Analysis of Umbrella Shaped Patch Antenna using Different Ground Shapes for UWB Applications

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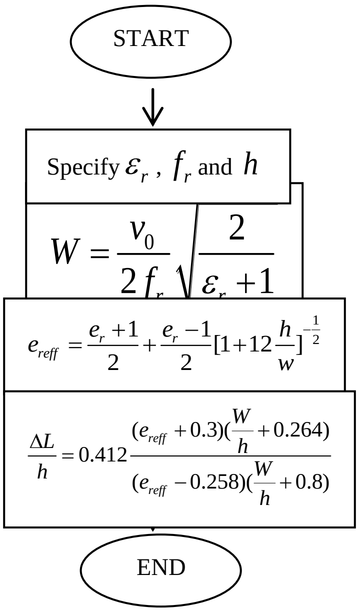
ABSTRACT
A novel design of the microstrip patch antenna is being proposed in this work. The patch antenna has been designed starting from rectangular patch with rectangular ground and ending with an umbrella semicircular shape for both the patch and a ground plane at an operating frequency of 5 GHz in order to enhance the bandwidth of the antenna using HFSS. On simulation it was observed that the -10dB impedance bandwidth of antenna increased from 15.94% to 43.07% showing the improvement of 27.13% with return loss of -37.77 dB with good VSWR. The semicircular patch with modified circular ground produced a bandwidth of 2.1537 GHz which can be used for the ultra-wide band (UWB) applications.

Keywords
Umbrella semicircular shape, HFSS, Bandwidth, Return loss, VSWR, UWB.

1. INTRODUCTION
Wireless communication is enduring to witness tremendous growth and broad implementation in a wide variety of applications. There has been an increasing worldwide interest in low profile, low-cost, light weight and wideband system designs. One of the most fundamental components of wireless systems is their antenna. Broad bandwidth antennas are always in demand so that various applications are covered by a single antenna. In order to meet these requirements microstrip antenna is a good choice since they have various applications in satellite communications, wireless systems. This antenna can be used in very high-data rate and short range wireless communication systems to modern radar systems [1], [2], [3].

Microstrip antennas are the low profile, economical low weight antennas conformable to planer and non-planer surfaces. These are the one of the useful antennas at the microwave frequencies but have the narrow bandwidth. The microstrip technique is a planar technique used to produce lines carrying signals and antennas coupling such lines and radiated waves [4]. It uses conductive strips and patches formed on the top surface of a thin dielectric substrate separating them from a conductive layer on the bottom surface of the substrate and constituting a ground for the line or the antenna [5]. A patch is typically wider than a strip and its shape and dimension are important features of the antenna. Microstrip antennas are predominantly appropriate for use as active antennas. Active antenna is the antenna having all of the essential components such as an antenna element, a feeding circuits, active devices, inherently provided on a monolithic substrate, thus producing compact, low cost, multi-function antenna equipment [6]. Microstrip patch antennas are undoubtedly the most widely used type of antennas today due to their advantages such as light weight, low volume, low cost, compatibility with integrated circuits and easy to install on the firm surface.

2. DESIGN METHODOLOGY
Recent examples of research on wideband microstrip patch design can be found in [6]. Following is the flow chart that describes the steps involved in designing the patch antenna [5], [8]:



3. ANTENNA DESIGN AND GEOMETRY
A low profile microstrip monopole patch antenna is proposed as shown in Fig.1. The rectangular and circular geometries were designed and simulated to enhance the performance of an antenna. The two cases of the antenna were designed and simulated starting from the rectangular ground plane and ending up with an umbrella semicircular shape for both the radiating patch and the ground plane.

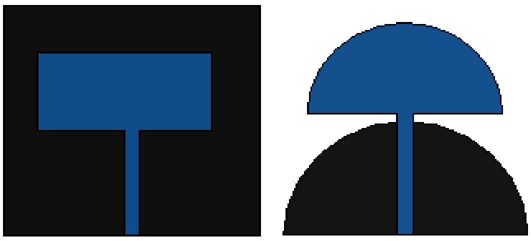


Fig 1: Steps towards the design of final design of proposed patch antenna

For first case, the shape of the rectangular microstrip patch antenna shown in Fig. 2 has a radiator dimensions of 12×24 mm^2 and rectangular ground plane with dimensions of 35×35 mm^2.The resonance frequency of antenna was set at 5GHz.

