

ALTERNATIVE APPROACH IN ENHANCING THE BANDWIDTH OF THE MICROSTRIP ANTENNA

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Abstract. Antenna is a vital component in wireless application systems. The microstrip antenna can be used for wireless applications as it has features such as light weight, easily mounted and it is easy to mass produce. Although there are many features that suits well for microstrip antenna to be deployed for wireless applications, there is a very serious limitation where it has a very narrow bandwidth. The typical bandwidth of the microstrip antennas is between 1 – 3%. If this limitation is eliminated, the microstrip antenna can be used to its full potential. An alternative bandwidth enhancement technique is studied and then proposed in order to broaden the bandwidth of the microstrip antenna. The wireless application that is selected to be studied is the Wireless Local Area Network (WLAN) based on the IEEE 802.11b standard. In Malaysia, this WLAN band spans from 2.4 GHz to 2.48 GHz. The bandwidth enhancement technique which is selected is the Identical Dual-Patch Microstrip Antenna with Air-Gap (IDMA). By using this technique, a bandwidth enhancement of about 11% has been achieved. This bandwidth very well covers the required WLAN band with an operating frequency of 2.45 GHz.

Keywords: Wireless local area network (WLAN); identical dual patch microstrip antenna with air-gap (IDMA)

Abstrak. Antena merupakan satu komponen penting dalam sistem komunikasi wayarles. Antena mikrojalur boleh digunakan untuk aplikasi wayarles kerana ia mempunyai ciri-ciri seperti ringan, mudah dipasang dan dihasilkan dalam kuantiti yang banyak. Walaupun antenna mikrojalur mempunyai ciri-ciri tersebut yang menjadikannya sesuai untuk digunakan dalam aplikasi wayarles, namun ia mempunyai satu kekurangan yang agak serius, iaitu ciri lebar jalur yang sempit. Selalunya, antenna mikrojalur mempunyai jalur di antara 1 – 3%. Tetapi, sekiranya kekurangan ini dapat diatasi, potensi antenna mikrojalur boleh dimaksimumkan. Satu teknik alternatif untuk memperluaskan lebar jalur antenna mikrojalur telah dikaji dan dicadangkan di sini. Aplikasi wayarles yang telah dipilih untuk dikaji ialah rangkaian kawasan tempatan tanpa wayar (WLAN) berasaskan kepada piawaian IEEE 802.11b. Di Malaysia, jalur WLAN adalah di antara 2.4 GHz hingga 2.48 GHz. Teknik yang dipilih untuk meluaskan lebar jalur ini ialah Antena Mikrojalur Dua Tampal Serupa Dengan Ruang Udara (IDMA). Dengan menggunakan teknik ini, perluasan lebar jalur hingga lebih kurang 11% dapat dicapai. Jalur ini sememangnya dapat merangkumi jalur WLAN dengan frekuensi operasinya pada 2.45 GHz.

Kata kunci: Rangkaian kawasan tempatan wayarles (WLAN); antenna mikrojalur dua tampal serupa dengan ruang udara (IDMA)

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1.0 INTRODUCTION

In recent years, the popularity of wireless applications is ever increasing in the industry as well as in our very own society. There is a very large demand for wireless applications because of its mobility. This is evident as the usage of mobile telephones which is integrated with wireless data services is very common these days. Portable devices which support data and telephony are being used in a mobile computing environment. There is a large investment that has been put into wireless communication by the major companies in the telecommunication industry. This shows that wireless applications are gaining an increase in its usage in our society. One particular wireless application that has experienced this trend is the Wireless Local Area Network (WLAN). According to the guideline by Malaysian Communications and Multimedia Commission (MCMC) on the provision of WLAN service, the unlicensed spread spectrum band in Malaysia for WLAN technologies are from 2.4 GHz to 2.48 GHz, 5.250 GHz to 5.350 GHz and from 5.725 GHz to 5.875 GHz [1]. In this design, the wireless application that is selected to be studied is the 2.4 GHz to 2.48 GHz frequency band which is based on the 802.11b WLAN standard. This frequency band is very popular due to its low cost.

