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Slot implementation on second iteration of fractal log periodic dipole antenna for UHF band application

Muhammad Hafeez Rosmin, Mohamad Kamal A Rahim, Nur Syahirah Yaziz, Muhammad Naeem Iqbal, Osman Ayop, Muhammad Amir Haziq Kamarusshahrin and Farid Zubir

Advanced RF and Microwave Research Group (ARFMRG), Communication Engineering Department, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

E-mail: mdkamal@utm.my

Abstract. In this paper, the design of the second iteration of Log Periodic Fractal Koch Antennas (LPFKA) with and without slot implementation is designed for Ultra High Frequency (UHF) band applications. The slot implementation is applied on each of the radiating elements to reduce the antenna's size and to prevent the shifting of a lower frequency to a higher frequency. The antenna is operated at a frequency between 0.5 GHz and 9.0 GHz. The Computer Simulation Technology (CST) software was used to design and simulate the antenna. The performance of the antenna such as reflection coefficient, radiation pattern and gain have been analyzed. The antennas have been fabricated using an FR4 laminated board with a dielectric constant of 4.6, tangent loss of 0.019, and a thickness of 1.6mm. The results show a positive outcome, with a stable radiation pattern over the operational bandwidth and a reflection coefficient of less than -10 dB for the designed frequency.

1. Introduction

Wireless communications are now one of the trendiest topics in rapid development because it offers enhanced network interaction, data transmission, video call and other services. This has led to various kind of antenna research.

One of them employs fractal-shaped antenna elements [1]. Most of these designs have shown to be especially effective in terms of lowering antenna size, while others try to incorporate multi-band properties [2–5]. Antenna elements with a fractal shape bring a number of advantages such as antenna size reduction, broad bandwidth and multiband frequency [6]. An example of a good self-similar fractals shape that has been used to construct multi-band and miniaturized antennas is Koch curve. Most of the constraints of small antennas can be solved by the Koch geometry's properties [7].

For this paper, we emphasis on the size of the antenna therefore a Koch curve shape is applied. For Koch curve shape, there are zero iteration which is the conventional shape of log periodic dipole antenna, first iteration, series iteration and second iteration. The more iteration it has, the more size reduction can be obtained. Even so, as the number of iterations increases, the operating frequency will shift more to the higher frequency. In order to avoid that, the slot implementation is done [8]. In this paper, we only analyze the slot implementation on the second iteration.

In theory, the slot implementation was done to improve the bandwidth of the antenna, for size reduction as well as to prevent the shifting of the lower frequency to the higher frequency.

This paper discusses the antenna design process by applying the log periodic technique, as well as the detailed results such as reflection coefficient, radiation pattern, and gain of the antenna design.

2. Antenna Design

Log periodic principles are used to construct fractal Koch antennas for the 2nd iteration. The scaling factor (τ), which is described as the ratio between 2 consecutive antenna elements in terms of length (l), width (w) of antenna elements, number of the elements (n) and distance between antenna elements (d) are given in Equation (1), is among the key parameters in constructing the log periodic antennas [9].

$$r = {d_{n+1}}/{d_n} = {l_{n+1}}/{l_n} = {w_{n+1}}/{w_n} \tag{1}$$

Initially, both antennas are constructed and modelled by using Computer Simulation Technology software as shown in figure 1. Then, the antenna is fabricated by using FR-4 laminated board with dielectric constant of 4.6, tangent loss of 0.019 and thickness of 1.6mm as shown in figure 2.

Each side of the antenna has 12 elements that have been lined in a crossed arrangement in order to generate enough electromagnetic radiation. The value of the scaling factor is 0.85 by referring to Carrel's table [9]. One side of the antenna is connected to the excitation port and another connected to the ground port. Both antennas are done at a 60-degree angle of second iteration.

