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Reconfiguration of Double Stub Feeding in Microstrip Antenna Array for WLAN and WiMAX

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ABSTRACT

Microstrip antennas are one ions in communication systems. However, microstrip antenna experiences imbalance impedance, which in turn affects the performance of the antenna with narrow bandwidth as well as reducing the radiation emission of the radio wave. Therefore, this paper presents are configuration method of impedance matching utilizing a ¼ λ transformer for a double stub feeding in microstrip antenna array. The double stub feeding is proposed for a dual-frequency band, in which at 2.4 GHz and 5.2 GHz, respectively with identical dimension of antenna patch elements. This proposed structure is placed on the main supply of the microstrip antenna, specifically to match the antenna impedance with the transmission line impedance. From the simulation results, the appropriate impedance (Z) parameter values of 52Ω at frequency of 2.4 GHz and 47Ωat 5.2 GHz were correspondingly obtained. The return loss (RL)of -34 dB at 2.4 GHz and -29 dBat 5.2 GHZ were also achieved. The voltage standing wave ratio(VSWR) has shown the best value of1.0 and 1.1 respectively at 2.4 GHz and 5.2 GHz. This antenna design has similar gain frequency capability as in the reference antenna that has been customized at a frequency of 5.8 GHz. Therefore, the proposed antenna can be used in Wireless Local-Area Network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) frequency bands.

Key words :antenna array, double stub feeding, microstrip, return loss, VSWR.

1. INTRODUCTION

The development of communication technology in several decades is rapidly developed and improved, especially in, wireless telecommunication with very high mobility, fast services and accessible from anywhere has become the main consideration to encourage users to abandon wired network communication technology. Many new ideas are developed in improving the performance of telecommunications equipment. Antennas are an important part of wireless communication devices, and various methods are used to develop antenna including material, shape, and size of the antenna so that high antenna performance can be achieved. The development can be in the form of a new design or reconfiguration of the existing antenna design.

In line with the development of communication device technology, many studies have been carried out on the antenna. Antenna development is rapid and it can be seen in various sizes, materials and shapes[1-9]. The development is carried out according to the needs and applications of microwave to satellite transmission systems[10]. Antennas that are implemented on mobile devices must have small dimensions with good transmitting and receiving power. These features can only be achieved by microstrip antennas, in which this antenna has a small, thin size, a wide range of radiation patterns and it is easy to fabricate[11-14]. In improving antenna performances, antennas are formed and arranged from several antenna elements called antenna arrays. Antenna arrays can be a single port or multiple ports [1, 4-6]. The current communication device which consists of several generations with different working frequencies also has led to the development of antenna technology that works on multi frequencies[7-9,12]. To generate a dual-frequency antenna, several methods can be done, namely orthogonal mode dual-frequency, multi-patch dual-frequency, and reactively-loaded dual-frequency. The most widely used to generate dual-frequency is reactively-loaded dual-frequency [8].

In addition, many research works have been proposed in overcoming the imbalance impedance experienced by a microstrip antenna. There are two methods for adjusting the impedance between the transmission line and the load on the microwave. The first method refers to the termination of the transmission line with the characteristic impedance of the line while the other method refers to the termination of common sources by conjugating complex source impedances. The final concept is a fundamental requirement of maximum power transfer. Several methods are used to adjust the impedance of the antenna such as by utilizing balun, transformers, and stubs [7,13-14]. Research on stubs is mostly done, but only limited to a single stub [5,15-21] while the use of double stubs as impedance adjusters are still very limited [22]. To get maximum power transfer, the antenna impedance must be equivalent to the transmission line impedance known as balanced impedance. Therefore, this paper presents the development of a microstrip array antenna at dual-frequency band by using a double stub matching on the feeding line. This microstrip antenna is designed in improving antenna performances at WLAN and WiMAX frequencies by obtaining optimum values of antenna parameters such as the impedance (Z), return loss (RL), voltage standing wave ratio (VSWR), bandwidth and antenna gain. The antenna is designed by utilizing microstrip material as the electromagnetic wave radiation by means of its simplicity and small in size. Initially, the antenna consisted of two identical dimensions of rectangular patch antenna elements that worked on dual-frequency, which are at 2.4 GHz and 5.8 GHz. In the rationing, a ¼ λ transformer was used, as a liaison between elements and reconfigured by using double stubs.

