Printed (2x1) Patch Array Antenna at 2.45GHz

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***Abstract* — This paper proposed of a microstrip rectangular patch array antenna with operating frequency at 2.45GHz for WLAN application. The antenna array of 2x1 microstrip rectangular patch antenna with microstrip line feeding based on quarter-wave impedance matching technique was designed and simulated using CST Microwave Environment software. The performance of the designed antenna was analyzed in term of return loss, VSWR, bandwidth, directivity, radiation pattern and gain. The antenna was then fabricated on the substrate type FR-4 with dielectric constant of 4.7 and thickness of 1.6mm respectively. The antenna was measured using Vector Network Analyzer (VNA) and the details of the proposed antenna design and simulation result for 2.45GHz WLAN band are promising. The return loss, s11 for the single patch antenna and (2x1) array antenna are -12.938 and -19.468 respectively. Other than that, the simulated bandwidth for the single patch antenna is 3.82%. Meanwhile for the (2x1) array antenna is 3.98%.This is proved that (2x1) array antenna is better than single patch antenna in term of wider bandwidth, higher gain and better directivity.**

***Keywords-* Microstrip Antennas, Array Antenna, Microstrip Line Feeding, substrate FR-4, CST.**

I. INTRODUCTION

In the era of globalization, this sophisticated, people always want change in every moment in their live. Because of that, these days there is a very large demand for wireless applications. Antennas which are used in these applications should be low profile, light weight, low volume and broad bandwidth [1].Request for an antenna caused by the current environment , where people want something new from the previous, easy to carry, and more beneficial to them. To meet these requirements, microstrip antenna is preferred. This antenna is low-profile, comfortable to planar and nonplanar surfaces, simple and inexpensive to manufacture, mechanically robust when mounted on rigid surfaces and when the particular patch shape and mode are selected they are very versatile in terms of resonant frequency, polarization, pattern and impedance [2]. Although microstrip antenna has several advantages, it also has several disadvantages such as low gain, narrow bandwidth with low efficiency. These disadvantages can be overcome by constructing many patch antennas in array configuration [3].

Wireless technology is rapidly involving, and is playing an increasing role in the lives of people throughout the world. Wireless communication has experienced an very large growth since it allows user to access network with no worries of the burden of wires infrastructures. Also, people today are very keen to the high capacity mobile accesses of network services which the access speed rate are the priority over the others. WLAN is a flexible data communication system implemented as an extension to or as an alternative for, a wired LAN within a building and campus. Using a electromagnetic waves, WLAN transmit and receive data on the air, minimizing the need for wired connection. It is a telecommunications technology that provides wireless transmission of data using a variety of transmission modes, from point-to-multipoint links to portable and fully mobile internet access. For application in a WLAN base station or access point, an antenna having omnidirectional radiation in the azimuth plane and narrow-beamwidth radiation in the elevation plane is usually required. The simplicity of microstrip patch antenna structure, its flat profile and reduced weight compare other antenna options [4].

Fig. 1: General view of rectangular patch antenna.

II. SCOPE OF WORK

The work was limited to design two elements of microstrip rectangular patch antennas array with microstrip line as feeding method. Quarter-wave transformer is used to match the feeding line to the antennas. The operating frequency is determined to operate at 2.45 GHz. The antenna design is using FR4 as the substrate with thickness of 1.6mm.

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Table 1: Microstrip patch antenna design specifications

Centre frequency, f_0	2.45 GHz
Return Loss	< -10 dB
VSWR	1
Other Scopes	Radiation Pattern, Directivity and Gain of Array Antenna

III. METHODOLOGY

Fig. 2 shows the steps to be taken in preparing this project. Literature review was done to obtain information of microstrip rectangular patch antenna. CST Microwave Environment was used to design and simulate to obtain the results. After the desired response of the simulation results was obtained then antenna was fabricated. To got the comparison with simulation and measurement result, fabricated antenna was tested in the laboratory and analyzed that result.

