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Second Iteration of Slotted Fractal Log Periodic Dipole Antenna for UHF Digital TV Band Application

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Abstract: This paper discusses the simulations and measurements of the antenna with and without slot implementation in terms of reflection coefficient (S_{11}) and radiation pattern. The slot implementation on each of the radiating elements on the 2nd iteration log periodic fractal Koch antenna (LPFKA) was described in this paper. This method is utilised to reduce the antenna's size while also preventing the lower designated frequencies from shifting to the higher band as the iteration increases. The antenna is designed to test and observe performance in the Ultra High Frequency (UHF) band, which ranges from 0.5 GHz to 3.0 GHz. Computer Simulation Technology (CST) software is used to design and model the antenna, which was then built using the wet etching technique. The antenna's substrate is made of FR-4 laminated board with a dielectric constant of 4.6, tangent loss of 0.019, and a thickness of 1.6mm. The results demonstrate good agreement, with a steady radiation pattern over the operational bandwidth and a reflection coefficient of less than -10 dB for the frequency range of interest. The antenna is being tested with Digital TV decoder and the result is observed towards the picture of the Digital TV.

Keywords: Fractal Koch geometry, Log periodic antenna, slotted technique, UHF band

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1. INTRODUCTION

Wireless communication has evolved into one of the most rapidly increasing and active technology sectors in the communication world over the centuries. This new generation of wireless communication allows users to make video calls, send video messages, listen to music, transmit data, and even use other computer functions like office applications.

Audio, data, and videos have always been transmitted via the Ultra High Frequency (UHF) spectrum. To acquire the transmission signal from the broadcasting station, you'll need to have an antenna that can receive the UHF spectrum. The UHF antennas used to receive these broadcasts are typically rather large. This has prompted antenna research in a variety of ways, one of which is the use of fractal designs to minimise antenna size while maintaining performance [1]. Fractal design is the replication of identical geometry structures that is achieved by scaling the geometry structures. [2-5]. A fractal shape antenna is extensively used in today's generation due to its good multiband performance, broad bandwidth, and little space needed. Koch curve is an excellent example of self-similar fractals to minimise antenna size [6].

Due to its broad bandwidth, the log periodic dipole antenna (LPDA) is one of the best antennas for receiving digital TV signals. LPDA is frequently utilized because of its high gain, broad bandwidth, high front to back ratio (F/B), and inexpensive cost. The Euclidean radiating elements are commonly used in the construction of wideband antennas [7-8].

The simulation findings indicate that the method may be applied to shorten the length of the arm LPA, but the lower frequency appears to be moving to the higher frequency as the number of iterations increases. In order to avoid that, each elements of the LPA is given a slot [9].

The suggested log periodic dipole antenna with fractal Koch shape and ring slot is designed in this research. The antennas design techniques are discussed, as well as the reflection coefficient (S_{11}), radiation pattern, and size reduction. The proposed antenna size is reduced by 5% as compared to the antenna without the slot implementation.

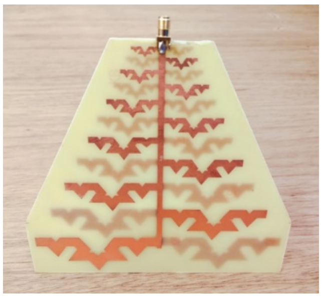
2. ANTENNA DESIGNS

Knowing the fractal Koch antenna characteristics is the first step in building the suggested antenna. 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) given in Equation (1), is among the key parameters in constructing the log periodic antennas [10].

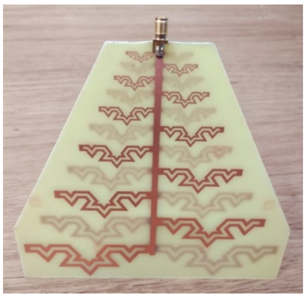
$$\tau = \frac{d_{n+1}}{d_n} = \frac{l_{n+1}}{l_n} = \frac{w_{n+1}}{w_n} \quad (1)$$

The antennas' bandwidth is influenced by the number of elements [11-12]. Due to that, the number of elements must be raised in order to get more bandwidth. The elements' structure can be found on both sides of the substrate. One side of the antenna is connected to the excitation port and another one is connected to the ground port. The antenna is laid out in a crossed arrangement to guarantee that each element's coupling is powerful enough as to generate and emit electromagnetic radiation.

