Log Periodic Dipole Antenna For UHF Band Application

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***Abstract*—This project presents the design of a microstrip log periodic dipole antenna. The antenna is designed for a center frequency of 2.4 GHz with 45% operating bandwidth for VSWR < 2. CST simulation software is fully utilized to simulate the response of return loss, VSWR, radiation pattern and gain. The antenna was designed to cover the standard frequency of IEEE 802.11 b/g (2.4-2.4835GHz), WiMAX (2.3-3.6GHz) and Wi-Fi of 2.4GHz band. This dipole antenna was fabricated on FR4 substrate with the dielectric constant of *εr*=4.9 and thickness *t*=1.6mm. Both simulated and measured results are compared, analyzed and presented in this paper.**

Keywords- Log periodic dipole antenna, CST, return loss, radiation pattern, VSWR, WiMAX, Wi-Fi

I. INTRODUCTION

In modern telecommunication systems, antenna with wider bandwidth and smaller dimensions than conventional ones are preferred. This has initiated antenna research in various directions; one of which uses Log-Periodic Dipole Arrays antenna.

Log-Periodic Dipole Arrays (LPDAs) are antennas with characteristics such as high gain, large bandwidth, high front-to-back ratio (F/B) and low cost [1]. They are attractive for different communication applications such as commercial broadcast and radio signal detection [2-4]. In addition, LPDA can also be implemented in UHF band applications such as WiMAX and Wi-Fi covering from 300MHz to 3GHz. It can achieve high directivity and low cross-polarization ratio over a very wide frequency range. The size of planar LPDAs should be considered for applications restrict the use of conventional dipoles in LPDAs array. The size of planar LPDA can be reduced significantly using different shapes for the planar dipoles used in the design LPDAs [5, 6]. It was shown that different monopole designs can have similar resonant properties [7]. Several works have introduced the minimization concept of LPDAs through different design methodologies. In this work, the design is made using a linear planar dipole scheme. The antenna has been designed to operate from 2GHz to 4GHz. Fig. 1 shows the schematic design of the antenna. The design methodology of the antenna using log periodic technique is discussed, and the detail results of the proposed antenna are presented in this paper.

II. SCOPE OF WORK

The antenna is designed by using the FR4 substrate. The chosen of FR-4 substrate is due to low cost and good reproducibility compare to other common substrate such as ROGERS which is very expensive [8]. Despite the low cost, FR-4 substrate has high dielectric constant which is good to feed the line impedance precisely [9]. The details about FR4 properties are shown below:

TABLE 1. FR4 SUBSTRATE PROPERTIES

Parameter	Value
Permittivity, ε	4.9
Loss Tangent	0.025
Permeability, μ	1
Substrate Height, h	1.6mm

III. METHODOLOGY

The planar LPDAs consist of *N*-flat dipoles fabricated on a substrate of thickness *t.* The dipoles are placed on the top layer of the substrate and the bottom layer alternatively [10, 11]. Single 50 ohm SMA connector was used to feed the antenna. To ensure a balanced feeding, the site of the SMA connector was soldered to the bottom layer of the LPDA and acts as ground plane which is used to reproduce the effect of the electric circuitry on the same PCB and also acts as reflector element. Meanwhile the center conductor (RF) was connected to the top layer using a small via through the substrate. In simulation, the SMA connector needs to be designed precisely to obtain 50 ohm impedance to match with the line of the dipole [12]. The excitation of the antenna was fed by using direct feeding technique. The design was fabricated using FR4 laminate substrate.

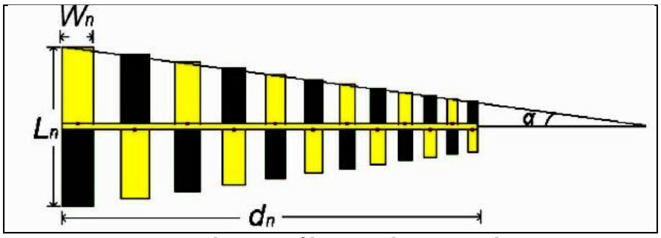

Figure 1: Schematic of log periodic antenna design

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The flowchart in Fig. 2 below shows all the processes involved in designing this antenna.

