Rectangular Microstrip 4x3 Patch Array Antenna at 2.4 GHz for WLAN Application

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Abstract **— In this paper, microstrip patch antennas are presented. Based on the array concept the array antennas were designed at 2.4GHz and investigated in terms of return loss, size and gain. It was found that 4x3 patch array antenna gave best performance compared to the other patch antennas. The 4x3 patch array antennas was then fabricated and measured using RO4350 microstrip substrate. Good agreement between simulation and measurement was observed for the 4x3 patch array antenna.**

Keywords**- Microstrip patch antennas, 4x3 patch array antenna.**

I. INTRODUCTION

Nowadays, an antenna plays a very important role in Wireless Communication Systems especially for Wireless Local Area Network (WLAN). For applications emerging of compact size technologies, microstrip antennas are used because of their low cost, portability, versatility, conformal and other factors supporting the needs. But microstrip antennas also have disadvantages like narrow bandwidth, low gain and excitation of unwanted surface waves [1][2]. Hence, antenna arrays are used to overcome for these disadvantages, thereby introducing microstrip patch arrays. This technology of microstrip arrays makes it possible to provide high gain, desired radiation pattern, appropriate beamwidth with less cost and less space. Recent advances have shown increases in the bandwidth and gain using microstrip array. In decree to overcome these problems, the design of rectangular microstrip 4x3 patch array antenna at 2.4 GHz for WLAN application is proposed [3].

WLAN provides wireless communication between the client devices with an access point in a local network [4]. According to the standard of IEEE for WLAN, the network works at 2.4 GHz band (2.4-2.483 GHz for IEEE 802.11 b/g) and 5 GHz band (5.15-5.35 GHz and 5.725-5.825 GHz for IEEE 802.11a) [5]. The antenna is an important device in WLAN communication system because its performance will directly impact on the quality of wireless communications [6].

In general, there are various types of antenna and one of them is microstrip antenna. Microstrip antenna can now be assumed as type of antenna that is confidently used by designers worldwide, especially when application which required low profile antenna is needed [6].

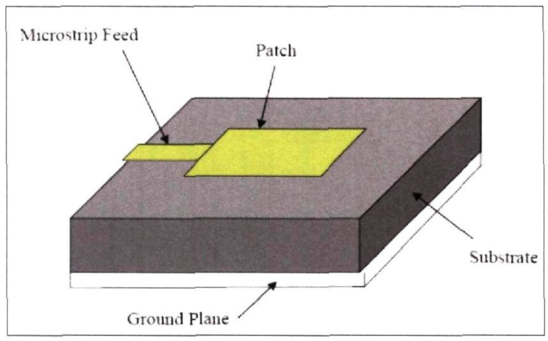

Figure 1: General view of rectangular patch antenna.

In this paper four by three (4x3) array, edge fed by a microstrip line for WLAN at 2.4 GHz is presented using inset feeding method. Quarter wave transformers are used to match the impedance of the transmission lines considering SMA connector at the input to the antenna [4]. The resonant frequency is determined to be 2.4 GHz. Using CST simulator, the optimized antenna array of 4x3 patches gives a return loss (S_{11}) of -19.73dB. Many optimizations are carried out by for getting better expected results for gain and directivity. Next part explains the antenna designing procedure respectively.

II. SCOPE OF WORK

The work was limited to design four 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 2.4 GHz. The antenna design is using Rogers RO4350 as the substrate with thickness of 0.075mm.

Table 1: Specifications of microstrip patch antenna design of WLAN application.

Centre frequency, f_0	2.4GHz
Return Loss	>10 dB
VSWR	1
Other Scopes	Radiation Pattern and Gain of Array Antenna

III. METHODOLOGY

Figure 2 shows the flowchart of the project. The literature review was done to obtain information of the microstrip rectangular patch antenna. CST Microwave Environment was used to design and simulate to obtain the results. Antenna was then fabricated after the desired response of the simulation results was obtained. The fabricated antenna was tested in the laboratory and analyzed by doing compared to the simulation results.