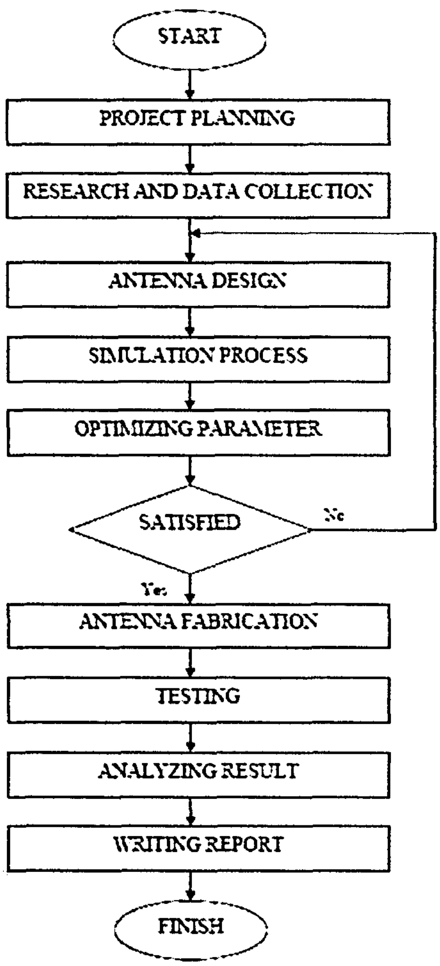

Fig. 2: Flowchart of antenna design

IV. ANTENNA DESIGN

The first step in design is to specify the dimension of a single microstrip patch antenna. The patch is in the shape of rectangular which is using FR4 substrate of thickness h=1.6mm and dielectric constant ε_r=4.7.The antenna to resonate at 2.45GHz. The ones that are most desirable for antenna performance are thick substrate whose dielectric constant is in lower end of the range because they provide better performance compared to thin substrate [3]. FR4 chosen as the substrate because FR-4 is made of woven fiberglass cloth with an epoxy resin binder that is flame resistant(self-extinguishing).FR-4 glass epoxy is a popular and versatile high pressure thermoset plastic laminate grade with good strength to weight ratios. The material is known to retain its high mechanical values and electrical insulating qualities in both dry and humid conditions [11].However, after going through the process of simulations, the results show that FR-4 meet the antenna specifications. With all these considerations, finally the proposed of single patch antenna design was established and the specifications are listed in Table 2.

Table 2: Design specification for single patch antenna

Operating Frequency, f_0	2.45 GHz
Substrate	FR-4
Dielectric Constant	4.7
Loss Tangent	0.019
Substrate Height	1.6 mm
Copper Thickness	0.035 mm

A. Single Microstrip Patch Antenna Design

The main purpose is to design a single microstrip patch antenna because to do the comparison with the array microstrip antenna. The single microstrip patch antenna consists of patch, quarter-wave transformer and feedline. The design of microstrip rectangular patch antenna is beginning by determine its patch dimension. To obtain an initial value of width, W and length, L equation (1) and (2)

$$W = \frac{c}{2f_o\sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

The effective dielectric constant:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{1/2} \tag{2}$$

The effective length:

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

And

The length extension:

$$\Delta L = 0.412\, h \frac{(\varepsilon_{reef} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reef} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (4)$$

The actual length of patch:

$$L = L_{eff} - 2\Delta L \quad (5)$$

Since a 50 Ω surface mount adapter (SMA) connector is going to be used to connect the feedline to the coaxial cable, the feedline will be a 50 Ω feedline. The feedline will be feed to the patch through a quarter-wave transformer The corporate feed network is chosen for designing four element array networks. matching network [8]. Fig. 3 below shows a single microstrip patch antenna which consists of patch, quarter-wave transformer and feedline.