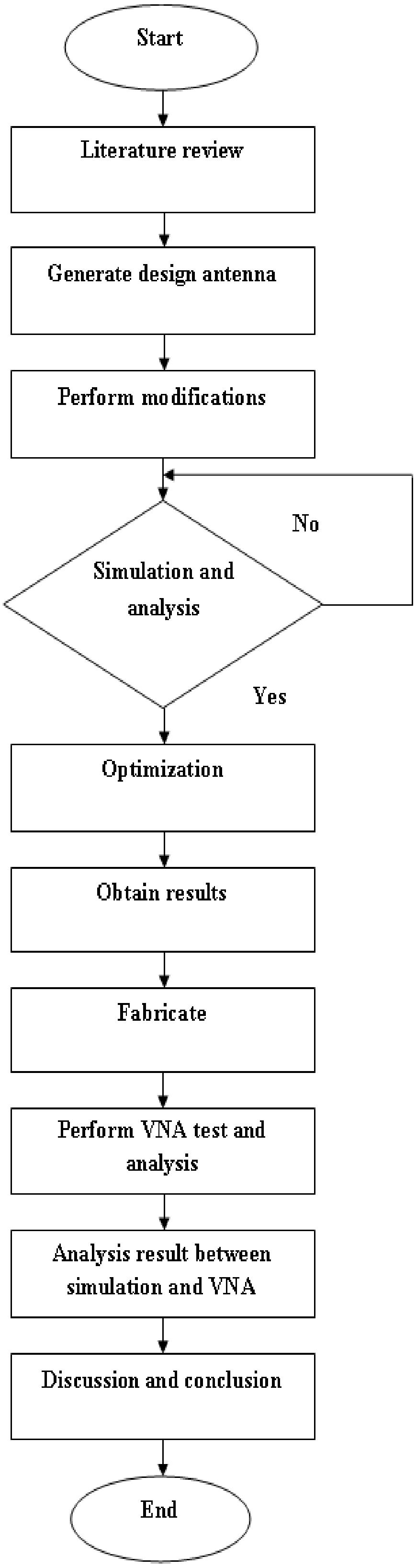

Figure 2. Design flowchart

The antenna`s log-periodic structure is described by a geometry ratio τ that represents the relation between the lengths and the widths of the LPDA elements as in equation (1) and by a spacing factor σ, which relates τ with the apex angle α as in equation (2).[9]. The design equations are as below:

$$\tau = \frac{Ln}{Ln-1} = \frac{Wn}{Wn-1} = \frac{dn}{dn-1} \qquad (1)$$

where *Ln* and *Wn* are the lengths and widths of the n^{th} antenna elements, while *dn* is the antenna`s lengths up to the n^{th} element.

For this work, the geometry ratio τ was chosen to be 0.9 and the spacing factor σ was 0.16 [9]. The apex angle in degrees, is given as a function of τ and σ as;

$$\alpha = tan^{-1}\frac{(1-\tau)}{(4\sigma)} \qquad (2)$$

And the value was 8.88^0. The calculated total number of elements N as in equation (5) is needed to cover the entire frequency bandwidth [9].

The design for the antenna starts by determining the length of the largest element of the planar LPDA, *Ln*. This length is selected so that the largest dipole element resonates at f = 2.4 GHz. The lengths for the remained elements which are related to each other were found from the log-periodicity of the structure or the geometry ratio τ and the spacing factor σ. The widths of the dipole elements were optimized to achieve maximum gain. The length of the largest element *L*n of the design was 64 mm and distance *d*n was 165 mm [10]. The width for the largest dipole for the design was 13 mm [9]. Carrel has introduced a semi empirical as in equation (3) to calculate the bandwidth of the active region *Bar* related to τ and σ [13].

