TRANSACTIONS ON ELECTROMAGNETIC SPECTRUM

A Compact Microstrip Patch Antenna for X-Band Applications

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Abstract: Nowadays, microstrip antennas are widely used in wireless applications. There are so many bands of frequency and they can be listed out L, S, X, Ka etc. For this work, it is only focused on X bands only. The range of frequency of X band is from 8 to 12 GHz. In this paper, the design and simulation of the compact microstrip patch antenna for X band applications are proposed and the main goal of this paper is to get good results from the designed antenna. The software used in this paper is HFSS 15 (High Frequency Structure Simulator 15). The proposed antenna is a rectangular microstrip patch with the dimensions of 6 mm x 5 mm and it is designed on the substrate material of FR4, with the dielectric constant of 4.4 and operating frequency of 11 GHz. After simulation, 2.8 dB gain is obtained and bandwidth equals to 700 MHz, directivity equals to 3.96 dB, VSWR (Voltage Standing Wave Ratio) equals to 1.24. These results show that antenna is very suitable for X bands applications such as satellite communication, wireless computer networks, etc.

Keywords: Patch antenna, X-bands, HFSS, Resonant frequency

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1. INTRODUCTION

Today, with the explosion of telecommunications, some constraints are found in commercial wireless applications [1,2]. The patch antennas have been proposed to meet to these requirements. In the past decade, it has witnessed the use rapidity of these antennas in communication and other systems such as satellite and radar. They combine small size, simplicity, ease of manufacturing and implementation, they adapt easily to flat and non-flat surfaces and exhibit a large sturdiness when mounted on rigid surfaces.

A microstrip antenna generally has 3 fundamental parts which are the patch (the most used shape is the rectangle, let's not forget to say that circular and triangular shapes are also used a lot), the substrate (which is a surface that is polarizable if electrical energy is applied to it and which allows communication between the ground plane and the patch) and the ground plane (which is a large copper surface which allows electromagnetic waves to be conducted) [3,4]. The general structure of patch antenna is given in Figure 1.

A printed antenna consists of a plate metal of any shape, called the radiating element, located on the upper face of a dielectric substrate. In another aspect, antennas are integral components in a communication system, communication which requires special study. While seeking to improve the performance of an antenna, it must be adapted to the most recent applications. The antenna should also meet the constraints of multiplying frequency bands, broadband and integration. Finally, the characteristics of the antennas must be little influenced by the environment. This study is more focused on X bands of frequency, especially at 11 GHz.

The patch antenna feeding technique is one of the most important parts in the design process, several techniques were then considered for this purpose [3], we can classify these techniques into two categories such as: Feeding by contact (Powered by a micro line, direct coaxial feed) and feeding by proximity (Powered by electromagnetic coupling, by opening coupling (slot) in the ground plane).

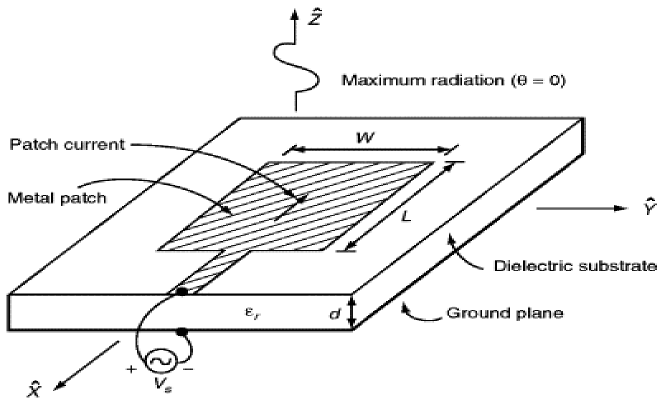

Figure 1. Rectangular Microstrip Patch Antenna [4]

The antenna is made by engraving of a printed circuit. Due to their manufacturing technology, these can be integrated into the electronic circuits by occupying a reduced volume and conforming to different types of surfaces. Their main advantage is their low manufacturing cost. Patch antennas are used in many applications from the X bands [4,5,6].