The role of antenna for wireless applications has become more vital because the antenna will ensure the efficient connectivity in a WLAN system. WLAN antennas required being low profile, light weight and broad bandwidth. The microstrip antenna suits the features very well except for its narrow bandwidth [2]. The WLAN antenna should have a minimum bandwidth of 100 MHz to fully utilize the WLAN band based on the 802.11b standard. The conventional microstrip antenna could not fulfill this requirement as its bandwidth usually ranges between 1 – 3%. Although the required operating frequency range is from 2.4 GHz to 2.48 GHz, at least double the bandwidth is required to avoid expensive tuning operations and to cause uncritical manufacturing [3–4]. Therefore, there is a need to enhance the bandwidth of the microstrip antenna for WLAN applications.

One technique of bandwidth enhancement is the microstrip antenna with air-gap. In this design, an air-gap is inserted between the dielectric substrate and the ground plane for bandwidth enhancement of the microstrip antenna. A relative bandwidth of 2.99% was achieved operating at a frequency of 2.5 GHz [5].

This paper investigates a technique which can enhance the bandwidth of the microstrip antenna without increasing the lateral size and the complexity of the microstrip antenna too much. The Identical Dual Patch Microstrip Antenna with Air-Gap (IDMA) bandwidth enhancement technique takes the advantage of using the air gap to increase the total thickness of the microstrip antenna which is essential for bandwidth enhancement [6]. The final design of the antenna was fabricated with an extra 11% bandwidth compare to the one reported in the literature [5] and can be used for the WLAN application operating at a frequency of 2.45 GHz.

2.0 DESIGN OF THE SINGLE-LAYER MICROSTRIP ANTENNA

The dimensions of the basic single-layer microstrip antenna as shown in Figure 1 consist of the width, W and length, L , of the patch. The shape for the patch which is selected is rectangular for ease of analysis and it is commonly used [4]. RT/Duroid 5880 which is a low permittivity substrate with a thickness of 1.575 mm was selected for the microstrip antenna. The type of copper cladding used for this substrate is the 35 μm thick rolled copper. The feeding method for this antenna is coaxial probe method. The 50 Ω SMA connector is used as the feed. The simulation was carried out using the full wave analysis simulation tool by Ansoft. The dimensions are calculated as follows [6 – 10]:

For $w/h > 1$

$$\epsilon_{\text{reff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{w} \right]^{-1/2} \quad (1)$$

$$W = \frac{c}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (2)$$

$$\frac{\Delta L}{h} = 0.412 \frac{(\epsilon_{\text{reff}} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_{\text{reff}} - 0.258) \left(\frac{W}{h} + 0.8 \right)} \quad (3)$$

$$L_{\text{eff}} = L + 2\Delta L \quad (4)$$

$$L = \frac{c}{2f_r \sqrt{\epsilon_{\text{reff}}}} - 2\Delta L \quad (5)$$

where ϵ_{ff} is the effective relative permittivity, ΔL is the extension of the length and L_{eff} is the effective length. The location of the coaxial probe can be computed as follows [8].

$$Y_f \text{ (along the width)} = \frac{W}{2} \quad (6)$$

$$X_f \text{ (along the length)} = \frac{L}{2\sqrt{\xi_{re}(l)}} \quad (7)$$

$$\xi_{re}(l) = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(1 + 12 \frac{h}{L} \right)^{-1/2} \quad (8)$$

and the operating bandwidth can be obtained using the formula in reference [4]:

$$BW (\%) = \left(3.77 \left(\frac{\epsilon_r - 1}{\epsilon_r^2} \right) \frac{W}{L} \frac{h}{\lambda} \right) \times 100 \quad (9)$$

These calculated dimensions are just approximations but they serve as the starting parameters for the simulation process. After numerous iterative processes to obtain the desired operating frequency and input impedance, the optimum dimensions are obtained and the relative bandwidth is recorded. The simulated and measured results of the single-layer microstrip antenna are almost similar as shown in Figure 2 and Table 1. However, the bandwidth achieved in both the simulation and measurements is still low.