The proposed LPDA is designed to be used in the UHF digital TV spectrum, which spans the frequencies from 0.5 GHz to 3.0 GHz. The antenna is fabricated using FR-4 laminated board with a dielectric constant of 4.6, tangent loss of 0.019, and thickness of 1.6mm, as shown in Fig. 1. The value of scaling factor is 0.85, according to Carrel's table [10].



(a)



(b)

Figure 1. Two configurations of log periodic antenna where a) is the standard log periodic 2nd iteration dipole antenna without slot implementation and b) is the standard log periodic 2nd iteration dipole antenna with slot implementation.

For each side, there are 11 computed elements. Figure 1 depicts two distinct designs: the standard 2nd iteration and the slotted 2nd iteration. The 2nd iteration with and without slot are both done at a 60-degree angle.

For the antenna designs, the slotted 2nd iteration of the antenna is 5% smaller than the 2nd iteration of the normal antenna.

3. RESULTS AND ANALYSIS

This section outlines the findings for the both antennas. The antennas are compared between slots and without slots. The results are discussed in term of reflection coefficient and radiation pattern of the 2nd iteration of Fractal Koch dipole antenna.

3.1 Reflection Coefficient (S_{11})

One of the most important parameters in determining the antenna's performance is the reflection coefficient (S_{11}). The simulated and measured reflection coefficient for the 2nd iteration with and without slot of FLPDA is shown in Figure 2 and Figure 3. It indicates that both antennas have a good result for the frequencies between 0.5 to 3.0 GHz with respect to -10dB. As a result, the antenna performed well in UHF Digital TV band applications due to the frequencies covered in that band.

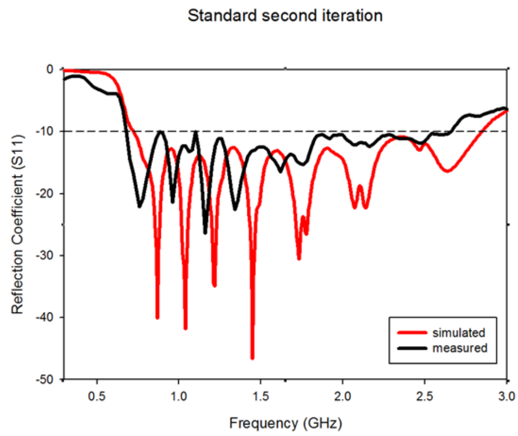


Figure 2. Simulated and measured reflection coefficient of standard second iteration antenna

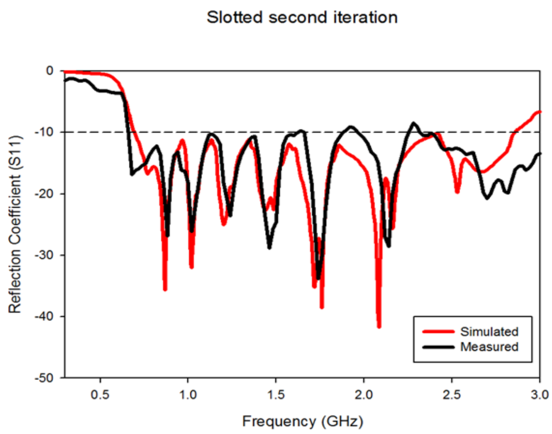
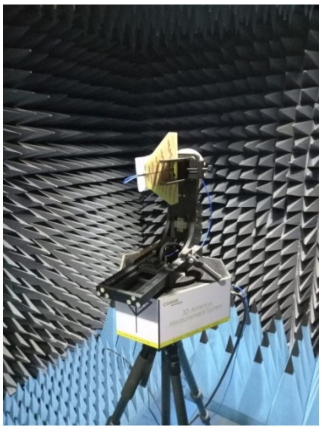


