A Log Periodic Dipole Array Antenna for UWB Applications

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Abstract—This paper presents the design of a microstrip antenna type log periodic dipole array (LPDA) with eight elements. The operating frequency range for this antenna is at Ultra Wide Band (UWB) from 3.1 GHz to 10.6 GHz. The antenna has been simulated using Computer Simulation Technology (CST) to obtain the response of return loss, VSWR, line impedance and radiation pattern. This LPDA antenna was fabricated using FR-4 substrate with a dielectric constant of 4.9 and thickness of 1.6mm. Both simulated and measured results are compared, analyzed and presented in this paper.

Keywords: ***microstrip, type log periodic dipole array antenna (LPDA), CST, return loss, VSWR, line impedance, radiation pattern.***

1. INTRODUCTION

Recently, a lot of attention has been paid to Ultra Wide Band (UWB) communications because their advantages make them attractive for consumer communications applications. Due to the simple transmit and receive structures used, a potentially powerful technology for low-complexity, low-cost and high data rate communications is developed [1]. A wide variety of antennas directional or non-directional are suitable for use in UWB applications [2].

The log-periodic dipole array antenna (LPDA) can be a powerful solution for UWB communications systems. The LPDA is a directional, wideband antenna which performance is not affected by the frequency variation. Its characteristics remain nearly constant and it radiates with high gain at frequencies within the operational bandwidth. The LPDA consists of dipoles whose lengths and spacing are arranged in a log periodic manner [3].

Several works have introduced the minimization concept of LPDAs through different design methodologies. From the previous works done by [4], [7] and [6], their results show that LPDA antenna have a frequency range rather than center frequency. These were shown by [4] that has frequency range from 340 MHz to 3.45 GHz, by [7] have frequency range of 750 MHz to 2.7 GHz and by [6] have frequency range covered from 570 MHz until 810 MHz.

Based on work done by Ali Mirkamali and Peter S Hall [7], they use switch in order to select a few elements of LPDA antenna in order to do the frequency reconfiguration as shown by reference [7].

In this work, the design is made using a straight planar dipole scheme. The antenna has been designed to operate from 3.1GHz to 10.6GHz. Fig. 1 shows the basic 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.

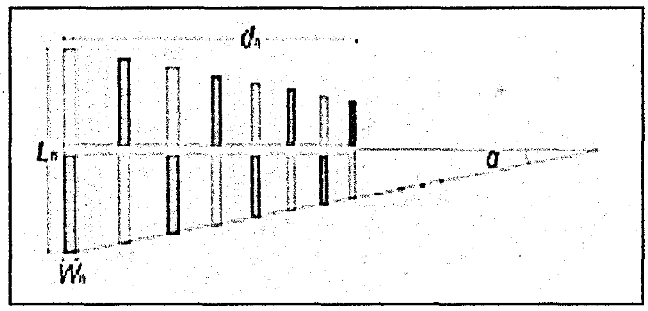


Fig. 1: Double-sided log-periodic array antenna design

2. SCOPE OF WORK

A straight dipole array antenna was design using log periodic technique. A log periodic dipole array antenna (LPDA) with eight elements was designed and simulated using Computer Simulation Technology (CST) software. The FR-4 board was used as a substrate material which has a dielectric constant of 4.9, tangent loss of 0.025 and thickness of 1.6mm. FR-4 substrate is more suitable at higher frequency band compared to lower frequency band due to the dielectric values [4].

The properties of the antenna such as return loss, VSWR, line impedance and radiation pattern were investigated and compared between simulation and measurement.

Fig. 2 elaborates the processes involved in designing this antenna. .