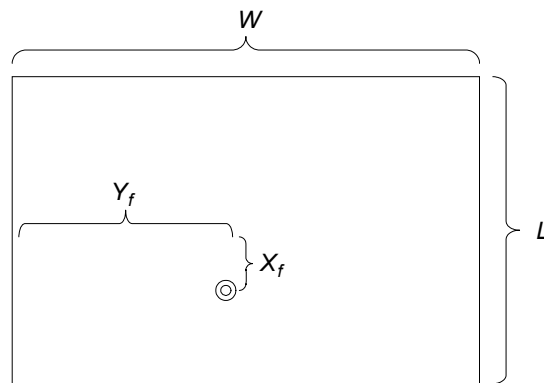
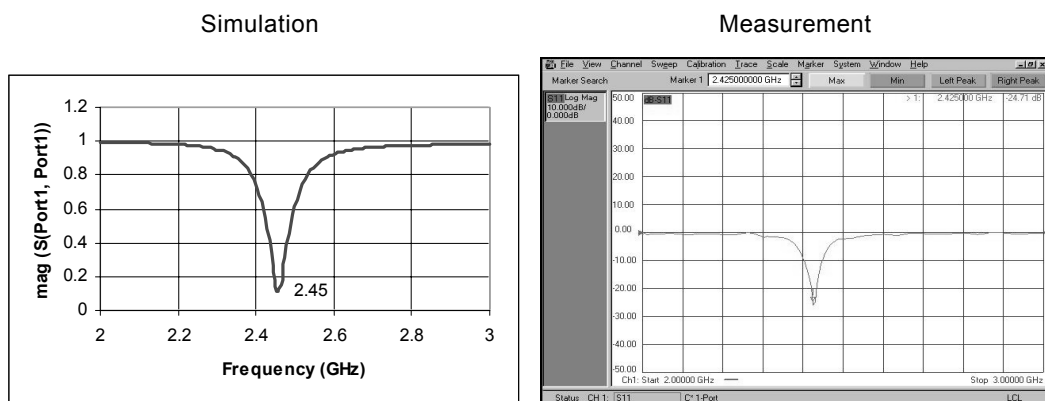


Figure 1 Single-layer microstrip antenna basic dimensions

Table 1 Simulated and measured results of the single-layer MSA

Dimensions	Simulated	Measured
Width	50 mm	same
Length	39.5 mm	same
Location of the probe	13.25 mm	same
Operating frequency	2.45 GHz	2.425 GHz
Input Impedance	50.69 Ohms	54.64 Ohms
Bandwidth	36 MHz (1.469%)	46.71 MHz (1.699%)



(a)