2. DUAL-BAND ARRAY ANTENNA DESIGN

In constructing a multi-frequency array antenna, it is built through the calculation of single frequency antenna, which is then organized into a multi-frequency antenna array. In this work, the main parameter in concern is the impedance matching between the antenna and the transmission line. It is desirable to have perfectly matched corresponding impedances or approximately matched to the channel impedance so that the return loss is minimized. In general, the process of designing a microstrip array antenna by using a double stub on a feeding line is to adapt the reference antenna impedance by correcting the impedance of the double stub. Frequency of the antenna is set by obtaining precise dimensions of antenna patch elements and the distance between stubsat the feeding line. Consequently, antenna dimensions are calculated by using several theoretical equations as shown in equation (1) to (5).

2.1 Geometry of the Antenna

The antenna geometry is designed and simulated by using PCAAD 5.0 and HFSS software and ultimately realized by using Epoxy FR4 material as an antenna element with dielectric constant,ε_r of 4 and thickness of substrate,h of 1.6mm. The size of the antenna width, W and length, L are obtained by using the following equations,

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r+1)}{2}}} \quad (1)$$

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

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

and

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(\frac{1}{\sqrt{1+12\frac{h}{w}}}\right) \quad (4)$$

Where c, f,ε_{reff}, L_{eff} and ΔL are the speed of light in vacuum, desired frequency, effective dielectric, effective length and incremental length, respectively. While, the distance, d between antenna patch elements is calculated by,

$$d = \frac{\lambda}{2} \quad (5)$$

The reference antenna works at frequencies of 2.4 GHz and 5.8 GHz, respectively by using a ¼ λ transformer impedance adjustment as shown in Figure 1. The dimensions of the reference antenna size settings and the simulation results of the reference antenna parameters are given (see Table 1 and Table 2).

The design of proposed antenna as shown in Figure 2 consists of an arrangement of two rectangular patch elements for wireless communication applications that work at 2.4 GHz and 5.2 GHz frequencies. The dimensions of both elements are at$L$= 26.6 mm and W= 38.8 mm. A patch antenna, rooting, and grounding are made of copper metal. Patch antenna and feeder are placed at the top of the substrate, while the ground is placed at the bottom of the substrate [8].

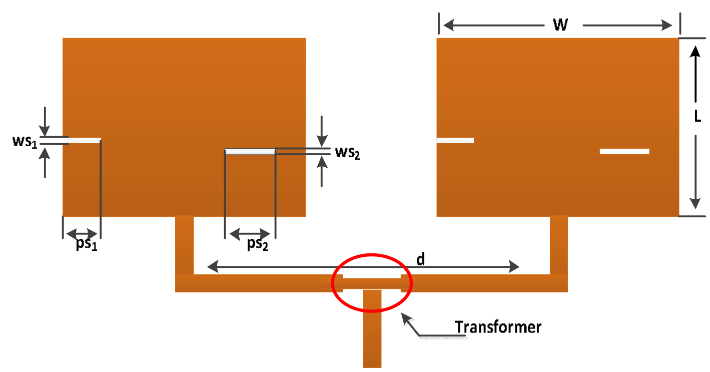

Figure 1: The Reference Antenna

Table 1: Size Settings for Reference Antenna

Dimensions	Size (mm)
W	40
L	27.7
w	3
l	13
S1	0.5 x 7
S2	0.5 x 8

Table 2: Simulation Results of Reference Antenna Parameters

Parameters	Frequency (GHz)	
	2.4 GHz	5.8 GHz
Impedance (Ω)	48	42
Return Loss (dB)	-13.5	-22.2
VSWR	1.3	1.5
Bandwidth (MHz)	33	10

