

Design, simulation and analysis a microstrip antenna using PU-EFB substrate

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Abstract. A low cost, light weight and easy to fabricate are the most important factor for future antennas. Microstrip patch antennas offer these advantages and suitable for communication and sensor application. This paper presents a design of simple microstrip patch antenna working on operating frequency of 2.4 GHz. The designed process has been carried out using MATLAB and HFSS software by entering 2.3 for the dielectric constant of PU-EFB. The results showed that high return loss, low bandwidth and good antenna radiation efficiency of which are -21.98 dB, 0.28 dB and 97.33%, respectively.

1. Introduction

Wireless transmission technology, a microstrip patch antenna was the most popular, especially in microwave systems because of their attractive features. The microstrip patch antenna was small in size, light weight and easy to fabricate. It is also give high performance and low cost in production[1,2]. The basic configuration of the microstrip patch antenna shown in Figure 1.

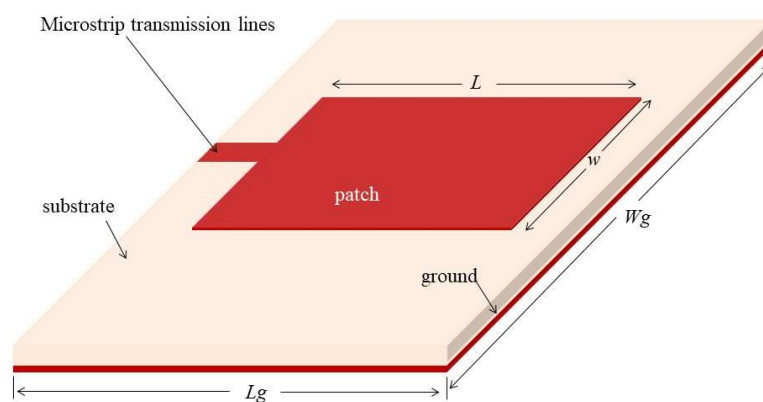


Figure 1. Rectangular Microstrip patch antenna configuration.



The geometry of a microstrip patch antenna consists of a patch on one side of a dielectric substrate and has a ground plane on the other side. The patch and ground are made of conducting materials such as copper and will connect. Feeding mechanism plays an important role in the design of microstrip patch antennas. A microstrip patch antenna can be fed either by coaxial probe or by microstrip feedline.[3]. In this study, microstrip patch antenna was using line feed for feeding technic. Microstrip feedline is easy to fabricate as it is a conducting strip connecting to the patch and therefore can be considered as extension of the patch[4]. The designing of patch antennas via using different software's has become most popular in recent years. This may be due to their useful dealings with much parameter, which extremely plays an important role in designing high performance antenna[5]. In this study, an antenna design was used polyurethane filled empty fruit bunch composite (PU-EFB) composite as a substrate[6]. The production of PU-EFB used low cost material. The main demand for technology in communication is the use of low cost and produce high-performance product. This study will designs and simulate an antenna to assess the effectiveness of dielectric material used as a substrate.

2. Patch Antenna design

The antenna is designed by using PU-EFB composites as substrate material with dielectric constant 2.3[6]. In designing the antenna, there are three steps follow as shown in Figure 2. First step is to calculate the dimension of the antenna using MATLAB2009a software. Follow by geometrical design by HFSS-13 software. The last step is to simulate the obtained antenna design using HFSS-13.



Figure 2. Steps in antenna's design and simulation.

2.1 Calculate dimension using MATLAB2009a

In calculate the dimension of antenna, other variables to be determined are the thickness of the substrate, dielectric constant of the substrate and the frequency of operation[2,7]. Here, the thickness value used was 3.0 mm, the dielectric constant was 2.3 and the frequency of operation was 2.4 GHz. The values that have to calculate in antenna design are

- Width of patch
- Length of patch
- Width of ground
- Length of ground

The width, w of the Microstrip patch antenna is given as:

$$w = \frac{c}{2f_o} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

Where,

f_o = operation frequency

c = speed of light

ϵ_r = dielectric constant of the substrate

In calculation of the length, L of the patch, there are several other computations included. The first unknown to be determine is the effective dielectric constant.[3] The effective value of dielectric constant ϵ_{eff} will be closer to the value of the actual dielectric constant ϵ_r of the substrate. The value of the dielectric constant of the substrate is given by:

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \left(\frac{h}{w} \right) \right]^{-\frac{1}{2}} \quad (2)$$

h = thickness of the substrate

ϵ_{eff} = effective dielectric constant of the substrate

The value for effective length can be calculated by using equation:

$$L_{eff} = \frac{c}{2f_o \sqrt{\epsilon_{eff}}} \quad (3)$$

Next to be calculating is length extension, ΔL . Because of fringing effects, electrically the micro strip antenna looks larger than its actual physical dimensions[7]] .The length extension is given by equation:

$$\Delta L = 0.412h \frac{(\epsilon_{eff} + 0.3) \left(\frac{w}{h} + 0.264 \right)}{(\epsilon_{eff} - 0.258) \left(\frac{w}{h} + 0.8 \right)} \quad (4)$$

The actual length of patch (L) is obtained by

$$L = L_{eff} - 2\Delta L \quad (5)$$

In designing patch antenna, it must have a finite ground plane, with the type of material being carried out. The ground has the same dimensions on the substrate but they are larger than the dimensions of the patch by six times the substrate thickness around the periphery[2,5]. The dimension ground plane could be calculated by equation

$$L_g = 6h + L \quad (7)$$

$$W_g = 6h + w \quad (8)$$

Where

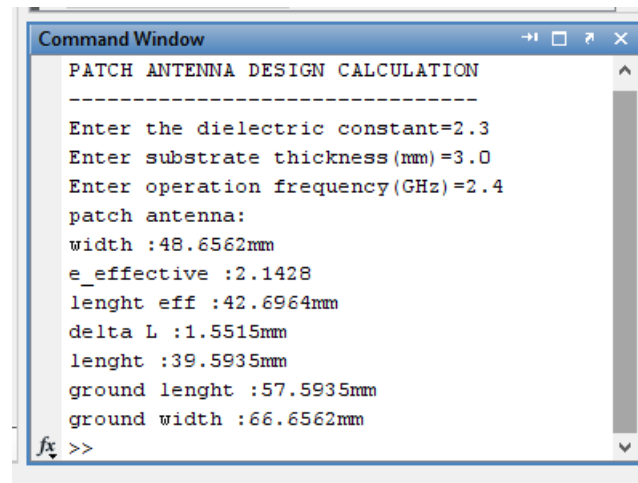
w = width of the patch antenna

L = length of the patch antenna

W_g = width of ground plane

L_g = length of ground plane

By using the parameter of dielectric constant of the substrate which is 2.3, thickness of the substrate 3.0 mm and operation frequency is 2.4 GHz, the dimension for patch and ground plane has been calculated via MATLAB 2009b software. The result for patch and ground shows in Figure 3.



```

Command Window
PATCH ANTENNA DESIGN CALCULATION
-----
Enter the dielectric constant=2.3
Enter substrate thickness (mm)=3.0
Enter operation frequency (GHz)=2.4
patch antenna:
width : 48.6562mm
e_effective : 2.1428
length eff : 42.6964mm
delta L : 1.5515mm
length : 39.5935mm
ground length : 57.5935mm
ground width : 66.6562mm
fx >>

```

Figure 3. Dimensions result for patch antenna obtained from MATLAB2009a.

Through MATLAB2009a programming, the dimensions for antenna obtained are list in the Table 1.

Table 1. Dimensions value for patch antenna design from MATLAB2009a software.

Parameter	Dimension (mm)
w = width of the patch antenna	48.656
L = length of the patch antenna	39.593
W_g = width of ground plane	57.593
L_g = length of ground plane	66.656

2.2 Geometrical design and simulation using HFSS-13.0

By using the dimensions in the table, the HFSS-13.0 software will be used to design the geometry for the antenna. HFSS stands for High Frequency Structural Simulation, commercial finite element method for electromagnetic structure from Ansys Corp. One of several commercial tools used for antenna design. The patch antenna is designed to be located at origin coordinates x-y plane while the height of the substrate lies in z-direction. Feeding technique used in antenna was microstrip line feed. The geometry design illustrates in Figure 4.