$$Bar = 1.1 + 7.7(1-\tau)^2 \cot \alpha \qquad (3)$$

In practice, a slightly larger bandwidth (*Bs*) as in Equation (4) is usually designed than desired bandwidth (*B*) which is required. The two parameters are related by:

$$Bs = BBar = B[1.1 + 7.7(1- \tau)^2 \cot \alpha] \qquad (4)$$

Where;
Bs = designed bandwidth
B = desired bandwidth
Bar =active region bandwidth

Then the number of elements is determined by:

$$N = 1 + \frac{ln(BS)}{ln(1/\tau)} \qquad (5)$$

The performance of the antennas are studied and presented in the following section.

IV. RESULTS AND DISCUSSION

The design of the antenna is based on log periodic concepts. The Computer Simulation Technology (CST) microwave software has been used to simulate the performance of the antenna. It consists of twelve elements for the desired frequency range. The antenna has been design with a double sided patch, or in other words multilayer printed dipole where the purpose is to get the better far field and radiation pattern result during simulation process using CST software. Fig. 3 below shows the schematic for the real design of CST software 3D design while Fig. 4 shows the schematic for fabricated design of the antenna.

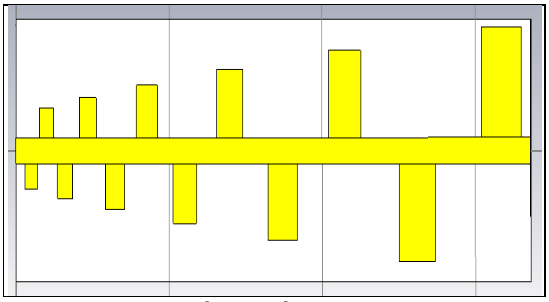

Figure 3: Schematic design in CST view

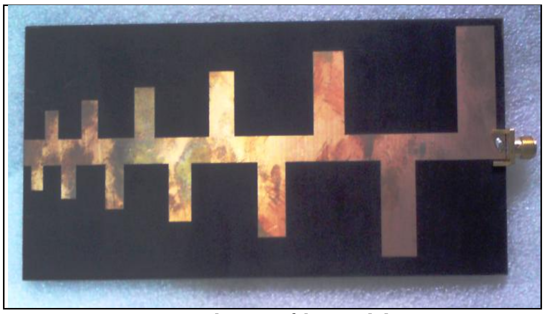

Figure 4: Schematic fabricated design

The simulated and measured result of the proposed antenna such as return loss (dB), radiation pattern and VSWR are discussed in this part.

4.1 Simulated and Measured Return Loss

Table 2 and Table 3 show the simulated result for designed antenna using FR4 substrate and ROGER4003C substrate for frequency range between 2-4GHz**.** The FR4 substrate consistently experienced good return loss, efficiency and VSWR more than ROGER4003C. So, it can be concluded that FR4 substrate give better performance compared to ROGER4003C substrate.

TABLE 2. USING FR4 SUBSTRATE

Parameter	**Value**			
Frequeny (GHz)	2.1	2.4	2.7	3.028
S11 (dB)	-12.8846	-18.0765	-16.3827	-16.7371
Efficiency(dB)	-0.7659	-1.254	-1.152	-1.907
VSWR	1.5869	1.2852	1.3575	1.3411

TABLE 3. USING ROGERS's 4003C SUBSTRATE

Parameter	**Value**			
Frequeny (GHz)	2.1	2.4	2.7	3.028
S11 (dB)	-11.0199	-11.1856	-11.4719	-6.2387
Efficiency(dB)	1.630	1.531	1.580	1.466
VSWR	1.7824	1.7619	1.7283	2.7606

Fig. 5 shows the result of simulated return loss. The design exhibited a very good simulated and measured return loss magnitude response over the entire design range (2-4GHz) which is less than -10dB. From the graph, it can be seen that the reflection value at center frequency of 2.4GHz is -18db. The simulated and measured bandwidths were 1.85GHz and 1.35GHz respectively. For this frequency range, the antenna designed would be applied for any of WLAN application such as WiMAX and WIFI.