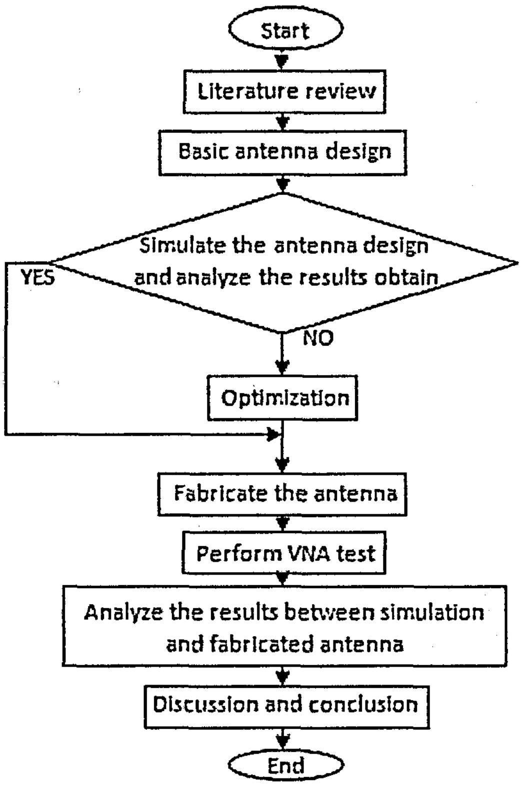


Fig. 2 : Flowchart of antenna design

3. ANTENNA DESIGN AND PROCEDURE

3.1 Design

A straight log periodic dipole array antenna(LPDA) with eight elements has been designed and simulated using Computer Simulation Technology software and fabricated using substrate type FR-4 with dielectric constant of 4.9 and tangent loss about 0.025. The operating frequency of this antenna is at UWB, ranging from 3.1 GHz -10.6GHz.

The planar LPDA consist of *N*-flat dipoles fabricated on a FR-4 substrate. The dipoles are placed on the top layer of the substrate and the bottom layer alternatively. The antenna was fed using 50 ohm SMA connector. It's connected to a central transmission line with a phase reversal between the dipole. This is required so that radiation is in backfire direction (towards smaller element). If the phase reversal is not used, radiation will occur in end-fire direction (towards larger element) [4]. In simulation, the SMA connector needs to be designed precisely to obtain 50 ohm impedance to match with the line of the dipole [4]. The excitation of the antenna was fed at the longest element feeding point.

Fig. 3 shows the simulated LPDA while Fig. 4 shows the fabricated LPDA. The antenna consists of eight printed dipoles. The lengths of the longest and shortest dipoles are 154.3mm and 43mm respectively. The longest dipole is 3mm width and the shortest is 0.78mm. The geometry ratio of the log periodic structure is 0.824 [7]. The length of the antenna is 12.5cm. The antenna is printed on the both sides of a 1.6mm thick FR-4 substrate with dielectric constant of 4.9. The antenna is fed by the parallel strips transmission line. The width of the strips is 4.3mm.

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 (1) and by a spacing factor σ, which relates τ with the apex angle α as in (2) [3]. The design equations are:

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

where Ln and Wn are the lengths and widths of the nth antenna elements, while dn is the antenna's lengths up to the nth element (Figure 1).

For this work, the geometry ratio of the log periodic structure is 0.824 [7]. The apex angle in degrees, is given as a function of τ and σ as;

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

The number of elements N as in (3) needed to cover the entire frequency bandwidth was 8.

$$N = 1 + \frac{\ln(B_s)}{\ln(1/\tau)} \qquad (3)$$

Carrel has introduced a semi empirical as in (4) to calculate the bandwidth of the active region Bar related to τ and σ [3].

$$Bar = 1.1 + 7.7(1-\tau)^2 \cot \alpha \qquad (4)$$

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

$$Bs = BBar = B[1.1 + 7.7(1-\tau)^2 \cot \alpha \qquad (5)$$

Where:

Bs = designed bandwidth
B = desired bandwidth (f_{max} / f_{min} = 10.6 GHz / 3.1 GHz)
Bar = active region bandwidth

3.2 Simulation Process

The antenna is then simulated using CST Microwave Studio and was optimized to achieve best response. Fig. 3

illustrate the optimized layout of the LPDA antenna. The size of the LPDA antenna is 15.6cm x 12.5 cm.