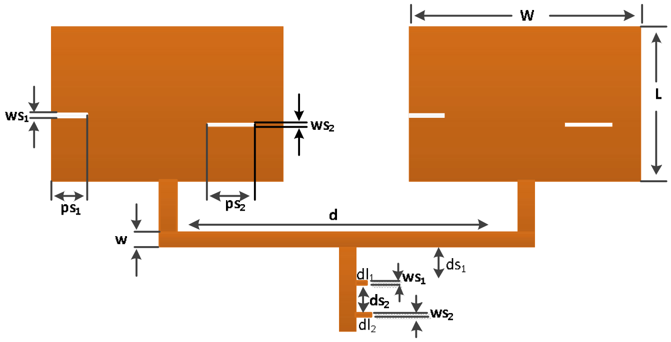

Figure 2: The Proposed Antenna

To minimize mutual coupling between patch antennas, each patch antenna is 62 mm spaced [8]. Appropriate spacing between patches gives optimal results of antenna parameters and allows the antenna to work on multiple frequencies. In this work, patch antennas are given a load of two slots [8,22], with each slot size of 0.5 x 8 mm and 0.5 x 7 mm, whereby the size and distance of the slots can vary [15]. The antenna works with direct rooting with a thickness of 0.035 mm. In rationing, the function of the stub is to adjust the impedance between patches [4,8,13,22] where each stub has a size of 0.5x1 mm.

2.2 The Simulation Process

The flowchart of the simulation process for the proposed antenna design is shown in Figure 3. The design begins by determining the antenna that has to be reconfigured. Subsequently, matching impedance of double stub on feeding line is corrected as per requirements. When the desired frequencies of 2.4 GHz and 5.2 GHz are obtained, the impedance matching between the stubs and feeding line is ensured to be approximately at 50 Ω. Otherwise, dimensions of the antenna patch elements have to be properly adjusted according to the desired frequencies before the impedance matching is established. Once the impedance of the antenna is matched to the impedance of the transmission line, hence, the required values of RL and VSWR are verified. In contrast, if the antenna impedance does not match to the impedance of the transmission line, the dimensions and distance of the double stub have to be adjusted until the impedance matching is realized at about 50 Ω.The simulation is done when the values of antenna parameters are achieved within the acceptable range.

3. SIMULATED RESULTS AND DISCUSSION

Simulation is carried out with several possibilities to get optimal results of the antenna parameters which are Z, RL, and VSWR. Changes in the lengths of stub 1 (S1) and stub 2 (S2) have highly influenced the antenna parameter sat both frequencies as when the length of S1 is varied and S2 is fixed (see Table 3). It can be seen that the changes of S1 length have affected the antenna impedance values. The variations of S1 length as well as the distance between stubs havealso shown impacts to the RL and VSWR values. Those changes effect

