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Truncated Patch Antenna with two Different Substrate Materials for GPS Application

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Abstract: In the wireless communication technology, the microstrip patch antenna has gained an intensive application due to their light weight, small size, easy reproduction, and integration ability with circuitry. Therefore, this research presents the work in designing planar microstrip patch antenna for GPS using microstrip line feed that can operate at 1.575 GHz with corresponding polarization. Furthermore, analysis done on a two different substrate that is Taconic TLC-32 and FR-4 with dielectric constant 3.2 and 4.3 respectively. Comparison is done among these two different substrates which use microstrip feed line, feeding insect and truncated two opposite edged of the squared patch. The performance of the patch antenna is demonstrated by the simulated bandwidth, return loss, gain and radiation pattern. From the study, shows that the antenna that used RF-4 substrate has a better performance and have a smaller size compared to Taconic TLC-32. The results show that simulated and measured resonate frequency for return loss is -14.60 and -14.15 dB at 1.575 GHz. It is also by implementing the feeding insect technique, it could improve the performance of antenna. Both simulated and experimental result shows that the prototype has good performance, and it is suitable for GPS application

Keywords: Microstrip, corner truncated, rf-4, taconic tlc-32, patch antenna

1. Introduction

The Global Positioning System (GPS) is a global navigation satellite system (GNSS) that can determine the precise position, time, and velocity information nearly everywhere on the globe. The Global Positioning System (GPS) radio navigation-satellite service L1 signal is broadcast on the 1575.42 MHz ± 12 MHz frequency for military, aviation, space, and commercial uses [1]. Next, microstrip antennas offer numerous advantages over conventional microwave antennas, it is widely applied in a wide range of practical applications. A microstrip patch antenna consists of a dielectric substrate, with a ground plane on the other side [2].

Microstrip antenna is a type of antenna that has dielectric substrate with permittivity and feasibility. It is being sandwich between metallic patch and ground plane. Patch structure is modified to have application specific resonating frequencies and to have higher gain and bandwidth response [3]. Thus, rectangular, circular, and triangular patch geometries are the most extensively analyzed antenna geometries, these geometries are modified to improve their performance [4]. Furthermore, truncated at the edge of square shape can achieve circular polarization (CP) [5]. The circularly polarized (CP) antenna is essential for optimal performance for Global Positioning System (GPS) [6].

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Microstrip line technique is connecting the edge of the microstrip patch and the conducting strip. The width of the conducting strip is shorter than the width of the patch, and this type of feed arrangement has the benefit of allowing the feed to be etched on the same substrate to produce a planar structure [7]. The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch input impedance without the need for any additional matching element [8].

Nowadays wireless systems require small antennas due to the small size of their equipment and the limited space available for antenna installation. The application of antenna with small size is very significant in the wireless systems [9]. Furthermore, he primary aspects of designing a microstrip patch antenna regardless of its purpose and design are to achieve a good performance parameter of return loss and gain using microstrip line feed. Without these two parameters, the patch antenna will not be able to reach its optimal potential. Good performance antenna indicated by having the return loss below -10dB where 90% of the signal being transmitted and reflected [10].

The objective of this project is to design and fabricate small size truncated patch antenna for GPS frequency 1.575GHz using microstrip line feed. Furthermore, to analyze the truncated rectangular microstrip antenna performance using two different substrate Taconic TLC-32 and FR-4 substrate for GPS application. Lastly is to compare performance of antenna in term of simulation using low-cost substrate Taconic TLC-32 and FR-4.

2. Methodology

2.1 Antenna Design and Specification

The flow chart of project shown in the Fig. 1. In the research and data collection phase, it was conducted as a comparison to previous research. This was included the study on resonant frequency of the patch antenna which is 1.575 GHz and dielectric material selected for this design is Taconic TLC-32 and FR-4 with dielectric constant of 3.2 and 4.3, the height of the dielectric substate is selected as 1.6mm and the copper thickness 0.035mm. Next, the truncated shape is chosen as the shape of the patch antenna. Then, inset feed is implemented as the feeding technique in this antenna to provide better impedance matching.

The design of antenna is based on the dimensions of a microstrip patch antenna obtained using a manual calculation and optimization method. However, using the calculation method, the antenna dimensions do not meet the desired operating frequency of 1.575 GHz. As a result, the antenna's size must be further improved. The methodology was adopted from recent literature review [11-17]. The simulation is done by using CST Microwave Studio 2018, then the performance of the antenna is investigated in term of reflection coefficient, bandwidth, gain and radiation pattern. The optimization method is used to achieve the required operating frequency and performance.