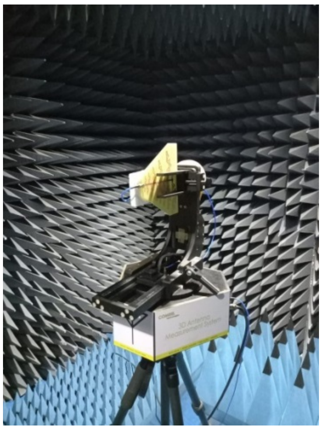
Figure 3. Simulated and measured reflection coefficient of slotted second iteration antenna

3.2 Radiation Pattern

This section discusses the radiation patterns for fractal Koch 2nd iteration with and without slot. Both antenna are evaluated at 3 different frequencies which are 0.9GHz, 1GHz and 2GHz. Figure 5 and Figure 6 show the 3D radiation pattern for standard 2nd iteration antenna and slotted 2nd iteration antenna respectively. From the result, it can be seen that both antenna radiate towards the smaller elements resulting in directional pattern.

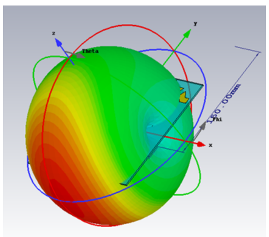


(a)

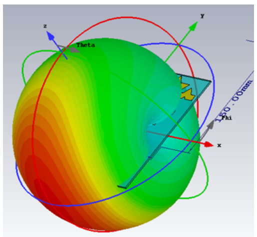


(b)

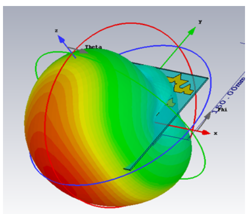
Figure 4. Shows the setup for measuring the antenna; a) Standard 2nd iteration antenna b) slotted 2nd iteration antenna



(a) 0.9GHz

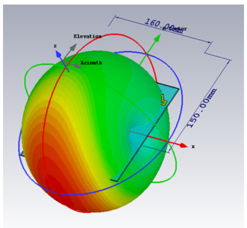


(b) 1GHz

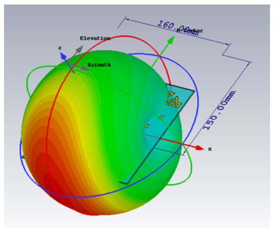


(c) 2GHz

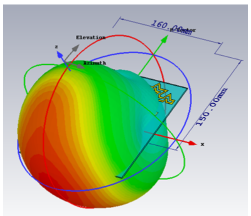
Figure 5. 3D radiation pattern for standard 2nd iteration antenna