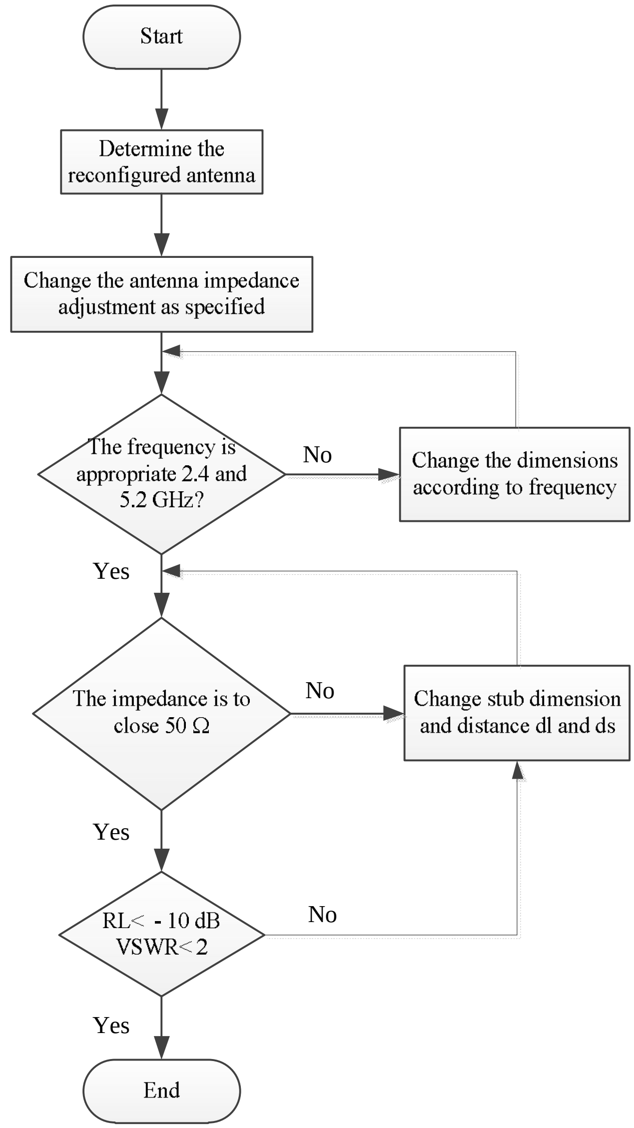

Figure 3: The Flowchart of the Simulation Process

each other's radiating elements especially during rationing and patching. In this work, the distance between stubs was fixed at 3 mm. By considering first scenario of the stubs lengths where S1 was varied and S2 was fixed, it can be revealed that at S1 with a length of 1.2 mm, the optimal impedance values were obtained at 52 Ω and 47 Ω for 2.4 GHz and 5.2 GHz, respectively. The VSWR has also achieved values of 1.04and 1.07at 2.4 GHz and 5.2 GHz (see Table 3).

Table 3: Simulation resultsof proposed antenna when the length of S1 is varied and S2 is constant at 1.0 mm.

S1 (mm)	S2 (mm)	Z (Ω)		RL (dB)		VSWR	
		2.4	5.2	2.4	5.2	2.4	5.2
1.0	1.0	56	47	-24	-20	1.13	1.21
1.1	1.0	59	43	-21	-22	1.20	1.18
1.2	1.0	52	47	-34	-29	1.04	1.07
1.3	1.0	64	41	-18	-20	1.30	1.22
1.4	1.0	55	44	-26	-24	1.11	1.14
1.5	1.0	57	48	-22	-23	1.17	1.15

Figure 4, 5 and 6 illustrate the simulation results of the Z, RL and VSWR obtained when the lengths of S1 and S2 were at 1.2 mm and 1.0 mm correspondingly. In Figure 4, it depicts that the impedance values were 51.98 Ω and 46.88 Ω at 2.4 GHz and 5.2 GHz, respectively. Meanwhile, the return loss has depicted values of -34.2 dB at frequency of2.4 GHz and -28.93 dBat 5.2 GHZ as shown in Figure 5. In Figure 6, the VSWR has portrayed promising values of 1.04 and 1.07 respectively at 2.4 GHz and 5.2 GHz.The bandwidth generated in Figure 6at the frequency of 2.4 GHz 100 MHz and at the frequency of 5.2 GHz, the bandwidth was slightly higher than 200 MHz. In comparison to the reference antenna, the bandwidth of the proposed antenna has shown a noteworthy improvement that has extended over three times higher or 300% increment particularly at frequency of 2.4 GHz where the bandwidths were 33 MHz and 100 MHz for reference antenna and proposed antenna, respectively. While Figure 7 and 8 depict the gain of the proposed antenna at the same stubs dimensions. At 2.4 GHz, the antenna gain was 3.21 dBm while at 5.2 GHz, 3.25 dBm of the antenna gain was achieved.

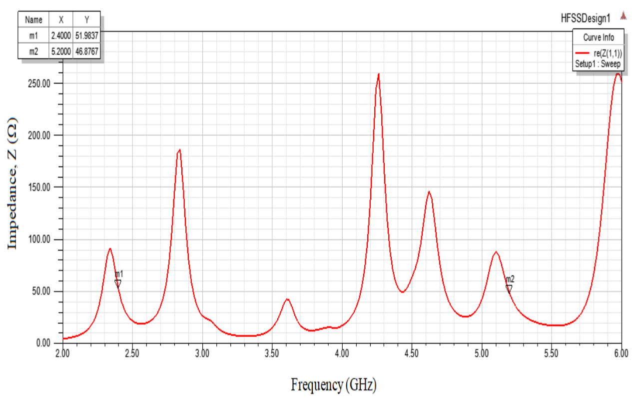

Figure 4: The impedance of the proposed antenna at lengths of S1 = 1.2 mm and S2 = 1.0 mm

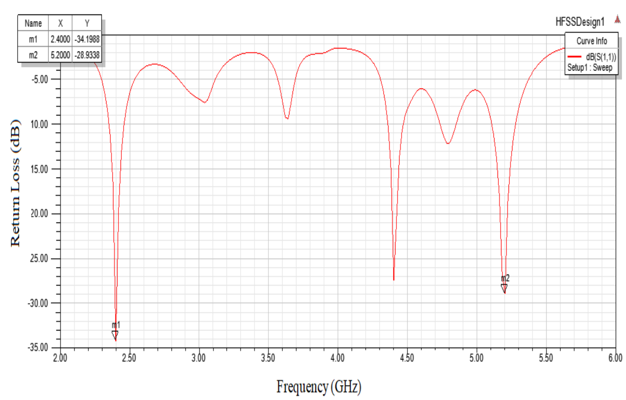

Figure 5: The return loss of the proposed antenna at lengths of S1 = 1.2 mm and S2 = 1.0 mm

