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Optimization of Parameters of Line-Fed Micro-Strip Patch Antenna Using Fr-4 And Rogers Tmm6 Substrates

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ABSTRACT: Micro-strip patch antennas are generally applied in compact and portable communication devices due to their low profile configurations, small size, conformity and low fabrication cost. Despite these significant advantages, the patch antenna suffers some serious problems like low gain and narrow bandwidth (due to small size). Micro-strip antenna with different shapes have been designed in order to overcome the challenges. Therefore, in this research, a line fed Micro-strip triangular patch antenna was designed, simulated and then optimized at a frequency around 2.45GHz. The antenna was designed and simulate using CST microwave studio with two different substrates, FR-4 and Rogers TMM6 whose dielectric constants are 4.4 and 6 respectively. Antenna with ROGERS TMM6 substrate demonstrated smallest effective length compared with FR-4 EPOXY, with a least directivity. However, antenna with FR-4 EPOXY substrate significantly exhibit the most optimized directivity, gain, VSWR and bandwidth. Similarly, the proposed antenna resonated at 2.45GHz may have a sufficient bandwidth compared to conventional patch antennas. This make it suitable in S-band (2400-2485MHz) for bluetooth and communication applications.

KEYWORDS: antenna, dielectric constant, gain, directivity, substrate.

1.0. INTRODUCTION

An antenna is one of the central elements in RF system that is assigned to radiate or receive radio wave signals (electromagnetic waves) in all horizontal directions uniformly (omnidirectional antennas), or discriminately in a particular direction (directional antennas) from and into the air as a medium. To serve the system well, some applications may require the optimization of the radiated energy in some directions while suppressing it in other directions. The operation of antenna system relies heavily on the radiation of EM waves at both the transmitting and receiving sites [1]. Microstrip patch antennas are small size antennas that can be printed right on a circuit board and due to their numerous attractive features have drawn attention of industries for an extreme solution for wireless communication. Wireless technology has advanced rapidly not only for military but also for commercial purposes, because it offers low cost alternative and a malleable way for communication. To simplify investigation and performance prediction, the patch is prevalently rectangular, square, triangular, circular and elliptical or some other common shapes [2].

Due to the low profile configurations, Micro-strip patch antennas are mostly applied in compact and portable communication devices. Despite these significant advantages, the patch antenna has some serious glitches such low gain and narrow bandwidth because of its small size. It was also found that that the use of substrate material with higher dielectric constant in Micro-strip patch antennas design causes degradation of antenna performance, but size of the antenna reduces [3]. Equilateral triangular micro-strip patch antenna using different substrate improve the performance, low permittivity value was observed but high thickness is required, as it offer better efficiency, larger bandwidth and better radiation. But such a design leads to antenna of larger size [4].

There is also limited studies directly comparing the performance of FR-4 and Rogers TMM6 under similar conditions. There is need for more comprehensive comparative analysis could yield insights into cost-effectiveness and performance trade-offs. Previous researches often overlooks how temperature, humidity, and other environmental factors affect the performance of antennas made from these substrates [5]. Investigating these variables could lead to better real-world applicability. While many studies rely on traditional simulation tools, there's room for the application of advanced computational techniques (e.g. machine learning, genetic algorithms) to optimize parameters more efficiently. Most research focuses on single-band antennas. Exploring multi-band or wideband designs using these substrates could address the growing demand for versatile communication systems [6].

Hence, in this research a line fed Microstrip Triangular Patch Antenna (MTPA) was chosen in order to have a low gain, narrow bandwidth as well as small size for Bluetooth

Application at 2.45GHz. this research is expected to have more detailed sensitivity analyses on how variations in substrate parameters affect antenna performance can help in robust design.

2.0. LITERATURE REVIEW

Many techniques have been suggested to improve the performance of conventional microstrip triangular patch antennas for practical applications. The performance of a microstrip triangular patch antenna with FR-4 substrate was analyzed using IE3D software and recorded a bandwidth of 32.96% with substrate thickness of 4mm at 2.66GHz, a gain of only 4.60dBi at 2.87GHz and a directivity of 5.07dBi at 2.87GHz that the use of substrate material with higher dielectric constant in microstrip patch antenna design, results in degradation of antenna performance, but size of the antenna reduces [7].

An equilateral triangular micro-strip patch antenna using different substrates was investigated to give clue about bandwidth variations with change of substrate material using Ansoft HFSS designer software. The results established that for good antenna performance, a dielectric with low permittivity value but high thickness is required, as it offer better efficiency, larger bandwidth and better radiation. But such a design leads to antenna of larger size and the authors did not consider the best feeding method [8].

Microstrip patch antennas can be fed by a variety of methods. These methods can be classified into two categories-contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch [9]. The four most popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes). However, as the thickness of the dielectric substrate increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna. This type of feeding technique results in undesirable cross polarization effects [10].