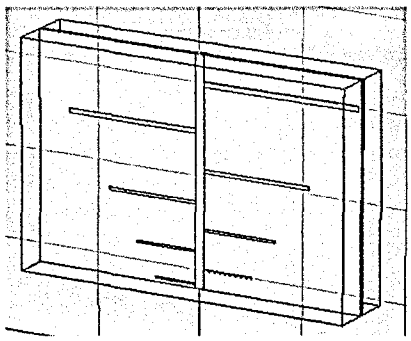


Fig. 3 : Simulated LPDA using CST

3.3 Fabrication Process

The final dimensions of the antenna layout using AutoCAD and was sent for fabrication. Fig. 4 illustrate the final fabricated layout of the LPDA antenna. The fabricated LPDA antenna size is 16.1cm x 12.6cm.

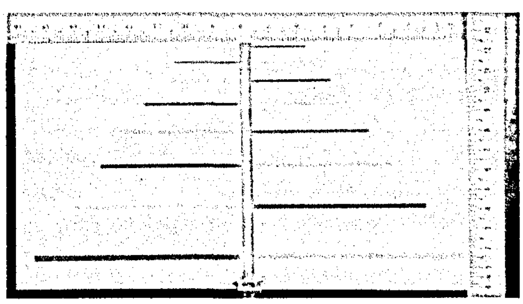


Fig. 4: Fabricated LPDA

4. RESULTS AND DISCUSSIONS

The simulation and measurement results of the LPDA antenna such as return loss, VSWR, line impedance and radiation pattern are discussed in this part. Table 1 shows the response specification for the LPDA antenna.

Table 1 : Response specification for LPDA antenna

	Specification
S11 (dB)	≤ -10dB
VSWR	< 2
Impedance	~ 50Ω

Table 2 show the comparison of simulated result for single sided and double sided LPDA antenna and Table 3 show comparison between simulated and measured results of double sided LPDA antenna.

Table 2 : Comparison between single sided and double sided simulated LPDA antenna results

	Single sided			Double sided		
Frequency (GHz)	4.9	5.7	9	4.9	5.7	9
S11 (dB)	-11.7	-11.5	-16.4	-12.3	-11.3	-13.3
VSWR	1.70	1.73	1.35	1.64	1.79	1.55
Efficiency (%)	51.42	47.02	32.49	53.04	47.56	33.92
Impedance (Ω)	0.00			50.22		

Table 3 : Comparison between simulated and measured LPDA antenna results

	Simulated			Measured		
Frequency (GHz)	4.9	5.7	9	4.9	5.7	9
S11 (dB)	-12.3	-11.3	-13.3	-22.9	-22.6	-23
VSWR	1.64	1.79	1.55	1.19	1.18	1.17
Impedance (Ω)	50.22			55.9	46.5	56.7

4.1 Return Loss

Fig. 5 shows the simulated return loss graph of the straight LPDA antenna. It can be observed that the antenna has a very good return loss which covers from 3.1 GHz to 10.6 GHz. At the lower band frequency, the graph seems to have multiple bands of resonant frequencies, compared to the upper band frequency. This might be due to the tangential loss effect of the dielectric constant used in this simulation [4]. In many cases, the uses of higher dielectric constant can reduce the size of the elements but their bandwidth reduces [4]. So, it can be concluded that FR-4 substrate is more suitable at higher frequency band compared to lower frequency band [4].