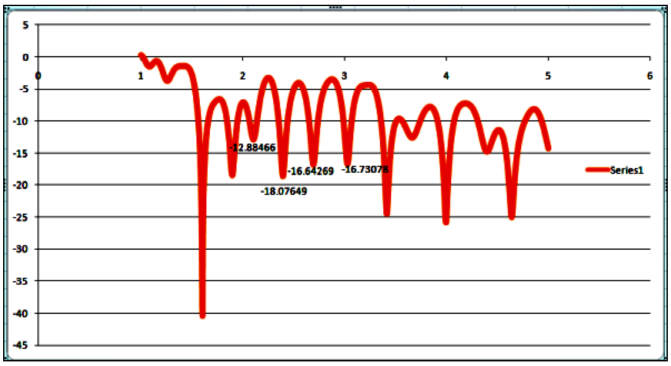

Figure 5: Simulated return loss in Microsoft excel view

Fig. 6 shows the measured result for return loss in dB with the percentage bandwidth of 45%. Meanwhile, Fig. 7 shows the comparison between simulated and measured return loss results. As we can see, the result for both simulated and measured is almost the same for each point which is less than -10dB. Nevertheless, there is some minor shifting for the resonant at the frequency 3.2GHz up to 4GHz due to approximation calculation done by the VNA software and the other reason is due to the surrounding external factor. Beside of those factors, fabrication process also would contribute to the resonant minor shifting. This is due to; during fabrication process it uses the wet etching technique that may not produce an accurate etching on the edges. Despite it was shifted, it is still can be considered well enough for radiation.

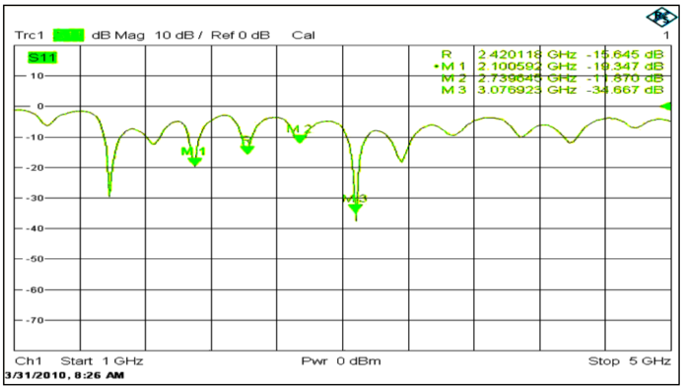

Figure 6. Measured return loss

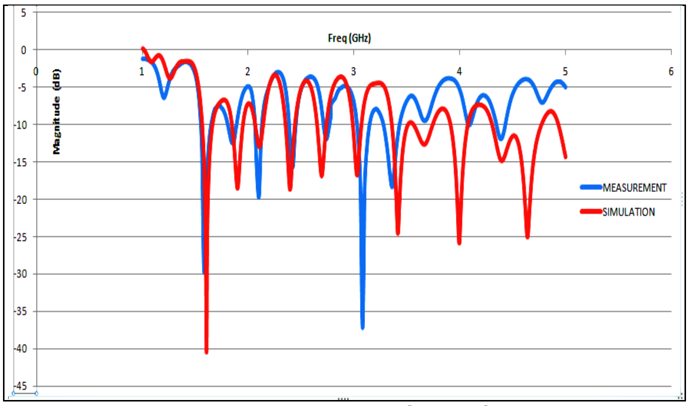

Figure 7. Comparison return loss graph

4.2 Simulated and Measured Smith Chart

Figures below show the simulated and measured Smith Chart for the design antenna. Fig. 8 shows value for line impedance of dipole antenna is slightly reaching 50 ohm which is good to get the best effect for the antenna and to feed the line dipole precisely. The measured result in Fig. 9 also shows the similar characteristics where the line impedance for each point is reaching 50 ohm and not less than 40 ohm.