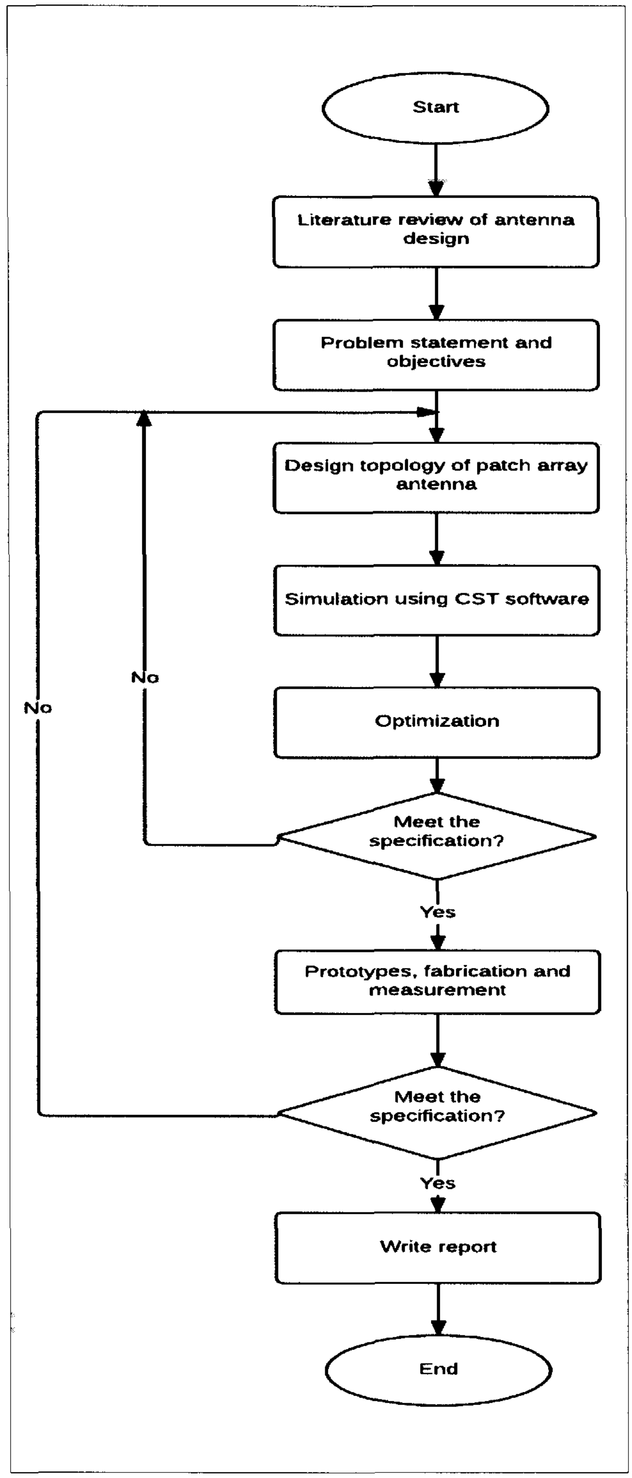

Figure 2: Flowchart of the antenna design

IV. ANTENNA DESIGN

After identifying the application that using frequency of 2.4GHz, the next step of antenna designing is to choose a suitable dielectric substrate of appropriate thickness and loss tangent. There are numerous substrates that can be used for the design of microstrip antenna and their dielectric constants are usually in the range of $2.2 \leq \varepsilon r \leq 12$ [7]. 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 [8].

Rogers RO4350 was chosen as the substrate as it has a low loss tangent which will not reduce the antenna efficiency, and has a relatively low dielectric constant.