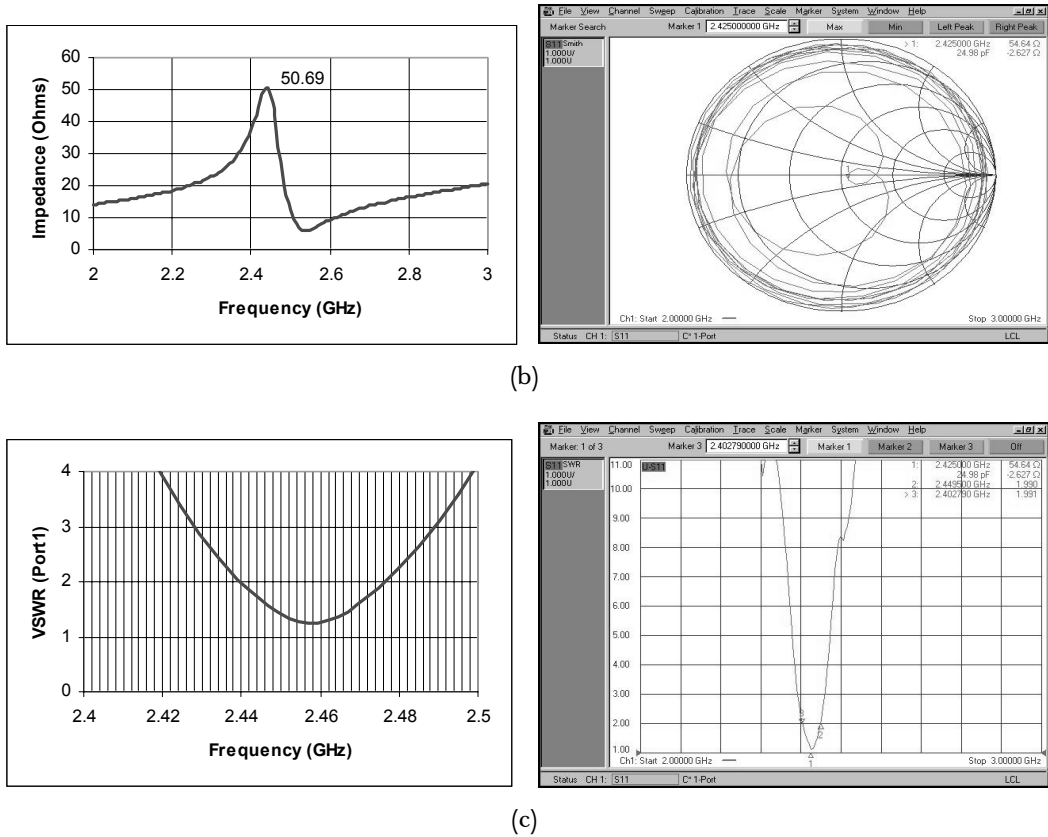


Figure 2 Simulated and measured of the single-layer microstrip antenna for (a) reflection coefficient plot indicating the operating frequency (b) input impedance and (c) voltage standing wave ratio plot indicating the bandwidth

3.0 DESIGN OF IDENTICAL DUAL PATCH MICROSTRIP ANTENNA WITH AIR-GAP (IDMA)

Initially, the basic single-layer microstrip antenna is designed and fabricated to serve as a benchmark for the design of the bandwidth enhanced microstrip antenna. The rectangular probe-fed patch was selected for both the microstrip antennas due to its ease of analysis and it is commonly used. The specifications of the material used for the antenna was given in Section 2. The fabricated microstrip antenna were measured with the E8362B Network Analyzer.

The Identical Dual-Patch Microstrip Antenna with Air-Gap (IDMA) takes the advantage of the air gap which increases the total thickness of the microstrip antenna which is an essential factor for bandwidth enhancement. Another advantage of this design is that the operating frequency of the fabricated microstrip antenna can easily be tuned without the need of a new design by just varying the size of the air gap. Therefore, this makes the design very cost effective. The structure of this bandwidth

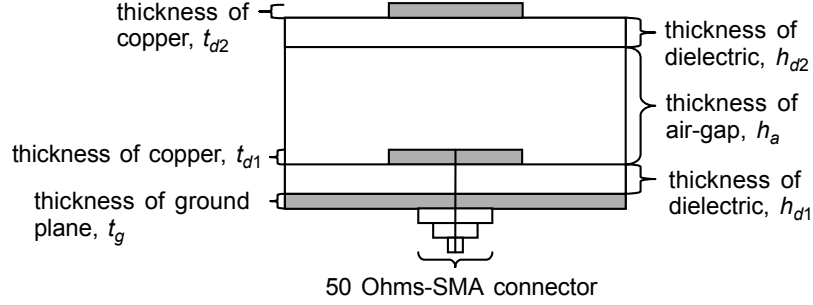


Figure 3 Structure of the IDMA bandwidth enhancement technique

enhanced microstrip antenna is shown in Figure 3. It uses the same substrate, feeding method and patch shape as the single-layer microstrip antenna.

The approximate bandwidth of the IDMA can be computed as follows [4 – 8]:

$$BW = \frac{\sqrt{2p}}{45\pi} \left(1 - \frac{1}{\epsilon_{av}} + \frac{2}{5\epsilon_{av}^2} \right) \left(\frac{1}{\epsilon_{av}} \right) \left(\frac{1}{\lambda} \right) \left(\frac{W}{L} \right) \quad (10)$$

where

$$p = 1 + \frac{a_2}{20} (k_0 w)^2 + a_4 \left(\frac{3}{560} \right) (k_0 w)^4 + b_2 \left(\frac{1}{10} \right) (k_0 L)^2 \quad (11)$$

where $a_2 = -0.16605$, $a_4 = 0.00761$, $b_2 = -0.09142$, $k_0 = 2\pi/\lambda$. ϵ_{av} , the average relative permittivity is as follows:

$$\epsilon_{av} = \left(\frac{(\epsilon_r h_{d1} + \epsilon_r h_a + \epsilon_r h_{d2})}{\left(\frac{h_t}{3} \right)} \right) \quad (12)$$

where $h_t = h_{d1} + h_a + h_{d2}$.

The calculated results are used as reference for the simulation work. Numerous iterative simulations were done to obtain the optimum configuration of the microstrip antenna. Once the desired operating frequency of 2.45 GHz and input impedance of 50 Ω are obtained, the bandwidth is taken at Voltage Standing Wave Ratio VSWR ≤ 2 .