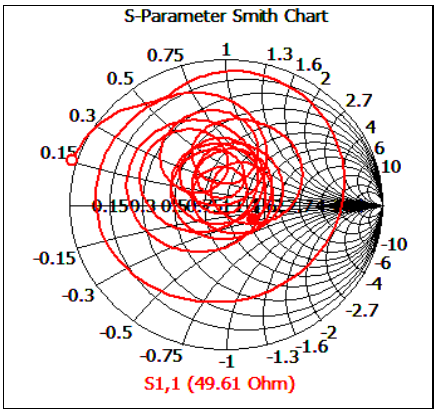

Figure 8. Simulated Smith Chart in CST view

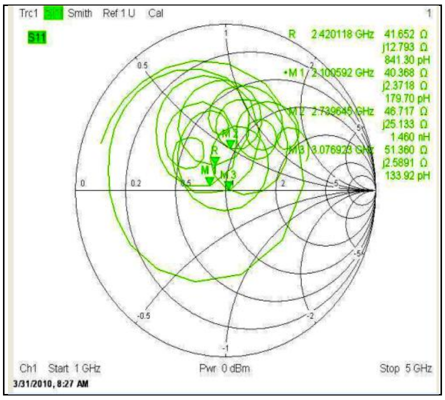

Figure 9. Measured Smith Chart

4.3 Simulated and Measured VSWR

A comparison of the results shows that both simulated and measured exhibit very similar characteristics. All four points in both simulated and measured results have successfully achieved VSWR < 2dB which is consistent with the objective.

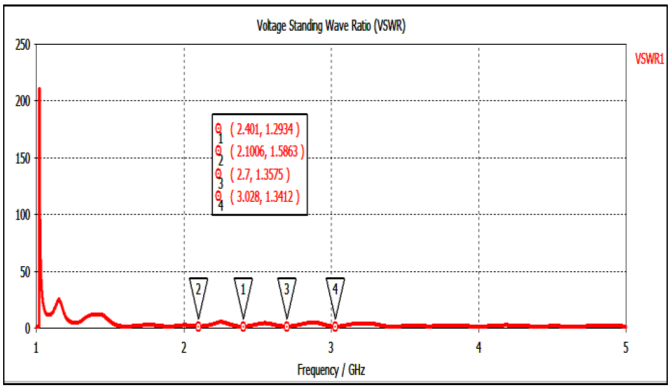

Figure 10: Simulated VSWR in CST view

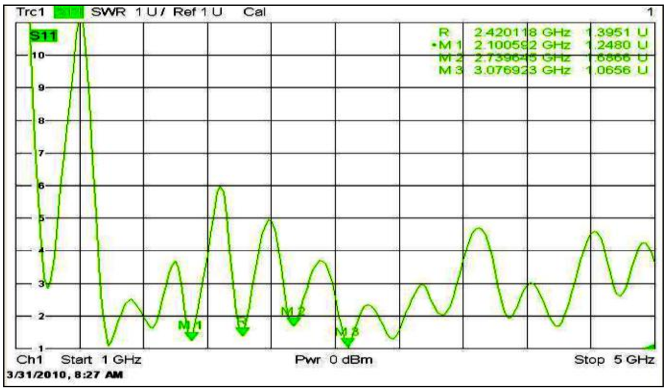

Figure 11: Measured VSWR

4.4 Simulated and Measured Radiation Pattern

Far field and radiation pattern for simulated and measured double-sided log periodic dipole antenna is shown in Fig. 12, Fig. 13 and Fig. 14. The dark radiation in Fig. 12 shows the strong radiation effect of the dipole antenna which is radiates towards more on the larger element rather than smaller element of the dipole. This phenomenon so called end fire radiation. It can be seen that the designed antenna at 2.4GHz gives efficiency and gain of 74.9% and 3.146dB respectively.