With all these considerations, finally the proposed of array patch antenna design was established and the specifications are listed in Table 2

Table 2: Microstrip patch antenna design specifications

Frequency	2.4GHz
Substrate	Rogers RO4350
Dielectric Constant, ε_r	3.3
Loss Tangent	0.004
Thickness of Substrate	1.52 mm
Copper Thickness	0.0175mm

A. Single Microstrip Patch Antenna Design

The objective of this part is to design a single microstrip patch antenna which consists of patch, quarter-wave transformer and feedline [9]. The design of microstrip rectangular patch antenna is beginning by determine its patch dimension. In order to do so, these following equations are used. The width, W and length, L of the patch is determined as follow [6]:

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

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

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

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

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

The structure shown in Figure 1 is of a single patch which is inset fed by design.

Calculation for feedline:

The width of the feedline is an important parameter for designing single patch as well as for the array designing [10],[2].

$$A = \frac{Z_0}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right) \quad (6)$$

$$B = \frac{377 * \pi}{2 * Z_0\sqrt{\varepsilon_r}} \quad (7)$$

Width of feedline:

$$W = \frac{2h}{\pi}\left\{B - 1 - \ln(2B - 1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left[\ln(B - 1) + 0.39 - \frac{0.61}{\varepsilon_r}\right]\right\} \quad (8)$$

B. Microstrip Patch Array Antenna Design

The corporate feed network is chosen for designing array networks. The array antenna consists of a branching network of two-way power divider [11]. But for inset fed method the 50 Ω is divided into two 100 Ω microstrip lines thus dividing the power and phase equally forming uniform array [12]. The 100 Ω and 50 Ω are matched by quarter wave transformer. Quarter-wave transformers (70 Ω) are used to match the 100 Ω lines to the 50 Ω lines as shown in Figure 3.

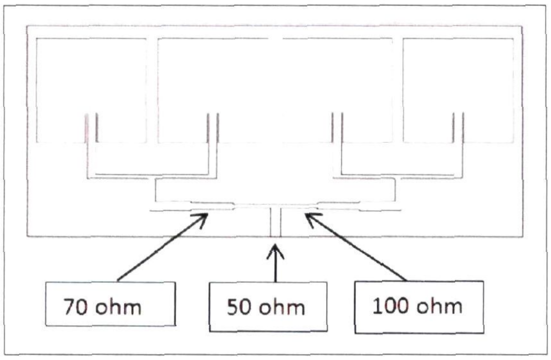

Figure 3: Patch array antenna with inset fed.

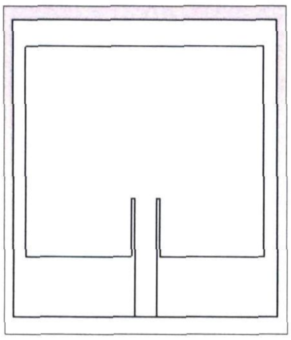

Figure 4: Single patch array design.

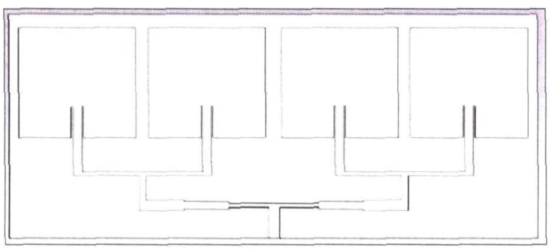

Figure 5: 4x1 patch array antenna design.

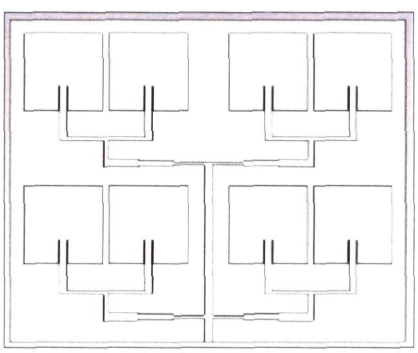

Figure 6: 4x2 patch array antenna design.

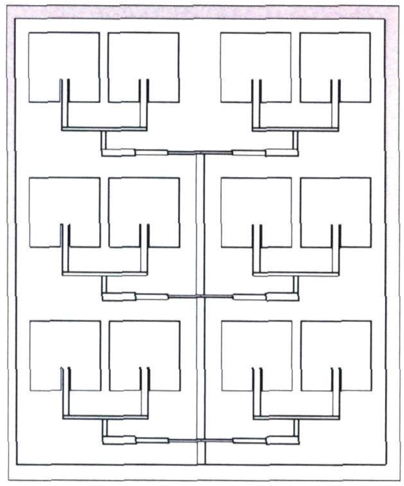

Figure 7: 4x3 patch array antenna design.

