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High Gain Triple-band Array Antenna for GSM, Wi-Fi and LTE Applications

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ABSTRACT

A high gain triple-band array antenna of 1.8 GHz, 2.4 GHz and 2.6 GHz covering wireless applications (GSM, Wi-Fi and LTE) is proposed. Four identical optimized radiating elements with 2x2 T-slotted patches are connected to quarter-wave transformer through copper via. It is found out that factor of T-shape slotted array elements with certain via positioning together have significantly influenced the performances of the proposed antenna towards gain and reflection coefficient. Comprehensive parametric studies have been carried out to prove this statement. The proposed T-shape slotted patch array antenna has been successfully generated a high gain of 9.06 dBi at 1.8 GHz, 7.57 dBi at 2.4 GHz and 7.31 dBi at 2.6 GHz. Such gain considered as 60% higher compared to the benchmark antenna as elaborated in the next section.

1. Introduction

Nowadays, researchers are attracted to design a multi-band antenna, as it can be a cost-effective solution by removing dispensable ones. For the benefit of the solution, several methods have been proposed for example; coplanar waveguide (CPW) fed monopole antenna with embedded slots [1,2], planar inverted-F antennas (PIFAs) [3-5], microstrip-line-fed antennas [6-8], probe-fed antennas [9]-[10] and different shapes of multimode monopoles [11-12]. From the literature, the antenna in [1, 6-8] have been generating a triple-band compared to other techniques that only capable to operate in/at dual-band [9] and [10]. However it has been noticed that the performance of antenna's gain need to be improved as it shows a lower reading due to a single element as shown in Table I. Single antenna can be arranged as multiple antennas on the same surface to enhance the gain but the desired operating frequencies might be produced or changed to unwanted frequencies as well as distorted the main lobe direction [13]. The antenna efficiency will be degraded due to this factor. Good antennas are expected to attain higher gain, broader bandwidth as well as consistent radiation pattern toward the designated frequency bands.

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To overcome the problem above, a T-shape slotted array patch antenna has been designed using via for triple-band frequency of 1.8 GHz, 2.4 GHz and 2.6 GHz. The radiating elements and transmission line are connected through copper via. This letter found out that the positioning of via near to slotted patch significantly influence the proposed antenna's desired triple-band frequencies.

While the combination of multiple T-shape slotted patches known as array are opt to achieve a higher gain within that frequency bands. Parametric studies on the array structure and positioning of via are carried out to suit the purpose. To the best authors' knowledge, currently none of these antennas [1-12] designed at 1.8GHz, 2.4GHz and 2.6GHz with a high gain for the application of GSM, Wi-Fi and LTE. For that reason, three common operating frequencies of 2.4/2.5 GHz,3.5 GHz and 5.5/5.8 GHz for WLAN/WiMAX applications as reported in [1,7-8] has been chosen to at least benchmark the value of gain with proposed antenna as illustrated in Table 1. It can be clearly seen that the gain of proposed antenna significantly increased as it can achieve the gain of 9.06 dBi at 1.8 GHz, 7.57 dBi at 2.4 GHz and 7.31 dBi at 2.6 GHz. The letter is prepared in few sections. Section 2 described the topology and the design approaches of the proposed antenna. Simulated results and discussion of the antenna will be explained in Section 3. Finally, the conclusion is drawn in section 4.

2. Antenna Design

The objective of this research is to design triple band antenna covering at 1.8GHz, 2.4GHz and 2.6GHz covering GSM, Wi-Fi and LTE applications in one antenna. First, a single of micro strip antenna is design. The dimension of antenna is design using a formula below with used a higher frequency of 2.6GHz as reference frequency.

$$w = \frac{c}{2f\left(\sqrt{\frac{\varepsilon r+1}{2}}\right)} \quad (1)$$

In this design, the antenna is squared and etched with four symmetry of T-shape dimension. The single antenna is design on 1.6mm thick of FR-4 substrate (εr of 4.7) of dimension Ls × Ws using 0.035mm thick copper that work as ground plane of the antenna. The antenna operate at 2.106 GHz is chosen as references as shown in Figure 1.