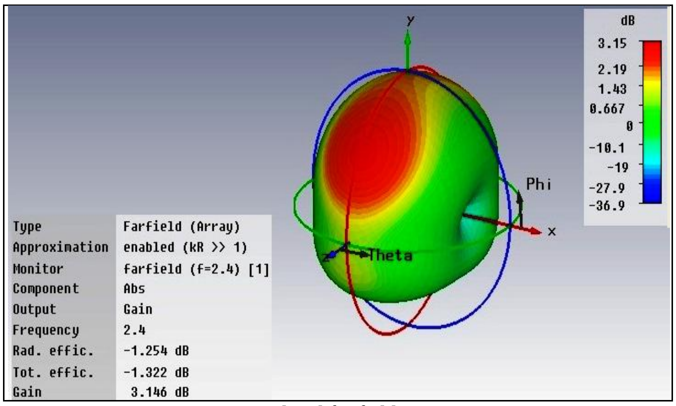

Figure 12: Simulated far field in CST view

The simulated E-plane radiation pattern at frequency 2.4GHz is demonstrated in Fig. 13 while the simulated result is demonstrated in Fig. 14. The radiation pattern radiated towards the center of the elements. It shows that the front-to-back ratio for simulated and measured result is 5dB and 11dB respectively. The pattern of radiation is almost the same which indicates that the feed is balanced and excites equal currents in each element.

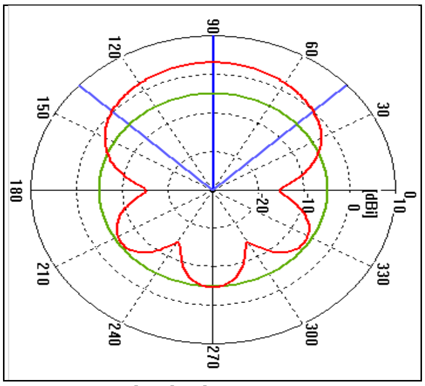

Figure 13. Simulated radiation pattern in CST view

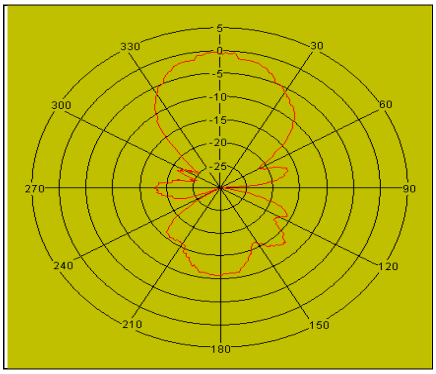

Figure 14. Measured radiation pattern at 2GHz

Table 4 shows a typical set of simulation and measurement results for the design antenna at 2.4GHz. The difference between the measured and simulated results is slightly small which less than 30%.

TABLE 4. COMPARISON BETWEEN SIMULATION AND MEASUREMENT RESULT AT RESONANT FREQUENCY

Parameter	**Simulated**	**Measured**	**Percent different**
Return loss	-18.0765	-15.645	13.45%
VSWR	1.2852	1.3951	7.87%
Percentage bandwidth	61.86%	45.33%	26.72%

V. CONCLUSION

A log periodic dipole antenna consisting of double sided twelve elements has been proposed and investigated. The good return loss of less than -10dB for the frequency range between 2-4 GHz has been successfully achieved. The measured antenna bandwidth of 45% and VSWR < 2 is also achieved**.** The radiation characteristic of this antenna is also measured at selected frequency, which represents the end-fire radiation pattern with a gain of about 3.2dB. This proposed antenna with the advantages of large bandwidth, high gain and low cost is applicable to UHF band application from 300MHz to 3GHz that can be applied for WLAN application such as WiMAX and Wi-Fi. For future recommendation, further works should be carried out in order to improve the bandwidth of the antenna. More number of elements should be added on the dipole as well as using different kind of planar structure such as the single side planar with surrounding ground plane. To improve the efficiency and gain of the design antenna, multilayer substrate less value of dielectric constant should be considered.

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