The simulated bandwidth was plotted together with the calculated bandwidth to determine the size of the air gap and we are compared in order to determine the exact size of the air gap. The results of these comparisons are shown in Figure 4. Once the size of the air gap is determined, the calculated bandwidth can easily be obtained. The reason this is done is because the calculated bandwidth is a straight line equation. This means that the size of the air gap is directly proportional with the bandwidth. However, this is true only up to a certain threshold. Therefore, the calculated and simulated bandwidths are compared to determine this threshold.

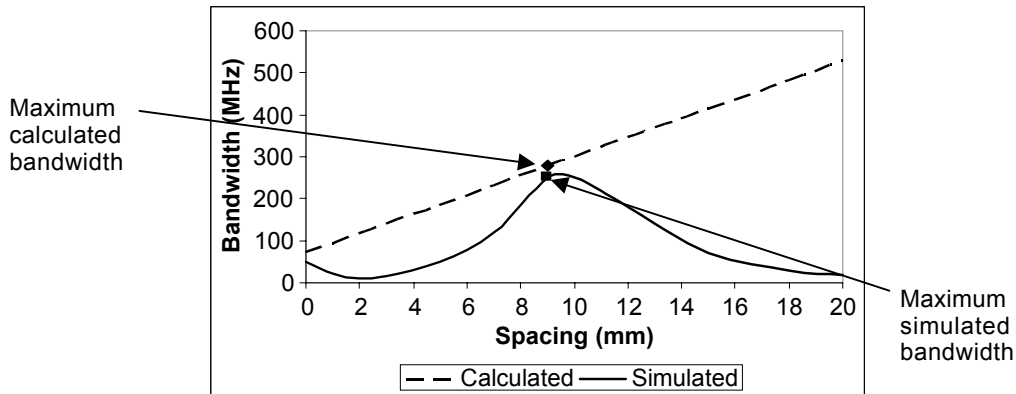


Figure 4 Comparison between the calculated and simulated bandwidth of IDMA

Once the optimum bandwidth is obtained which is 250 MHz, the spacing between the probe-fed patch and the stacked patch can be determined. To further increase the accuracy of the simulated results, fine-tuning is done. After fine-tuning, the maximum achievable simulated bandwidth is 270 MHz. The final dimension of the microstrip antenna is shown in Table 2 and the simulated results are shown in Figure 5.

Table 2 Simulated and measured results of IDMA

Dimensions	Simulated	Measured results
Width	51 mm	51 mm
Length	41 mm	41 mm
Location of the Probe (from the edge)	3.5 mm	3.5 mm
Spacing (air-gap)	9 mm	9 mm
Operating frequency	2.45 GHz	2.44 GHz
Input Impedance	50.15 Ω	61.63 Ω
Bandwidth	270 MHz (11.020%)	287.77 MHz (11.794%)