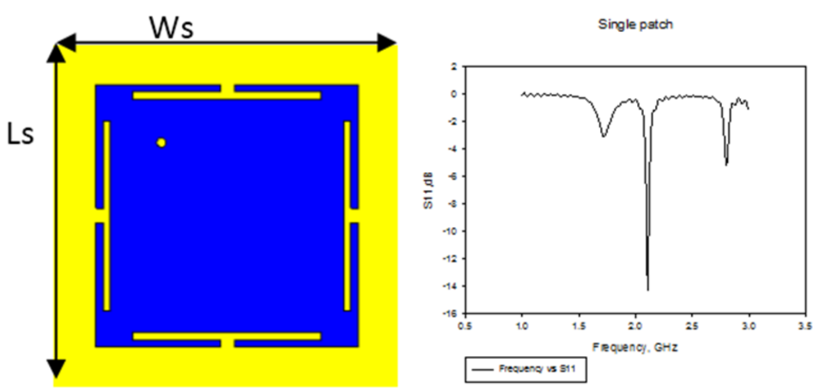
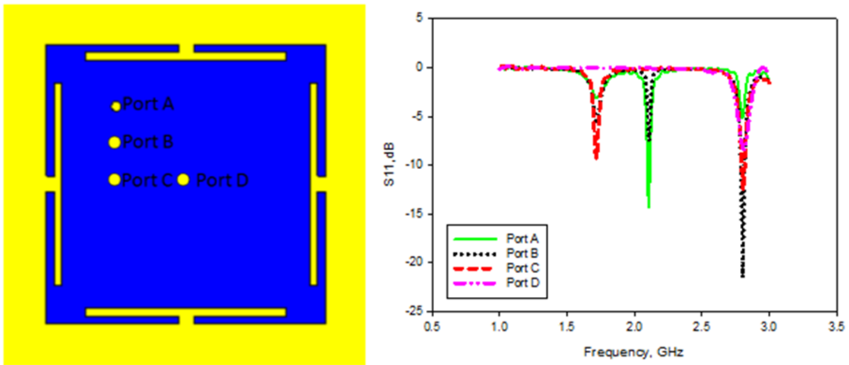


Fig. 1. The single T-shape slotted patch antenna

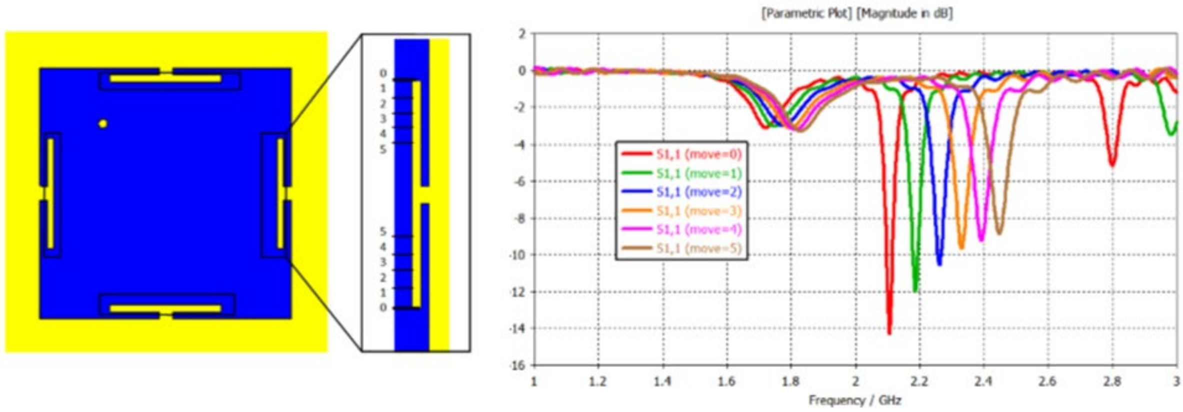
Next, we had design the antenna with different location of port on slotted patch antenna as shown in Figure 2(a). The position of port were analysis to investigate the effect to the antenna in frequency resonance. The position of port can be seen had control the lower of resonant frequency as shown in Figure 2(b).The different placement of port near to slotted T-shape can change the current flow and automatically change the resonant frequency.