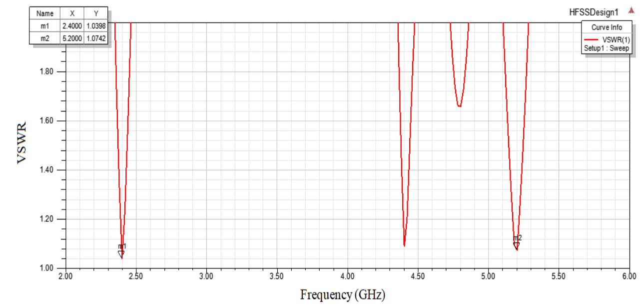

Figure 6: The VSWR of the proposed antenna at lengths of S1 = 1.2 mm and S2 = 1.0 mm

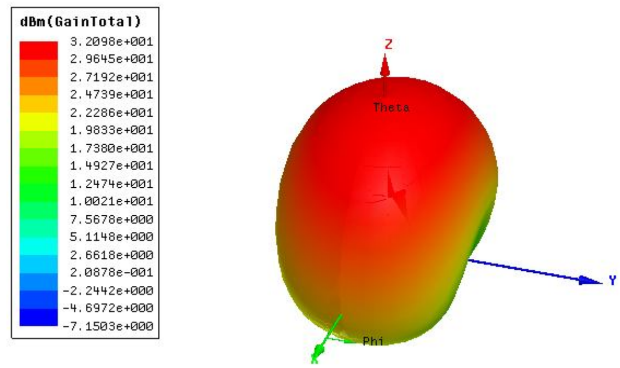

Figure 7: The gain of the proposed antenna for frequency of 2.4 GHz at lengths of S1 = 1.2 mm and S2 = 1.0 mm

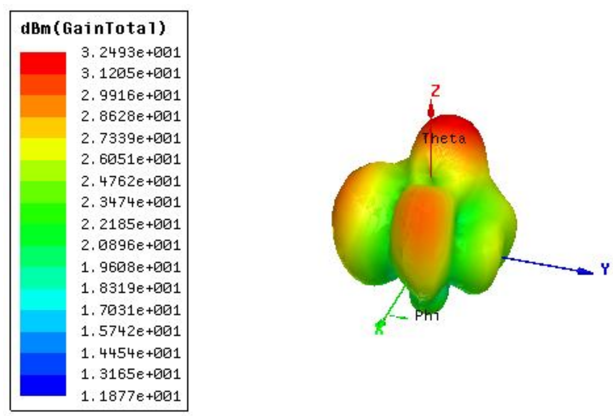

Figure 8: The gain of the proposed antenna for frequency of 5.2 GHz at lengths of S1 = 1.2 mm and S2 = 1.0 mm

In order to verify the findings of the parameters obtained from the proposed antenna based on the first scenario, another scenario was considered where S1 was fixed while S2 was varied. By increasing the length size of S2, it only shown slightly different effects to the impedance values at both frequencies (see Table 4). This is due to both elements that influence each other mainly from S1 and the main supply. At a length of 1.2 mm of S2, it was found that the optimal impedance values were attained at 53 Ω and 49 Ω for the frequency of 2.4 GHz and 5.2 GHz, respectively.The VSWR values of 1.09 at 2.4 GHz and 1.23 at 5.2 GHz were achieved. In this simulation design, the channel impedance parameter was set at 50 Ω.

Table 4: Simulation resultsof the proposed antenna when the length of S1 is constant at 1.0 mm and S2 is varied.