After the designation is complete, the best performance of patch antenna is selected to be fabricated. In the fabrication process there is a few steps which is print layout using DXF file, UV Exposure, developing, etching, stripping and lastly solder the SMA connector to patch antenna. After, the ideal patch antenna is fabricated, the VNA was used to obtain the S-parameter for a microstrip patch antenna measurement. The measurements were conducted at the Makmal Getaran Dan Kebisingan, Universiti Tun Hussein Onn Malaysia UTHM Pagoh Block E with the assistance of a laboratory instructor. Lastly, the S-parameter was evaluated and compared using simulation and measurement findings

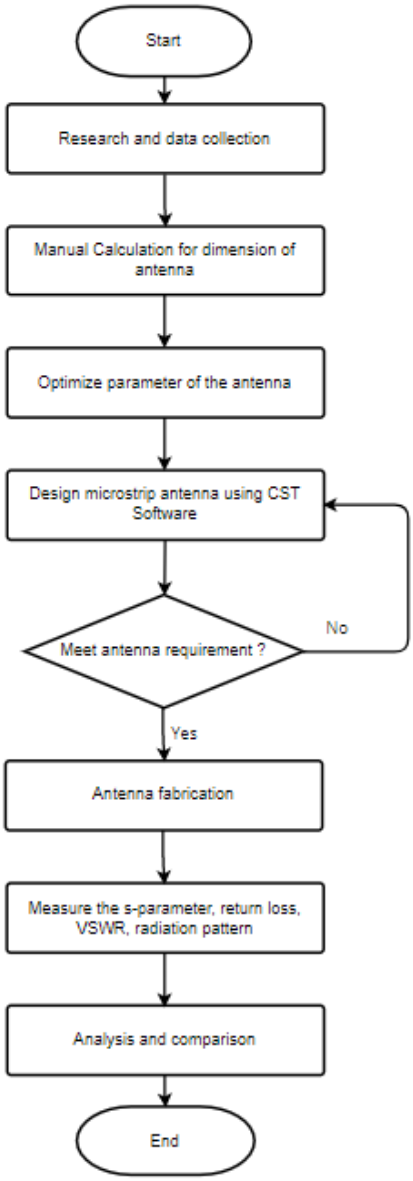


Fig. 1 - Flow chart of project

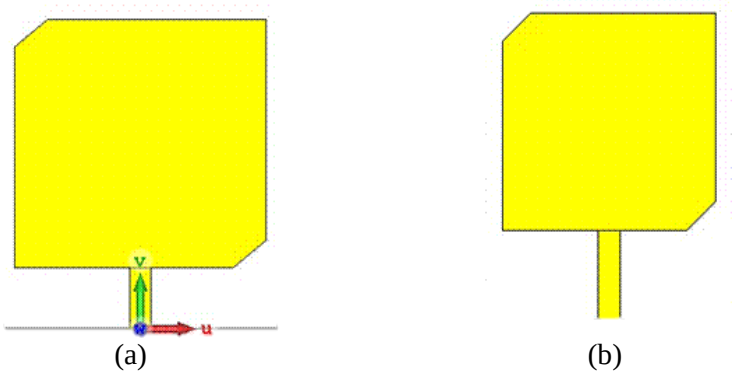
The parameter used to design the microstrip antenna is shown in Table 1:

Table 1 - Parameter to design rectangular microstrip antenna

Substrate	FR-4	Taconic TLC -32
Resonant frequency,	1.575GHz	1.575GHz
Substrate permittivity	4.3	3.2
Substrate height	1.6mm	1.6mm
Loss tangent,	0.0004/0.009	0.0004/0.009
Thickness of patch	0.035mm	0.035mm

To get the best simulation result, the width, W_p, and length, L_p parameter values are changed. The ideal W_p and L_p values are 80 mm and 80 mm for FR-4, meanwhile 45.2 mm and 46.52 mm for Taconic TLC-32, respectively, based on the parametric research. As a result, the rectangular patch antenna replaces by truncated patch antenna.

The Fig. 2 shows the geometry of the proposed truncated patch antenna. The design using Taconic TLC-32 substrate has smaller dimension compared to FR- 4 substate. Table 2 shows the parameter to design rectangular microstrip antenna. A truncated patch antenna having width of patch 52.2mm and length of patch 53.2mm in total, is printed on a Taconic TLC-32 substrate (thickness 1.6mm and permittivity 3.2) that is placed at the height of substrate above the ground shown in Table 2. While two opposite edges of the truncated corner have side length for about 7mm. Meanwhile, the dimension of FR-4 is having width and length of patch 89.9mm in total. Furthermore, another measurement is remained constant.