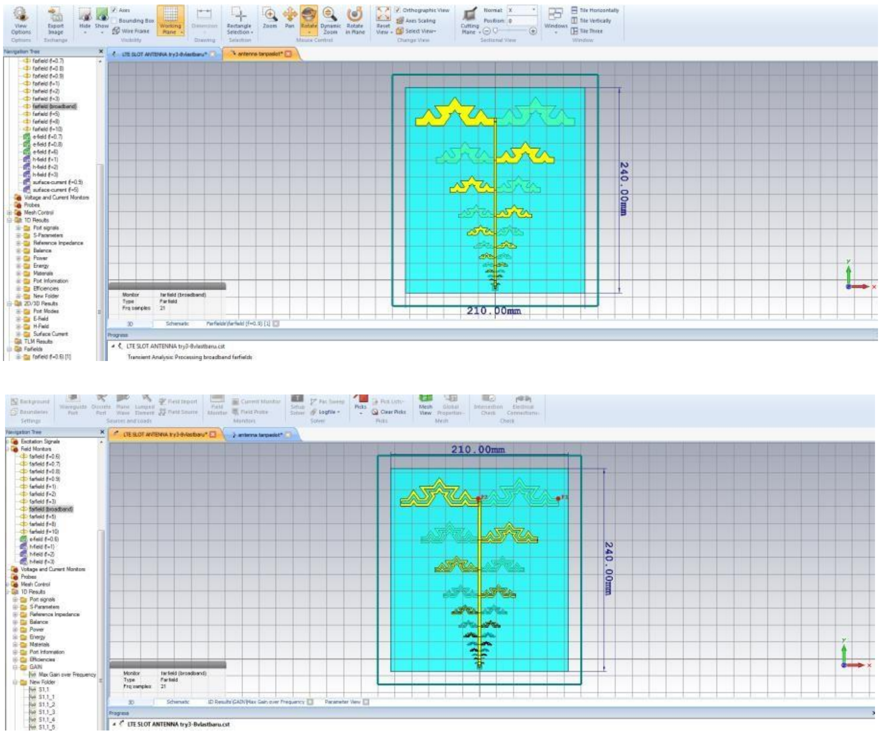


Figure 1. Design of standard and slotted 2nd iteration antenna in CST software.

a) Standard 2nd iteration b) Slotted 2nd iteration

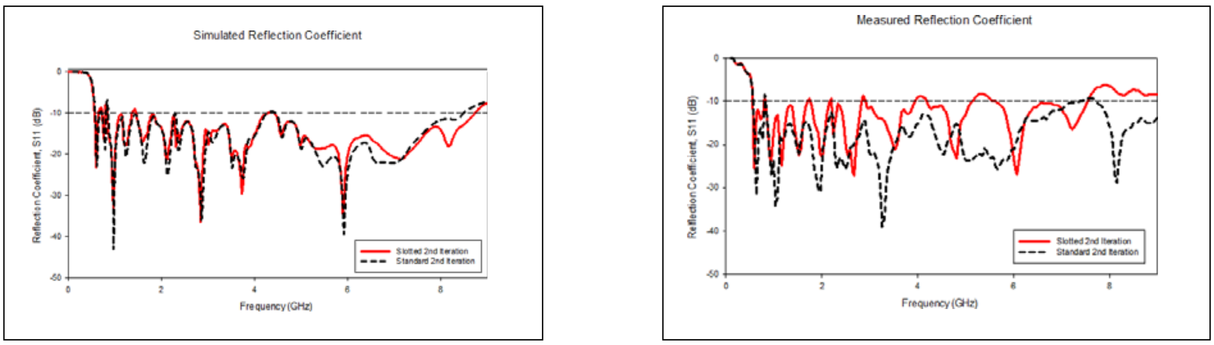
Figure 2. Show the fabricated antennas.

3. Results and analysis

This section presents the outcomes for both antennas with respect to their reflection coefficient, radiation pattern and gain.

3.1. Reflection Coefficient

Figure 3 show the simulated and measured reflection coefficient for the standard 2nd iteration and slotted 2nd iteration antennas. From the simulated readings, it can be seen that even though we implement the slot, the reflection coefficient of both antenna doesn't really change much and in fact much similar to each other. Figure 4 show the comparison of simulated and measured reflection coefficient for each antenna. From both figures, the antennas demonstrate a satisfactory response with respect to -10 dB over the desired frequency.



a) Simulated reflection Coefficient b) Measured reflection coefficient

Figure 3. Simulated and measured reflection coefficient for standard 2nd iteration and slotted 2nd iteration of fractal Koch antenna.

