Gain Enhancement of Corporate Feed Linear Array Microstrip Antenna

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***Abstract* – In this paper 2.4 GHz corporate feed linear array microstrip antenna for point to point communication system is designed. The 2 by 8 corporate feed linear array antenna were designed, simulated with the aid of Computer Simulation Tool (Microwave Office Studio). After fabricated, the prototype antenna been measured. Stub matching technique was introduced to tune the required frequency that has been shifted in the measurement results of return loss to 2.4 GHz. The simulation results of radiation pattern produced high gain, 16.54 dB.**

Keywords: *Array, corporate feed, point to point communication*

I. INTRODUCTION

An antenna consists of a metallic structure, which converts electromagnetic waves into electrical currents and vice versa. In wireless communication system for both transmitter and receiver same antennas are been used. Extensively and continuously received an attention for several decades, point to point communication brings high responsibility to antennas since they are expected to offer the wireless transmission between one point to another point [4]. To meet requirement in good performance point to point application, microstrip antenna is preferred because of size, weight, cost performance ease of installation are constrains and low profile antenna.

Microstrip patch antennas have many advantages such as low profile, conformability, cheaper fabrication cost and design simplicity with feed networks [2]. Besides that, microstrips are also able to operate in a wide range of frequencies. In wireless communication, microstrip antennas has commonly used due to their advantages. Microstrip antennas also have disadvantages such as brings lower performance (gain) with narrow bandwidth [6-8]. Many researchers have studied the way to solve these problems. One of the ways to solve low gain problem is by designing patches in array configurations. In this paper the array configurations is being discussed for the antenna array structure.

Main objective of this project is to design, simulate and measure corporate feed linear array patch antenna operate at 2.4 GHz and study the performance of microstrip antenna for point to point communication. Other intention of this project is to accomplish good performance in terms of gain of the microstrip patch array antenna.

II. ARRAY STRUCTURE

Microstrip antennas are used not only as single patch but also trendy in arrays antenna. Arrays antenna are very multipurpose and used to produce a required pattern that hardly contributes by a single patch element [4, 10]. Microstrip antennas with array configurations used to scan the beam of an antenna system, increase the gain, and come out with many advantages that would be difficult by designing using single patch element. To satisfy the instance of long distance communication, high gain is needed particularly in point to point communication [4]. The elements of array can be design by using a single or by multiple lines in a feed network arrangement, as shown in figure 1.

The single line or known as series feed usually consists of a constant transmission line from which small proportion of energy are gradually attached into the individual element disposed along the line [4].

The multiple lines or known as corporate-feed network is used to provide power splits of 2n (i.e., n = 2, 4, 8, 16, 32, etc.). Corporate-fed arrays are universal and multipurpose.

An advantage of using corporate feed array is the flexible control of the feed of each element (amplitude and phase) [10]. The corporate feed technique will be discussed more detail in this paper.

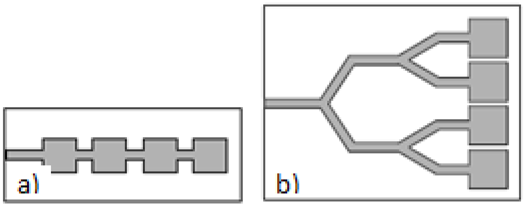


Figure 1 a) series-feed b) corporate feed network arrangements for microstrip patch arrays.

III. DESIGN CONSIDERATION OF CORPORATE FEED LINEAR ARRAY MICROSTRIP ANTENNA

Antenna array design was started with the single patch microstrip antenna with inset feed to operate at 2.4 GHz using FR4 substrate with dielectric constant (ε_r = 4.7), loss tangent (δ) 0f 0.019 and height of 0.8 mm. Then the single patch microstrip antenna is simulated using Computer Simulation Technology (CST) Studio Suite 2010.

Calculation of the width and length of patch antenna is using equation below:

$$W = \frac{C}{2 f_0 \sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (1)$$

where; c = 3x10^8 m/s

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

With the value of ε_{eff}, the fringe factor ΔL can be calculated using equation (3),

$$\Delta L = 0.412h \frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0..8\right)} \quad (3)$$

$$L_{eff} = \frac{C}{2 f_0 \sqrt{\varepsilon_{eff}}} \quad (4)$$

Therefore;

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

The transmission line width is:

$$Wt = \exp\left(\frac{Z_c\sqrt{(\varepsilon_r + 1.41)}}{87}\right)\frac{0.8}{5.98h} \quad (6)$$

Where;
L = length of the patch
W = width of the patch
ε_{eff} = effective substrate
Δl = fringing field of the antenna
Wt= transmission line width

In simulation, the parameters that have been calculated earlier have to be tuned via optimization process to get the best antenna response. Figure 2 shows there is a regular pattern in change of resonant frequencies with change in the patch length. After optimizing the patch length, the required length to achieved 2.4 GHz is 27.118 mm. The final design of single patch shown in figure 3. This design is used as a benchmark in designing array antenna.

