



Dual Frequency Microstrip Patch Antenna for WLAN Applications

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ABSTRACT

This paper describes an antenna design with dual band microstrip patch antenna for WLAN applications. The objective of the paper is to describe the design of a dual band antenna operating at 2.4 GHz and 5 GHz. The design of the antenna is developed using the transient solver in the Computer Simulation Technology (CST) software. The antenna was fabricated after obtaining the desired output from the simulation performance study. The fabricated antenna was using a network analyzer. The simulation results show the directivity is achieved for 2.4 GHz and 5 GHz which are 6.32 dBi and 7.7 dBi respectively. The simulated and measured results showed good agreement to each other.

Key words : microstrip antenna, dual band antenna, computer simulation technology (CST), WLAN applications.

1. INTRODUCTION

Wireless communication is dominating the world with its capabilities, especially in the communication sector. In radio communication, Wireless Local Area Network (WLAN), Worldwide Interoperability for Microwave Access (WiMAX), and Global System for Mobile Communications (GSM) microstrip patch antennas play a vital role in materializing the mobile communication [1]. WLAN is a wireless computer network that links two or more devices using a wireless distribution method within a limited area such as at home, school, computer laboratory, or office building. It provides short-range wireless high-speed data connections between mobile data devices such as laptops, PDAs or phones and nearby Wi-Fi access points [2].

Microstrip patch antennas are well known for their low cost and small size and also in their ease to be fabricated. In addition, microstrip antennas are capable in producing both circular and linear polarization. The cost is cheaper to fabricate a microstrip antenna in this modern day [3]. The

major drawbacks of the microstrip patch antennas are narrow bandwidth surface wave excitation, low gain and low efficiency. Despite of these, it is still being widely used [4] due to cost and ease of fabrication.

To maximize space, antennas may be designed to operate at more than one frequency. There are many methods in order to create dual band antenna. Slots and multiple patches are some of the examples in obtaining dual frequency antennas [5]. Researchers had been studying on the behaviour and characteristic of microstrip patch antenna for many years. Researches that had been conducted showed that slot creations had turn out to be one of the most effective way in obtaining dual frequency. U-slot creation, for instance, can be used for multiband purposes as seen in Huynh and Lee [6].

SwarajPanusa and Mithilesh Kumar [7] proposed that to achieve dual-band operation certain steps had to be taken which involve altering the dimensions of single H-slot and moving the feed point position vertically and horizontally from its center position. Meanwhile, Diponkar Dutta et. al [8] designed a single band compact triple C shaped microstrip patch antenna for WLAN and WiMAX applications with a center frequency of 2.5 GHz. It had a planar geometry and consist of a monopole arrangement. Md. Ashiqul Amin et. al [9] designed a multiband microstrip antenna using CST software with resonant at four frequencies which are 0.45 GHz, 1.35 GHz, 1.92 GHz and 2.57 GHz. The design of the antenna has a novel shape and used a coaxial feeding technique.

In this paper, we present a microstrip patch antenna that is designed to operate at 2.4 GHz and 5GHz for WLAN applications. Dual U-slots were created and implemented in order to create the two resonant frequencies. The feeding technique used here is a microstrip line feed for simple and ease of fabrication. The rest of this paper is ordered as follows. The material and method is discussed in Section 2. The results and discussion are given in Section 3 and the conclusion in section 4.

2. MATERIAL AND METHODS

2.1 Material

The microstrip antenna proposed were targeted to be small in size, thus a suitable substrate had been chosen. The substrate used for this antenna is the FR-4 dielectric material. The dielectric constant for this material is 4.3. A substrate with high dielectric constant will enable the reduction of the antenna dimension. The thickness of this substrate is 1.5 mm. The conducting material used is copper and the copper has a thickness of 0.035 mm. Resonant frequencies are chosen for the operating frequencies of the antenna. Table 1 provides the specifications of the antenna.