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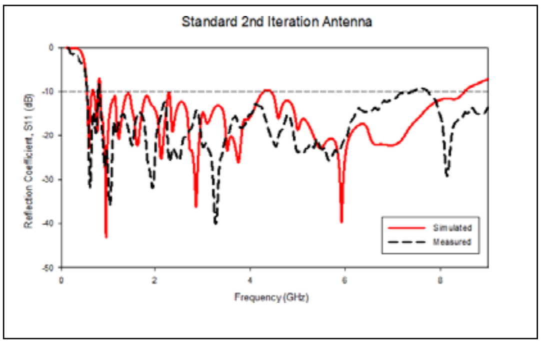
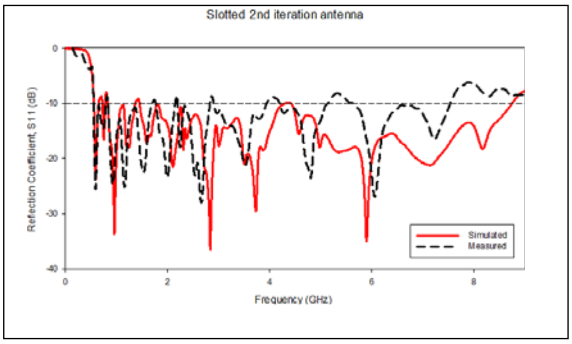


a) Standard 2nd iteration



b) Slotted 2nd iteration

Figure 4. Comparison of simulated and measured reflection coefficient for each antenna.

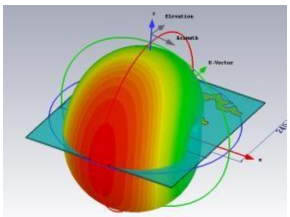
From the reflection coefficient (S11) of both antennas, the bandwidth improvement is observed. From Table 1, it can be seen that the slot implementation improves the bandwidth performance as well as prevent the frequency shifting due to second iteration implementation.

Table 1. Bandwidth improvement.

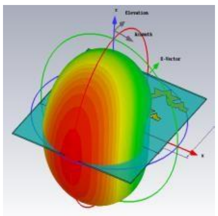
Type of antenna (FKLPA)	Operating Frequency (GHz)	Bandwidth Improvement (MHz)
Standard 2nd iteration	0.57 – 8.50	-
Slotted 2nd iteration	0.55 – 8.80	320

3.2. Radiation Pattern

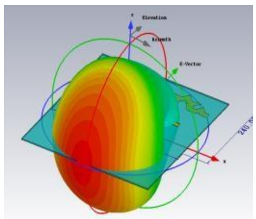
This section discusses the radiation patterns for both antennas. Figure 5 shows the simulated 3D radiation pattern for standard 2nd iteration while figure 6 for slotted 2nd Iteration. Figure 7 and figure 8 shows the simulated and measured 2D radiation pattern for standard 2nd iteration antenna and slotted 2nd iteration antenna respectively. Both antennas are evaluated at 0.9 GHz, 1 GHz, 2 GHz and 3 GHz. From both the 2D and 3D radiation patterns, it can be seen that all antennas radiate towards the smaller elements resulting in directional patterns. All of the 2D and 3D radiation patterns shows that the simulated and measured readings is almost similar.



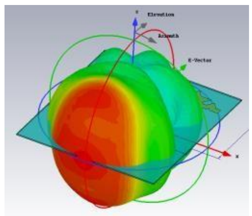
a) Frequency at 0.9 GHz



b) Frequency at 1 GHz

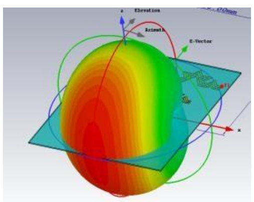


c) Frequency at 2 GHz

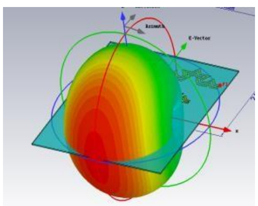


d) Frequency at 3 GHz

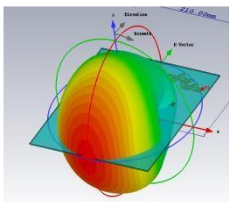
Figure 5. Simulated 3D radiation pattern for standard 2nd iteration antenna