S1 (mm)	S2 (mm)	Z (Ω)		RL(dB)		VSWR	
		2.4	5.2	2.4	5.2	2.4	5.2
1.0	1.0	56	47	-24	-21	1.13	1.21
1.0	1.1	42	31	-21	-12	1.21	1.65
1.0	1.2	53	49	-29	-23	1.07	1.15
1.0	1.3	55	43	-27	-20	1.09	1.23
1.0	1.4	54	43	-27	-20	1.09	1.23
1.0	1.5	51	41	-39	-20	1.02	1.23

Meanwhile, figure 9, 10 and 11demonstrate the Z, RL and VSWR obtained from the simulation results when the lengths of S1 and S2 were at 1.0 mm and 1.2 mm respectively. Figure 9 shows the impedance values of 52.86 Ω and 48.98 Ω at 2.4 GHz and 5.2 GHz, correspondingly, while in Figure 10, the return loss has shown values of -28.86 dB at frequency of2.4 GHz and -23.29 dBat 5.2 GHZ. The VSWR has also depicted good values of 1.07 and 1.15 respectively at 2.4 GHz and 5.2 GHz as can be found in Figure 11.

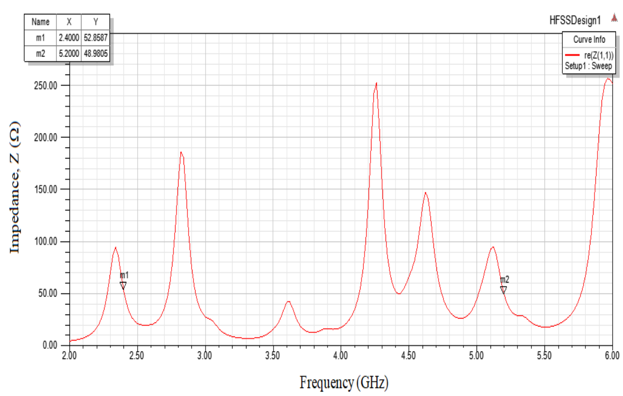

Figure 9: The impedance of the proposed antenna at lengths of S1 = 1.0 mm and S2 = 1.2 mm

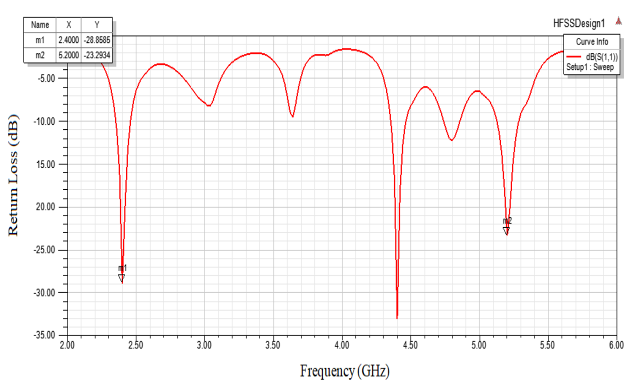

Figure 10: The return loss of the proposed antenna at lengths of S1 = 1.0 mm and S2 = 1.2 mm

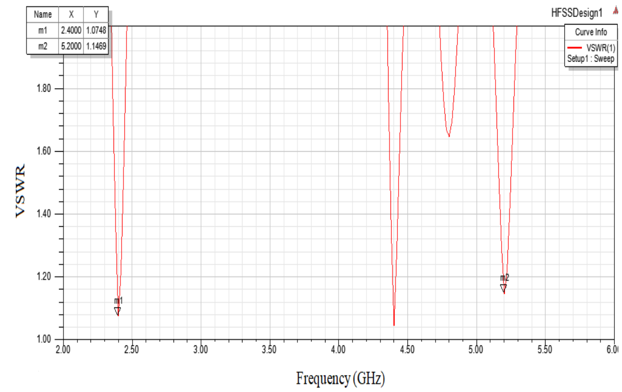

Figure 11: The VSWR of the proposed antenna at lengths of S1 = 1.0 mm and S2 = 1.2 mm

Similarly, the bandwidth of the proposed antenna based on second scenario can be obtained from Figure 11. The antenna bandwidth was also 100 MHz at the frequency of 2.4 GHz and the bandwidth was about 180 MHz at the frequency of 5.2 GHz. In comparison to the reference antenna, in this scenario, the bandwidth of the proposed antenna has also revealed a significant improvement that has extended above three times higher at frequency of 2.4 GHz in particular. In the meantime, Figure 12 and 13 represent the gain of the proposed antenna at S1 and S2 lengths of 1.0 mm and 1.2 mm respectively. The antenna gain was 3.22 dBm at frequency of 2.4 GHz and 3.03 dBm at 5.2 GHz. These findings have proved that the appropriate lengths of both stubs are at 1.0 mm and 1.2 mm interchangeably in order to obtain optimum values of antenna parameters where the distance between stubs was fixed at 3 mm.