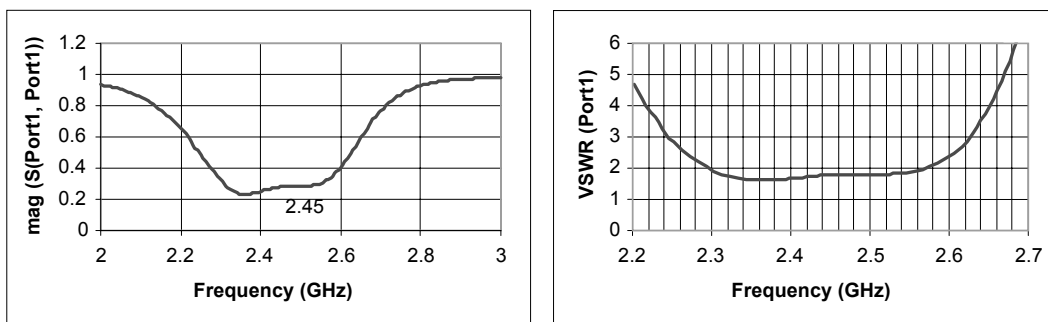
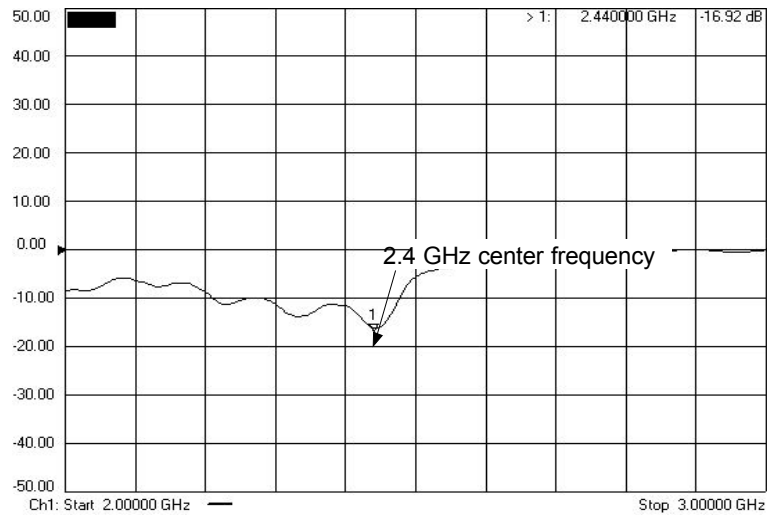
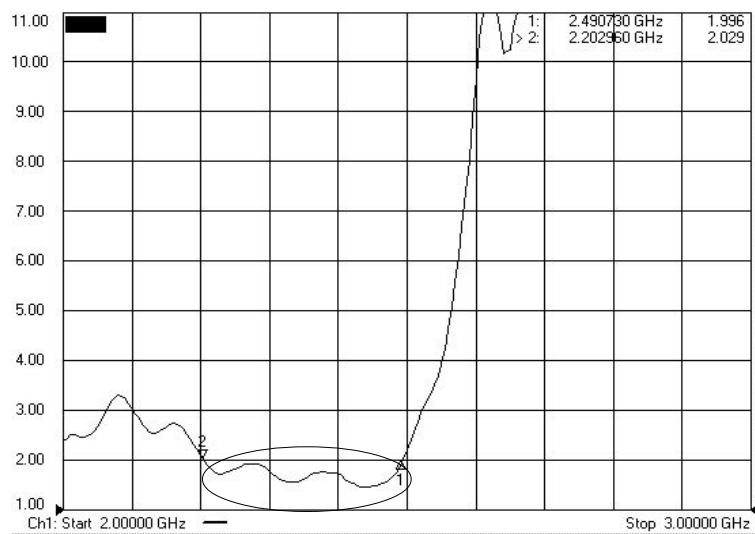


Figure 5 Simulated (a) reflection coefficient plot indicating the operating frequency and (b) voltage standing wave ratio plot indicating the bandwidth of IDMA

Using the optimized configuration of the microstrip antenna in the simulation results, this design is fabricated. The measured results of this bandwidth enhanced microstrip antenna are shown in Table 2, Figure 6.



(a)



(b)

Figure 6 Measured (a) operating frequency and (b) bandwidth of IDMA

4.0 DISCUSSIONS

Based on the results from the simulations and measurements, it is found that the single-layer microstrip antenna has a very narrow bandwidth that is less than 2% which

is not sufficient to fully cover the WLAN band based on the 802.11b standard. There is a need to use a bandwidth enhancement technique in this microstrip antenna and the IDMA is deployed. Using this technique, both the simulated and measured results give a bandwidth enhancement at more than 11%. Furthermore, there is a very good agreement between the simulated and measured results of this design. The comparison between the simulated and measured bandwidths of IDMA is shown in Figure 7.

The comparison between the simulated bandwidth of the single-layer microstrip antenna and the IDMA is shown in Figure 8. As for the comparison of the measured bandwidth between those microstrip antennas, this is shown in Figure 9. Figure 10

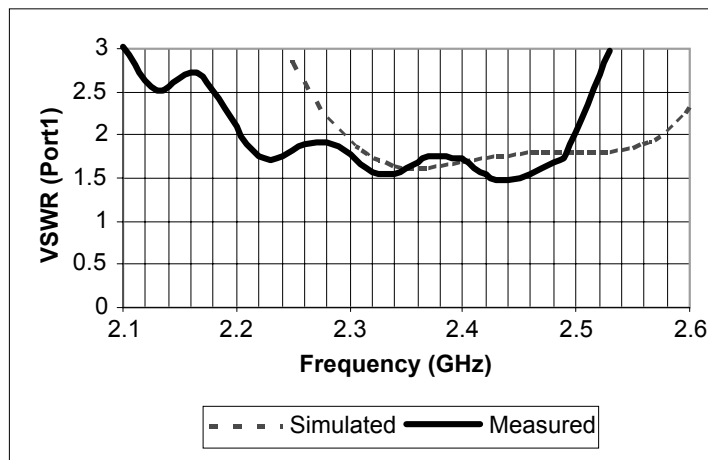


Figure 7 Comparison between the simulated and measured voltage standing wave ratio plot indicating the bandwidth of IDMA