The parameters values in single element antenna are used again to design 2 by 2 corporate feed linear array antenna. The lengths of the patch again need to be optimized to obtain the best return loss, S11 that falls on the required frequency of 2.4 GHz as shown in figure 4.

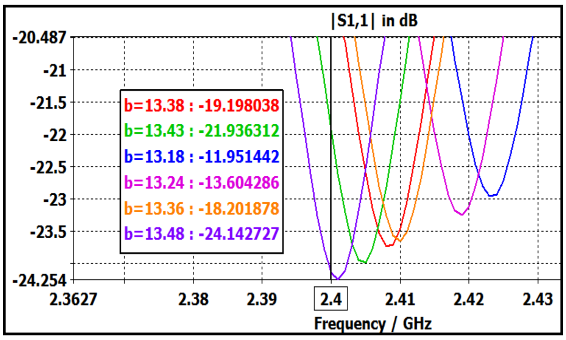


Figure 2: Analysis of change in patch length of design antenna

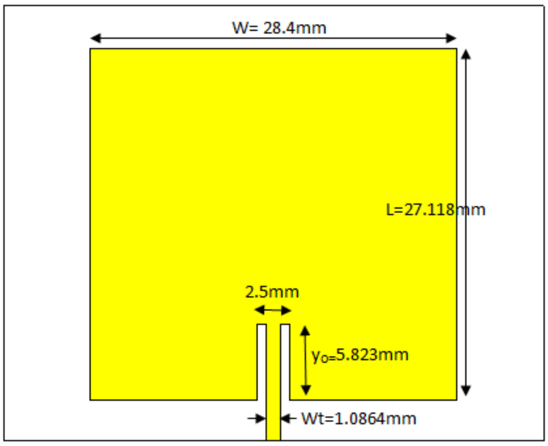


Figure 3: Single element patch antenna

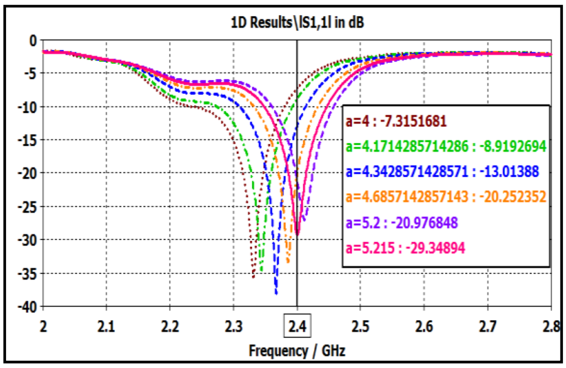


Figure 4: Analysis of change in patch length of design

Figure 5 shows the structure of the 2 x 2 corporate feed linear array antenna design at requires frequency. In order to reduce the effect of mutual coupling, the spacing of antenna elements in array structure plays an important role. In this case the inter-element spacing is approximately λ/2. A corporate feed technique used to connect all element of the array. T-junction power divider and quarterwave transformer impedance matching sections are used to connect the power to each element for radiation. The T-junction power divider as shown in figure 6 has 50 Ω (Zo) line input impedances at each port. Quarter wavelength transformer is used in the corporate feed network to maintain the input impedance at 50 Ω with an impedance of (Z_1). Below is the equation involved in quarterwave transforemer impedance calculation.

$$Z_1 = Zo / \sqrt{2} \qquad (7)$$

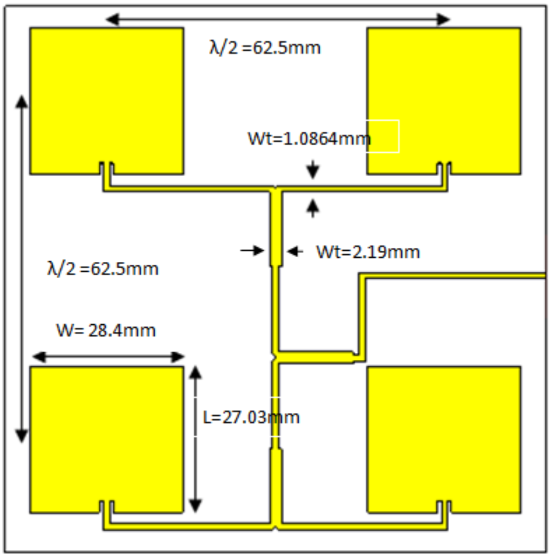


Figure 5: 2 by 2 corporate feed linear array antenna

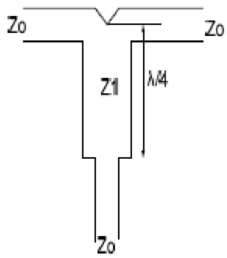


Figure 6: T-junction power divider

The 2 by 8 array structure comprises four sub-arrays of 2 by 2 corporate feed linear array antenna design. Figure 7 shows the design of 2 by 8 corporate feed linear array.