(a) (b)

Fig. 2. Influenced of port on antenna (a) Image position of port (b) Reflection coefficient of parametric study

Then, the length of T-slotted has been analysis. Numerical simulation has been done and the results finding the T-shape slotted length capable to give effect to the alteration of upper frequency. Regardless about below 10dB, it can obviously see that the slotted antenna give an effect to the upper frequency when the length is reduced, the upper frequency had shift to the right side.



(a) (b)

Fig. 3. Influenced of dimension length of T-shape slotted (a) Image of T-shape slotted on patch antenna (b) Reflection coefficient of parametric study

The aim in this research is to design the multiband array antenna that capable to generate multiband covering GSM, Wi-Fi and LTE applications with high gain. In the proposed of array antenna, four single T-shape slotted patch of previous design are engrave on one antenna as shown in Figure 4(a) and (b). The quarter wave length in Figure 4(c) is printed on the bottom of substrate and connect to the patches thru copper via. The purpose of this technique is used to allow us to do an assignment of port position to the required position x-axis and y-axis. Meanwhile, a full ground plane that works as a reflector with an optimum gap of 10mm is applied as in Figure 4(d). Numerical simulations of parametric studies of T-shape slotted dimension and position of via have been carried out in order to obtain finest design. Table II and III show the detail of final dimension based on optimized parameter.

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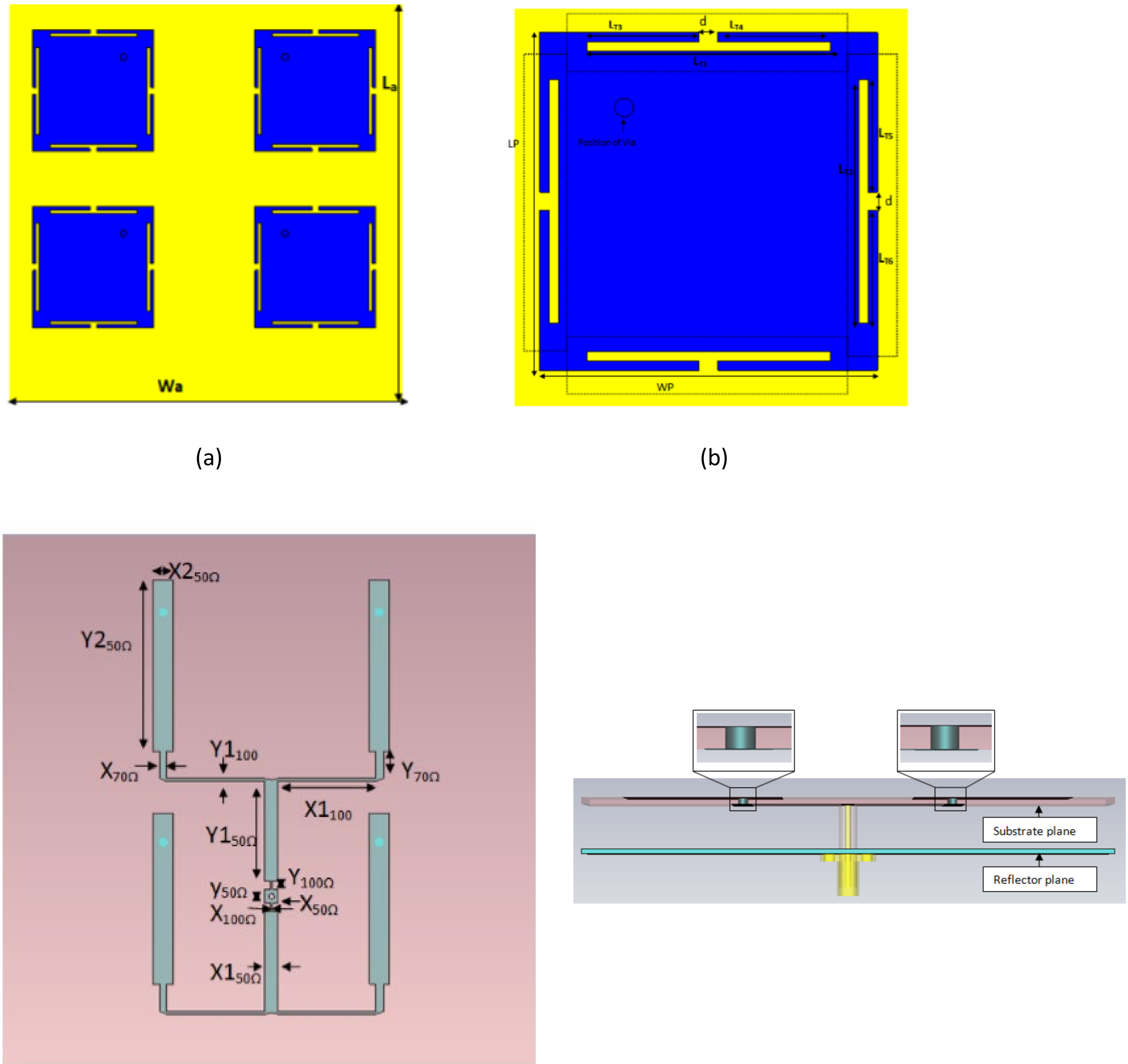