2. DESIGN PROCESS

To design any antenna, it is needed to consider some parameters like frequency, substrate material and thickness of the antenna. For this paper, it is designed an antenna at 11 GHz as operating frequency, FR4 material, 1.6 mm of thickness (h) and dielectric constant (ε_r) 4.4. Based on those parameters, it could be able to calculate the dimensions of antenna (W= width and L= Length) with the Equations 1-7 below where c = 3 x 10^8 m/s.

$$W = \frac{c}{2f} * \sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (1)$$

$$\Delta L = 0.412h \frac{(\varepsilon_r+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_r-0.258)(\frac{W}{h}+0.8)} \qquad (2)$$

$$L = \frac{c}{2f}\left(\frac{\varepsilon_r + 1}{2} - \frac{\varepsilon_r - 1}{2}\sqrt{\left[1 + 12\frac{h}{w}\right]}\right)^{-\frac{1}{2}} - 2\Delta L \qquad (3)$$

And the dimensions of substrate are calculated using the following Equations 4-5.

$$L_g = 6h + L \tag{4}$$

$$W_g = 6h + W \tag{5}$$

To feed an antenna, there are several types of feedings mechanisms and it is chosen as a microstrip feeding. So, the Equations 6 and 7 are used for the calculation of its dimensions [10]. The parameters of the antenna are given in Table 1.

$$Lf = \frac{L}{2}\sqrt{\varepsilon_r} \tag{6}$$

$$Wf = \frac{W}{2} \tag{7}$$

Table 1. Antennas Parameters

Symbols	Details	Values
f	frequency	11 GHz
h	thickness	1.6 mm
Wp	Width of patch	6 mm
Lp	Length of patch	4.5 mm
Wg	Width of ground	9 mm
Lg	Length of ground	7 mm
Wf	Width of feeding	0.6 mm
Lf	Length of feeding	2.25 mm
a		0.5 mm
b		1.5 mm
c		0.3 mm
d		1 mm

HFSS 15 software is used to design and simulate the proposed antenna. The figure 2 shows the proposed compact microstrip patch antenna designed in HFSS program.

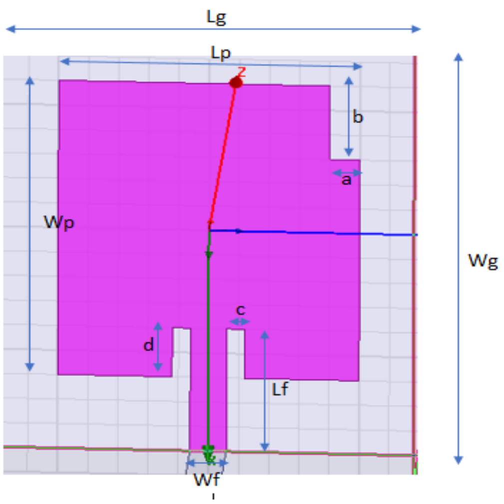

Figure 2. Compact microstrip patch antenna

Figure 2 shows the compact microstrip patch antenna with a microstrip feeding line. For a getting better result, it is slotted from (a x b) the patch to improve the value of parameters.

3. RESULTS AND DISCUSSION

The simulation of the proposed antenna has been done through HFSS 15, and the results have been discussed in this part. Gradually, it is found out the reflection coefficient, VSWR, gain, directivity and radiation pattern.