Table 1:Antenna Specifications

Antenna Specifications	Value
Substrate	Fr-4
Dielectric constant	$\epsilon_r = 4.3$
Substrate thickness	1.5mm
Conducting material	copper
Copper thickness, Ct	0.035mm
Operation frequency, f_o	2.4GHz, 5GHz

The weight, feed weight and width of the single patch are determined using the formula from antenna theory [10]. A double U-slot was implemented in the design to create two resonant frequencies. The formulas are obtained from [10] and the usage are supported by [11], [12] and [13]. The width (W) and length (L) of patch can be calculated from the following mathematical formula:

Width of patch:

$$W = \frac{C}{2f_0 \sqrt{\frac{\epsilon_r + 1}{2}}} \quad (1)$$

Effective dielectric constant (ϵ_{reff}):

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2 \sqrt{1 + 12 \frac{H}{W}}} \quad (2)$$

Length extension (ΔL):

$$\Delta L = 0.42H \times \frac{(\epsilon_{reff} + 0.3) \left(\frac{H}{W} + 0.264 \right)}{(\epsilon_{reff} - 0.258) \left(\frac{H}{W} + 0.8 \right)} \quad (3)$$

Length of patch:

$$L = \frac{C}{2f_0 \sqrt{\frac{\epsilon_r + 1}{2}}} - 2 \Delta L \quad (4)$$

Initially two antennas were created to study and understand the antenna parameters. Separate calculations were made for

each operating frequency which is 2.4 GHz and 5 GHz. These antennas were created with a FR-4 board with a dielectric constant of 4.3.

A microstrip line feed were used in the designs. This feeding technique has a conducting strip that is smaller in width compared to the patch. The feed current lines were co-polarized with the patch. One of the major drawbacks of this technique is it will produce a less accurate return loss compared to simulation. Ease of fabrication compensates this. The input impedance Z_c , of the microstrip line is set to be 50 ohm. The width of the microstrip feedline can be calculated as below:

$$Z_c = \frac{\frac{60}{\sqrt{\epsilon_{reff}}} \ln \left[\frac{8h}{W_f} + \frac{W_f}{4h} \right]}{120\pi \sqrt{\epsilon_{reff}} \left[\frac{W_f}{h} + 1.393 + 0.677 \ln \left(\frac{W_f}{h} + 1.444 \right) \right]} \quad (5)$$

2.2 Method

A. Design of single band antenna

A basic structure of the antenna starts with a rectangular shape patch and etched on top of the substrate. The operating frequency of the antenna is 2.4 GHz and the layout of the antenna is displayed in Figure 1. The dimension of the single band antenna is provided in Table 2.

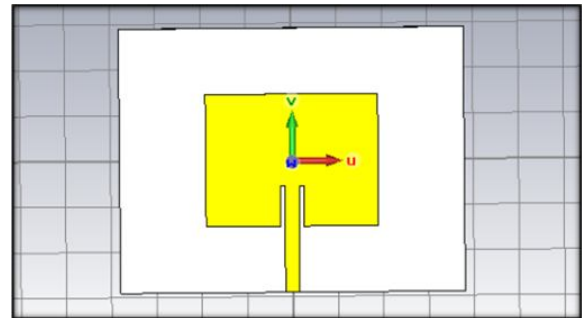


Figure 1:Top view of 2.4 GHz microstrip patch antenna

Table 2:Parameter of single band antenna

Parameter	Dimension (mm)
Length of substrate	58
Width of substrate	76
Width of feed	3.137
Feed inset	8.85
Length of patch	29
Width of patch	38

B. Dual band antenna configuration

In order to create two resonant frequencies a dual U-slot was created to have an antenna that fulfills the objectives. The antenna is designed to operate at the two frequencies of 2.4 GHz and 5 GHz respectively. This technique was first introduced by Huynh and Lee in their research [4]. Slot method was used in this design to create a dual band.