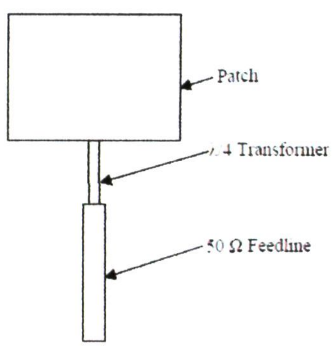

Fig. 3: Patch antenna with quarter-wave transformer

The impedance of the quarter-wave transformer is given by (6) [8]:

$$Z_1 = \sqrt{Z_0 \times Rin} \quad (6)$$

Where Z_1 is the transformer characteristic impedance and Z_0 is the characteristic impedance (real) of the input transmission line (50 Ω). *Rin* is the edge resistance at resonance. *Rin* can be calculated by using (6)[8]:

$$R_{in} = \frac{1}{2G_e} \quad (7)$$

where

$$Ge = 0.0025 \quad (8)$$

Ge represent of edge conductance [8].

Next, for the width and length of the quarter-wave transformer and 50 Ω feedline are determined by the [8]

$$\frac{W}{D} = \frac{8e^{A}}{e^{2A} - 2} \quad (9)$$

$$\frac{W}{D} = \frac{2}{\Pi}[B - 1 - \ln[2B - 1] + \frac{\varepsilon r - 1}{2\varepsilon r}\{\ln(B - 1) + 0.39\frac{0.61}{\varepsilon r}] \quad (10)$$

where

$$A = \frac{Zo}{60}\sqrt{\frac{\varepsilon r + 1}{2}} + \frac{\varepsilon r - 1}{\varepsilon r + 1}\left(0.23 + \frac{0.11}{\varepsilon r}\right) \quad (11)$$

$$B = \frac{377}{270} \frac{\Pi}{\sqrt{\varepsilon r}} \quad (12)$$

B. *Patch Array Antenna Design*

The array antenna consists of a branching network of two-way power dividers [8]. Quarter-wave transformers (100 Ω) are used to match the 50 Ω lines. Fig. 4 below shows the impedance for individual lines in the two element rectangular array antenna.

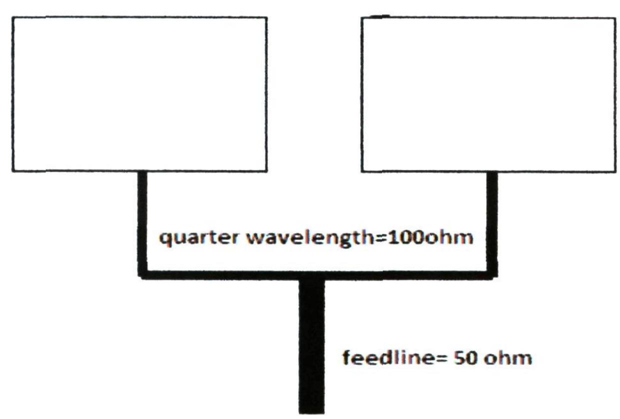

Fig. 4: Two elements array line impedance design layout

Similarly, the patch dimensions are obtained through equations (1) and (2). Calculation for impedance is also similar as a single patch calculation by using (5) to (7). However to matching the 100 Ω to 50 Ω transmission lines, the calculation step is shown below. Using the (5), where by replacing Z_o= 50 Ω and R_{in} = 200 Ω, the transformer characteristic impedance is [8]:

$$Z_1 = 100\ \Omega$$

All impedance dimensions for 50 Ω feedline, 100 Ω quarter-wave transformer are obtained by using the same (8), (9) and (10). Table 3 below show all the dimension of microstrip line impedance:

Table 3: Microstrip line impedance dimension

Impedance	Width (mm)	Length (mm)
50 Ω	2.9108	32.63
100 Ω	0.6547	34.30

C. CST Simulations

The variations of the design are made in order to choose the best and accurate result, for the last design to make a simulation. For this letter, the single antenna also be consider same as the array antenna where the variation of the design have done. The single patch antenna design is needed for performance comparison with the patch array antenna. Thus, the extent of effectiveness of array configuration can be observed when comparing both types of configuration. Besides that, it will be necessary to vary the patch width, length and other parameter such as length of microstrip line of 100 Ω in order to optimize the performance of antenna. Because of that, the best result for single patch antenna and microstrip rectangular patch array antenna design is the red colour highlighted row as shown in the table 4.After all this calculation and consideration has been taken to account, both antenna were simulated using CST Microwave software. The single antenna and patch array antenna then was fabricated.

