uses the Finite Element Method of problem-solving, which produced experimental results of the reflection coefficient and radiation pattern of the designed antenna. Upon fabrication, it was found that the results of the fabricated antenna and simulated antenna were in good agreement.

Index Terms— Antenna, Bandwidth Enhancement, Circular Patch, Microstrip, Partial Groundplane, Ultra Wideband

1 INTRODUCTION

ANTENNAS are vital to the working of almost all of technology, right from basic communication devices to high-performance aircrafts, space crafts and satellites. In these cases, constraints such as size, weight, performance and cost of the antenna have to be considered. Microstrip antennas are perfect for these applications as they are small in size, can be adjusted to both planar and non-planar surfaces, they are relatively simple to design and inexpensive to fabricate. One major disadvantage of MSAs though, is that they tend to have a very narrow frequency bandwidth, at most times just a few percent [1]. Since most applications require antennas to work over a wider range of frequencies, we have to modify MSAs to conform to our requirements and applications.

The antenna was designed with a full ground plane initially, but since the results were not desirable, different bandwidth enhancement techniques were explored, like feed gap optimization [2], bevels [3], ground plane slits and shaping [4], [5], multiple feeding configurations and orientations [6], [7], and variations in monopole shape [8] and partial ground technique was selected.

HFSS [9] stands for High Frequency Structural Simulator, a commercial finite element method solver for electro-magnetic structures from Ansys.

HFSS was used because it uses integral equations or advanced hybrid methods to solve a wide range of problems and it incorporates a powerful, automated solution process.

Since complex patch geometry makes analysis of the antenna almost impossible, a circular patch is chosen for ease of analysis. [8] The designed antenna has a FR4 substrate which has a relative permittivity of 4.4.

analyzed by using cavity model and the cylindrical coordinate system. The cavity can be considered as two perfect electric conductors at the top and bottom representing the patch and the ground plane, and by a cylindrical perfect magnetic conductor around the circular periphery of the cavity. The FR4 is assumed to be trimmed beyond the full scope of the patch. [1]

We can show that for TM_z modes, electric and magnetic fields are related to the vector potential A_z. Depending upon our application and required bandwidth, we select the resonant frequency to be 800MHz so we can tune the antenna to higher necessary frequencies.

Based on the cavity model formulation, a design procedure is outlined which leads to practical designs of circular MSAs for the dominant TM_{z110} mode. [1]

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

Where

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\epsilon_r}}$$

a: radius of the patch
f_r: resonant frequency
ε_r: dielectric constant of substrate
h: height of the patch

2 ANALYSIS AND DESIGN

2.1 Analysis of Circular Patch

Consider a circular Microstrip Patch design. We can only analyze a circular MSA by cavity model analysis other than full-wave analysis. A circular Microstrip patch can be easily

TABLE-1 DIMENSIONS OF THE CIRCULAR MSA

Dimensions	Millimetres [mm]
Width of the Substrate (W)	200
Length of the Substrate (L)	152
Width of the 50-Ω Feed line (W_f)	3
Length of the 50-Ω Feed line (L_f)	50
Radius of the Printed Disc (R)	51.73
Length of the Partial Ground Plane (L_g)	50
Width of the Partial Ground Plane W_g)	200
Substrate Thickness (H_{sub})	1.6

