Design of a Compact Circular Patch Antenna using DGS for UWB Applications

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Abstract

In this project, an efficient design of circular shaped microstrip patch antenna for Ultra-Wide Band (UWB) applications is proposed with partial ground structure. In the recent era, microstrip patch antenna plays a vital role as they are found to be immensely useful due to its compact nature, easy integration and its light weight. UWB systems are popular because of their larger bandwidth and power management efficiencies but the design of UWB based applications requires low profile antennas. It has been found that circular antenna gives better return loss, good directivity and radiation pattern. The line feeding technique used in the proposed model provides good impedance matching, which further improves the characteristics of the antenna.

***Keywords— Microstrip Patch Antenna; UWB; Circular Patch; Bandwidth; Directivity; Radiation Pattern*.**

I. INTRODUCTION

The latest growth in the field of wireless technology requires the antenna which can perform multiple capabilities and functions [4]. Hence, Ultra-Wide Band (UWB) communication systems achieve huge attention in both academics and industrial fields. Ultra-Wide Band has a number of boosting advantages that are reasons why it presents more powerful solution to wireless broadband than other technology. Ultra-Wide Band (UWB) has been chosen extensively due to larger bandwidth range proposed by the FCC (Federal Communications Commission) in 2002 by United States of America (USA). According to the commission the bandwidth allotted for the wireless communication ranges from 3.1GHz to 10.6GHz [5]. UWB is preferred mostly because of its high data rate i.e., hundreds of Mbps (Megabits per seconds) or several Gbps (Gigabits per seconds) with distance coverage of 1 to 10 meters and also for its low power utilization [9][7]. So, many researchers are paying more attention in this field because the FCC has released commercial use of UWB for indoor applications [3].

Microstrip Patch Antennas plays a vital role in the field of wireless communication due to its less weight, compact size, ease of fabrication and low cost [1]. This antenna basically consists of a dielectric substrate, in which one side of the substrate comprises of the radiating patch and another side with the ground plane. There is more number of substrate available for the design of micro-strip patch antenna and its dielectric constant ranges from 1.17 to 2.5. The top layer of the antenna is called as the metallic patch which can be made of Gold or Copper and the lower layer is the ground plane which has to be infinite theoretically [2]. The efficiency of the patch antenna depends on its patch shape and size, substrate thickness and its dielectric constant, and also depends on the feed point location and type.

Circular microstrip patch antennas are one particular configuration of the antenna, which has more potential in the applications of low-profile antennas while considering its geometry. There are many shapes available for constructing microstrip patch such as Dipole, Square, Rectangular, Triangular, Circular, Circular Ring, Ring sector and Disc sector in which Circular patch has more advantages like flexibility in design and has largest bandwidth in terms of GHz and also it can give better return loss, radiation pattern and good directivity [8].

The radiation properties of the microstrip patch antenna can be improved by providing the partial ground plane. Hence, in this paper a partial ground plane is introduced at the bottom of the dielectric substrate to improve the bandwidth of the proposed design model.

The basic design model of the proposed antenna is given under the section I. Section II specifies the antenna dimensions and configuration using the conventional design formula. The last section deals with the result analysis of the depicted model with partial ground provided to it.

II. ANTENNA DESIGN

The proposed model of the antenna consists of a perfectly conducting patch and the ground plane with the FR4 substrate sandwiched in between them at the middle. The dimension of the designed microstrip patch antenna is of 55 × 56 × 1.6 mm3. The FR4 substrate has a relative permittivity of 4.4 and a loss tangent of 0.02. The thickness of the dielectric substrate used is of 1.6 mm. the upper radiating part comprises of a circular patch of radius of 12 mm calculated using the formula (3) given below for the resonant frequency of 3.5 GHz.

$$a = \frac{F}{\left[1 + \frac{2h}{\pi \varepsilon_r F}\left[l_n\left[\frac{\pi F}{2h}\right] + 1.7726\right]\right]^{1/2}} \tag{1}$$

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\varepsilon_r}} \tag{2}$$

$$a_e = \frac{1.8412 v_o}{2\pi f_r \sqrt{\varepsilon_r}} \tag{3}$$

The feeding technique given for excitation to the circular patch is of line feeding. The width of the line feed is calculated using (5), and a value of 25.88 mm is obtained for the resonant frequency of 3.5 GHz. Due to the design constraints, the width is slightly adjusted to 20.59 mm. The length of the line feed used is of 3 mm and is calculated using the formula from (5) to (7). The obtained result from the formula [6] has a dimension value of 19 mm. But for better resonant characteristics, only 1/6 times of the above obtained value is considered.

$$W_l = \frac{C_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{4}$$

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-\frac{1}{2}} \quad ; \quad \frac{W}{h} > 1 \tag{5}$$

$$\frac{\Delta L}{h} = 0.412 \frac{(\epsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\epsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \tag{6}$$

$$L = \frac{C_0}{2f_r\sqrt{\epsilon_{reff}}} - 2\Delta L \tag{7}$$

The ground plane used is of partial ground with a dimension of 20 mm as length and 55 mm as breadth. The length of the ground plane is assumed to be approximately 21 mm with a manipulation from (8) with a resonant frequency of 3.5 GHz.

$$L_g = \frac{\lambda}{4} = \frac{c}{4\, f_r} \tag{8}$$

III. ANTENNA CONFIGURATION

The design parameter for the depicted antenna is calculated using the above formula and the values for the design parameters are shown below in the tabular column.