Types of antenna		Patch Width (mm)	Patch length (mm)	S11 (dB)	VSWR	Directivity (dBi)	Gain (dB)
Single	Length Adjustment	40.27	26.26	-11.77	1.8745	6.792	3.152
		40.27	26.00	-12.83	1.8730	6.787	3.100
		40.27	27.50	-9.585	2.8408	6.792	2.918
		40.27	27.73	-9.263	2.8409	6.779	2.693
	Width Adjustment	40.00	26.655	-10.29	2.3579	6.796	3.134
		40.27	26.655	-10.91	2.0174	6.798	3.152
		43.87	26.655	-12.95	1.581	6.838	3.362
		44.00	26.655	-13.02	1.678	6.848	3.374
Array 2 x 1	Length Adjustment	34.7	26.676	-13.56	0.6879	6.848	3.399
		44.7	26.676	-14.03	1.4959	8.994	6.255
		30.7	26.676	-25.88	1.1070	8.329	5.025
		32.7	26.676	-22.63	1.1594	8.460	5.242
	Width Adjustment	36.7	26.676	-18.31	1.2765	8.666	5.302
		36.7	25.676	-19.25	1.2448	8.603	5.293
		36.7	26.329	-19.47	1.2399	8.659	5.392
		36.7	26.576	-18.58	1.2670	8.661	5.293

Table 4: Design specifications

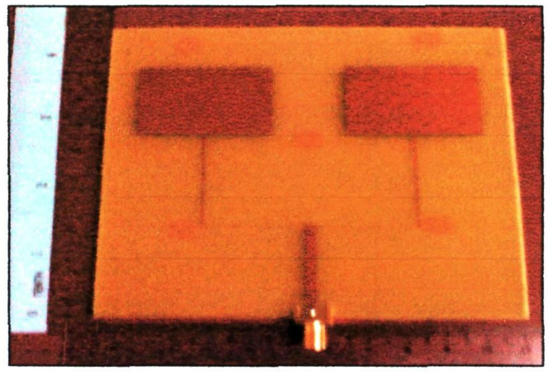

Fig. 5: Fabricated 2x1 microstrip rectangular patch array antenna

V. RESULTS AND DISCUSSIONS

Fig. 6 shows the return loss of microstrip patch antenna array in dB for both simulation and measurement. The simulation result gives a return loss of -19.468 dB at operating frequency 2.45GHz while the measurement result gives a return loss of -11.199 dB at 2.640GHz. The flaw during the fabrication process may leads to the shift of the operating frequency of measurement result. The return loss graph of measurement has been shifted about 7.8% from its original operating frequency.

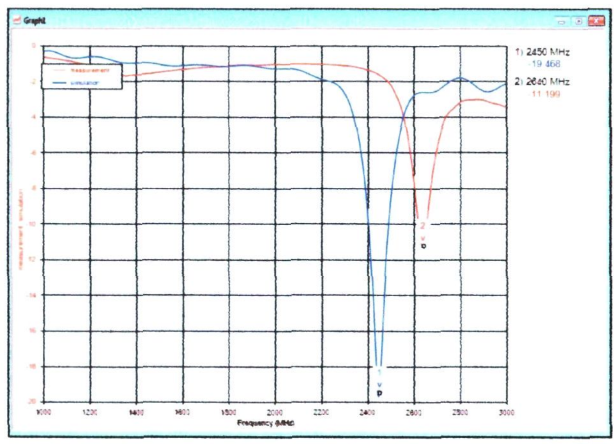

Fig.6: Return loss of simulation result

Fig. 7 and 8 show the bandwidth for both single and array antenna. Refer to fig. 7, the bandwidth of single antenna estimated is about 3.82%. Meanwhile, for the bandwidth of patch array antenna, the percentage is increase to 3.98%. This shows that microstrip antenna has shortcomings in terms of narrow bandwidth. But, it is also proven in the result below, this setback can be counter by constructing many patch antennas array configuration as suggested in theoretical part.