(a) (b)

(c) (d)

Fig. 4. Configuration of proposed antenna (a) Top and side view (b) Detail of each patch of antenna substrate (c) Copper via (d) Quarter-wave transformer at the reverse side of substrate.

Table 1
T-shape Slotted Array Antenna Dimension

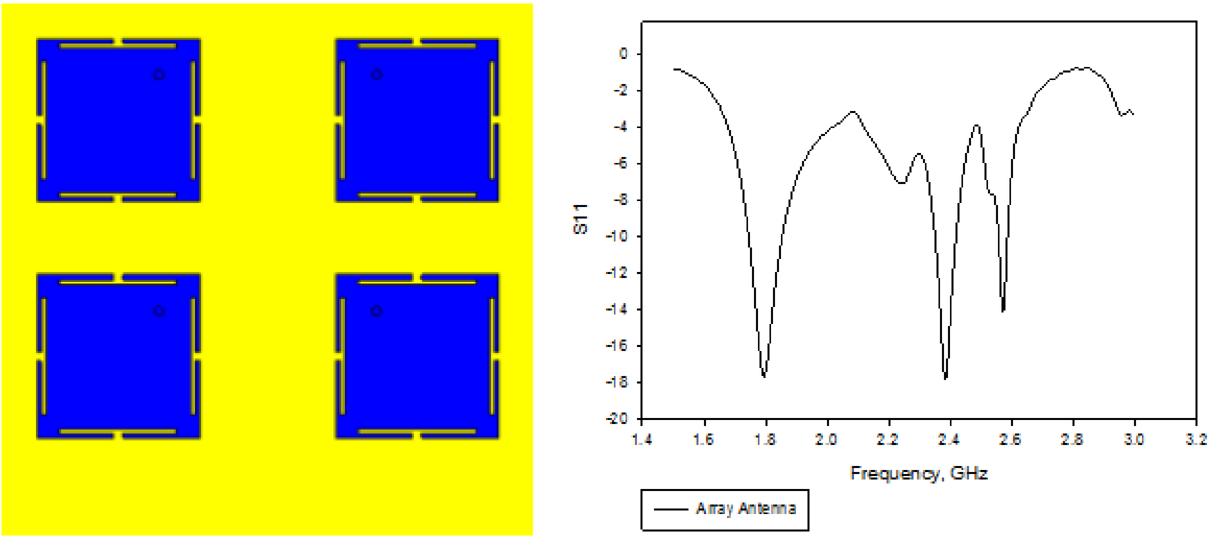
Parameter	Value(mm)	Parameter	Value(mm)
Length of slot , L_{T1}	26	Width of Patch, W_P	36
Length of slot , L_{T2}	25	Length of Patch, L_P	36
Length of slot , L_{T3}	11	Height of substrate, h	1.6
Length of slot , L_{T4}	13	Height of Air gap, Ag	10
Length of slot , L_{T5}	11	Height of Ground, g	1
Length of slot , L_{T6}	12	Width of Antenna,Wa	120
Length of slot, d	2	Length of Antenna, La	120