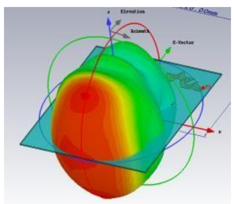
a) Frequency at 0.9 GHz



b) Frequency at 1 GHz

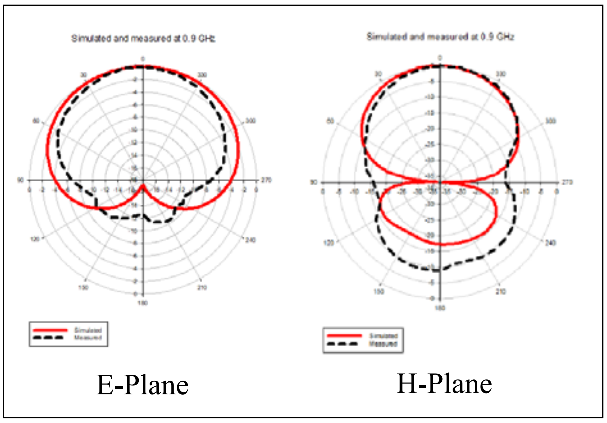


c) Frequency at 2 GHz

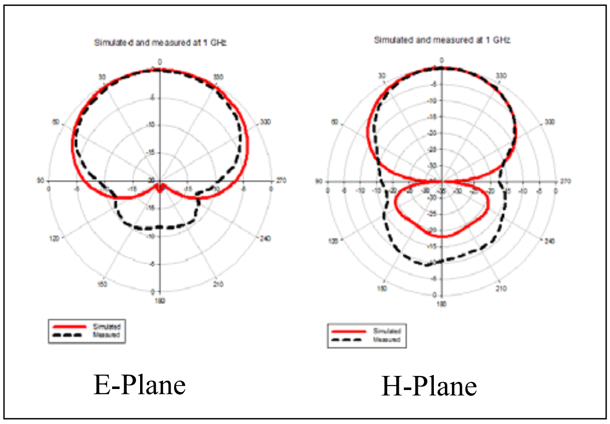


d) Frequency at 3 GHz

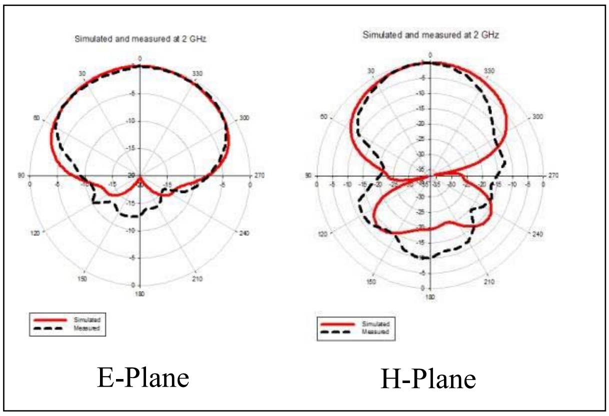
Figure 6. Simulated 3D radiation pattern for slotted 2nd iteration antenna