A dual band antenna can be developed by adding a double U-slot into the single patch antenna. Table III are the

equations used to derive the slots. The U-slot created can be adjusted with respect to length and thickness for achieving a better simulation result.

Table 3: Slot characteristics

Characteristics	Formula
The thickness of slot, x	$x = \text{wavelength of light} / 60$
Width of the slot $A1, B1$	$A1 \text{ or } B1 = co * 2 \cdot flow^{0.5} - 2(L + \Delta L - E)$ $co = \text{speed of light}$
Height of the slot $A2, B2$	$A2 = A1 \times 0.75$ or $B2 = B1 \times 0.75$
Height from the slot to the base, K	$K = L - E + 2\Delta L - E - H - (1/\epsilon_{ff})^{0.5} * [co / f_{high} - (2co - d)]$

Figure 2 and Table 4 show the antenna layout and the parameters value. Figure 3 depicts the prototype of the dual band antenna. The microstrip patch antenna is soldered to a SMA connector as a port for antenna measurement.

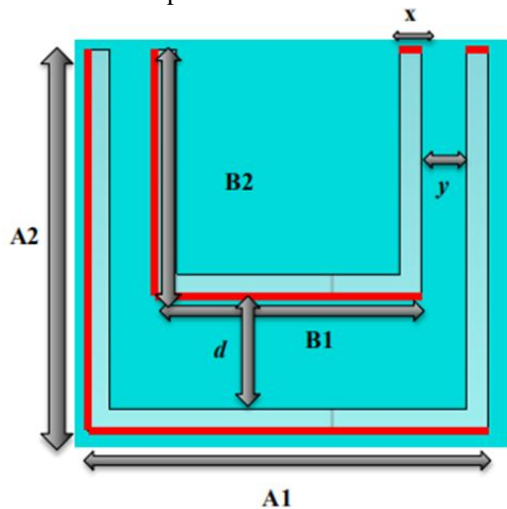


Figure 2: Antenna layout

Table 4: Parameters value

Parameters	Value (mm)
A1	9
A2	8
B1	6
B2	5
x	0.5
y	1
d	3

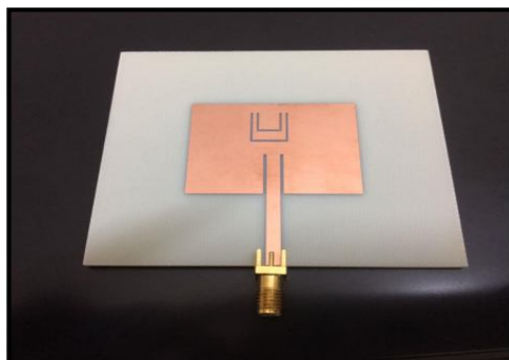


Figure 3: Fabricated of dual band antenna

3. RESULTS AND DISCUSSIONS

3.1 Single band antenna, 2.4 GHz

Figure 4 and 6 illustrates the reflection coefficient and farfield radiation of single band antenna. The rectangular patch antenna has a reflection coefficient (S_{11}) of -20 dB at the operating frequency of 2.4 GHz. The bandwidth obtained is about 200 MHz. The farfield radiation has a magnitude of 6.95 dBi at 2.4 GHz.