Table 2
Quarter-Wave Transformer Dimension

Parameter	Value (mm)	Parameter	Value (mm)
Width 50Ω, $X_{50\Omega}$	2.91	Width 100Ω, $X1_{100\Omega}$	23
Length 50Ω, $Y_{50\Omega}$	3	Length 100Ω, $Y1_{100\Omega}$	0.65
Width 100Ω, $X_{100\Omega}$	0.65	Width 70Ω, $X_{70\Omega}$	1.526
Length 100Ω, $Y_{100\Omega}$	2	Length 70Ω, $Y_{70\Omega}$	6
Width 50Ω, $X1_{50\Omega}$	2.91	Width 50Ω, $X2_{50\Omega}$	4.436
Length 50Ω, $Y1_{50\Omega}$	22	Length 50Ω, $Y2_{50\Omega}$	38

3. Result and Discussion

The array antenna successfully design using the reference single antenna in previous section. Figure 5 shows the array antenna with reflection coefficient result. It shows that the antenna capable to generate triple band. However, this array antenna need to be adjusted to enhance the reflection coefficient of operating frequency that required. The antenna generated 1.8GHz at -17.367dB, 2.4GHz at 14.093dB, and 2.6 GHz at -6.144 (<-10dB).



(a) (b)

Fig. 5. Array antenna structure (a) The combination of four single patch antenna using quarter wave transform thru via (b) Reflection coefficient of array antenna

New parametric studies of positioning of copper via is analysis. It is done with numerical simulations as can be seen in Figure 6(a). The results in Figure 6(b) indicated that the positioning of via is another important factor to generate and optimize desired lower frequency. This might be due to current distribution at the amendments of via position that in turn affect to the obtaining frequency. Port A is chosen as an optimized via position of the proposed array antenna.

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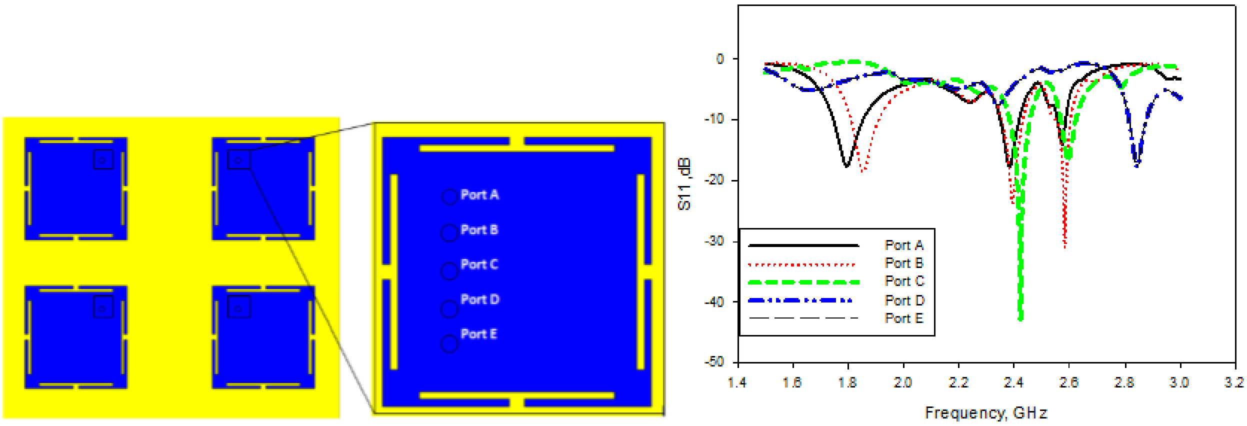