3.0. RESEARCH METHODOLOGY

In this research, the geometry of the microstrip triangular patch antenna was designed using two different substrates; FR-4 Substrate and Rogers TMM6 substrate. The simulation will be done using CST Microwave Studio software. However, when simulating the antenna, the calculated values of the parameters were optimized in order to get a better and more accurate antenna response and to maintain the resonant frequency at 2.45 GHz

Many micro-strip patch antenna parameters are compared and analysed. Some parameters are return loss, VSWR, radiation pattern, gain, bandwidth, surface current, and efficiency. In designing antennas, the antenna gain, the reflection coefficient, and the power transfer efficiency are the factors that are evaluated. These factors are broken down even further into their directivity, radiation pattern, and beam width components. The antenna gain, its radiation pattern, and its directivity was defined with the pattern command. The beam width code makes it possible to observe the antenna's beam width and directivity. Based on the range of frequencies, the s-parameter made it possible to figure out the return loss and, in turn, the design's reflection coefficient.

On the other hand, the operating frequency of 2.45 GHz was chosen before the design process. The frequency at which the antenna vibrates most strongly is called its resonating frequency (-10 dB) [16]. The resonating frequency was lower than the operating frequency due to various factors, such as fringing fields etc. The resonant frequency is the frequency at which the patch receives the most significant amount of power or the frequency at which the impedance of the patch and feedline are most closely matched.

A microstrip line with an impedance of 50 ohms was attached to the patch in this configuration. The port is connected at the other end of the additional microstrip line introduced, which acts as a feeding point for the microstrip patch antennas. The length of the feeding line does not depend on any other characteristics. In contrast, the width is determined by applying the more traditional equations to the same frequency and impedance of 50 ohms.

4.0. DISCUSSION OF RESULT

Results for the simulation of the two antennas with different substrates was discussed below;

4.1. Results for the simulation of Antenna with FR-4 Substrate

Various parameters like Return loss, Directivity, Gain, Bandwidth, VSWR and Efficiency of the MTPA with FR-4 substrate were analysed. Figure 1 shows the antenna resonated at 2.45GHz with S11 value of -32.414dB which indicates better coupling that result to high value of the directivity and gain for the antenna designed. For this particular substrate, the measured -10dB bandwidth is 41MHz as shown in figure 3. Figure 4 shows the VSWR plot of 1.05.

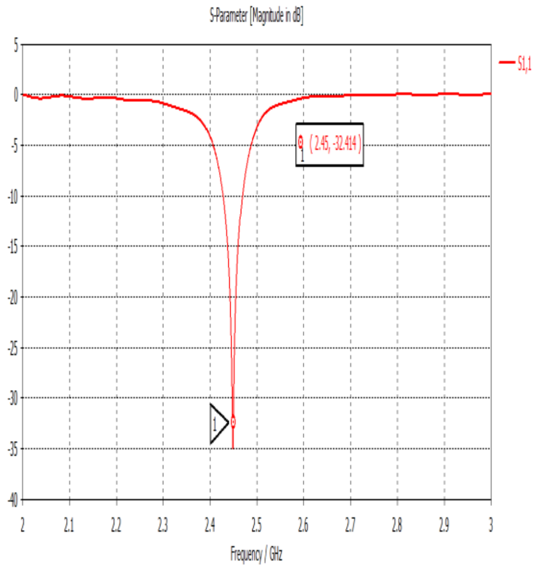
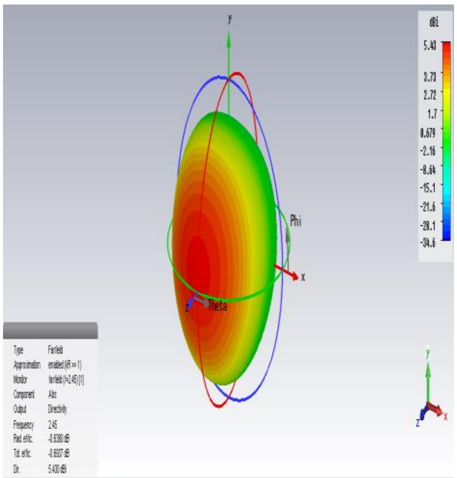


Fig. 1: Return Loss of Simulated Antenna

Figures 2(a) and 2(b) represents the 3D and polar directivity plots of the antenna resonating at 2.45GHz with a directivity value of 5.43dBi which means the designed antenna radiates more by an amount of 5.43dBi in a particular direction when compared with an isotropic antenna.