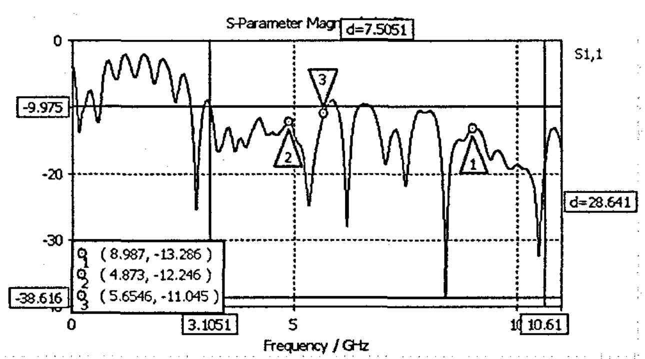


Fig. 5: Simulated return loss

Fig. 6 show the measured result for return loss in dB. Markers have been represented at each point to be easily compared with the simulated result. It can be observed that at frequencies 4.9GHz, 5.7GHz and 9GHZ the responses are exceed than -10dB. But, there is some shifting for the resonant at the frequency 5GHz up to 6GHz due to approximation calculation (rounding up) during basic antenna design and effect of the surrounding. Despite of the shifting frequencies, return loss response of the LPDA antenna meet the design specification of an antenna as in Table 1.

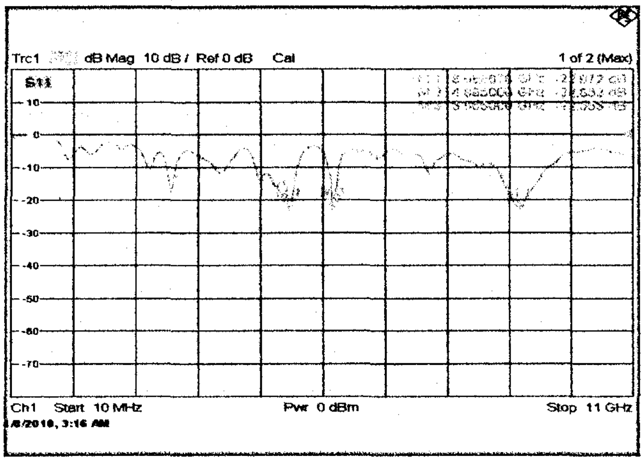


Fig. 6 : Measured return loss

4.2 VSWR

The results in Fig. 7 and Fig. 8 show that both simulated and measured have very similar response. All points in the required bandwidth (3.1GHz to 10.6GHz) have successfully meet the design specification of an antenna as in Table 1 (VSWR < 2dB).