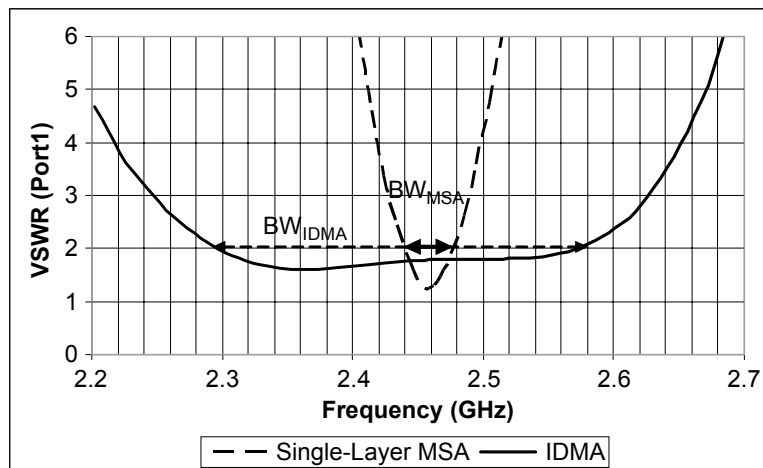


Figure 8 Comparison of the simulated bandwidth between the single-layer microstrip antenna and IDMA

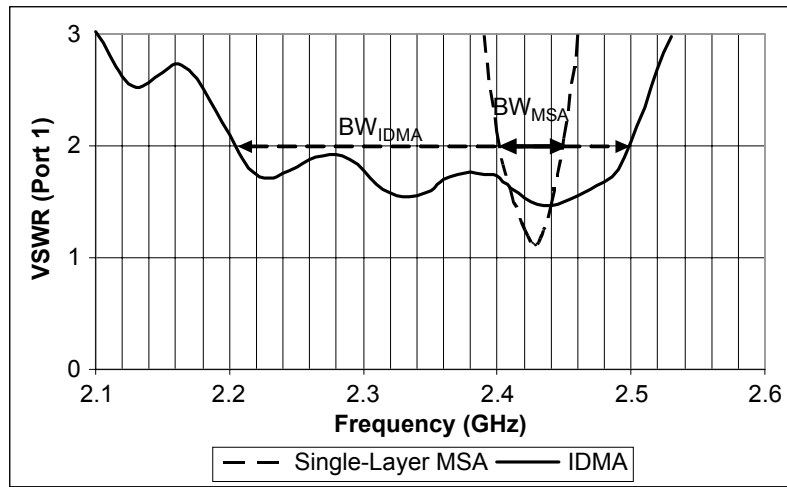


Figure 9 Comparison of the measured bandwidth between the single-layer microstrip antenna and IDMA

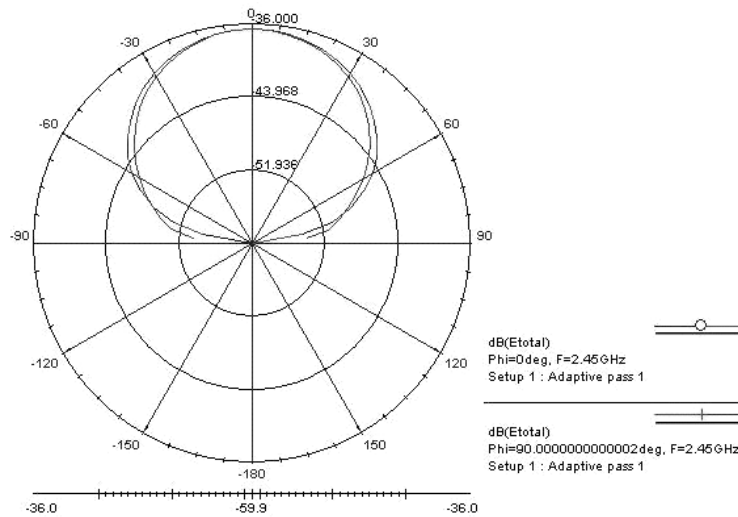


Figure 10 Simulated radiation pattern of IDMA

shows the simulated radiation pattern of IDMA. Figure 11 shows the fabricated microstrip antennas.