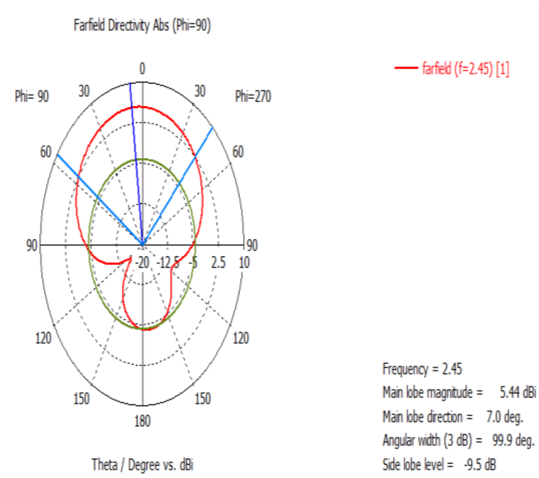
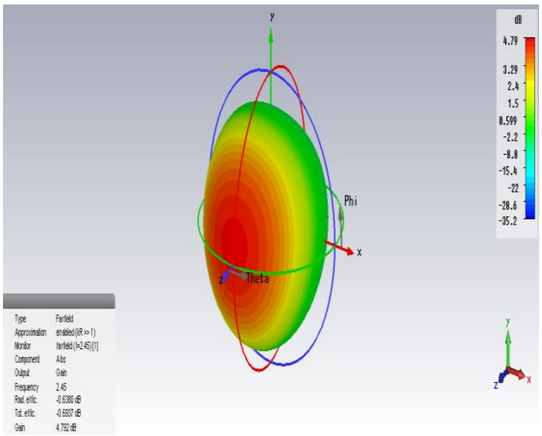


Fig 2(a): 3D Directivity of Triangular Patch Antenna **Fig. 5(b): Polar Directivity of Triangular Patch Antenna**

Figure 3(a) and 3(b) shows the 3D and polar gain plots of the antenna. The antenna resonated at 2.45GHz with a gain value of 4.79dB. It is clear that the proposed antenna is good for Bluetooth application in wireless communication systems.



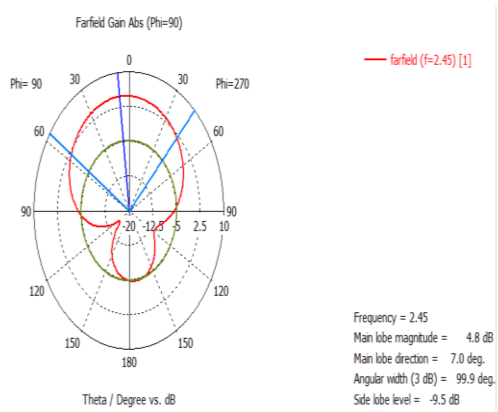


Fig. 3(a): 3D Gain of Triangular Patch Antenna **Fig. 3(b): Polar Gain of Triangular Patch Antenna**

4.2. Results for the simulation of Antenna with FR-4 Substrate

Similarly, Figure 4 shows that the MTPA resonated at 2.45GHz with a S_{11} of -34.38dB. For this particular substrate, the measured -10dB bandwidth is 40 MHz as presented above with a value of 1.04.

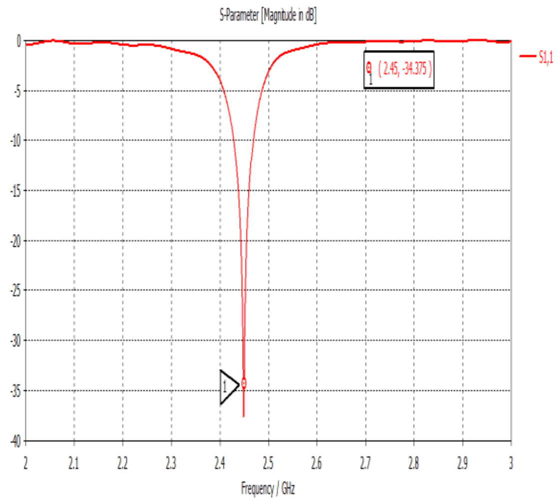


Fig 4: Return Loss of Simulated Antenna

Figures 5(a) and 5(b) represents the 3D and polar directivity plots of the MTPA resonating at 2.45GHz with a directivity value of 5.11dBi which means the designed antenna radiates more by an amount of 5.11dBi in a particular direction when compared with an isotropic antenna.