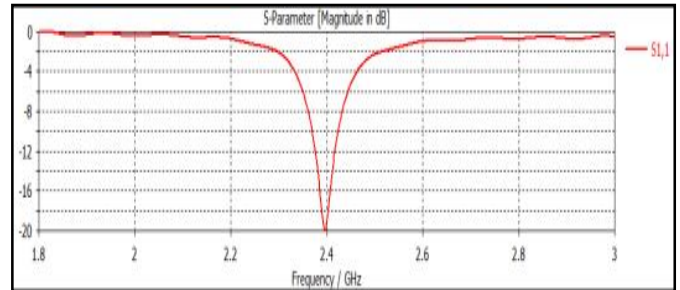


Figure 4: The reflection coefficient of a single band antenna

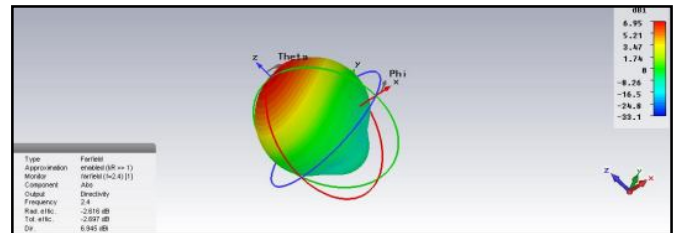


Figure 6: The farfield radiation

3.2 Adjusting the U-slot

The U-slot was adjusted until the desired resonant frequencies were achieved. The size of the slot is important to determine the resonant frequency. Thus, many different size of slots was created to investigate this matter. The slot thickness, length and distance between the two U-slot was changed to observe the reflection coefficient.

A. Case 1: Adjusting the Height of the Outer U-slot

The outer U-slot was adjusted for analyzing the reflection coefficient of the microstrip patch antenna. The height of the outer slot was increased by 3 mm to see the difference from the original antenna. Besides that the position of the U-slot was moved to the center. Figure 7 and 8 below shows the front view of the antenna and the adjustment made.

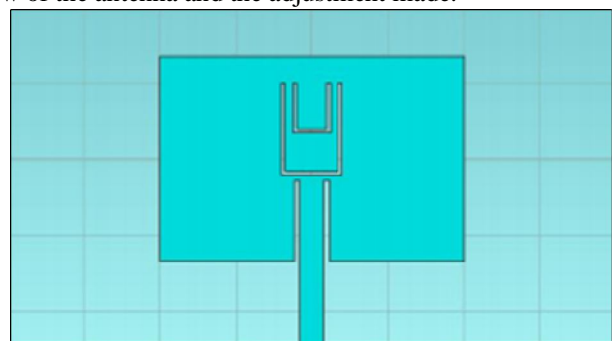


Figure 7: Front view Case 1

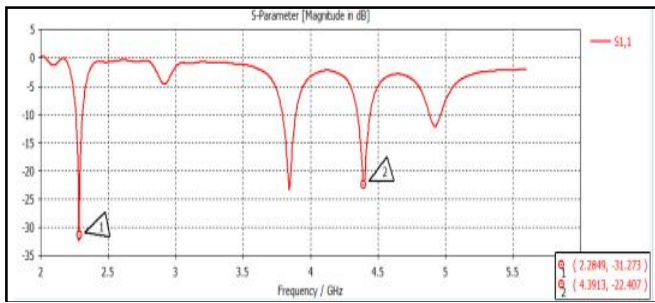


Figure 8: Reflection coefficient Case 1

The reflection coefficient obtained was 2.2849 GHz at 31 dB and the second resonant frequency obtained was 4.39 GHz at -22 dB. The graph of reflection coefficient was shifted to the left and with a smaller resonant frequency.

B. Case 2: Adjusting the Distance between the Two U-slots

Figure 9 demonstrates that the distance between the 2 slots had been reduced after the outer slot length was increased from Case 1. This is done to study whether the distances between the 2 slots affects the reflection coefficient. A bigger resonant frequency was achieved when the distances between the 2 slots were reduced. The first resonant frequency was achieved at 2.4 GHz, -20 dB and the second resonant frequency drops at 4.8 GHz with a poor drop of a magnitude -9 dB as displayed in Figure 10.