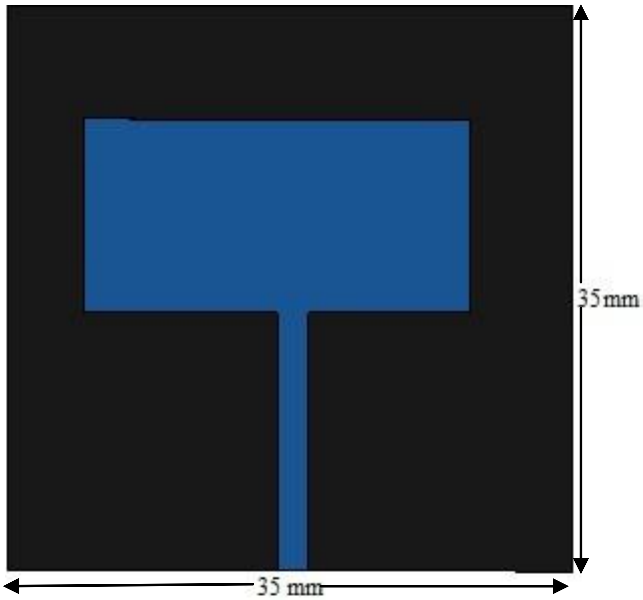


Fig 2: Rectangular microstrip patch antenna with rectangular ground

In second case the umbrella semicircular shapes of both the radiating patch and ground pane was designed with radius R #1 = 15 mm and R #2 = 12 mm as shown in Fig. 3. The length of the microstrip feed line that is used is F #L = 16mm with the width of F #W = 1.9 mm which is shown in Fig. 4. The antenna was designed on the FR4 substrate with thickness of 4.0 mm with ε_r = 4.7.

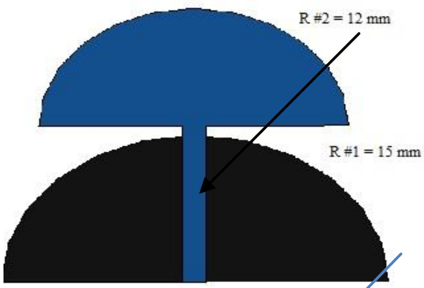


Fig 3: Umbrella shaped semicircular microstrip patch antenna with semicircular ground

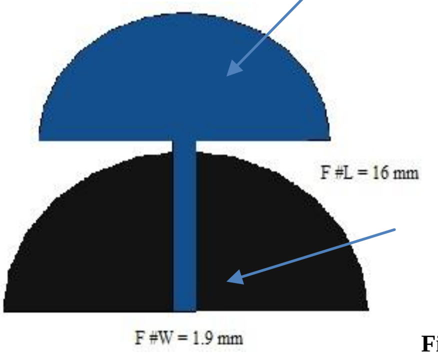


Fig 4: Umbrella shaped semicircular microstrip patch antenna with semicircular ground

4. SIMULATION AND RESULTS

The simulation was completed through HFSS v.12 tool from where the reflection coefficient and VSWR was studied to investigate the bandwidth of the antenna on changing the shape of ground and radiating patch. Since the VSWR defines how well matched the antenna is to the transmission line or receiver [7]. It is related to the reflection coefficient by equation 1:

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

Where Γ = Reflection Coefficient

The bandwidth is calculated as the -10dB impedance bandwidth which is given by equation 2:

$$BW = f_h - f_l \qquad (2)$$

In terms of percentage the bandwidth is given by equation 3:

$$BW = \frac{f_h - f_l}{f_c} \times 100 \qquad (3)$$

Where f_h = highest frequency.

f_l = lowest frequency.

f_c = centre frequency.

The antenna was matched with the 50 Ω with the transmission line.

Starting with the first case, the rectangular shape for both radiating patch and ground, the dimensions of patch are 12 $\times$ 24 mm^2 and for ground plane the dimensions are 35 $\times$ 35 mm^2. The simulation results are shown in the Fig. 5 and Fig. 6.