(a) 0.9GHz

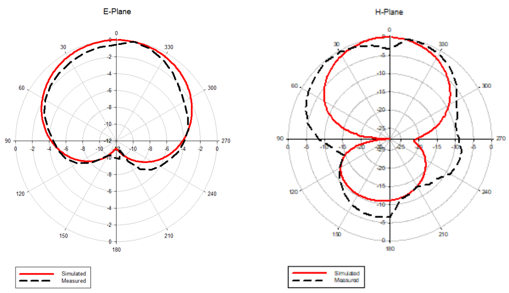


(b) 1GHz

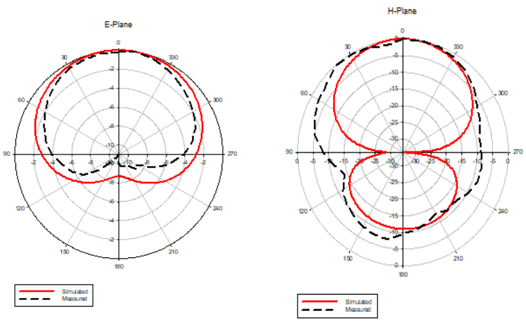


(c) 2GHz

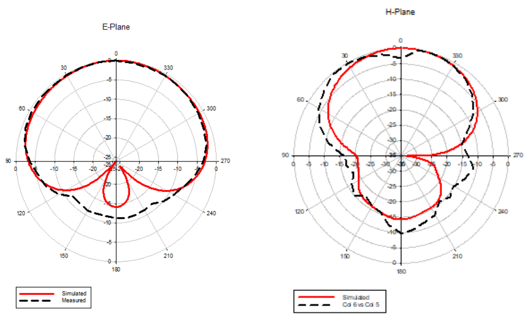
Figure 6. 3D radiation pattern for slotted 2nd iteration antenna



(a) 0.9GHz

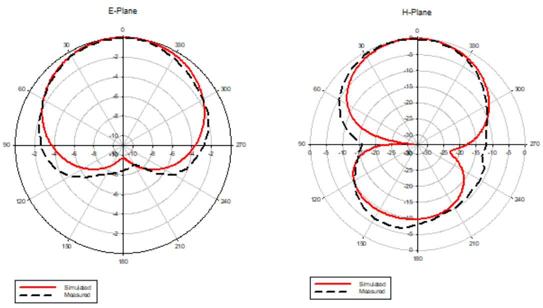


(b) 1GHz

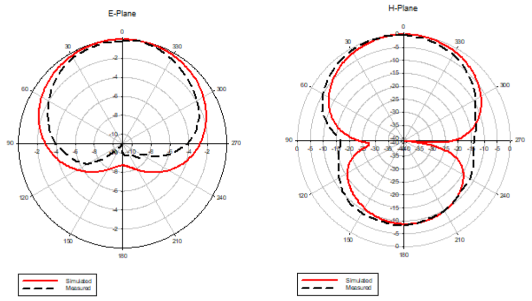


(c) 2GHz

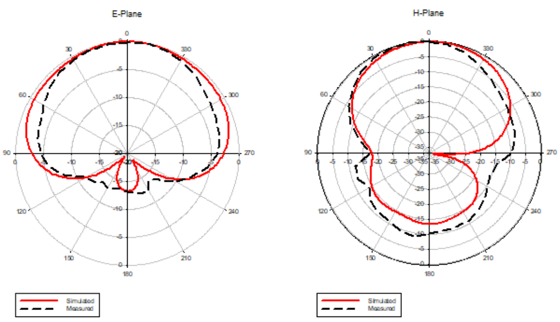
Figure 7. 2D radiation pattern for standard 2nd iteration antenna



(a) 0.9GHz



(b) 1GHz



(c) 2GHz

Figure 8. 2D radiation pattern for slotted 2nd iteration antenna

Figure 7 and Figure 8 show the 2D radiation pattern for standard 2nd iteration antenna and slotted 2nd iteration antenna respectively. From both figure, the simulations and measurements have similar patterns. Both measured and simulated pattern produced major directional main lobe that gives the antenna a maximum directional pattern.

4. ANTENNA WITH TV DECODER

This section shows the application of the antenna in receiving the UHF band for the terrestrial television channels. Figure 9 shows the antenna with the DTV Box and it can be seen that the antenna is able to receive the signals.

5. CONCLUSION

The design development, fabrication, and measurement of the 2nd iteration fractal Koch dipole antenna with and without slot have been analysed. The slotted 2nd iteration of the log periodic fractal Koch antenna is 5% smaller than the 2nd iteration of the log periodic fractal Koch antenna. As the number of iterations increases, the shifting at lower frequencies can be restored by introducing slots at each of the elements of the fractal Koch antenna. Both antennas have $S_{11}<$ -10 dB bandwidth from 0.5 GHz to 3.0 GHz. Over the specified frequency spectrum, the antennas' performance is preserved.

(a) Without antenna, no signal detected

(b) with antenna, signal detected

Figure 9. The antenna TV and decoder

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