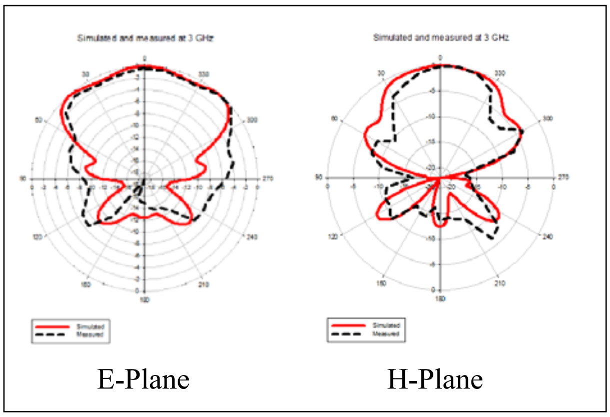
a) Frequency 0.9 GHz



b) Frequency 1 GHz

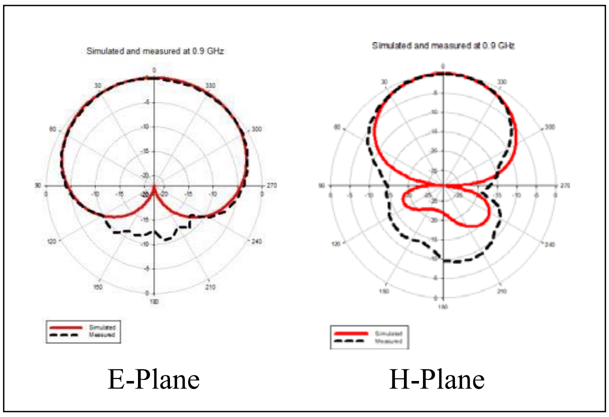


c) Frequency 2 GHz

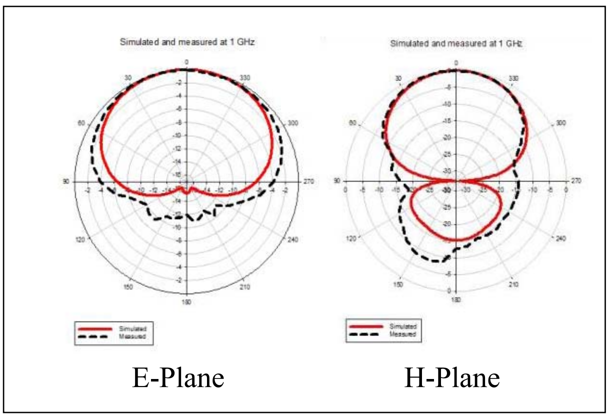


d) Frequency 3 GHz

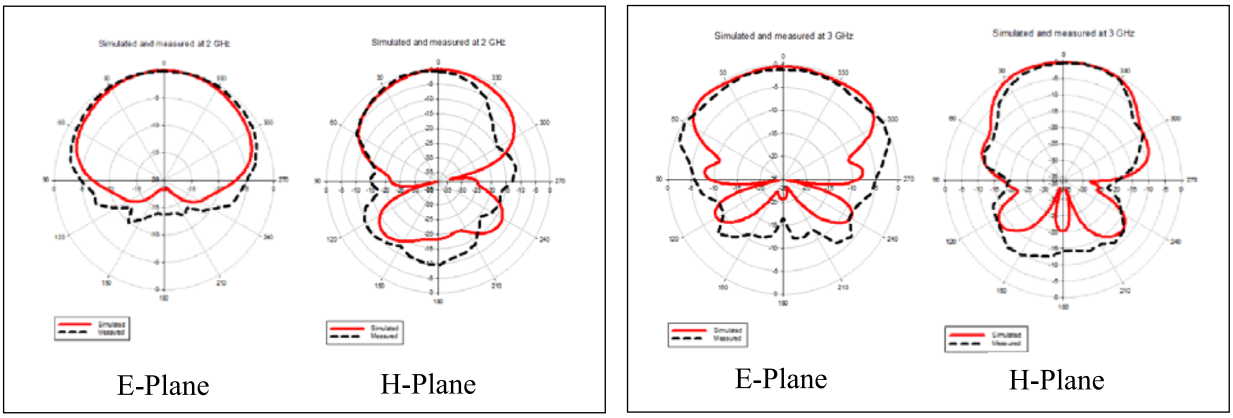
Figure 7. Simulated and measured 2D radiation pattern for standard 2nd iteration Fractal Koch antenna.



a) Frequency 0.9 GHz



b) Frequency 1 GHz



c) Frequency 2 GHz d) Frequency 3 GHz

Figure 8. Simulated and measured 2D radiation pattern for slotted 2nd iteration Fractal Koch antenna.

3.3 gain

Figure 9 shows the simulated realized gain for standard 2nd iteration antenna and slotted 2nd iteration antenna. Both antennas give good result that maintain higher than 5dBi throughout the designed frequency which is from 0.5GHz until 9GHz. For directional antenna, the gain must be higher than 5dBi to consider it a good antenna in order to reduce the energy loss from the antenna.

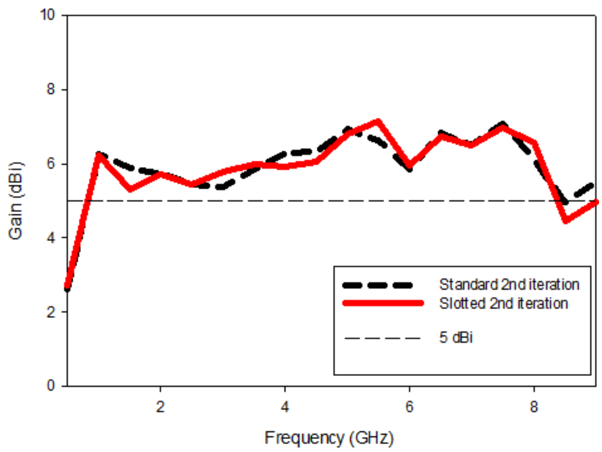


Figure 9. Simulated realized gain for both antennas.

4. Conclusion

In this paper, 2nd iteration fractal log periodic dipole antenna with and without slot implementation has been proposed. Both antennas show a good reflection coefficient result with respect to -10 dB for the frequency between 0.5 GHz and 9.0 GHz. As the number of iterations increases, the shifting of lower frequency has been restored by implementing slot to each radiating elements of the antenna. The slotted 2nd iteration antenna has 320MHz bandwidth improvement compared to the standard 2nd iteration antenna. From the result, the proposed antenna can be used for many applications.

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