In the table column X and Y denotes the breadth and length of the substrate, where X is of 55 mm and Y is 56 mm. The radius of the circular patch of the microstrip patch antenna is calculated using the formula (3), and the obtained radius is 12 mm, and it is represented as R in the Fig. 1.

TABLE I. DIMENSIONS OF THE PROPOSED MODEL

S.No.	Variable Representation	Designed Values
1	Radius of the circular patch, R	20 mm
2	Length of the substrate, Y	56 mm
3	Breadth of the substrate, X	55mm
4	Width of the line feed, W_l	20.59mm
5	Length of the line feed, L_l	3 mm
6	Length of the ground plane, L_g	20mm

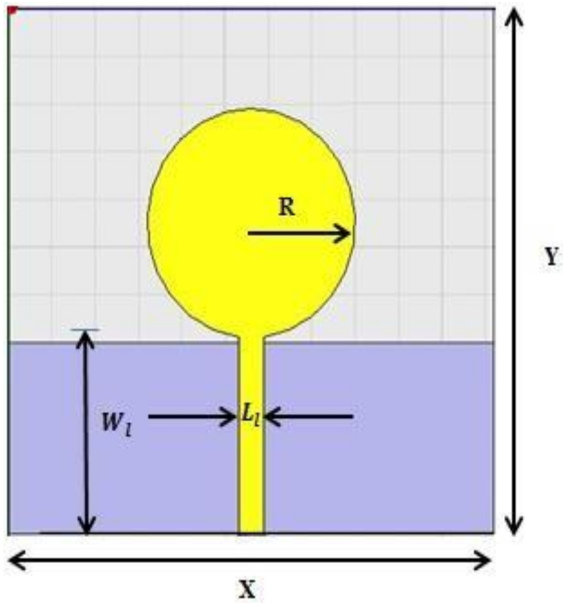

Fig. 1. Front view of the proposed model

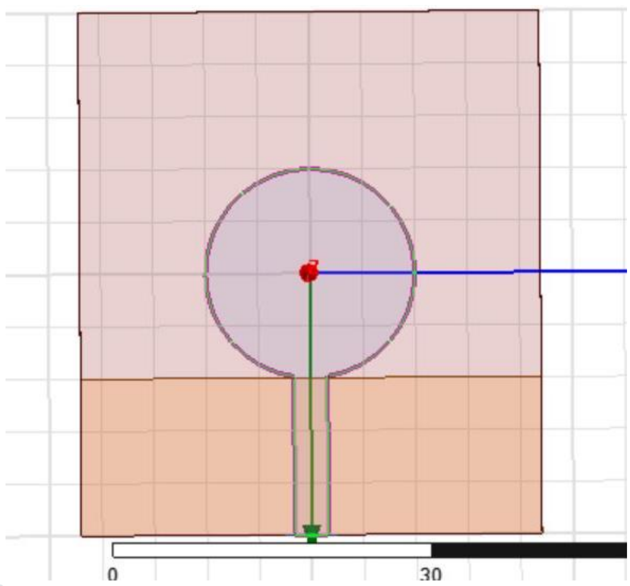

Fig. 2. Actual implemented antenna in HFSS Simulation Software

IV. RESULTS AND DISCUSSIONS

The proposed circular microstrip patch antenna is designed using the above parameters, and it is simulated using the Ansoft High Frequency Structural Simulator (HFSS V.12) software. The simulated graphical results such as return loss plot, Voltage Standing Wave Ratio (VSWR), gain, current distribution and directivity for the designed model is given as follows:

A. Return Loss

Return Loss is the plot of Reflection Coefficient in dB vs. frequency in GHz; Return Loss plot for the above proposed design is shown in the following figure. And the obtained graph shows that the proposed antenna resonates under three frequencies namely 2.32 GHz, 6.33 GHz and 10.21 GHz which has a return loss of -14.62 dB, -18.92 dB and -24.97 dB respectively. The obtained bandwidth for the resonant frequency starts from 1.58 GHz and ends with 11.54 GHz.