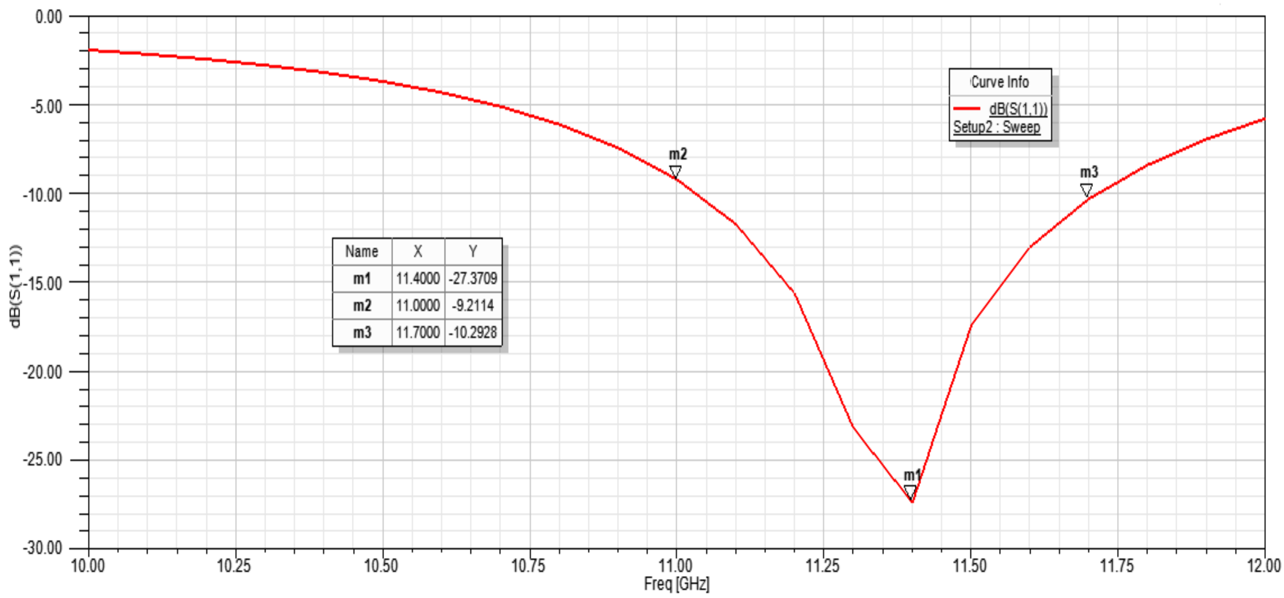

Figure 3. S11 of the compact microstrip patch antenna

The points m1, m2 and m3 on the Figure 3 represent respectively the place of the lower frequency, the operating frequency and the highest frequency. Based on that, we can calculate the range of frequencies where the antenna can operate which is call bandwidth (B). The Equation 8 below will show how it is calculated.

$$B = F_h - F_l \qquad (8)$$

In this equation, Fh is the highest frequency and F_l is the lowest frequency. As it is seen in the Figure 3, the bandwidth of the antenna is equal to 700 MHz and the reflection coefficient is equal to -27.37 dB, that means only 0.18% of the transmitted power have been reflected back (to know the value of the transmitted power reflected back in watts (W) from the transmitted power reflected back in dB, it can be calculated using Equation 9) [7,9]:

$$P(W) = 10^{\frac{P(dB)}{10}} \qquad (9)$$

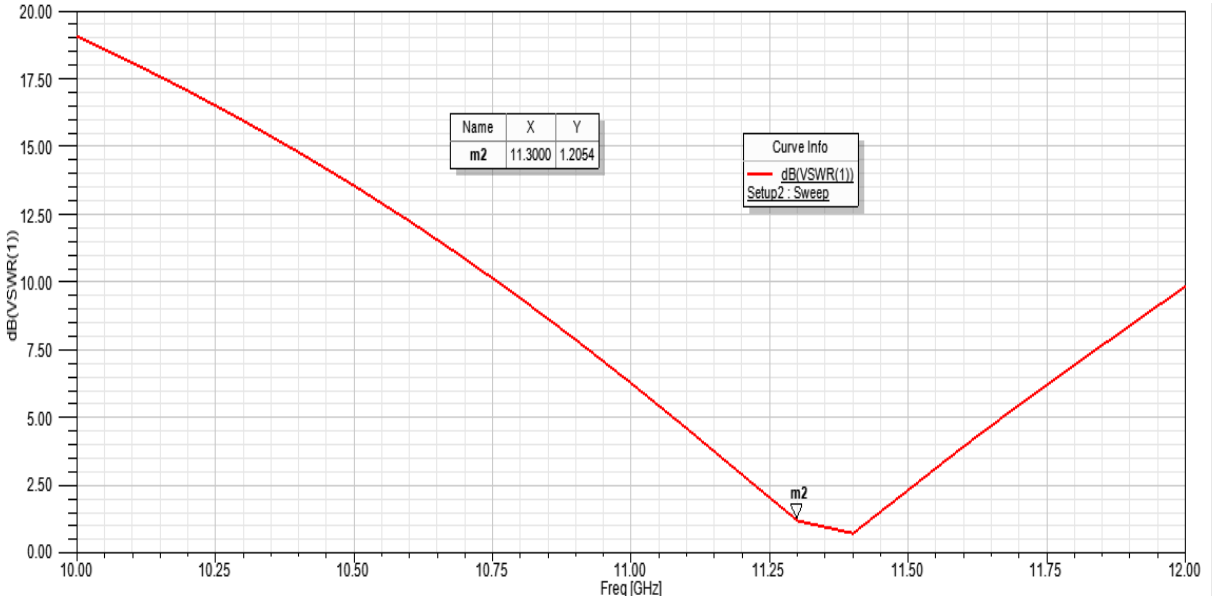

Figure 4. VSWR of the compact microstrip patch antenna

VSWR of the antenna can be easily calculated from the following Equation 10:

$$VSWR = \frac{|1 + r|}{|1 - r|} \qquad (10)$$

In this equation, r is the reflection coefficient, based on that equation, VSWR of the antenna equals to 1.24 and based on the Figure 4, VSWR of the antenna equals to 1.2064. It can be said that the calculation and simulation result are almost same. VSWR shows the amount of the signal that has been reflected back due to mismatch components in the system.