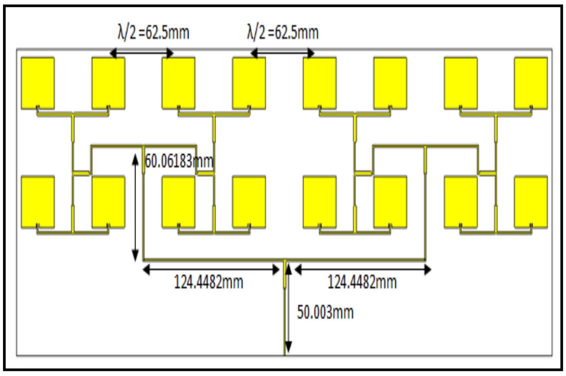


Figure 7: 2 by 8 corporate feed linear array

After the simulation and optimization, the 2 x 8 corporate feed linear array is fabricated using FR4 substrate, with dielectric constant of 4.7 and height of the FR4 is 0.8 mm. Figure 8 shows the prototype of 2 by 8 corporate feed linear array microstrip antenna. Lastly the purposed antenna is test using the network analyzer.

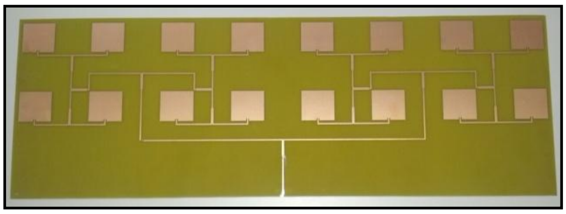


Figure 8: Prototype of 2 by 8 corporate feed linear array microstrip antenna

IV. RESULT AND DISCUSSION

Some parameters from the simulation results tabulated in table 1. Larger return loss indicates higher power being radiated by the antennas which will increases the gain. Gain enhancement can be seen clearly in the table. From the simulation results, it can be proven that by increasing the number of element (patch), the gain also increase.

Table 1: Enhancement gain of microstrip antenna

	Single	2 by 2	2 by 8
Dimension (substrate) in mm	41.82 x 33.63	100 x 101	475 x 161.5
Dimension (patch) in mm	28.4 x 27.118	28.4 x 27.05	28.4 x 27.05
Freq (GHz)	2.4	2.4	2.4
Line Imp. (Ohm)	50	50	50
Return Loss (dB)	-24.14	-29.35	-36.32
Gain (dB)	5.51	11.71	16.6

Figure 9 shows the comparison of return loss. The simulation result gives a return loss 0f -36.32 dB at 2.4 GHz while the measurement results give a return loss of -21.64 dB at 2.72 GHz. From the result, the frequency shifted is clearly shown. To tune the shifted frequency a single stub is necessary for a good matching.

Stub matching technique is a method where a copper strip (stub) added to the feed line to produce pure reactance to the point of attachment [7]. Single stub matching with length 55 mm is determined by try-an-error, added to microstrip feeding lines as shown in figure 10.

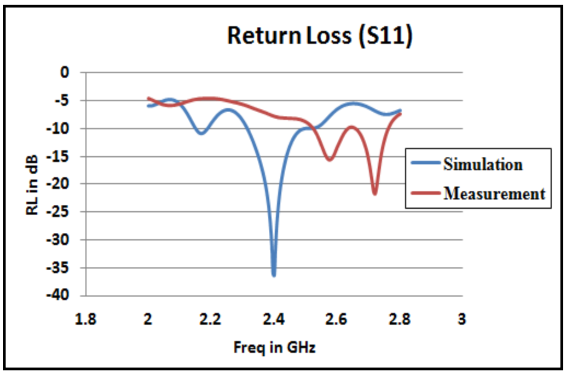


Figure 9: Return loss of 2 x 8 microstrip patch antenna array

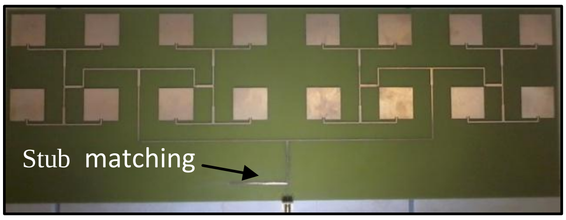


Figure 10: Stub matching implemented in prototype antenna

Figure 11 shows the return loss with stub matching technique added to the design. From the graph, the frequency shifted back to 2.384 GHz, with return loss of 34.24 dB.