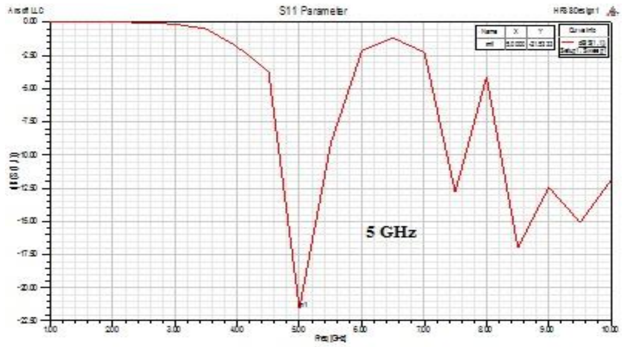


Fig 5: S11 parameter of Rectangular patch antenna with rectangular ground

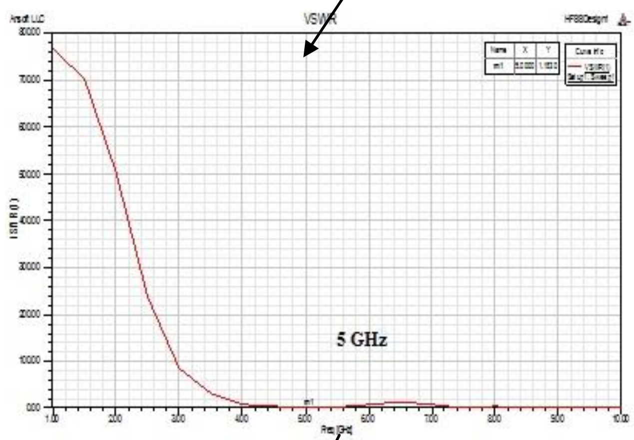


Fig 6: VSWR of Rectangular patch antenna with rectangular ground

In the final case, the shape of both radiating patch and ground plane were converted to half circular shapes with radius of 12 mm and 15 mm respectively and simulation results are shown in the Fig 7 and Fig 8.

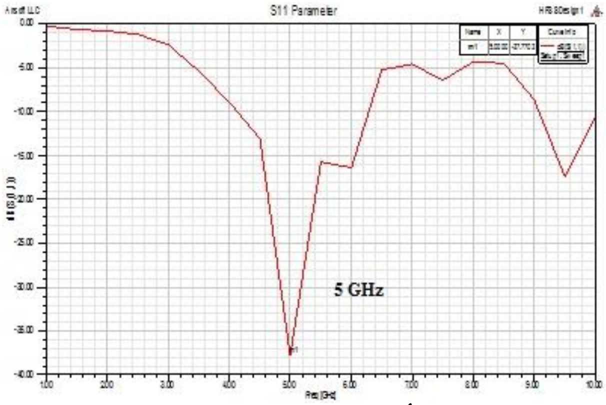


Fig 7: S11 parameter of umbrella shaped semicircular microstrip patch antenna with semicircular ground

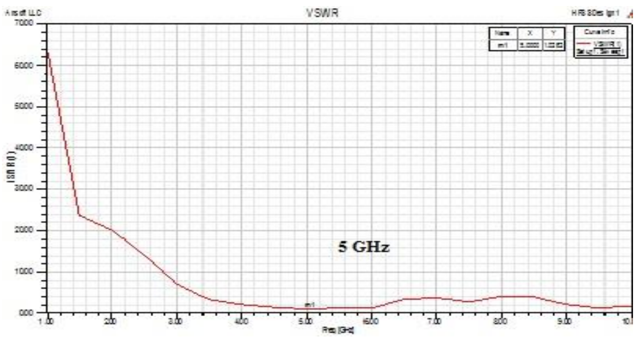


Fig 8: S11 parameter of umbrella shaped semicircular microstrip patch antenna with semicircular ground

4.1 Comparison between Two Antennas

The comparison between the results of the two cases of the antenna studied on varying the shape of radiating patch and ground plane is shown in Table 1.

Table 1. Comparison between two antennas

Antenna Shape	S11	VSWR	Band-width	Percentage Bandwidth
Rectangular patch and ground plane	-20.4469 dB	1.21	0.7973 GHz	15.94%.
Semi-circular patch and ground plane	-37.770 dB	1.02	2.1537 GHz	43.07%

It is clear from the table that in first case the antenna suffers from the narrow bandwidth and then varying the shape of ground plane and radiating patch the bandwidth of the antennas tends to increase and finally when semi circular shape is attained by both radiating patch and ground antenna bandwidth increases from 15.94% to 43.07% with s11 parameter of -37.770 dB, thus it attains the bandwidth which is required for the ultra-wide-band (UWB) operation.

5. CONCLUSION

In this proposed work two cases of the microstrip antenna has been studied starting with the rectangular patch with rectangular ground and ending with umbrella semicircular shape for both patch and ground plane. In 1st case the bandwidth of antenna came out to be 0.7973 GHz (15.94%) with good return loss of -20.4469 dB but when the shape of both the ground and radiator was changed the bandwidth of the antenna increased up to 2.1537 GHz (43.07%) with return loss of -37.770 dB with good VSWR. Thus the performance of antenna in terms of bandwidth increases by 27.13%.

6. REFERENCES

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