2.2 Bandwidth Enhancement Using Partial Ground Plane Method

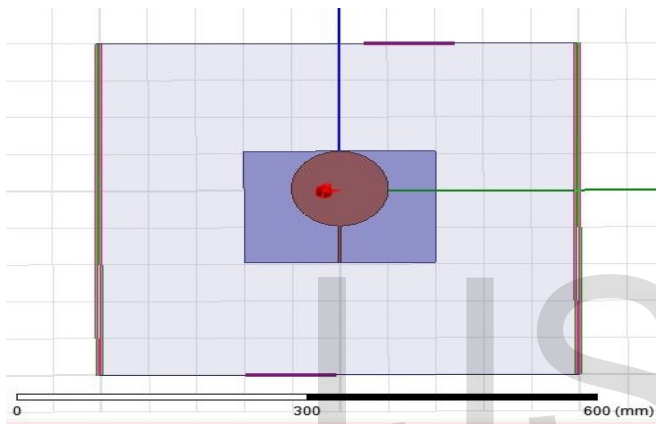


Figure 1: Front view of designed antenna

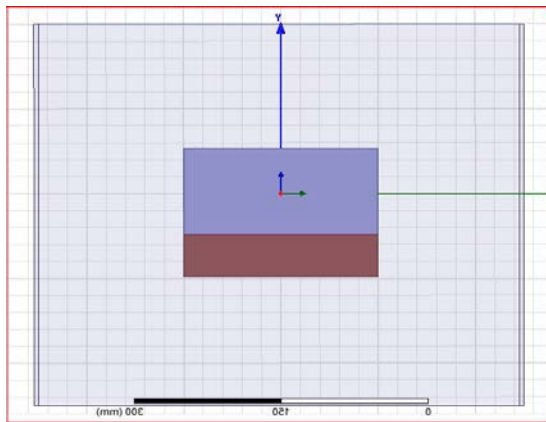


Figure 2: Back view of designed antenna

The proposed antenna design consists of a circular patch etched on the top of the substrate and a partial ground plane on the other side.

Substrate material is FR4 with a relative permittivity of 4.4. Height of the substrate is 1.59 mm. The patch and ground plane are made of Copper. Radius of the patch, as obtained in the previous section is 51.73 mm.

The circular patch is fed with a Microstrip line of width 3 mm and length 50mm with an SMA connector attached to it.

It is not just the shape, radius and substrate material that causes changes in the characteristics of an antenna, but it has been found that changing the dimensions and length of the ground plane causes noticeable changes in characteristics of the antenna.

Reduction of the ground plane is a popular method of antenna characteristic enhancement. It has been used to increase efficiency [10], improve impedance matching [11], enhance the front-to-back ratio [12] and also increase bandwidth of rectangular antennas [13]. Therefore, this paper explores the method of increasing the bandwidth of Circular Microstrip antennas with the use of partial ground plane technique.

3 RESULTS AND DISCUSSIONS

The antenna was designed with a full ground plane and the results were found to be unsatisfactory since the S11 value wasn't consistently good (<-10dB) and the VSWR wasn't consistently low (<2) throughout the entire range.