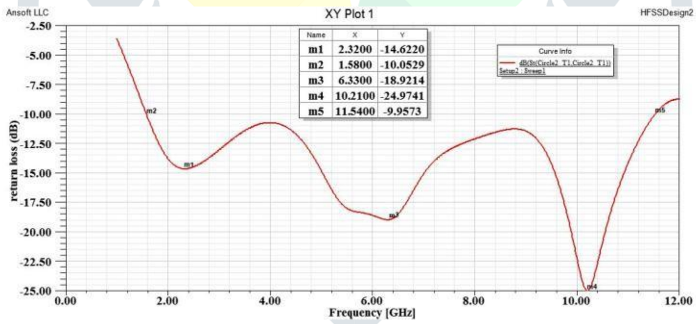

Fig. 3. Return loss plot for the depicted model

B. VSWR

Voltage Standing Wave Ratio (VSWR) generally refers to the ratio of Voltage Maximum to Voltage Minimum of the wave, which is stored internally in the dielectric. For efficient performance, the range of VSWR must fall under the value from 1 to 2. The VSWR obtained for the resonant frequencies of the designed antenna are 1.45, 1.25 and 1.12 for the frequencies 2.32 GHz, 6.33 GHz and 10.21 GHz respectively.

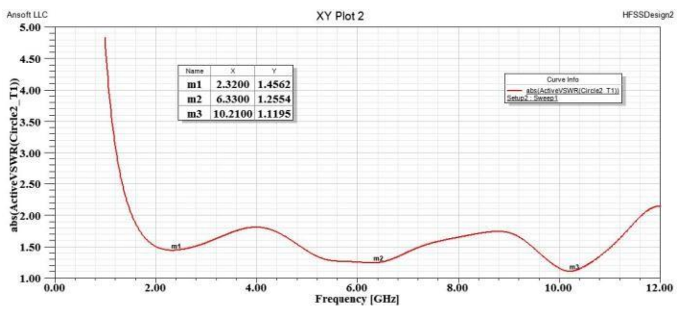

Fig. 4. VSWR vs frequency plot for the proposed UWB model

C. *Gain*

It is an important parameter of an antenna that defines the total power radiated in a particular direction. The unit of gain is dBi, which represents the logarithmic value of power based on Isotropic Antenna. The following figures represent the 3D polar plot for the obtained resonant frequencies.

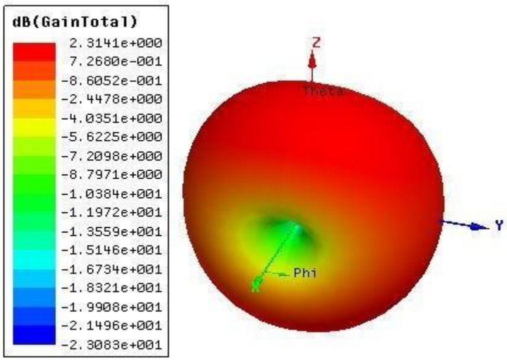

Fig. 5. 3D Polar plot of gain at 2.32 GHz

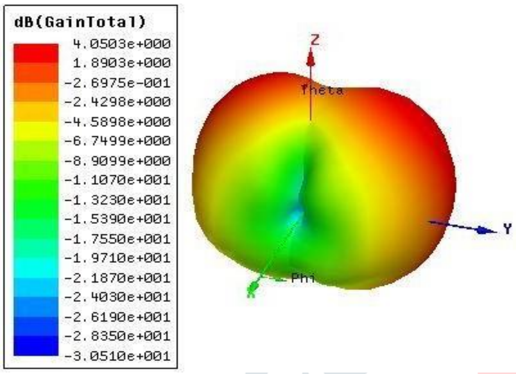

Fig. 6. 3D Polar plot of gain at 6.33 GHz

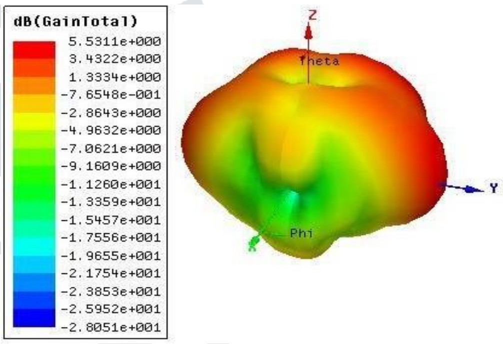

Fig. 7. 3D Polar plot of gain at 10.21 GHz

D. *Characteristic Impedance*

The plot of the characteristics impedance for the proposed model is shown in the Fig 8. For an antenna to function properly the value of the characteristics impedance should be 50Ω. And this is proved for the proposed model at various frequencies with an exact matching of 50Ω.