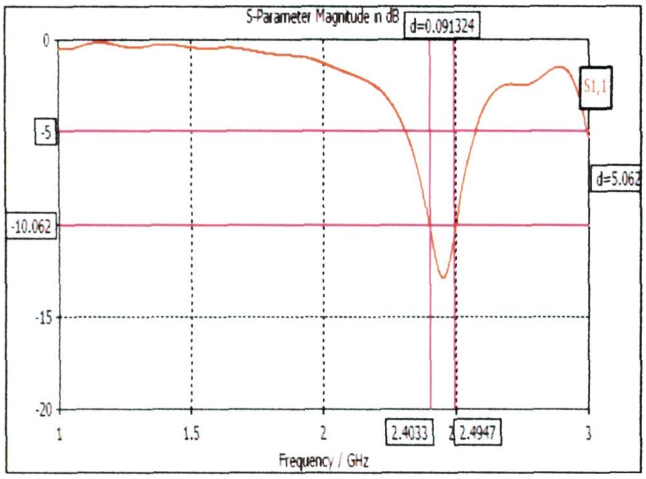

Fig. 7: Bandwidth of single patch antenna

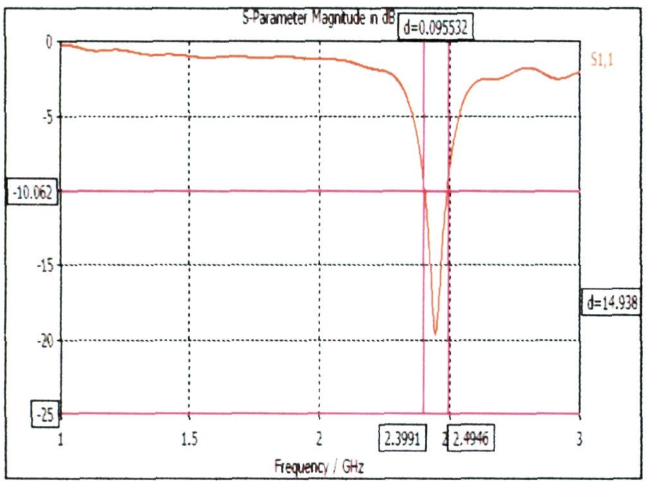

Fig. 8: Bandwidth of patch array antenna

Fig. 9 is the simulation result of voltage standing wave ratio. At centre frequency 2.45GHz, the VSWR value is 1.237983. Fig. 10 on the other hand is the VSWR of measurement which portrays the VSWR is about 1.5336 at frequency of 2.45GHz. Since, when concerning the effect of losses and errors that could happen in fabrication, this result could still achieve a good fabrication result.