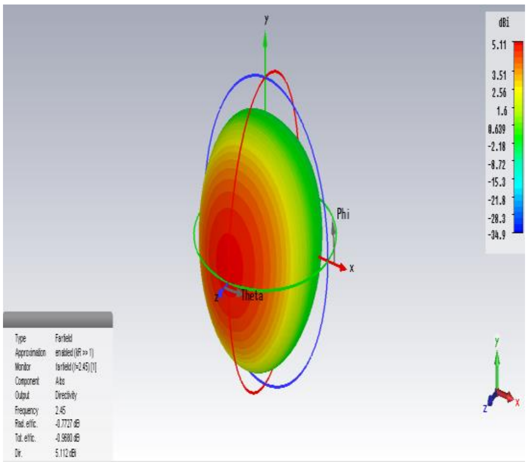


Fig. 5(a): 3D Directivity of Triangular Patch Antenna

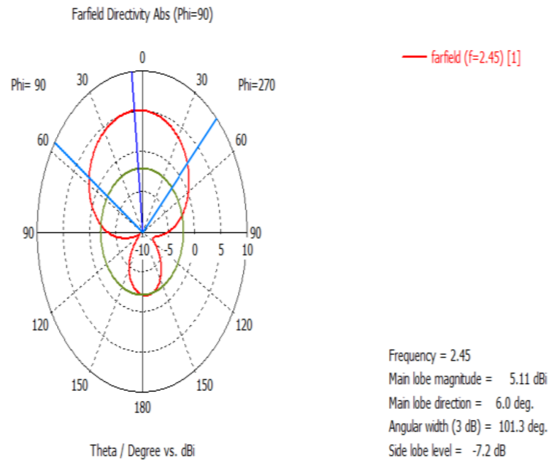


Fig. 5(b): Polar Directivity of Triangular Patch Antenna

Figures 6(a) and 6(b) shows the 3D and polar gain plots of the antenna. The antenna resonated at 2.45GHz with a gain value of 4.34dB. It is clear that the proposed antenna is also good for Bluetooth application in wireless communication systems.

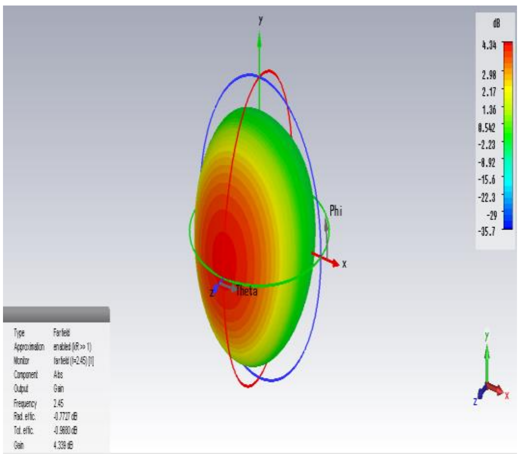


Fig. 6(a) 3D Gain of Triangular Patch Antenna

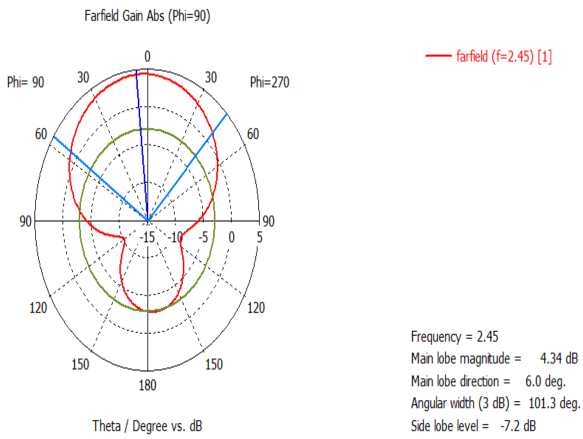


Fig. 6(b) Polar Gain of Triangular Patch Antenna

4.3. Comparison of the results of the two antennas of different substrates

The MTPA designed with FR-4 substrate showed S11 of -32.414dB, directivity of 5.43dBi, gain of 4.79dB, Bandwidth of 41 MHz, VSWR of 1.05 and efficiency of 86% respectively. Similarly, the MTPA with Rogers TMM6 substrate showed a return loss value of -34.38dB, directivity of 5.11dBi, gain value of 4.34dB, bandwidth of 40MHz, VSWR of 1.04 and efficiency of 84% respectively. Comparatively, Rogers TMM6 is the best in terms of size and return loss only, but when directivity, gain, bandwidth and efficiency are the required properties, FR-4 is the best option. These deductions are in line with [11], [14].

It was further observed that, as the permittivity of substrate increases, the return loss also increases while bandwidth, VSWR, directivity and gain decreases. These deductions agreed with [12], [13]. This implies that the simulated results in table 2 showed good agreement with published works.

5.0. CONCLUSION

A line fed MTPA antenna was successfully designed and simulated; deductions have been made on several parameters like: return loss, directivity, gain, VSWR, bandwidth and efficiency in two cases. From the results obtained, it was deduced that the use of substrate material with higher dielectric constant results in low antenna performance, but with improved antenna size reduction and vice versa. Hence, it can be concluded that the proposed line fed MTPA gave better performance with FR-4 substrate whose permittivity is 4.4. It can therefore be implemented at S-band range for Bluetooth application at 2.45GHz.

6.0. ACKNOWLEDGMENT

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