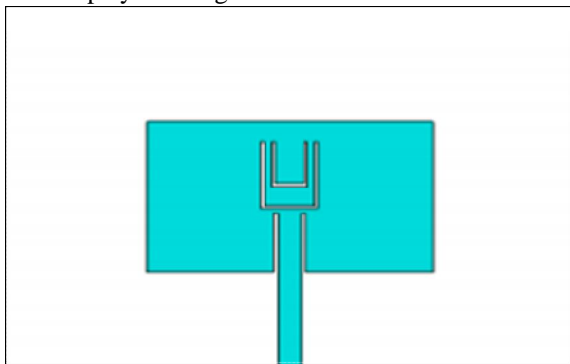


Figure 9: Front view Case 2

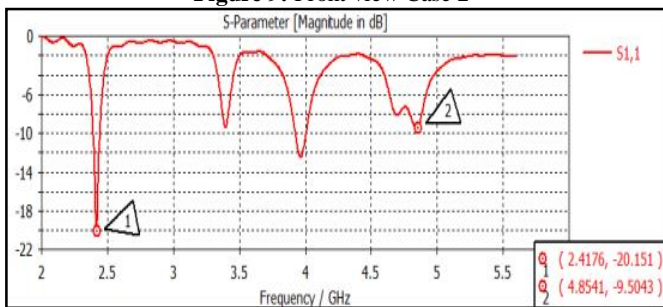


Figure 10: Reflection coefficient Case 2

C. Case 3: Further Adjusting the Distance between the Two U-slots

Figure 11 shows that the distance of the 2 slots have been altered. The inner slot has been shifted further up in order to observe the changes in the reflection coefficient. The reflection coefficient in Figure 12 shows that the first resonant

frequency achieved was 2.378 GHz at -25 dB and the second resonant frequency had a poor drop at 4.95 GHz.

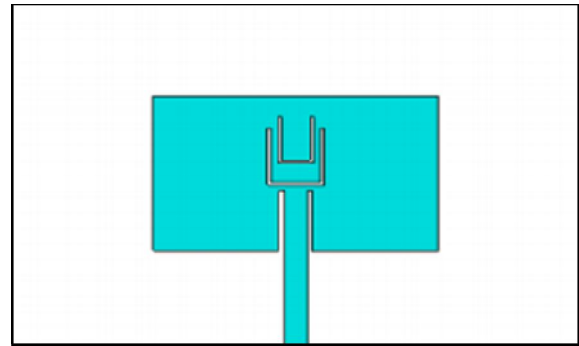


Figure 11: Front view Case 3

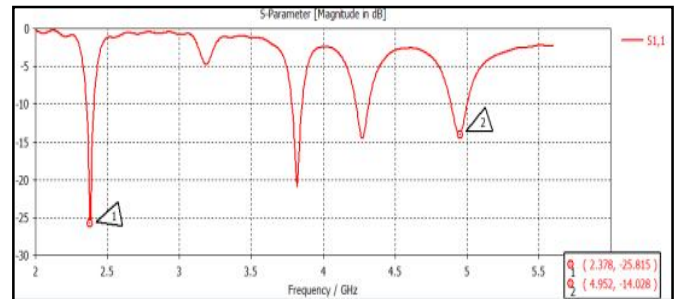


Figure 12: Reflection coefficient Case 3

D. Final U-slots Design

The final double U-slot design is provided in Figure 13. Figure 14 shows the view of the patch and dual band antenna design.