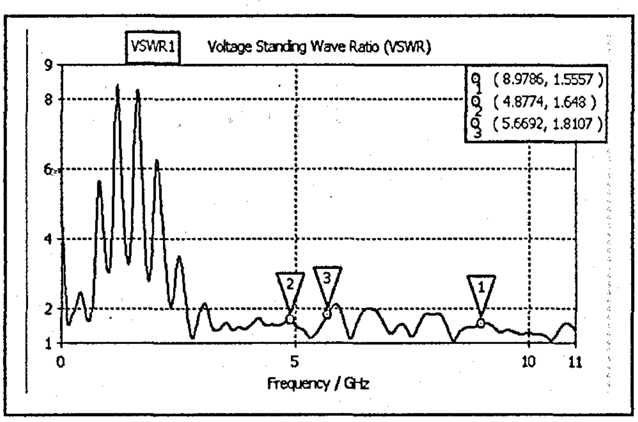


Fig. 7: Simulated VSWR

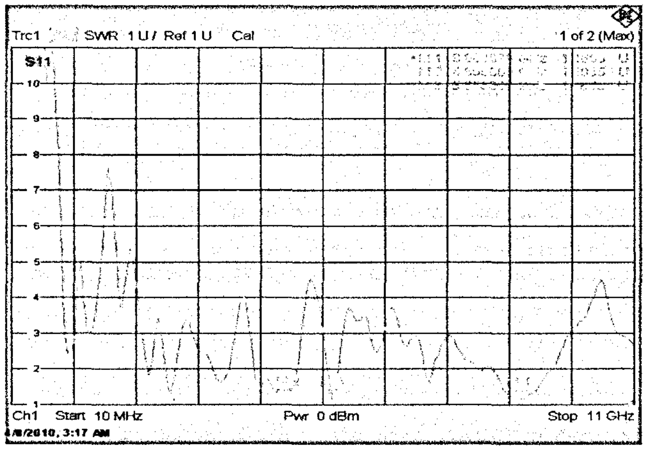
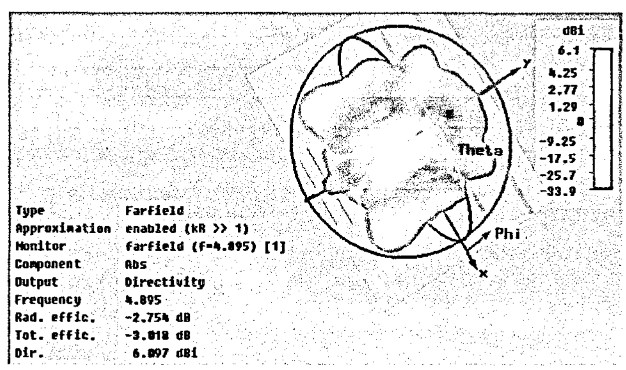


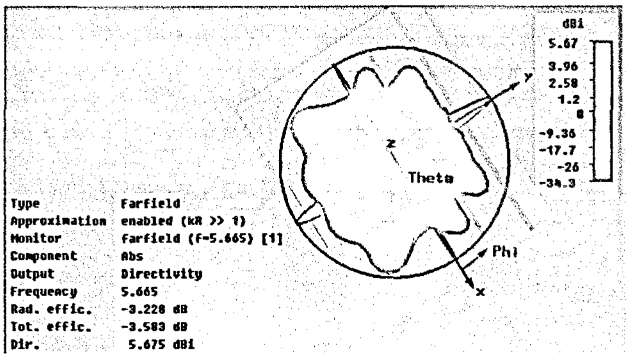
Fig. 8: Measured VSWR

4.3 Radiation Pattern

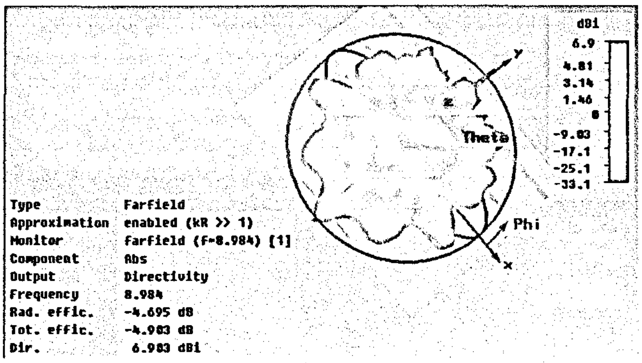
The simulated radiation patterns for the double sided LPDA antenna have done and some of them are shown in Fig. 9. From this figure, the power radiates towards the smaller elements that so called end fire radiation [4]. The dark pattern shows the strong radiation effect compared to light pattern as indicated in simulation software. Besides that, the parameter that can be observed from this simulator such as efficiency and many more can be monitor and it depends on the setting at the simulator. The radiation efficiencies that were obtained in this simulation are shown in Table 2. However, the measurement radiation patterns cannot be obtained due to equipment limitation in the laboratory.



(a) Radiation pattern at 4.9 GHz



(b) Radiation pattern at 5.7 GHz



(c) Radiation pattern at 9 GHz

Fig. 9 : Simulated Radiation Pattern a) at 4.9 GHz, b) at 5.7 GHz, c) at 9 GHz

5. CONCLUSION

A double sided log periodic dipole array antenna with eight elements has been successfully designed, simulated and measured. The good return loss of less than -10dB at certain frequencies in the range of 3.1-10.6 GHz has been successfully achieved. This antenna can be use for any application that utilizes frequencies from 3.1GHz up to 10.6GHz. Due to equipment limitation, the radiation pattern measurement at those frequencies cannot be performed. For the future recommendation, further research can be done to reduce the size of the antenna. The application of fractal geometry (Fractal Koch) to conventional antennas can reduce the antenna size.

