Reconfigurable Fractal Tree Antenna for Multiband Applications

***Hüseyin Altun*[1], *Erdal Korkmaz*[1], *Bahattin Türetken*[2],**

[1]Department of Electrical and Electronics Engineering, Fatih University, Istanbul, Turkey
haltun@fatih.edu.tr, ekorkmaz@fatih.edu.tr

[2] The National Research Institute of Electronics and Cryptology (UEKAE), TUBITAK, Gebze, Turkey
bahattin@uekae.tubitak.gov.tr

Abstract

This paper evaluates reconfigurable specification of the fractal tree antenna. Fractal tree antenna fed by a 50 ohms round coax from its middle. Making PIN-diodes on or off state, the characteristic of antenna changes and it results changes in the operation frequency and radiation pattern. The proposed antenna demonstrates reconfigurable frequency range from 1.51 GHz up to 8.6 GHz. Analysis of the antenna has been done by means of commercial software CST Microwave Studio to discuss the impression of different dimensional parameters by controlling the PIN diode switches on radiation pattern, directivity and operational frequency.

1. Introduction

With the rapid development in communication, reconfigurable antennas gain great attention. Reconfigurable antennas have more benefits and better prospects compared with conventional antennas since they show interesting characteristics providing various functions, for example, resonant frequency, radiation patterns and polarization reconfigurabilities [1-2]. The most common application about reconfigurable antenna is related to the operation frequency [3-4] since it might be the simplest feature to alter. The literature become narrower when it comes to radiation pattern reconfiguring since it is related to the radiation principles of each antenna which cannot be altered in many ways [5].

PIN diodes are generally used as switching devices for RF and microwave front-end communication systems since they have several crucial properties such as, low insertion loss, good isolation, low power handling and low cost [5].

The term fractal, means broken or irregular fragments, was originally entitled by Mandelbrot [6] to describe a family of complex shapes that possess an inherent self-similarity in their geometric structure. As a result of small observation in the nature a lot of example for fractal can be seen as trees, clouds, snowflakes, leaves, galaxies and much more. Fractal tree structures can be applied into antenna design to produce multiband characteristics [7-9].

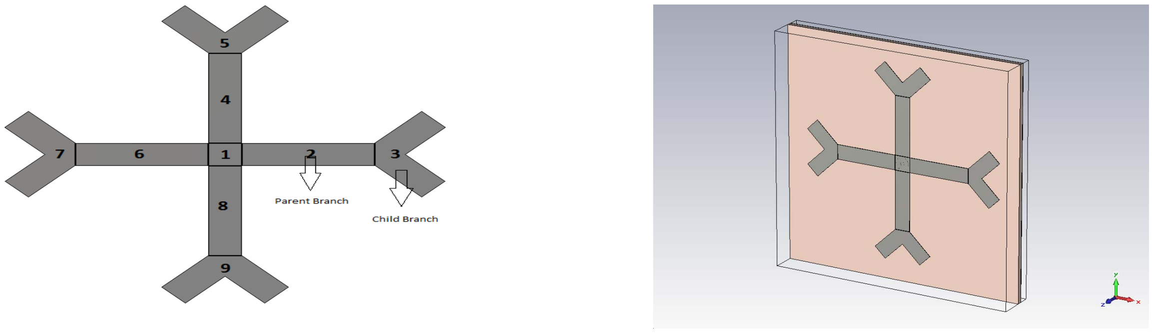
The aim in this paper is showing the design of a new shape of fractal tree antenna for multiband applications which is made reconfigurable by using of PIN diodes. By switching PIN diodes, the resonant frequency and radiation pattern variation simulation is presented.

2. Antenna Design

Antenna schematic is presented from its top view in Figure 1.a and perspective view in Figure 1.b. The antenna is designed on a substrate of 80x80 mm surface and 1.6 mm thickness with Rogers RT5880 (lossy) material having $\varepsilon_r = 2.2$. The ground has been chosen from PEC material with a thickness of 0.1 mm. The antenna is fed by a 50 ohm round coax. The inner conductor of the coax has diameter of 0.689 mm and the shield is 2.13 mm Rogers RT5880. The feeding line is 5 mm long from end to top.

As can be seen in Figure 1.a each part of the antenna has been numbered for the description. Part 1 is called the root and it is on the feed. Its mission is delivering the power to the parent branch. Part 2, 4, 6 and 8 are parent branches and they are connected to the root with PIN diodes; D12, D14, D16, D18. For example D12 is the diode between the root (part 1) and parent branch (part 2).