Fig. 6. Influenced of via positioning (left) Image position of via at Y-axis (right) Reflection coefficient of parametric study

Next, the numerical simulation is extended to analysis the effect of T-shape on resonant frequency of array antenna. Figure 7 (a) and (b) depicted the comparison of with and without etched of T-shape slotted patch of array antenna with remain the position of copper via. The array antenna without T-shape slotted only capable to generate and remain a lower frequency and while T-shape slotted array antenna obtained triple-band as it can be verified in Figure 7(c). The involvement of T-shape slotted can be defined as one of the factor that giving significant impact to the respected upper frequency.

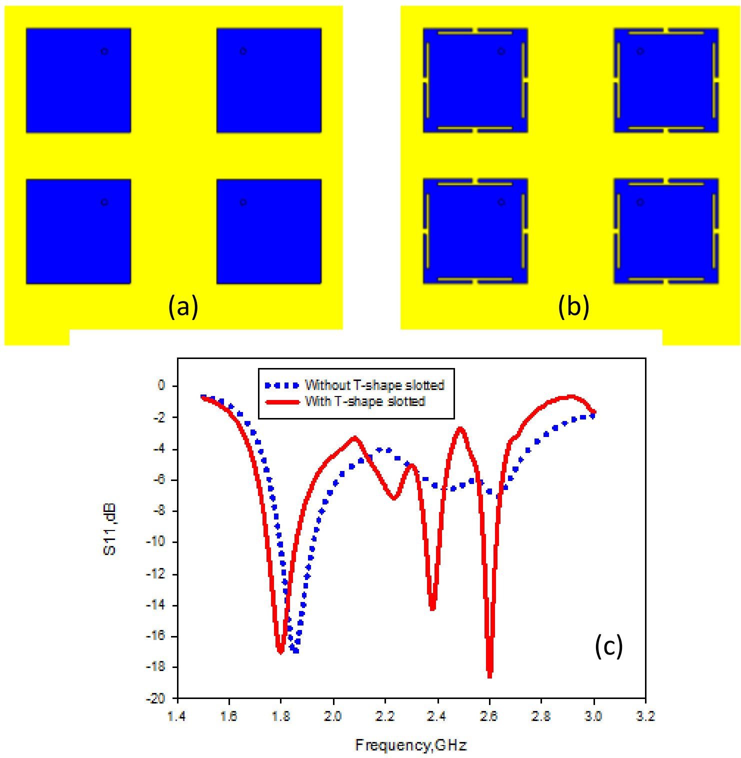

Fig.7. TGA and DTG curve of rNBR. Comparison of with and without T-shape slotted on the patch antenna (a) Image of antenna without T-shape slotted (b) Image of antenna with T-shape slotted (c) Simulated reflection coefficient

Figure 8 shows excellent agreement of reflection coefficient at three different resonance frequencies for simulated and fabricated antenna. However, due to the differ complexity degree in fabricated and simulated during embedding and aligning the via into the substrate, the results have been slightly different between simulated and measured but still acceptable. In Figure 9, the antenna successfully reach a high gain of 8.76 dB (simulated) and 8.26 dB (measured) at 1.8 GHz, 6.896 dB (simulated) and 6.546 dB (measured) at 2.4 GHz, and 6.007dB (simulated) and 5.583 (measured) at 2.6 GHz. Figure 8 indicates the simulated and measured normalized far field radiation patterns at 1.8 GHz, 2.4 GHz and 2.6 GHz, respectively. The stability of radiation pattern at three resonant frequencies obviously reveals the positive effect and considered as a good antenna.