(a) (b)

Fig. 2 - The proposed antenna design using 2 different substrate material.
(a) FR-4, (b) Taconic TLC-32

Table 2 - Parameter to design rectangular microstrip antenna

Parameter	FR-4 (mm)	Taconic TLC -32 (mm)
Width of Patch, Wp	80	45.2
Length of Patch, Lp	80	46.52
Width of substrate, Ws	100	67
Length of substrate, Ls	120	80
Truncated edge of Patch, Wt	9.9	7
Length of Line, Ll	22	22
Width of Line, Wl	7.5	5.4

2.2 Optimized Truncated Microstrip Patch Antenna with an Inset Feed

An inset feed is implemented as the feeding technique in this antenna to provide better impedance matching. The design of the microstrip patch antenna with an inset feed is shown in Fig. 3. The antenna dimensions are listed in Table 3.

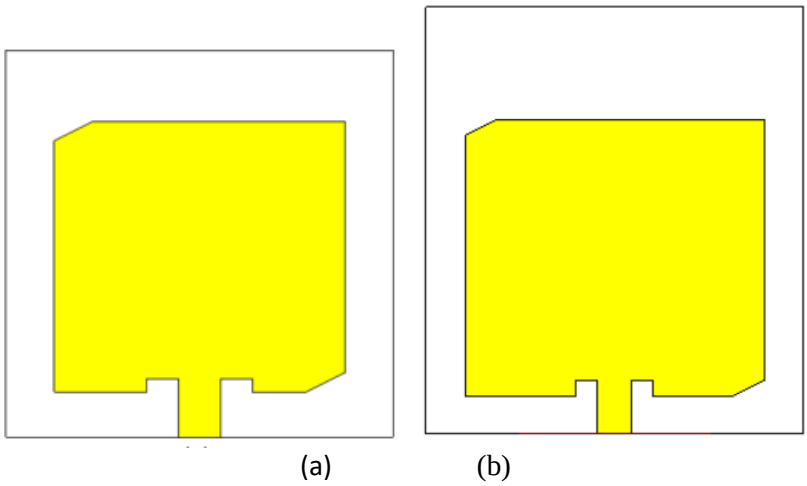


Fig. 3 - The proposed antenna with inset feed design using 2 different substrate material (a) FR-4; (b) Taconic TLC-32

Table 3 - Table compare dimension of two different Substrate

Parameter	FR-4 (mm)	Taconic TLC -32 (mm)
Width of Patch, Wp	39	50.2
Length of Patch, Lp	39	48.52
Width of substrate, Ws	60	71
Length of substrate, Ls	60	80
Truncated edge of Patch, Wt	6	7
Length of Line, Ll	7	22
Width of Line, Wl	6.5	5.4
Length of Inset feed	2	3
Width of Inset feed	5	4

3. Results and Discussion

In this section, the simulation results are obtained by using CST Microwave Studio software. It will compute parameters such as return loss, bandwidth, gain, and radiation pattern.

3.1 Simulation Result of FR-4 and Taconic TLC- 32

The Fig. 4 shown, the first design simulation is using FR-4 substrate with dielectric permittivity is 4.3. Return loss is very important parameter to determine the performance of the antenna. The result of return loss is depicted in Fig. 4 below. As seen in Fig. 4, the simulated reflection coefficient of FR-4 substrate is -19.27 with bandwidth of 23.6 MHz shown in Fig. 5 is obtained. Although, the S_{11} is only – 19.27, the value is below -10dB, it is considered as a good performance of antenna. The simulation of truncated patch antenna using Taconic TLC-32 substrate ($\varepsilon r = 3.2$) was done to demonstrate its performance. The simulated reflection coefficient of Taconic TLC-32 substrate is -28.97dB with bandwidth of 27.7 MHz shown in Fig. 6 is obtained at the resonant frequency 1.575GHz.