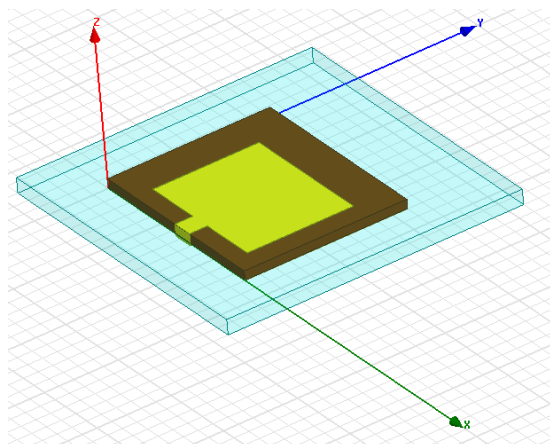


Figure 4. The image of patch antenna from HFSS-13 software.

In this type of feed technique, a conducting strip is connected directly to the edge of the microstrip patch. Through this method, the fabrication process is easier [8]. A polyurethane filled empty fruit bunch (PU-EFB) composite with a thickness of 3.0 cm and an approximate dielectric constant of 2.3

was used. By using data from MATLAB calculations and predefined values, this antenna needs to be adjusted so that the antenna can operate at a 2.4 GHz resonant value. All data from HFSS-13 simulated provided in table 2.

Table 2. Data obtained from HFSS-13.

Parameter	Material	Dimension (mm)		
		Width	Length	Height
Ground	Copper	65	55	0.1
Substrate	PU-EFB	65	55	3.0
Patch	Copper	45	36	0.1
Feed line	Copper	7	20	0.1

3. Result and Discussion

The performance of designed antenna determine by a few parameters such as return loss, bandwidth, VSWR, radiation pattern, directivity and antenna gain.

3.1 Return loss

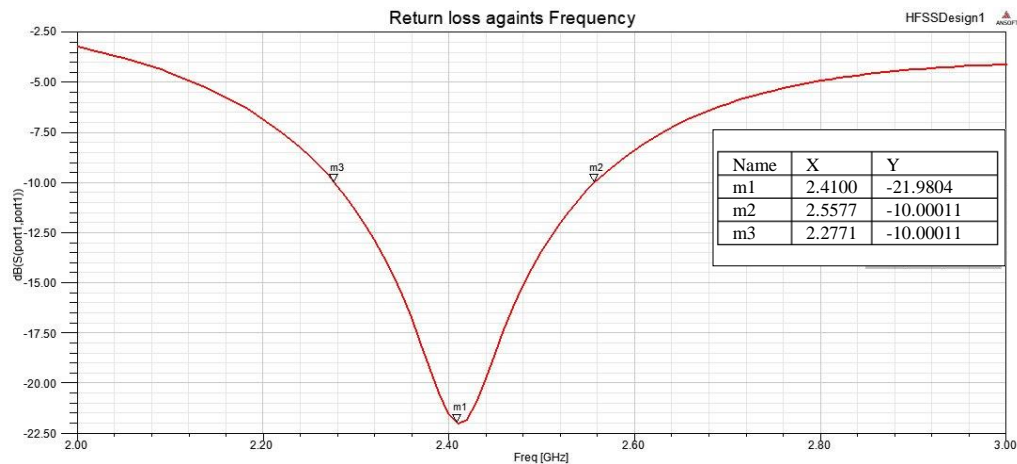


Figure 5. Return loss vs. frequency for patch antenna at 2.4 GHz frequency.

The return loss represents how much feeding power that was reflected back at the port of patch antenna as a result of the mismatches between the transmission line and the feeding points[5]. When the antenna and transmission line are not perfectly matched, reflections at the antenna port travel back towards the source and cause a standing wave to form[1]. Good antenna must have high return loss[9]. From figure 5 implies that the antenna radiates best at the chosen resonance frequency, 2.4 GHz, where the return loss is equal to -21.98 dB.