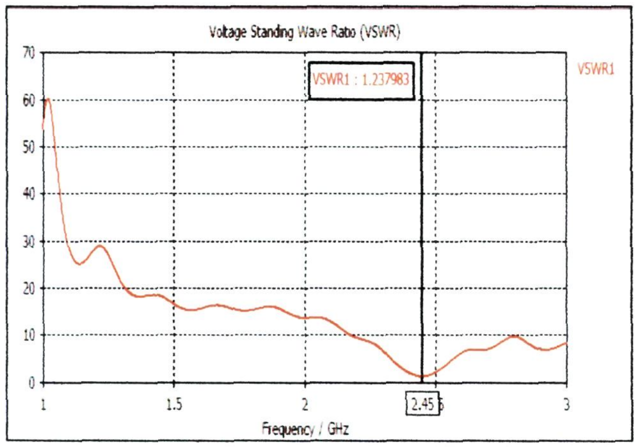

Fig. 9: VSWR of simulation result

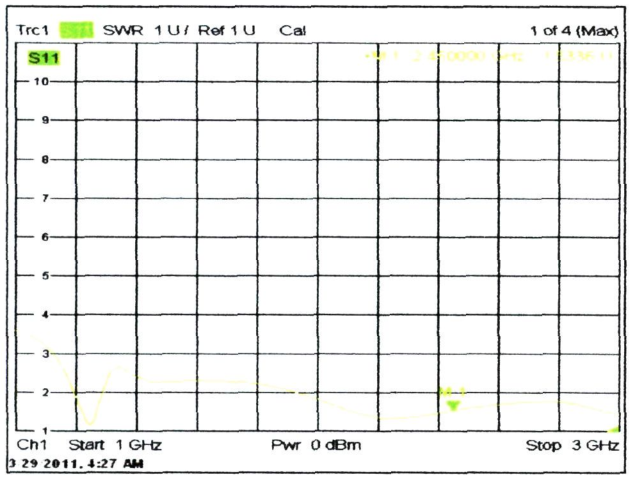

Fig. 10: VSWR of measurement result

Fig. 11 is the simulated radiation pattern of single patch antenna with directivity of 6.838 dB and gain of 3.362 dB. Fig. 12 is the simulated radiation pattern of patch array antenna with directivity and gain of 8.659 dB and 5.392 dB respectively. As both radiation patterns compared, it can be concluded that the array design antenna generates more intensity or focus at the center of the radiation. This comparison is parallel to the theory that the array antenna itself is used to increase the directivity of antenna besides used to increase the bandwidth.

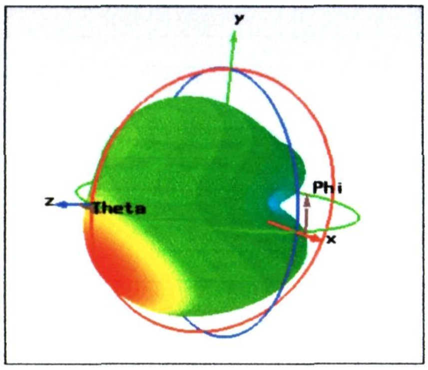

Fig. 11: The radiation pattern of single antenna

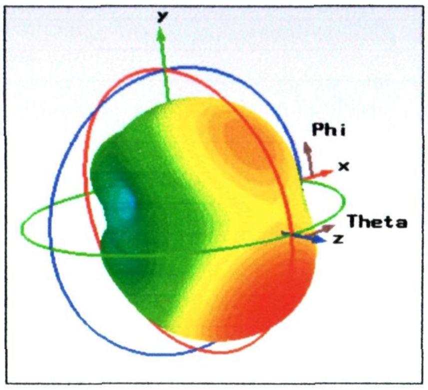

Fig. 12: The radiation pattern of array antenna

Fig.13 and 14 show the radiation pattern for simulation and measurement of patch array antenna. The simulation result shows the major lobe directed the signal at 0° with beamwidth (HPBW) of 55.0 °. The measurement result shows the major lobe is shifted few angle to the left of centre angle 0° at 328° with beamwidth (HPBW) of 23.5 °. This is possibly because of the noise floor from the equipment itself and also the measurement is done in open space where this should be done in the chamber to reduce the effect of noise.