Figure 4, 5, 6 and 7 portrays the topologies of the single patch, 4x1 array, 4x2 array and 4x3 array respectively.

Table 3 below shows the simulated results from the single patch, 4x1 patch array, 4x2 patch array and 4x3 patch array antenna that obtain from CST simulation.

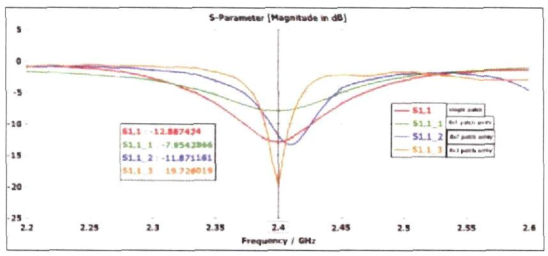

Figure 8: Comparison of return loss, S_{11}

Table 3: Comparison of simulation results for all the four antenna designs.

Type of antenna	Patch width, W (mm)	Patch length, L (mm)	Size reduction (%)	S_{11} (dB)	Gain
Single patch	**32**	**18**	**-**	**12.89**	**4.25**
4x1 array	32	17	5.6	7.95	9.19
4x2 array	29	14.5	27	11.48	7.55
4x3 array	**27.5**	**15.5**	**26**	**19.73**	**9.08**

Figure 8 illustrates the simulated return loss for all the four antenna designs. It can be seen that the performance of the 4x3 patch array antenna achieved the highest level of return loss which is 19.73 dB.

Table 3 summarized the return loss and gain for all the antennas. It was proven that the 4x3 patch array antenna achieved highest gain compared to the other three antenna designs. Therefore, the 4x3 patch array will transmit the highest power in the direction to that of an isotropic source. Based on these results, the 4x3 patch array antenna was chosen for further analysis and then fabricated to validate the work.

V. RESULTS AND DISCUSSION

In this section, the performance of the 4x3 array antenna is discussed. As shown in Figure 9, the simulation result of Voltage Standing Wave Ratio (VSWR) at 2.4 GHz is 1.23. While the simulated radiation pattern of 4x3 patch array antenna with directivity and gain of 10.39 dB and 9.08 dB are respectively are illustrated in Figure 9.

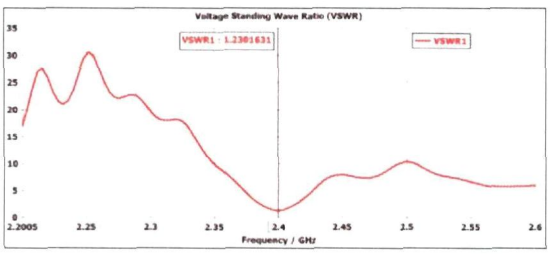

Figure 9: VSWR of simulation result of the 4x3 array antenna.

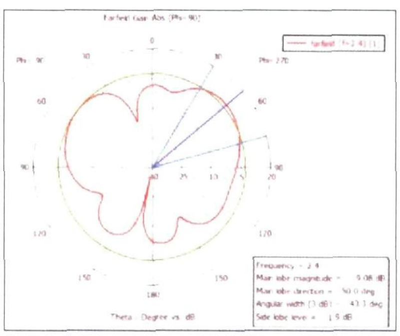

Figure 10: The simulated radiation pattern of 4x3 array antenna in polar form.