3.2 Bandwidth

The bandwidth of an antenna refers to the range of frequencies over which the antenna can operate correctly. The antenna's bandwidth is the number of Hz for which the antenna will exhibit an SWR less than 2:1[10]. The value of bandwidth can be by referring to the graph return loss against frequency at point 10 dB[11]. As shown in graph return loss against frequency in figure 5, the value of bandwidth is 0.28 dB. Different types of antennas have different bandwidth limitations[7].

3.3 Voltage Standing Wave Ratio (VSWR)

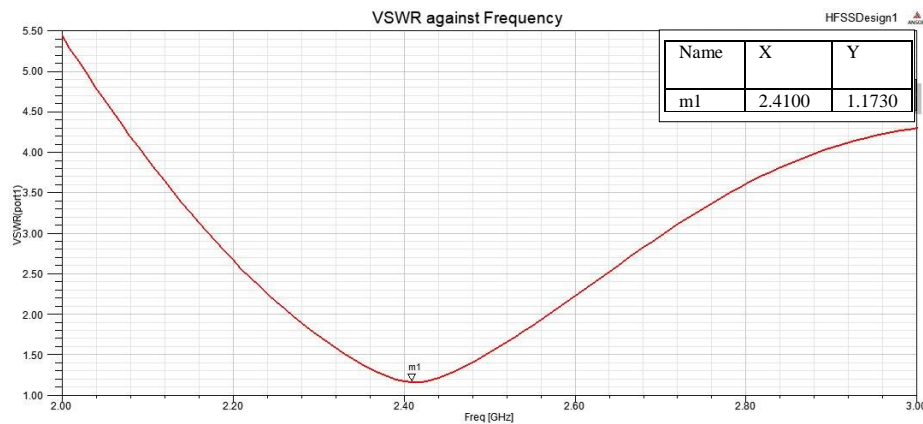


Figure 6. VSWR against frequency plot of the patch antenna.

VSWR shows how much power is reflected back from the antenna towards the source. The good value that accepted for antenna is $1 \leq \text{VSWR} \leq 2$ [1,12]. If the VSWR value equals 1, means all of the given power to the antenna is transmitted. From figure 6, the value for designed antenna is 1.17.

3.4 Radiation Pattern

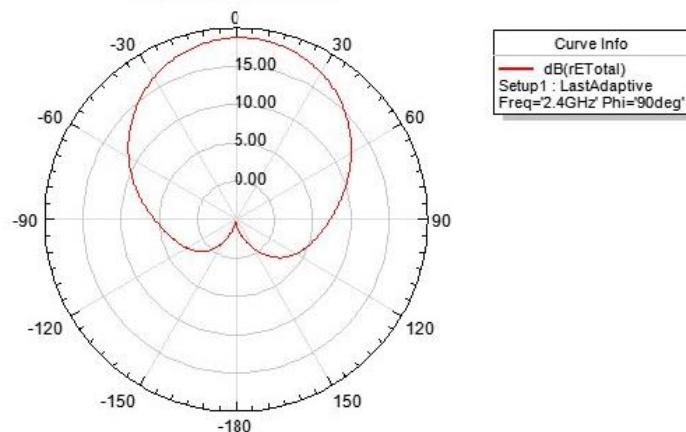


Figure 7(a). 2D radiation pattern at 2.4 GHz frequency.

The energy radiated by antenna is represented by radiation pattern of the antenna. There are a few types of radiation pattern such as 3D radiation pattern, 2D radiation pattern and Lobe formation radiation pattern. Figure 7(a) present the radiation pattern of 2D radiation pattern at 2.4 GHz at phi equals 90deg. The radiation pattern of an antenna has a normal radiation distribution to its surface and it gives an image nature of the value and direction of radiation, by which the antenna emits or receives the electromagnetic waves[5]. Figure 7(b) shows the elevation pattern for designed antenna in 3D radiation pattern