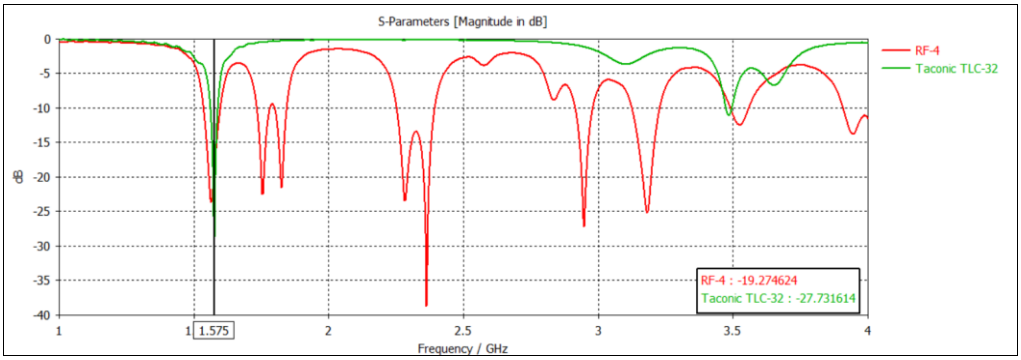


Fig. 4 - Simulated result of return loss (S_{11}) FR-4 and Taconic TLC-32 substrate

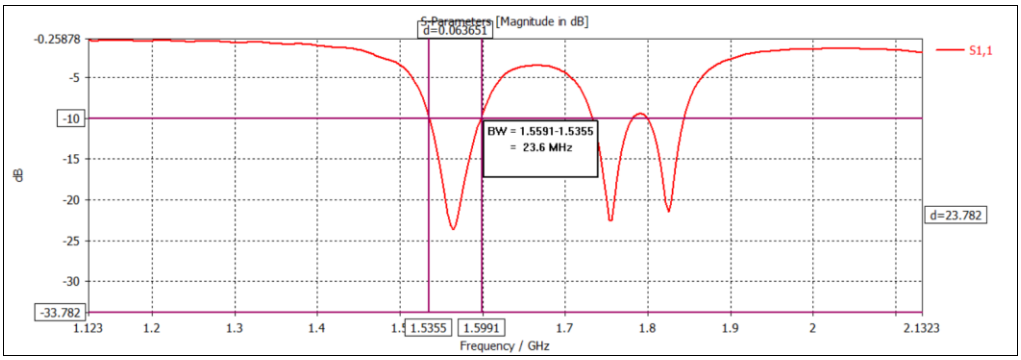


Fig. 5 - The Simulated result of bandwidth FR-4 substrate

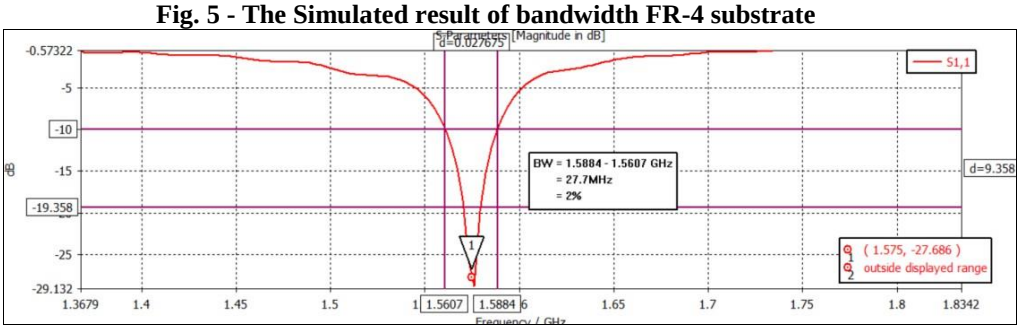


Fig. 6 - Simulated result of bandwidth for Taconic TLC-32

Meanwhile for the directivity shown in Fig. 7 antenna design using RF-4 substrate obtains 5.42 dBi. On the other hand, Taconic TLC -32 has 6.18dBi shown in Fig. 8.