The simulated results comparisons of the antenna parameters between the reference antenna with ¼ λtransformer impedance matching technique and the proposed antenna with double stub impedance matching technique are presented (see Table 5).The results have demonstrated improvements in the impedance values and have achieved significant performance of the antenna parameters mainly in the improvement of the bandwidth at frequency of 2.4 GHz in particular.

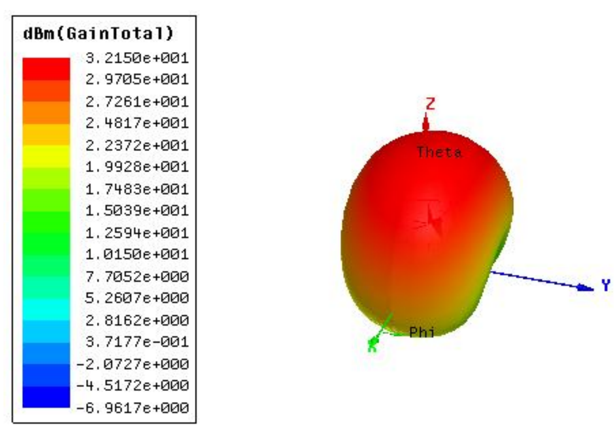

Figure 12: The gain of the proposed antenna for frequency of 2.4 GHz at lengths of S1 = 1.0 mm and S2 = 1.2 mm

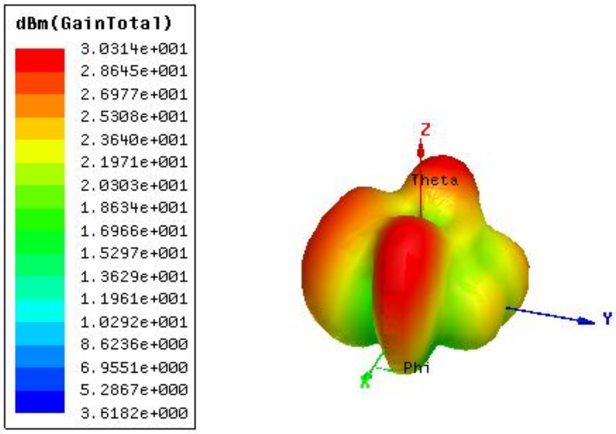

Figure 13: The gain of the proposed antenna for frequency of 5.2 GHz at lengths of S1 = 1.0 mm and S2 = 1.2 mm

Table 5: Antenna parameters comparisons between the reference antenna (1/4 λtransformer) and the proposed antenna (double stub)

Parameters	Frequency			
	¼ λ Transformer		Double Stub	
	2.4	5.8	2.4	5.2
Impedance (Ω)	48	42	52	47
Return Loss (dB)	-13.5	-22.2	-34	-29
VSWR	1.3	1.5	1.04	1.07
Bandwidth (MHz)	33	10	100	210
Gain (dBm)	3.13	2.98	3.21	3.25

In this work, all simulations are performed in achieving optimum antenna parameters performance which can be realized when the antenna impedance is in accordance with the channel impedance of $Z_o = Z_L$. It is expected that once the transmission line impedance is perfectly matched to the antenna impedance, undoubtedly the other parameters are achieved according to the specified requirements such as the RL and VSWR.

4. CONCLUSION

In conclusion, this work has presented a dual-frequency band microstrip antenna array design utilizing double stub feeding. Two identical dimensions of rectangular antenna patch elements were demonstrated for frequency of 2.4 GHz and 5.2 GHz with proper impedance matching technique at the feeding line. The simulation of the proposed antenna has been carried out and optimum configuration and parameter performance have been presented. Two scenarios were considered for the stubs design and it was found that appropriate lengths of both stubs are at 1.0 mm and 1.2 mm interchangeably in order to obtain optimum values of antenna parameters. Apart from improvements on the Z, RL as well as the VSWR of the proposed antenna, in comparison to the reference antenna, the most significant finding was that the proposed antenna has the bandwidth value that was extended approximately three times higher or 300% of increment particularly at frequency of 2.4 GHz. The simulation design of the proposed antenna was realized by considering the FR4 properties as the antenna element. This design will later be fabricated and experimentally tested by using sweep generator and vector analyzer to further validate the performance of the antenna as a feasible transmitter and receiver.

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