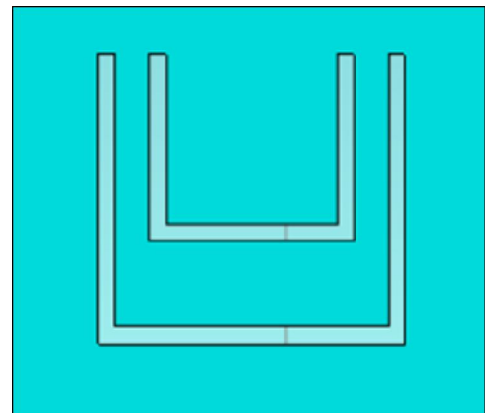


Figure 13: U-slot created

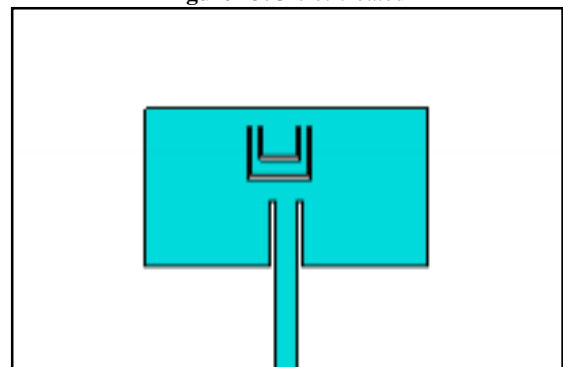


Figure 14: Top view of dual band antenna design

The reflection coefficient in Figure 15 demonstrates the drops at 2.4 GHz and 5 GHz for the antenna. On the drop at 2.4 GHz the S_{11} is recorded as -18 dB and at 5 GHz the S_{11} is recorded as -26 dB. Both of these readings confirm suitability for the WLAN range. However, the results show two more frequencies that have drops too, which is roughly at 3.3 GHz and 3.9 GHz resulting magnitude of -8 dB and -13 dB respectively.

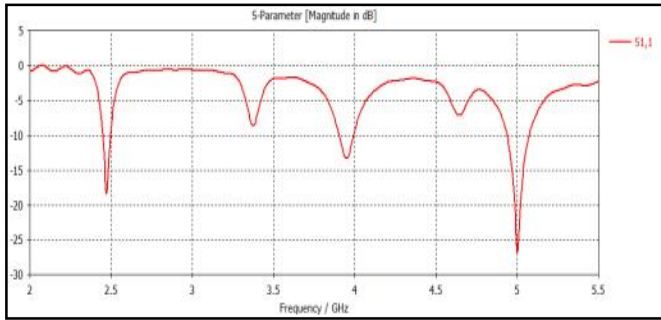


Figure 15: Reflection coefficient of dual band antenna

Figure 16 and 17 shows the farfield array obtained from 2D polar coordinates for 2.4 GHz and 5 GHz. Phi= 90 was used and the main lobe magnitude obtained for 2.4 GHz was 6.83 dBi and for 5 GHz was 7.71 dBi.

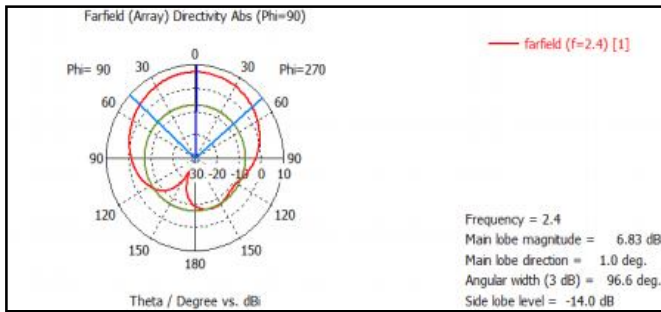


Figure 16: Phi= 90, 2.4 GHz

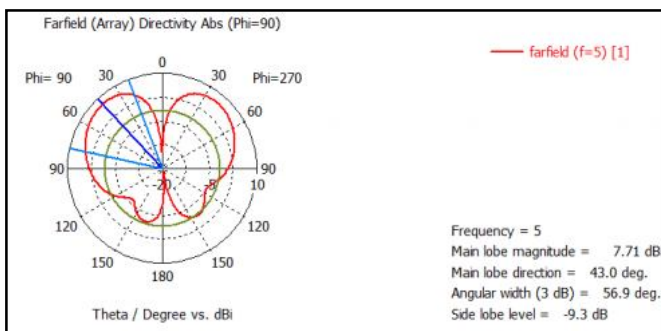


Figure 17: Phi= 90, 5 GHz

Figure 18 shows the 3D radiation pattern for both resonating frequencies. The directivity obtained for the 2.4 GHz farfield was 6.82 dBi. Based on Figure 19, the directivity obtained for 5 GHz is 7.7 dBi.