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REFERENCES

[1] M. Ghavami, L. B. Michael, R. Kohno, *"Ultra Wideband Signals and Systems in Communication Engineering"*, John Wiley & Sons, 2004.

[2] B. Allen et al, *"Ultra-wideband Antennas and Propagation for Communications, Radar and Imaging"*, John Wiley & Sons, 2007.

[3] C.A. Balanis , *"Antenna Theory: Analysis and Design"*, John Wiley & Sons, Inc, 1997.

[4] Mohd Nazri A. Karim, Mohamad Kamal A.Rahim, Thelaha Masri, Osman Ayop, *" Analysis of Fractal Koch Dipole Antenna For UHF Band Application"* , Radio Communication Engineering Department (RaCED) Faculty of Electrical Engineering, Universiti Teknologi Malaysia.

[5] Ahmad A. Gheethan*, and Dimitrios E. Anagnostou, *"The Design of Reconfigurable Planar Log-Periodic Dipole Array (LPDA) Using Switching Elements"*, South Dakota School of Mines and Technology, IEEE, 2009.

[6] Mohd Nazri A. Karim, Mohamad Kamal A.Rahim, Thelaha Masri, Osman Ayop, *" Fractal Koch Dipole Antenna For Digital TV Application "*,IEEE International RF and Microwave Conference Proceedings, Kuala Lumpur, Malaysia, December 2-4, 2008.

[7] Ali Mirkamali, Peter S Hall, *" Log Periodic Printed Dipole Array for Wideband Frequency Reconfiguration"* , Electrical Engineering Department Iran University of Science and Technology, Narmak Tehran Iran.

[8] Christina I. Tsitouri, Stylianos C. Panagiotou, Themistoklis D. Dimousios and Christos N. Capsalis, *"A Circular Switched Parasictic Array of Log Periodic Antennas with Enhanced Directivity and Beam Steering Capability for Ultra Wideband Communications Applications"*, National Technical University of Athens School of Electrical and Computer Engineering Division of Information Transmission Systems and Material Technology 9, Iroon Polytechniou str.,15773, Zografou, Athens, Greçce.

[9] Ben Allen ,3 Tony Brown[2] ,4 Katja Schwieger4, Ernesto[3] Zimmermann , Wasim Malik , David Edwards , Laurent Ouvry , Ian Oppermann ," Ultra Wideband: Applications, Technology and Future perspectives", *International Workshop on Convergence Technology (IWCT)*, 2005.

[10] Shih-Yuan Chen, Po-Hsiang Wang, and Powen Hsu, *"Uniplanar Log-Periodic Slot Antenna Fed by a CPW for UWB Applications"*, IEEE Antennas and Wireless Propagation Letters, Vol. 5, 2006.

[11] M.H Jamaluddin, M.K.A. Rahim, M.Z.A. Abd Aziz and A. Asrokin, "Direct Conversion Receiver with Active Integrated Antenna", *Pacific Conferenceon Applied Electromagnetics Proceedings*, December 20-21, 2005, Johor bahru, Johor, Malaysia.

[12] M.H Jamaluddin, M.K.A. Rahim, M.Z.A. Abd Aziz and A. Asrokin, "Microstrip Dipole Antenna Analysis with Different Width and Length at 2.4 GHz", *Pacific Conferenceon Applied Electromagnetics Proceedings*, December 20-21, 2005, Johor bahru, Johor, Malaysia.

[13] Richard W. Ziolkowski, Peng Jin, *"Metamaterial-Based Dispersion Engineering to Achieve High Fidelity Output Pulses From a Log-Periodic Dipole Array"* , IEEE Transactions on Antennas and Propagation, Vol. 56, No. 12, December 2008.