The measured results shown in Table 2 show that the f_o obtained is 2.44 GHz and Z_{in} is 61.63 Ω . There is a significant increase in this bandwidth if compared to the single-layer microstrip antenna. The measured bandwidth achieved is 287.77 MHz or 11.794% of relative bandwidth. When the simulated and measured results of the IDMA are compared, it is found that the bandwidths are all very similar that is approximately

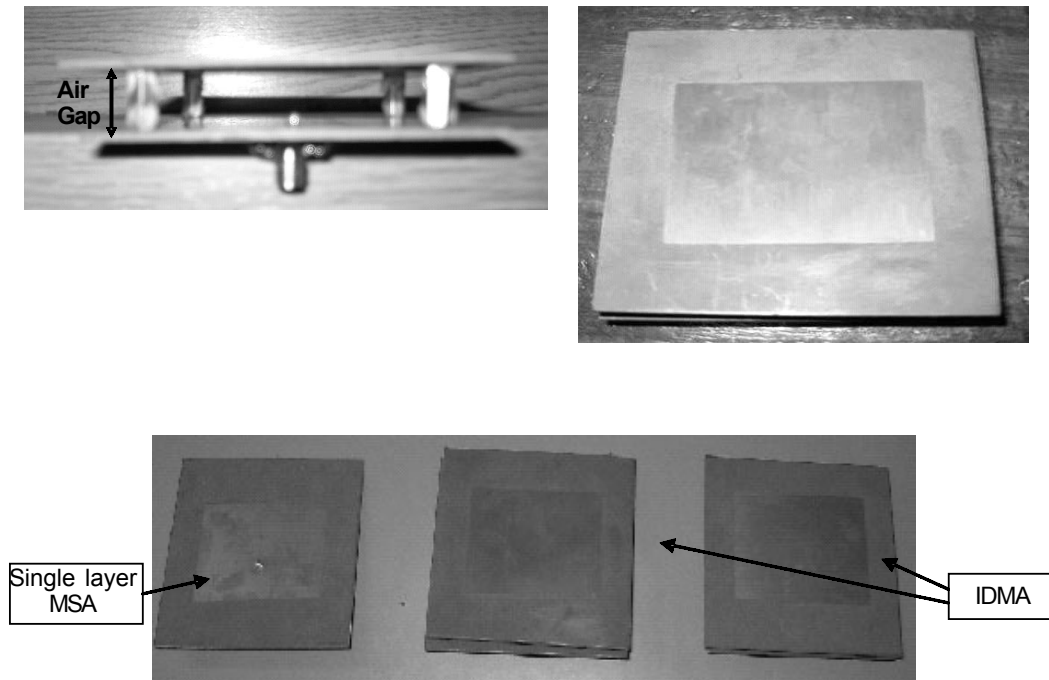


Figure 11 The fabricated microstrip antenna (a) side view of IDMA, (b) top view of IDMA and (c) single-layer microstrip antenna and IDMA

11%. It can be seen that the simulated and measured bandwidth for the single-layer microstrip antenna is not sufficient to fully utilize the required WLAN band as shown in Table 1. The bandwidth achieved for this microstrip antenna is less than the minimum 100 MHz that is required. After deploying the IDMA bandwidth enhancement technique, there was a significant increase in the bandwidth. The simulated and measured bandwidths are 270 MHz and 287.77 MHz respectively. These bandwidths very well meet the minimum bandwidth of 100 MHz which is required for the WLAN application.

5.0 CONCLUSIONS

The summary of the results obtained are shown in Table 3. It is shown clearly that the simulated and measured results are very similar. This bandwidth enhanced microstrip antenna is suitable for the required WLAN application. As mentioned, this technique has its advantages such as it does not increase the lateral size of the microstrip antenna and disadvantages such as it increases the height of the microstrip antenna. Therefore, in microstrip antenna design, it is very important to determine which feature to be prioritized as trade-off issues will always be present.

Table 3 Comparison between the simulated and measured results of the single-layer microstrip antenna and IDMA

Parameters	Single-Layer Microstrip Antenna		IDMA	
	Simulated	Measured	Simulated	Measured
Operating Frequency (GHz)	2.45	2.4248	2.45	2.44
Impedance (W)	50.69	50.15	51.238	61.63
Bandwidth (MHz)	35	46.71	270	287.77
	(1.429%)	(1.699%)	(11.020%)	(11.794%)

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