978-1-4244-6051-9/11/$26.00 ©2011 IEEE



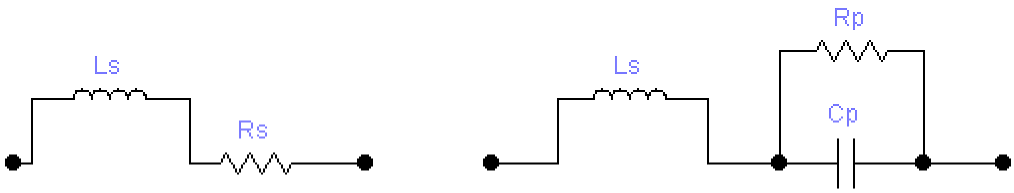
(a) (b)

Figure 1: Designed antenna schematic; (a) Top view and (b) perspective.

Part 3, 5, 7 and 9 is called child branches and they also connected to parent branches with the PIN diodes; D23, D45, D67, D89. In our structure totally eight PIN diodes are deployed to change the length of the antenna for operating at difference resonant frequencies.

Dimension of the root (part 1) is 2.5x2.5mm, parent branches (part 2, 4, 6, 8) are 20x2.5 mm and child branches (part 3, 5, 7, 9) are 10x2.5 mm with the rotation angle of 45 degree. Fractal structure has thickness of 0.1mm. The length of PIN diode is 0.1mm.

The PIN diodes are modeled as a series RL circuits for ON state, and a combination of series-parallel RLC circuits for the OFF state. As a result of searching for suitable PIN diodes, MACOM-MA4AGBLP912 was chosen for the simulation since it has high switching cut off frequency, low series inductance and small forward resistance [10]. The equivalent circuit of the PIN diode, shown in Figure 2, is used in the simulation.



(a) (b)

Figure 2: The equivalent circuits of the pin diode. (a) ON state, (b) OFF state

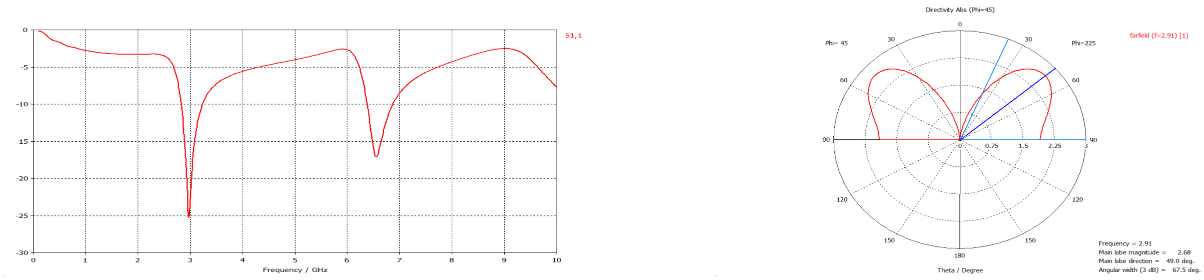
The values of the elements of the equivalent circuits for simulation are given in Table 1. Lumped elements are used in modeling the PIN diode within CST Microwave Studio.

TABLE I
The values of the elements of the PIN diode simulation equivalent circuit

Element	Value
Serial Resistance (Rs)	5 Ω
Parallel Resistance (Rp)	1 KΩ
Serial Inductance (Ls)	0.5 nH
Parallel Capacitance (Cp)	0.02 pF

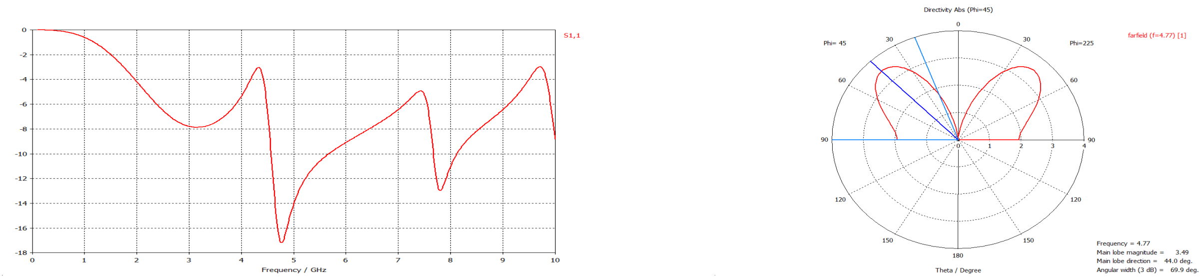
3. Simulation Results

The designed fractal tree antenna has been simulated using CST Microwave Studio. By changing the diodes condition we are reconfiguring the characteristic of the antenna so that we have different operational multi frequency and radiation pattern. Figure 3 shows the S_{11} and directivity of the fractal while all the diodes are ON state. In this stage antenna have resonances at 2.97 GHz and 6.57 GHz. In Figure 4 the results are depicted for switching all diodes in OFF state, resulting to operate at 4.77 GHz and 7.79 GHz. When the one side (child-parent-root-parent-child) activated fractal antenna start to operate at 2.87 GHz, 5.99 GHz and 8.6 GHz shown in Figure 5. A detailed compilation of the results are given in Table II.