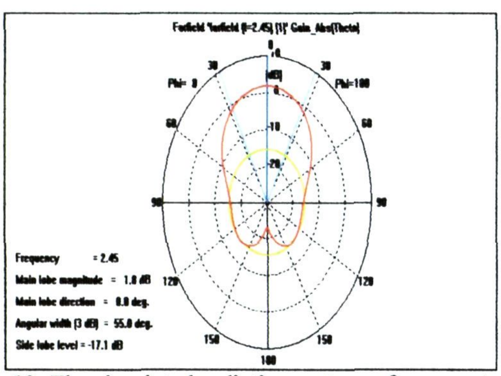

Fig. 13: The simulated radiation pattern of array antenna

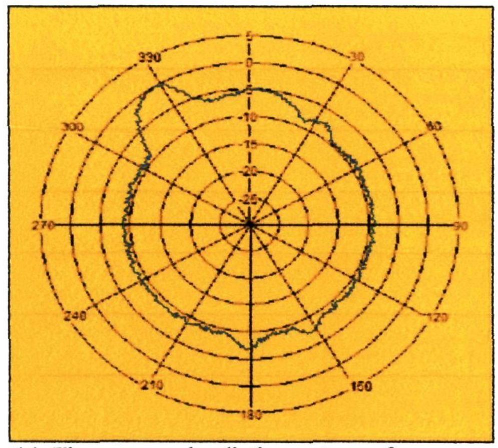

Fig. 14: The measured radiation pattern of array antenna

VI. CONCLUSSION

A microstrip rectangular patch array antenna that feed by microstrip line has been designed, simulated, fabricated, measured and analyzed. Overall, the performance of the antenna meets the desired requirement in term of return loss and VSWR. The simulation return loss is equal to -19.468 dB and VSWR is 1.237 at the centre frequency of 2.45GHz. However, in measurement, the centre frequency has been shifted about 7.8% from its original state. The performances of the microstrip antenna strongly depend on several factors such as type of substrate, the thickness and dielectric constant of substrate respectively. One of the ways of increasing the performances of the antenna is by doing an array configuration instead of use single element of the antenna. The way antenna has been fed is also important where the matching technique contribute to a massive impact to the performances of antenna. For the simulated and measured results, it is proved that (2x1) array antenna offer better than performances than single element.

VII. FUTURE RECOMMENDATIONS

In future, the microstrip rectangular antenna can be upgraded. The substrate FR4 used in this project can be replaced by another substrate. Theoretically, the objective of this project maybe can be achieve through the use of higher substrate such as RT Duroid 5870 which is have low relative permittivity or dielectric constant and higher substrate that will improve the bandwidth. or this which has low loss tangent, thus increasing the efficiency of the antenna. In term of configuration, the total size of antenna can be reduced by changing the feeding technique. Instead of using microstrip line, the inset feed technique can also be used.

REFERENCES

[1] Doraisingam, Yoharaaj, "*Bandwidth Enhancement Of Microstrip Antenna For Wireless Local Area Network Applications,*" Masters thesis, Universiti Putra Malaysia.

[2] C. A.Balanis, *Antenna Theory*, 2nd. Edition ed. Arizona State University: John Wiley & Sons,Inc., 1997.pp.722-723.

[3] M. A. R. Osman, "*Microstrip Array Antenna For Automobile Radar System,*" Master of Electrical-Telecommunication Engineering Master's Thesis, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, May,2006.

[4] IEEE Std 802.16-2004, "*IEEE Standard for Local and Metropolitan Area Networks, Part 16: Air Interface for Fixed Broadband Wireless Access Systems*", March 2004.

[5] IEEE P802.16e, "*Draft amendment to IEEE standard for local and*

metropolitan area networks, Part 16: Air Interface for Fixed Broadband Wireless Access Systems", amendment for physical and medium access control layers fro combined fixed and mobile operation in Licenziata.

[6] A. A. M.K.A. Rahim, M.H Jamaluddin,M.R. Ahmad,T.Masri and M.Z.A. Abdul Aziz, "*Microstrip Patch Antenna Array at 5.8GHz for Point to Point Communication,*" 2006 International RF and Microwave Conference Proceedings, 12-14 September 2006.

[7] D. M.Pozar, *Microwave Engineering,* 3rd Edition ed. University of Massachusetts at Amherst: John Wiley & Sons,Inc.

[8] M. H. Azizan, "*Developments of Microstrip patch array antenna for wireless local area network (WLAN),*" School of Computer and Communication Engineering, Universiti Malaysia Perlis, May,2007.

[9] M. T. I. Norbahiah Misran, Mohammed Nazmus Shakib and Baharudin Yatim, "*Design of Broadband Multi-slotted Microstrip Patch Antenna for Wireless System,*" 2008.

[10] M. P. Annalisa Durantini, Fulvio Ananasso, "*Experimental Evaluation of IEEE 802.16 WiMAX Performances at 2.5GHz Band*".

[11] *http://geography.kosmix.com/topic/Fr4#ixzz1GrkZv8xX*