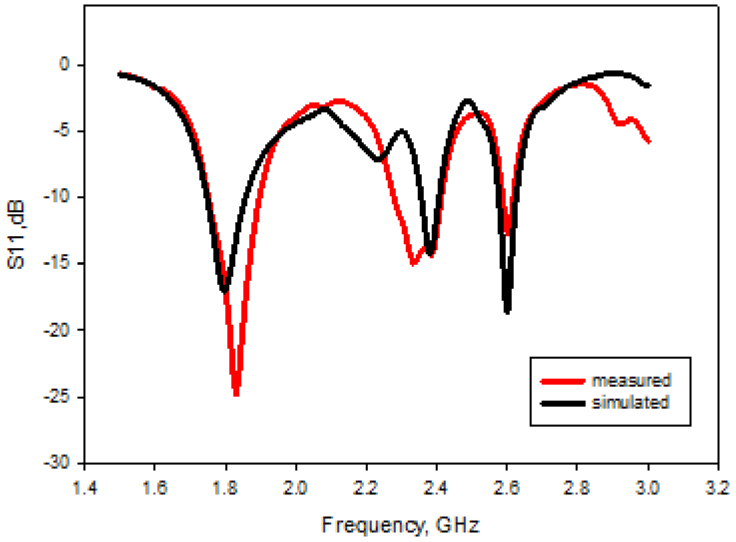

Fig. 8. Reflection Coefficient of simulated and measure antenna

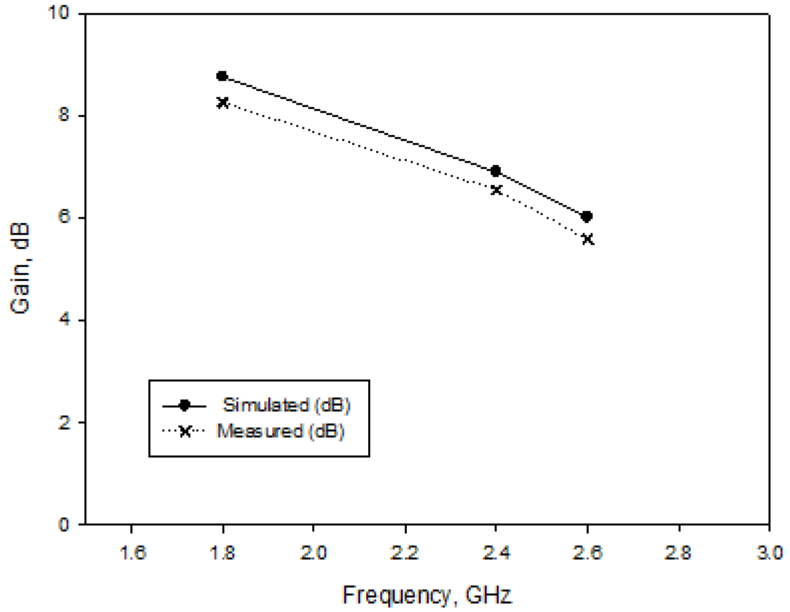

Fig. 9. Graph of Gain of simulated and measured antenna

4. Conclusion

T-shape slotted array antenna through via for triple band has been presented. Both the simulated and measured results show that the demonstrated antenna can successfully obtained three operating bands with high gain and it is suitable candidate for wireless communication systems. The parameters such as the position of via, the width and length of T-shape slot at the edge of the patch have been optimized to ensure the desired frequencies are successfully generated. In addition, the proposed antenna also provides good radiation patterns and stable gains in the working bands.

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