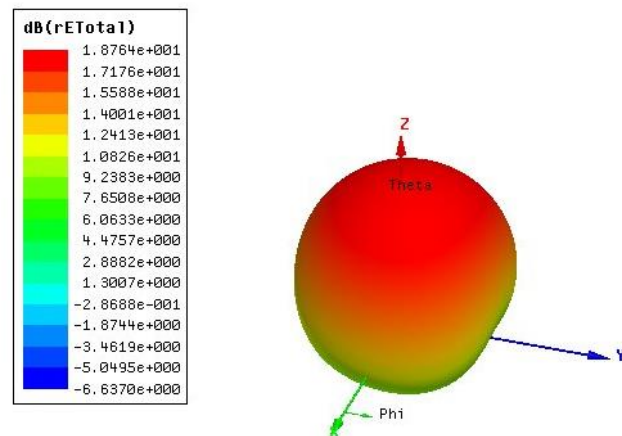


Figure 7(b). 3D radiation pattern at 2.4 GHz frequency.

3.5 The directivity

Directivity is the ability of an antenna to focus energy in a particular direction when transmitting, or to receive energy better from a particular direction when receiving [7]. An antenna that radiates equally in all directions would have effectively zero directionality, and the directivity of this type of antenna would be 1 (or 0 dB)[1]. Figure 8 shows the directivity of designed antenna at 2.4GHz

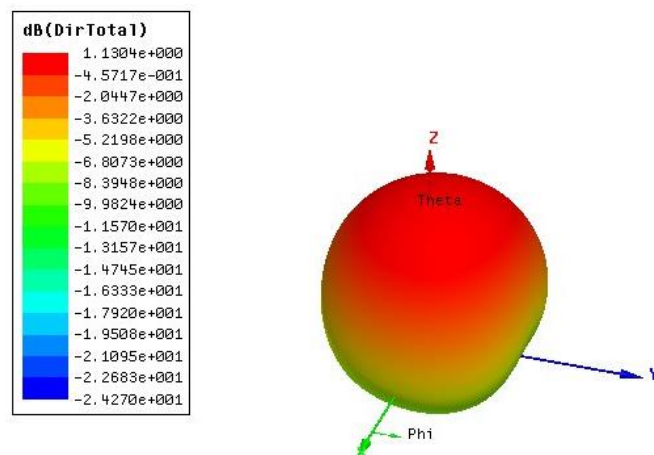


Figure 8. Directivity of patch antenna at 2.4 GHz frequency.

3.6 The Antenna gain

Figure 9 shows represent the antenna gain for phi equal to 90°. The gain of an antenna is defined as the ratio of intensity in a given direction to the radiation intensity that is obtained if the power accepted by the antenna is radiated in an isotropic manner [1]. The gain of the antenna is closely related to the directivity. The gain of an antenna is the efficiency of the antenna as well as directional capabilities [1,7]. Equation (9) gives the relation between gain and directivity of an antenna.

$$G = \eta * D \quad (9)$$

Where, η = the efficiency, D = the directivity

An antenna is not a lossless system, and some energy entering the antenna terminals is lost due to heat losses etc. The gain of an antenna describes the rates of power transmitted to peak radiation through isotropic source.

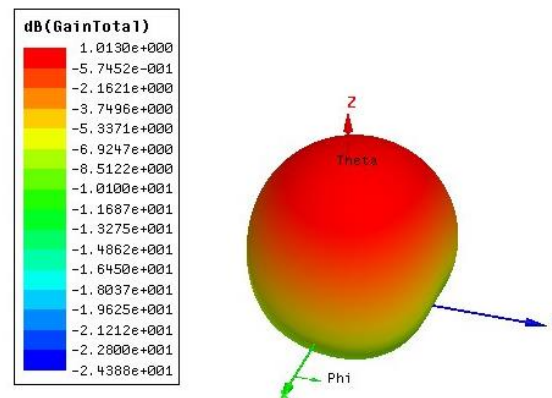


Figure 9. 3D gain total of patch antenna at 2.4 GHz.

4. Conclusion

A microstrip antenna for PU-EFB substrate bands has been successfully designed in a single patch with $50\ \Omega$ probe feed. The antenna simulation give the value for return loss below -10dB [12] which is the value for the design antenna is -21.98dB . Antenna radiation efficiency is 97.33% in the designated for frequency 2.4GHz . The gain of the antenna is in conformity to work perfectly and directivity of the proposed antenna shows that it has a good directional performance.

Acknowledgments

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