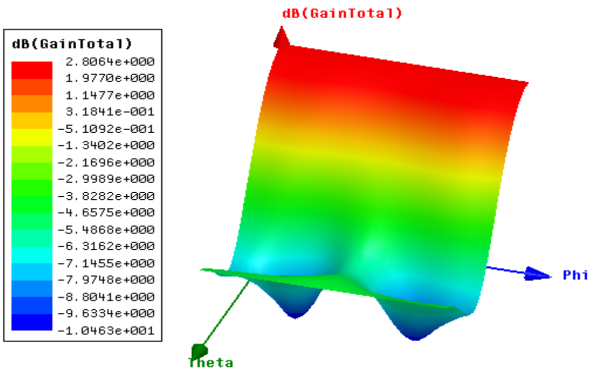

Figure 5. Gain of the compact microstrip patch antenna

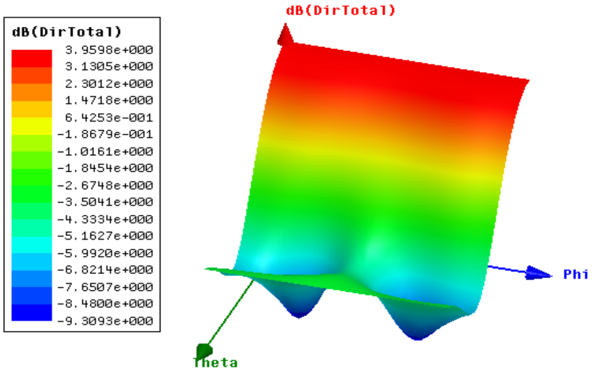

Figure 6. Directivity of the compact microstrip antenna

The Figure 5 and Figure 6 show respectively the highest value of the gain and directivity of the compact microstrip patch antenna which are the 2.806 dB and 3.96 dB. Those values are good for an application that has a frequency with the value of 11 GHz.

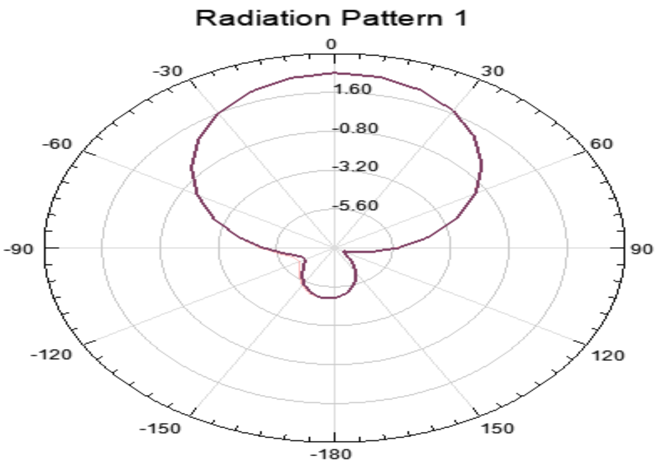

Figure 7. Radiation pattern of the compact microstrip patch antenna

The Figure 7 shows the radiation pattern of the proposed antenna and it can be easily said that the quantity of the reflected power is very small. So, the antenna only has the main lobe with a percentage of the transmitted power equals to 99.82 % and the back lobe with a percentage of the reflected power equals to 0.18%.

Table 2. Summary of results

Parameters	Values
Operating frequency	11.3 GHz
Dimensions of the patch	6mm x 5mm
Bandwidth	700 MHz
Gain	2.8 dB
Directivity	3.96 dB
VSWR	1.24
Reflection coefficient	-27.37

4. CONCLUSION

In this paper, it is proposed a compact microstrip patch antenna for X band applications using HFSS 15 at 11 GHz of frequency. The proposed antenna can be suitable for wireless applications since it has a wideband of frequency. Table 2 shows the summary results of the proposed antenna. The further work will consist to fabricate the antenna and compare the results with the simulated ones.

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