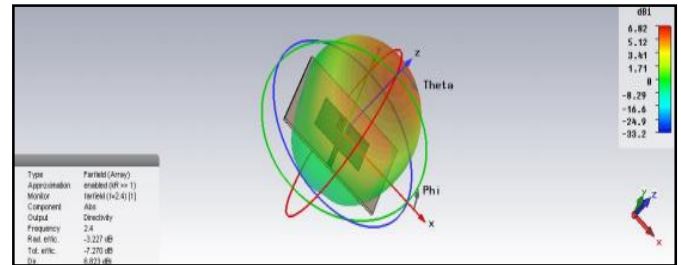


Figure 18: 3D radiation for 2.4 GHz

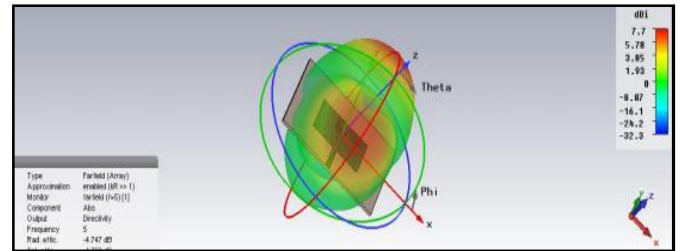


Figure 19: 3D radiation for 5 GHz

One of the most important aspects in antenna performance are the radiation, gain and directivity. All these aspects are taken into consideration depending on the antenna's operating frequency. We can see that different frequency bands show different radiation angles based on the results obtained.

3.3 Reflection coefficient measurement

The fabricated antenna was measured using a network analyzer. Figure 20 shows the measurement results obtained from the network analyzer. The reflection coefficient of measured results and simulated results for 2.4 GHz and 5 GHz showed good agreement as in Figure 21.

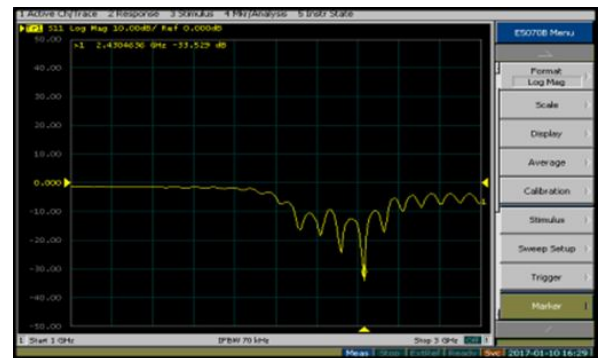


Figure 20: Reflection coefficient for 2.4 GHz

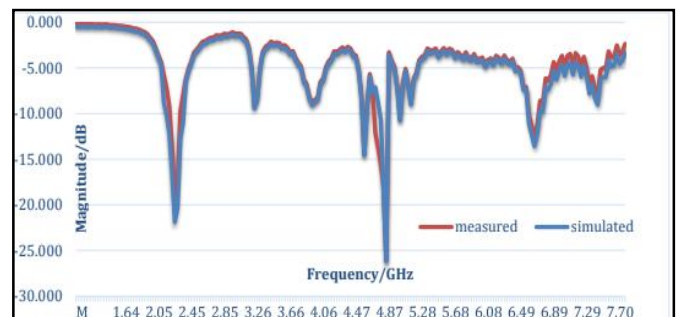


Figure 21: Comparison of reflection coefficient between measured and simulated result

4. CONCLUSION

The main idea of this project was to design an antenna that is able to operate dual band frequencies for WLAN applications. The frequency band applied were 2.4 GHz and 5 GHz. The antenna was designed and simulated in CST software. A study was done on the antenna in terms of parameter changes and slot changes to identify the effect on the reflection coefficient to get the final design. This antenna was successfully designed for WLAN applications. For future work, the antenna can be further designed into different shapes and made smaller in size.

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