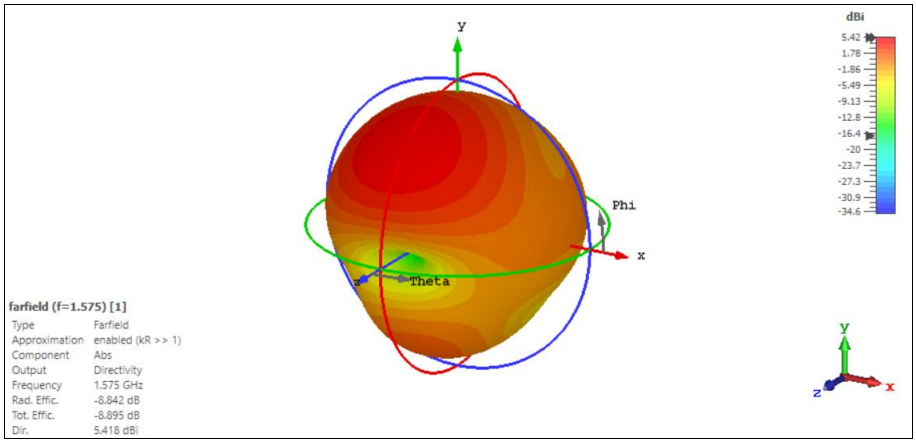


Fig. 7 - Simulated result of gain for Taconic TLC-32

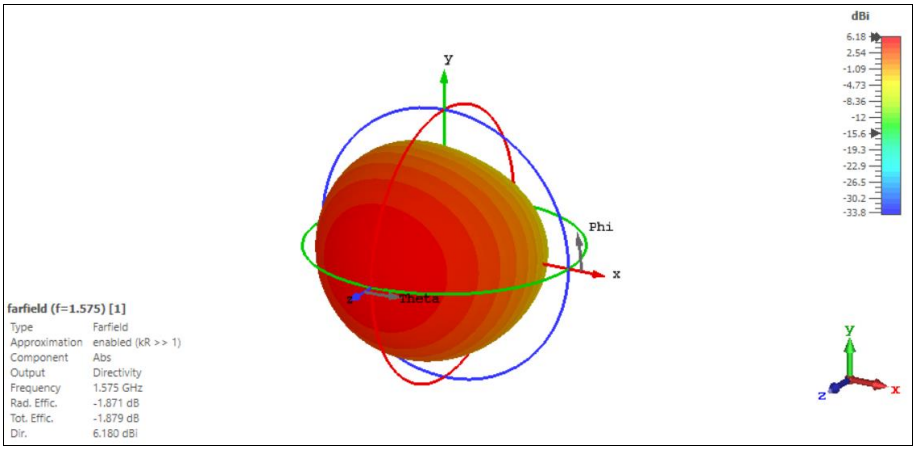


Fig. 8 - Simulated result of gain for Taconic TLC-32

3.2 Simulation Result of FR-4 and Taconic TLC-32 for truncated microstrip patch antenna with an Inset Feed

The simulation of Truncated patch with Inset Feed was done to demonstrate its performance. The designated antenna has also been simulated and the numerical analysis result are shown in Fig. 9 obtain in CST studio suite 2018. As seen in Fig. 9 the simulated reflection coefficient for FR-4 and Taconic TLC-32 is –14.606dB and -14.987dB with bandwidth of 69.9 MHz and 16.4MHz presented at Fig. 10 and 11.

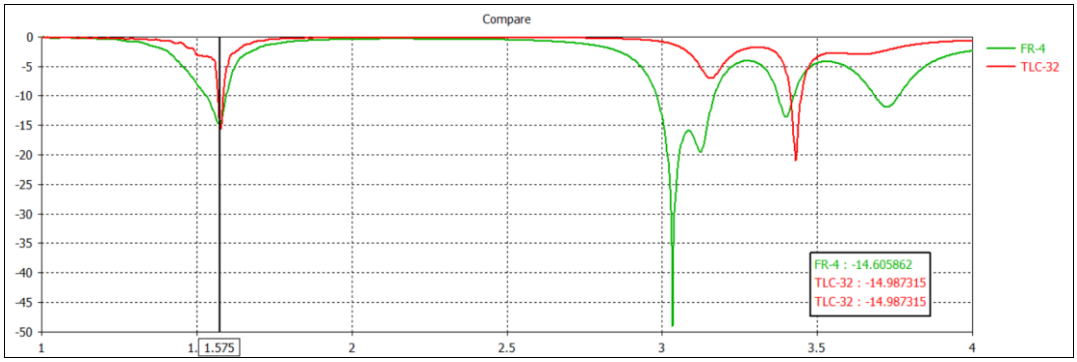


Fig. 9 - The simulated result of reflection coefficient of FR-4 and Taconic TLC-32 for truncated microstrip patch antenna with an Inset Feed