3.1 Results of Antenna with Full Ground Plane

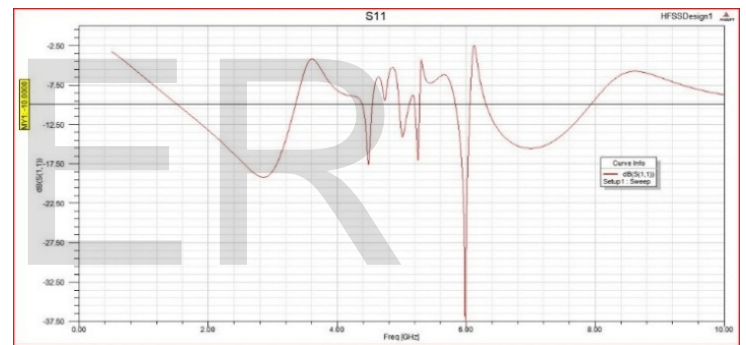


Figure 3: S11 characteristic of Antenna with full ground plane

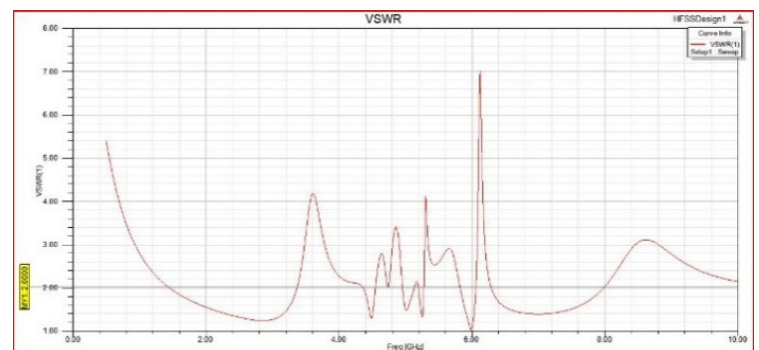


Figure 4: VSWR characteristic of Antenna with full ground plane

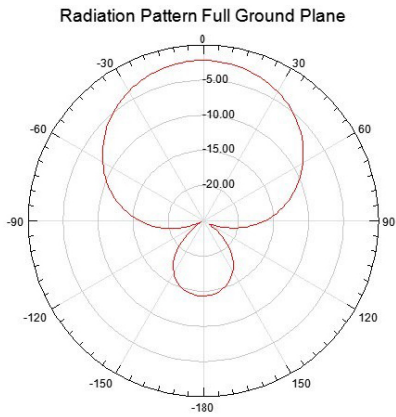


Figure 5: Total Gain (dB) 2D Radiation Plot of Antenna with Full Ground Plane

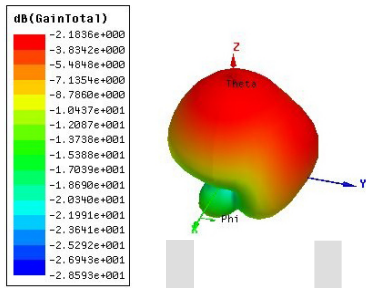


Figure 6: Total Gain (dB) 3D Radiation Plot of Antenna with Full Ground Plane

The ground plane was reduced systematically in increments of 10 mm at a time and simulated, while the characteristics were observed. There was a marked improvement in the desired characteristics when the length of the ground plane was reduced.

3.2 Results of Antenna with Partial Ground Plane

The most optimum characteristics, with $S_{11} < -10$ dB and $VSWR < 2$, for the entire range of 1 GHz to 8 GHz are obtained at the partial ground length 50 mm. The design of the antenna presented in the following sections fulfils the high bandwidth requirement necessary in the present world scenario.

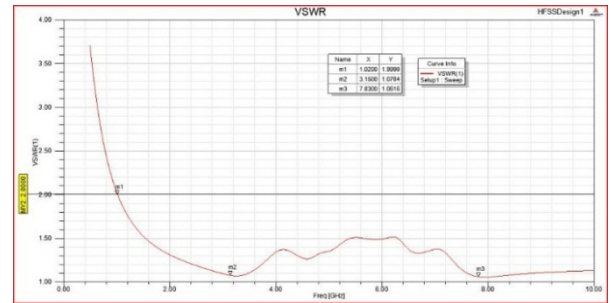


Figure 8: VSWR characteristic of Antenna with partial ground plane

Radiation Pattern Partial Ground Plane

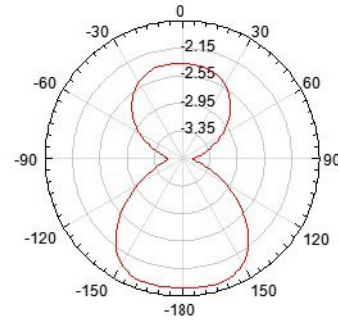


Figure 9: Total Gain (dB) 2D Radiation Plot of Antenna with Partial Ground Plane

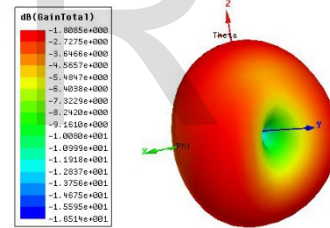


Figure 10: Total Gain (dB) 3D Radiation Plot of Antenna with Partial Ground Plane

As the antenna functions in 1GHz - 8GHz range, it shows satisfactory performance in the two ISM bands (2.45 GHz, 5.8 GHz) which fall in the aforementioned frequency range.

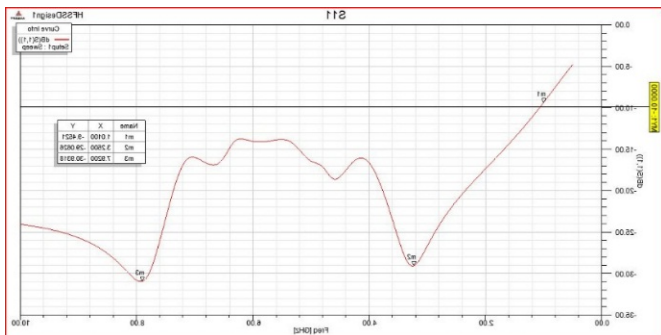


Figure 7: S11 characteristic of Antenna with partial ground plane

3.3 Comparison of Results using Partial Ground Plane & Using Full Ground Plane

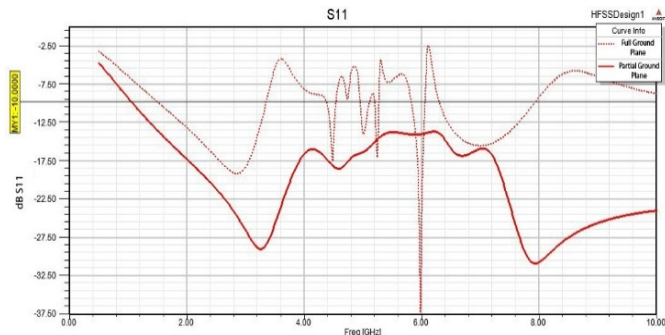


Figure 11: Comparison of S11 characteristic of Full ground plane and partial ground plane antennas