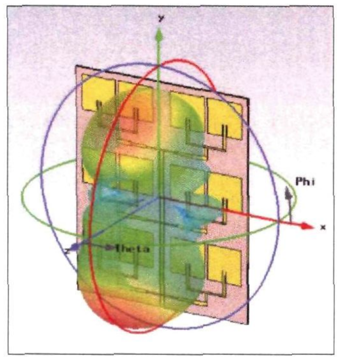

Figure 11: The 3-D radiation pattern of 4x3 array antenna

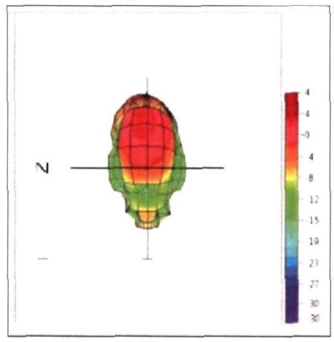

Figure 12: Measured radiation pattern (in 3-D front view) for 4x3 array antenna.

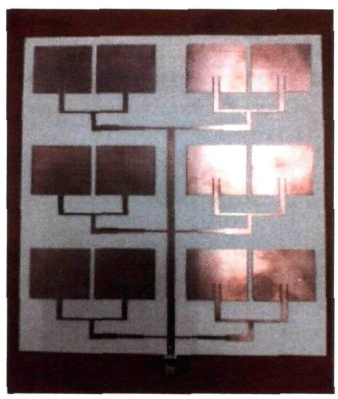

Figure 13: Fabrication of 4x3 patch array antenna

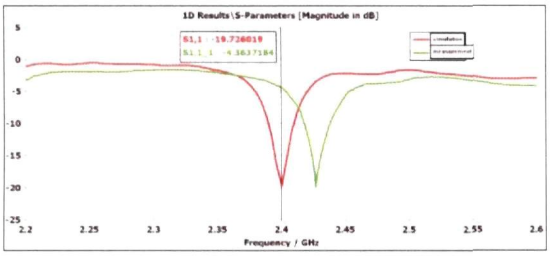

Figure 14: S-Parameter: Return loss, S_{11} of the 4x3 array antenna.

Figures 11 and 12 show the radiation pattern for simulated and measured respectively for the 4x3 patch array antenna. Both the radiation patterns portray the omnidirectional antenna that suit with WLAN applications. The simulation result in Figure 10, shows the major lobe directed the signal at 0° with beamwidth (HPBW) of 43.3°. It can be concluded that the 4x4 patch array design antenna generates more intensity of the radiation in the farfield region because in the farfield, the radiation pattern does not change shape with distance [13].

Finally the 4x3 array antenna was fabricated using microstrip substrate (Roger RO4350). The fabricated antenna is demonstrated in Figure 12 as proof of work. The return loss of the antenna was measured and compared with simulated result as illustrated in Figure 14. It was found that the measured return loss of 19.85 dB was found at 2.427 GHz, shifted by 0.027 GHz from the simulated result. The flaw during the fabrication process may leads to the shift of the operating frequency of measurement result. This shifted also can happened due to the effect of parasitic element on the fabricated substrate.[14].

Table 4: Comparison between this work with previous designs.

Reference	Size (mm^2)	S_{11} (dB)	Gain
Single patch [15]	12.4 x 9.33 = 115.7	37.5	5.00
4x1 array [10]	34.93 x 25.48 = 890.01	20.24	5.73
4x2 array [11]	38.39 x 29.78 = 1143.25	19.64	6.74
4x3 array: This work	27.5 x 15.5 = 426.25	19.73	9.08

Table 4 shows the comparison between the 4x4 patch array antenna with previous designs according to size patch, return loss and gain. In terms of size and return loss, the [13] had a lowest size and highest return loss respectively compared to other design when compared to [10] and [11], the 4x3 patch array antenna is much smaller in size. In terms of gain, the 4x3 patch array antenna achieved the highest gain compared to the antenna in [13], [10] and [11], So, 4x3 patch array antenna is the best design that can give the best performance.

VI. CONCLUSION

A microstrip rectangular 4x3 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 -19.73 dB and VSWR is 1.23 at the centre frequency of 2.4GHz. However, in measurement, the centre frequency has been shifted about 1.125% 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 contributes to a massive impact to the performances of the antenna.

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