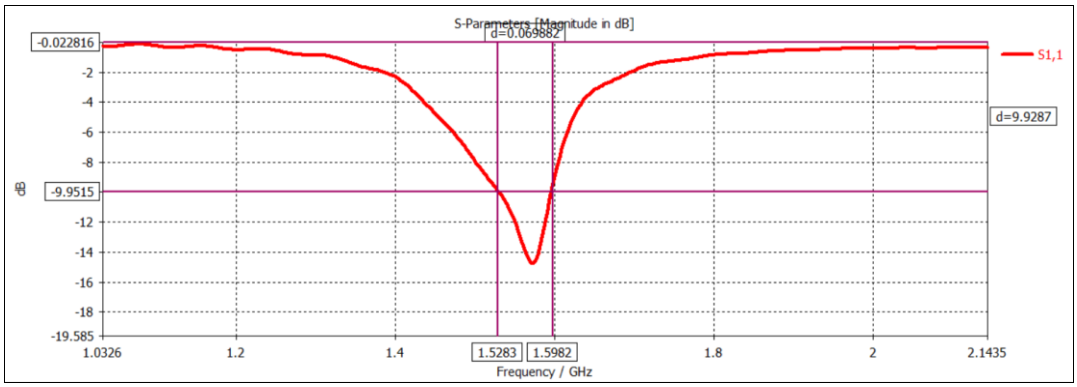


Fig. 10 - Simulated result of bandwidth of FR-4 for truncated microstrip patch antenna with an Inset Feed

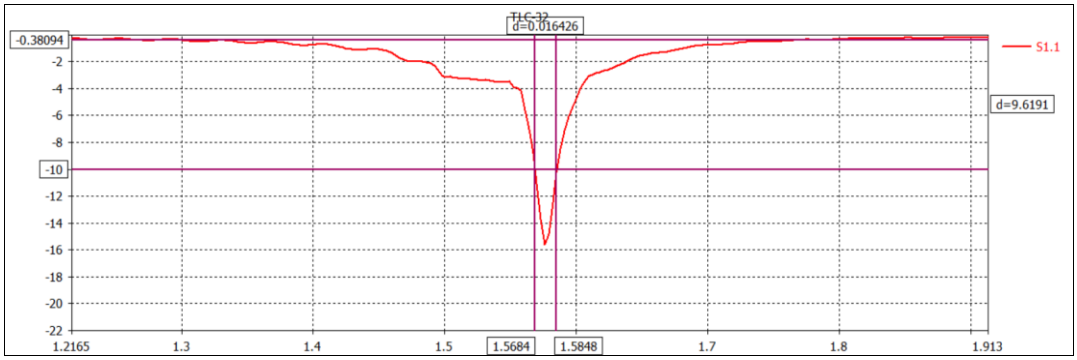


Fig. 11 - Simulated result of bandwidth of Taconic TLC-32 for truncated microstrip patch antenna with an Inset Feed

Based on Fig. 12 and Fig. 13, the radiation pattern shows a directional pattern at 1.575 GHz which had a directivity of 5.26dBi and 3.85dBi. The amount of radiation intensity indicates by the red radiation pattern of radiation from the directivity plot, The electric field distribution for the patch also indicates that the fields are more concentrated at the edges, with excellent field distribution.

On Fig. 14 the radiation pattern polar plot at condition phi is 90º that having a good response over the frequency band with main lobe directed at an angle of 7.0 degree with gain 12dB and the angular beam width is 97.2 degree.

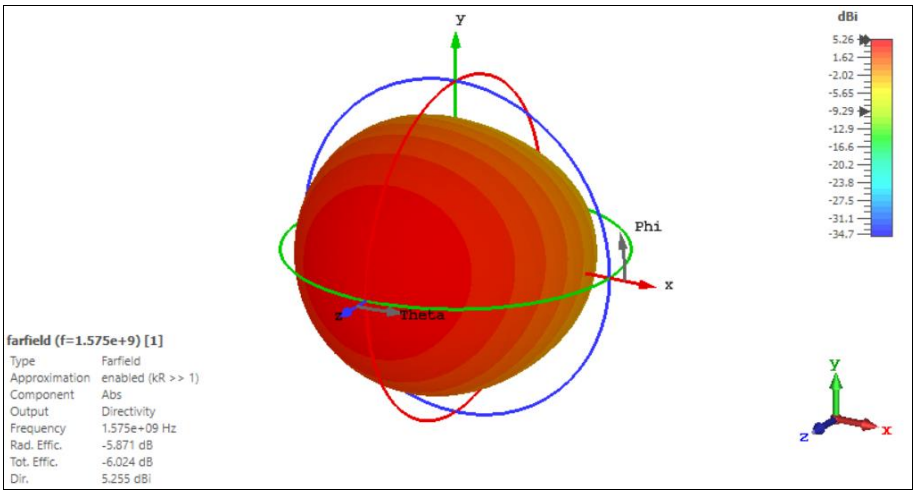


Fig. 12 - Simulated result of bandwidth of FR-4 of truncated microstrip patch antenna with an Inset Feed