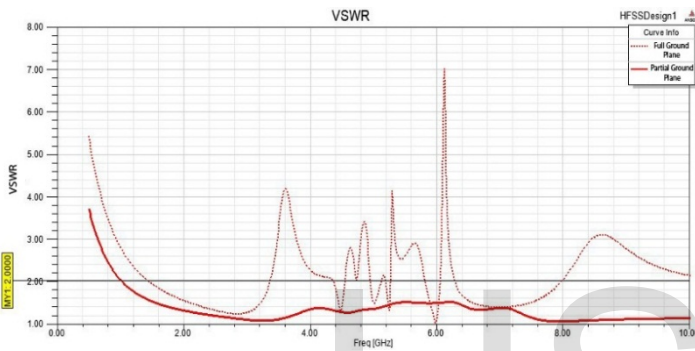


Figure 12: Comparison of VSWR characteristic of Full ground plane and partial ground plane antennas

3.4 Fabricated Antenna

The fabricated antenna was tested by attaching the SMA connector to a Vector Network Analyzer to measure the S11 and VSWR for different frequencies falling within the antenna's range.



Figure 9: Antenna connected to Vector Network Analyzer

3.4 Comparison of Results of Simulated Antenna with Results of Fabricated Antenna with Partial Ground Plane

Similarity between Simulated and Fabricated Results is shown in the graphs below.

S11

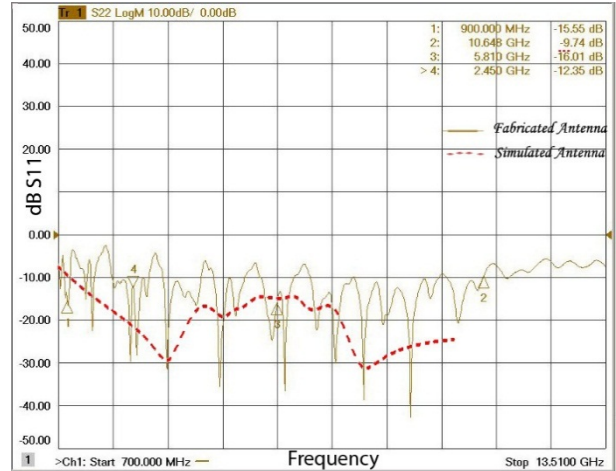


Figure 10: Comparison of S11 characteristic of Fabricated Antenna with Simulated Antenna

VSWR

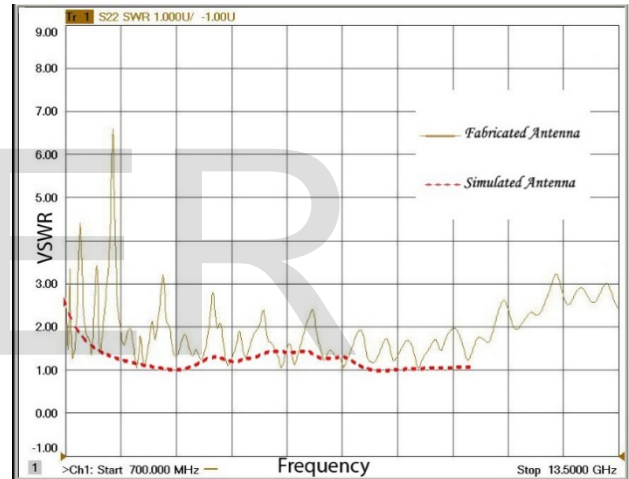


Figure 11: Comparison of VSWR characteristic of Fabricated Antenna with Simulated Antenna

4 CONCLUSION

On comparing the simulation results with the results given by the fabricated antenna, it is found that the Circular Patch Microstrip Antenna with Partial Ground Plane gives a higher bandwidth and improved impedance matching. The measured frequency parameters are well within the agreeable limit for the entire range in the simulation (VSWR < 2; S11 < -10dB). Since the fractional bandwidth is 175%, we can say that the antenna is an UltraWideband Antenna [14]. Additionally, the fabricated antenna, when tested on a Vector Network Analyzer, shows results which conform to the simulated results. Thus, we conclude that partial ground is a simple and effective method for increasing the bandwidth of a Microstrip Patch Antenna

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