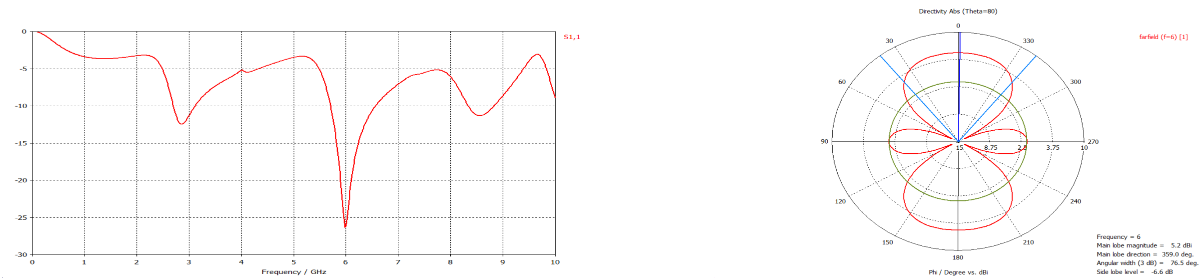
(a) (b)

Figure 3: When all diodes are ON state (a) return loss and (b) linearly scaled radiation pattern.



(a) (b)

Figure 4: When all diodes are OFF state (a) return loss and (b) linearly scaled radiation pattern.



(a) (b)

Figure 5: When only one side diode is ON state (a) from child to child return loss and (b) radiation pattern.

TABLE II
Compilation of results

Mode	ON State Diodes	Resonant Frequency (GHz)	Peak Gain (dBi)
I	D12, D14, D16, D18	4.70, 7.75	5.142
II	D23, D45, D67, D89	2.72, 6.57	5.482
III	D12, D16, D23, D67	2.87, 5.99, 8.6	6.895
IV	D12, D14, D45, D23	1.51, 3.28, 5.11, 6.22, 8.24	5.581
V	D12, D23	3.34, 4.74, 6.03, 7.82	5.605
VI	ALL	2.97, 6.57	4.276

4. Conclusion

In this paper a multiband frequency reconfiguration is studied by using of a fractal tree antenna controlled by PIN diodes. The effect of the biasing lumped elements on the antenna performance is discussed based on the simulation results. PIN diodes reconfiguration causes frequency shift in the resonance frequency of the antenna.

5. References

1. F.Yang and Y. Rahmat-Samii, “A reconfigurable patch antenna using switchable slots for circular polarization diversity” IEEE Microwave Wireless Compon. Lett., vol. 12, no. 3, pp. 96-98, 2002.

2. Zhang Jiajie; Wang Anguo; Wang Peng; “A Survey on reconfigurable antennas “, Microwave and Millimeter Wave Technology, 2008. Volume: 3 Publication Year: 2008 , Page(s): 1156 - 1159

3. J. T. Aberle, S.-H. Oh, D. T. Auckland, and S. D. Rogers, “Reconfigurable antennas for wireless devices,” IEEE Antennas Propag. Mag., vol.45, no. 6, pp. 148–154, Dec. 2003.

4. G. H. Huff, J. Feng, S. Zhang, G. Cung, and J. T. Bernhard, “Directional reconfigurable antennas on laptop computers: Simulation, measurement and evaluation of candidate integration positions,” IEEE Trans. Antennas Propag., vol. 52, pp. 3220–3227, Dec. 2004.

5. Nikolaou, S.; Boyon Kim; Vryonides, P., “Reconfiguring antenna characteristics using PIN diodes” Antennas and Propagation, 2009. EuCAP 2009. 3rd European Conference on Publication Year: 2009 , Page(s): 3748 - 3752

6. B. B. Mandelbrot, The Fractal Geometry of Nature, New York, W. H. Freeman, 1983.

7. M. Sindou, G. Ablart, and C. Sourdois, “Multiband and wideband properties of printed fractal branched antennas,” IEE Electron. Lett., vol. 35, no. 3, pp. 181–182, Feb. 1999.

8. C. Puente, J. Claret, F. Sagues, J. Romeu, M. Q. Lopez-Salvans, and R. Pous, “Multiband properties of a fractal tree antenna generated by electrochemical deposition,” IEE Electron. Lett., vol. 32, no. 25, pp. 2298–2299, Dec. 1996.

9. Petko, J.S.; Werner, D.H.,“Miniature reconfigurable three-dimensional fractal tree antennas “,Antennas and Propagation, IEEE Transactions on Volume: 52 , Issue: 8 Publication Year: 2004 , Page(s): 1945 – 1956.

10.Available at: http://www.alldatasheet.com/datasheet-pdf/pdf/301066/MA-COMCOM/MA4AGBLP912.html.