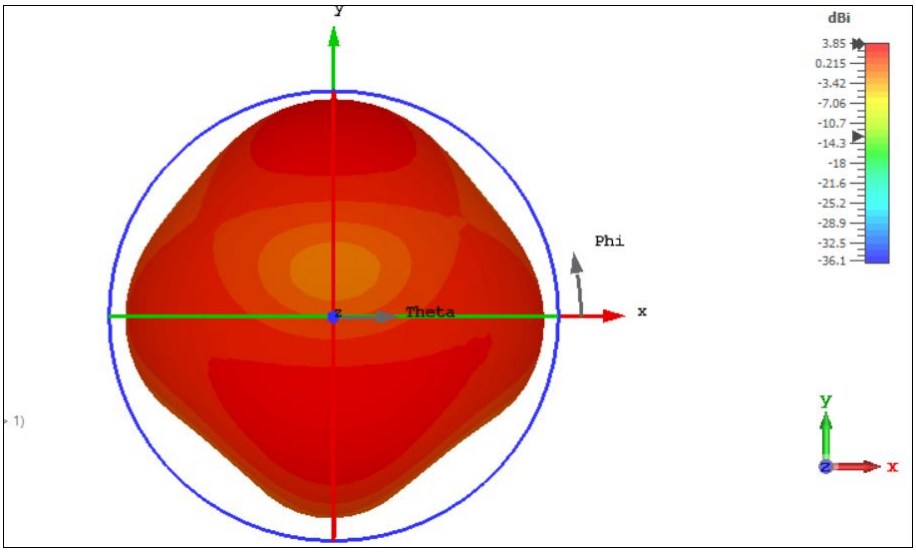


Fig. 13 - Simulated result of bandwidth of FR-4 of truncated microstrip patch antenna with an Inset

Feed

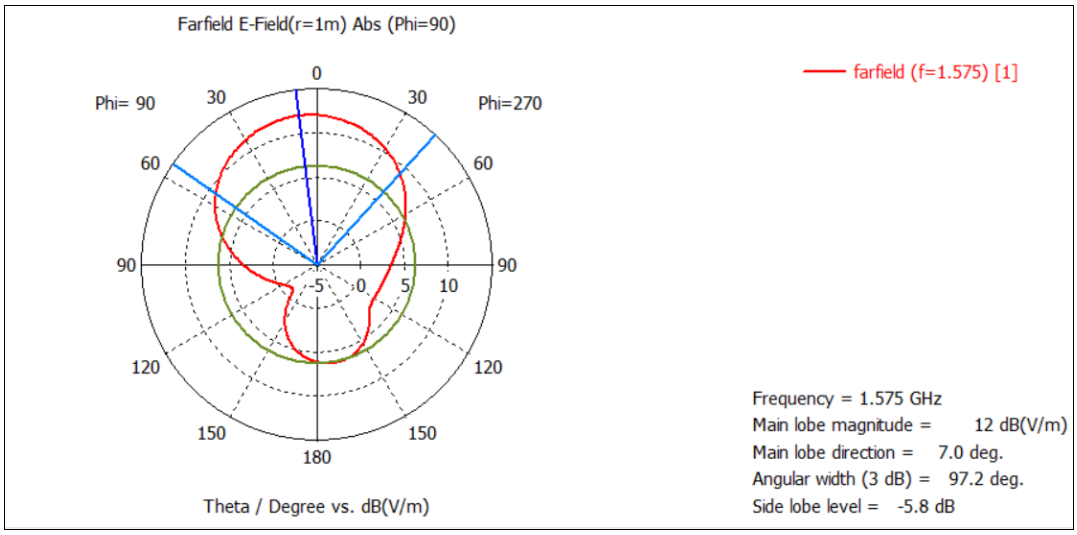


Fig. 14 - Simulated result of bandwidth of FR-4 of truncated microstrip patch antenna with an Inset Feed

3.3 Measured Result

FR-4 substrate patch antenna is measured by using Vector Network Analyzer to measure parameter of Return Loss (S_{11}) and Bandwidth. The range between 0-4GHz has been used for the measurement.

Fig. 15 illustrates the microstrip patch antenna's observed reflection coefficient. The resonant frequency has been changed slightly at 1.575 GHz, with an S_{11} of -14.15dB. Meanwhile the bandwidth is 20.1MHz.