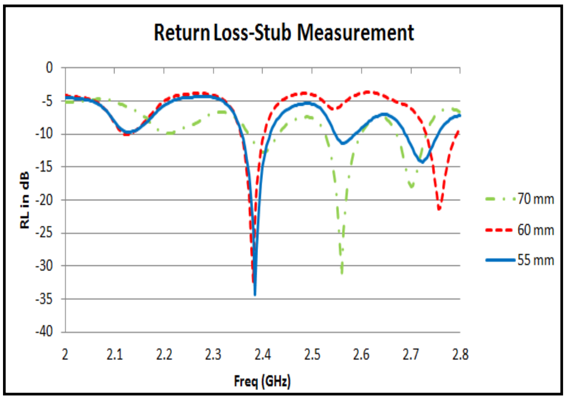


Figure 11: Return loss with stub matching technique

The radiation pattern in figure 12 shows that the gain is 16.6 dB, which can be considering as high gain. High gain is desirable in point to point communication because of long distance communication requirement.

Figure 13 (a) and (b) shows the analyze results of radiation pattern.

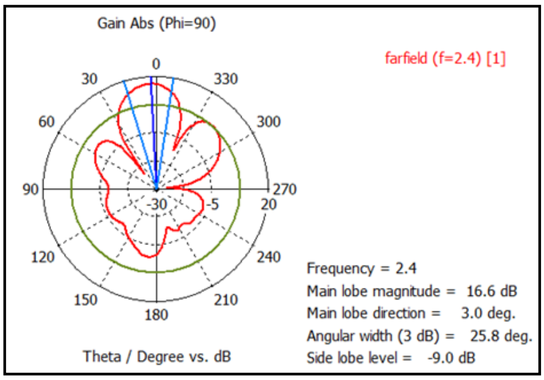
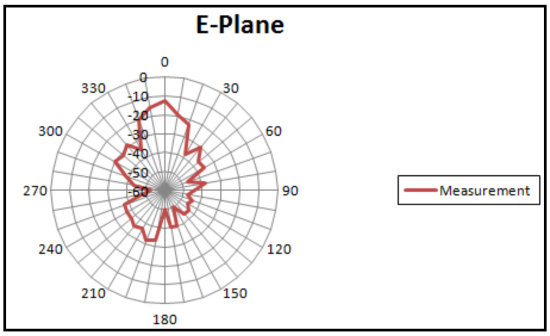
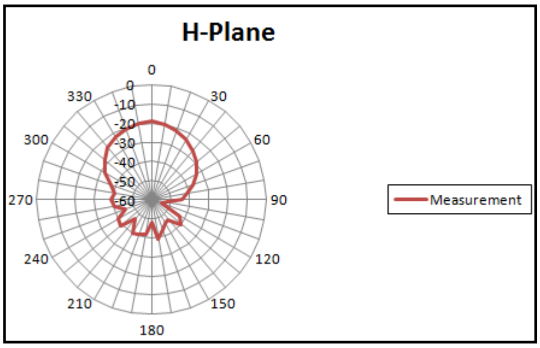


Figure 12: Radiation pattern result from simulation



(a) E Plane



(b) H Plane

Figure 13: Radiation pattern measurement result

Figure 14 shows the narrowside of antenna array in 3D radiation pattern from CST simulation software.

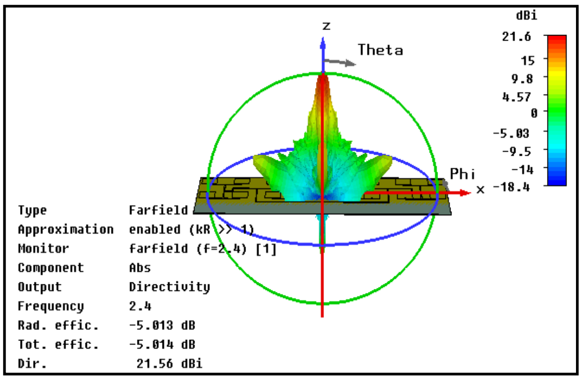


Figure 14: 3D Simulation radiation pattern

V. CONCLUSION AND RECOMMENDATION

2 by 8 corporate feed linear array microstrip antenna have been designed, simulated and compared. Measurement results of return loss shifted due to the FR4 board that has fluctuate from 4.0 to 4.8. The weakness during the fabrication process also contributed to the frequency shifting of measurement result. From simulation results, by creating many patch antennas in array configurations can achieve high gain. Objective of this project to design, simulate and fabricate corporate feed linear array of microstrip patch antenna have been achieved at the end of this project. Besides that, objective to obtained high gain also successful.

As a recommendation, corporate feed linear array microstrip antenna with the separated feed line technique can be research. In [3] this technique reduces spurious effect from the feed line was presented and as results the sidelobe level was suppressed. Different shape of patch also can be studied.

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