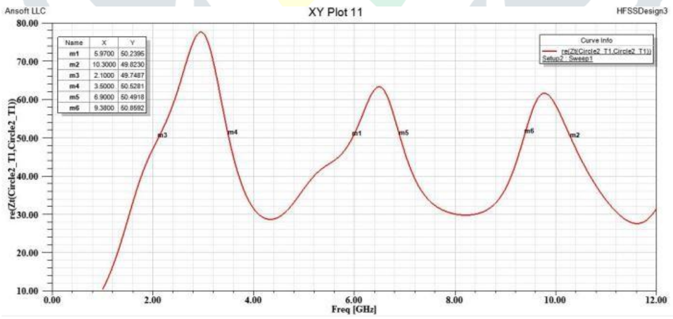

Fig. 8. Characteristic impedance of the proposed model

E. *Surface Current Distribution*

The flow of current in a microstrip patch antenna for a particular resonant frequency can be analysed using the Surface Current Distribution on the patch. The following figures from Fig. 9 to Fig. 11 depict the surface current distribution on the patch and the ground plane.

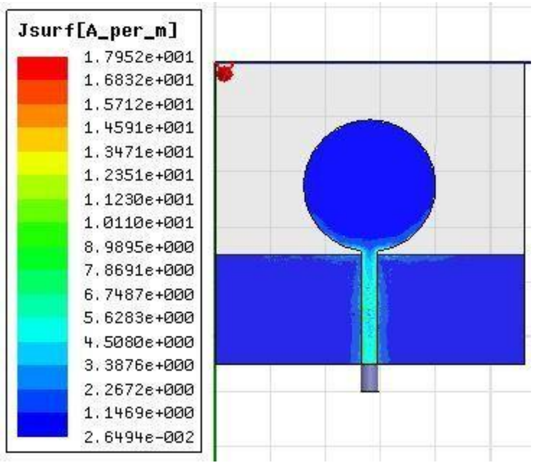

Fig. 9. Surface current distribution at 2.32 GHz

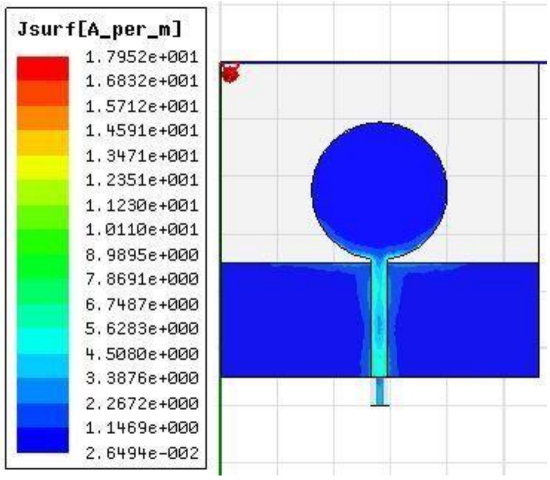

Fig. 10. Surface current distribution at 6.33 GHz

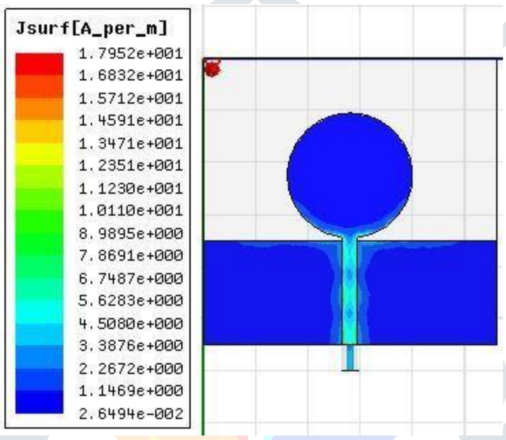

Fig. 11. Surface current distribution at 10.21 GHz

From the above figures, the current distributions for the resonant frequencies are mostly along the edges and with respect to ground. Hence, the radiation of the patch is more along the edges which lead to effective radiation.

TABLE II. RESULT OF THE PROPOSED CIRCULAR PATCH ANTENNA MODEL

Antenna Parameters	**Proposed Model (Circular Shape)**
Resonant Frequency	6.3 10.22
Return Loss (dB)	-19.3391 -24.0508
Gain (dBi)	4.0503 5.5311
VSWR	1.2554 1.1195
Bandwidth (GHz)	1.6 - 11.6 (10 GHz)

Thus, the proposed model results in good gain compared to that of the existing model (elliptical) and also it covers the entire UWB frequency range.

V. CONCLUSION

Thus, the circular microstrip patch antenna with partial ground structure is designed and simulated for UWB application. The obtained return loss plot covers the range from 1.58 to 11.54 GHz that includes the UWB range of 3.6 to 10.6 GHz. The other antenna parameters like gain, VSWR and current distribution obtained for the depicted model gives a satisfactory performance. The partial ground included in the model, enhances the radiation characteristics further to produce three resonant frequencies. Hence, the circular microstrip patch antenna designed with partial ground structure can be used for multi-band wireless communication.

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