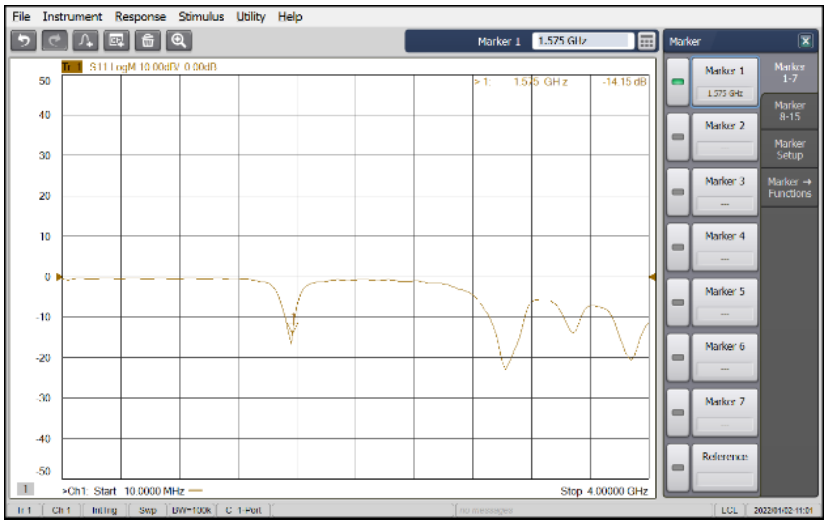


Fig. 15 - Measurement result of return loss (S_{11}) and bandwidth FR-4 substrate

3.3 Comparison between Simulation and Measurement Analysis

In this section, the comparison of simulation and measured results are analyzed and discussed in term of Return loss (S_{11}). The simulated and measured result for truncated patch antenna using FR-4 shown in Fig. 16. The measured result clearly shows that the antenna's resonate frequency was shifted to the left with a return loss of -14.15 dB at 1.575 GHz.

This is due the effect of etching inaccuracy cause results of measured is different from the simulation result. Hence improper etching results in either a wider copper or smaller patch antenna. Furthermore, the inaccuracy of the etching process results in the formation of unwanted conductive materials and unwanted open circuits between ground and patch antenna. The performance of the patch antenna is affected due to an inaccurate size of patch antenna design on substrates. Other than that, it is also caused by to insertion loss of SMA connectors, during the fabrication of the patch antenna, the patch needed to solder with SMA Connector. In this process a good soldering technique are prominent.

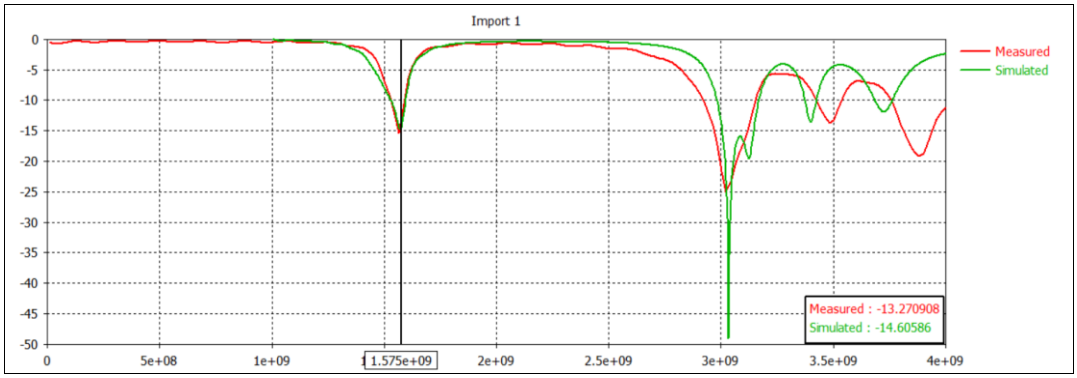


Fig. 16 - Comparison of simulated and measured result for FR-4 substrate

4. Conclusion

In this project, the antenna was design and fabricated by frequencies range between 0-4GHz. The objective of the project is to compare performance of antenna in term of simulation using low-cost substrate Taconic TLC-32 and FR-4 is achieved. The simulation was complete using CST Microwave Studies Software. The simulated reflection coefficient of FR-4 substrate is -19.27dB with bandwidth of 23.6 MHz and Taconic TLC-32 substrate is -28.97dB with bandwidth of 27.7 MHz are obtained at the resonant frequency 1.575GHz.

Although the Taconic TLC-32 has smaller reflection coefficient than FR-4 substrate, both of substrate has value is below -10dB, it is considered as a good performance of antenna. Furthermore, the size of Truncated patch antenna using FR- 4 is 50% smaller than Taconic Substrate. So, truncated patch antenna design that used FR-4 substrate was selected to be fabricated and measured by using Virtual Network Analyzer. The simulation and measured result are slightly different due to some factor during fabrication process and measurement process but overall, the antenna performance is good.

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