Reconfigurable Fractal Tree Antenna for multi-frequency Applications using PIN Diode

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***Abstract*— This paper presents the design and the analysis of a conformal fractal tree reconfigurable antenna having adaptive multi beam radiation patterns and adaptive operation frequency characteristics. The proposed antenna covers some service bands such as: WiMAX (2.400{2.483) GHz, m-WiMAX (3.4{3.6) GHz and WLAN (5.15{5.825) GHz and operates some other frequencies between 2 GHz to 9 GHz. The designed antenna is by using PIN diode switches. For biasing the diodes on the antenna characteristics is presented in the results. The optimization in biasing and integration of these switches into the antenna is also discussed.**

Keywords*— Reconfigurable antenna, Pin Diode, Computer Simulation Technology, Fractal Tree antenna.

I. INTRODUCTION

In radar and modern communication systems the demand on multi-functional antennas is increasing. The requirements for these antennas are the abilities to have multi radiation patterns, adapting the operation frequency and polarization, keeping the physical dimensions and positioning unaltered. Reconfigurable antennas with switching capability used as a multiple input multiple output (MIMO) system have been used in recent years to full these requirements. By means of switches with compatible antenna elements the antenna and its feed structure can be physically reconfigured to provide radiation pattern, frequency band and polarization diversity so they have more advantage to compare with conventional antennas [1]. The most prevalent implementation about reconfigurable antenna is related to the operation frequency [2] since it might be the easiest feature to alter. Polarization and pattern reconfigurable antennas are also attractive since they can provide diversity features which leads to an increased signal to noise ratio and therefore a higher quality of service of whole systems [3{5].PIN diodes are generally used more than transistors and switches 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 [6].

Although a reconfigurable antenna can take many shapes we will focus on fractal tree antennas in this work. In terminology, fractal means broken or irregular fragments which were originally entitled by Mandelbrot [7] to describe a family of complex shapes that possess an inherent self-similarity in their geometric structure. As a result of small investigation in the environment a lot of example for fractal shapes can be seen as trees, clouds, galaxies, leaves, and much more. Fractal tree structures can be applied into antenna design to produce multiband characteristics [8{10]. A conformal antenna is an antenna that conforms to something or it conforms to prescribed shape. The shape can be some part of a train, airplane or other vehicle. The purpose in conformal antenna is to make surface matched structure so that it becomes integrated with the structure and does not extra drag. Since they have very low profile and can be applied on exile substrates they can behave \hidden" antennas [11]. The target in this paper is showing the design of a new shape of fractal tree antenna for multiband and multi radiation pattern applications. PIN diodes are used as switches for multi frequency and multi beam reconfiguration. By switching PIN diodes, the resonant frequency and radiation pattern variation simulation by using CST is presented.

II. Antenna Design

A designed reconfigurable fractal tree antenna schematic is presented from its top view in Figure 1(a) and perspective view in Figure 1(b). Antenna is designed on a substrate with a FR4_epoxy material. The Fractal tree structure design has following specification Length of main stem L=20mm, width of the stem W=8mm, Substrate height h=1.6 mm. The proposed geometry is excited by probe feeding technique [3].we exploit the iteration factor= 0.66. The PIN diodes are connected at the connecting place of the branches. The 6 PIN diodes are used in this geometry. The numbered part are called trunk and they make the connection from source to branches. For switching, PIN diodes are used. The connection between feed line and trunks are established by the diodes namely, D1, D2 while the connection between trunks and branches are established by diodes D3, D4, D5, D6. In our structure totally eight PIN diodes are deployed to alter the electrical length of the antenna to operate at difference resonant frequencies. In our structure six Pin diodes are deployed to alter the electrical

length of the antenna to operate at different resonant frequencies. Dimensions of the trunks (Part 1, 2, 3, 4, 5, 6) are 2 mm and branches are 2 mm with the rotation of angle 45 degree with the rotation angle 90 degree at the middle. Fractal structure has thickness of 0.1 mm and PIN Diodes are 0.5 mm.

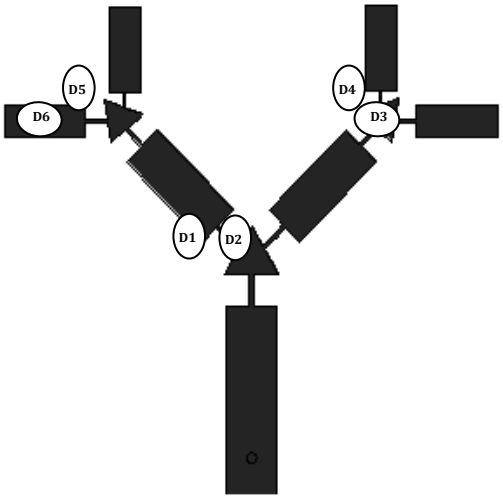

Fig. 1 Design for fractal Tree antenna

The Pin diodes are modelled as a series RL circuit for ON state and a combination of series parallel RLC circuits for the OFF state which can be seen in fig. 2. As a result of searching for suitable PIN diodes, MACOM-MA$AGBLP 912 was chosen. It has high switching cut off frequency, low series inductance and small forward resistance [12]. The value of the element of the circuit for the simulation is given in table 1. The lumped elements are used in modelling the PIN diode within CST Microwave Studio.

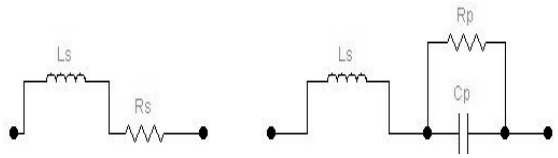

Fig 2. The equivalent circuits of the Pin diode. (a) ON state, (b) OFF state.

Table. 1 Design specification for Pin diode.

Element	Value
Serial Inductance (*Ls*)	0.5 nH
Serial Resistance (*Rs*)	5 Ohm
Papallel Resistance (*Rp*)	1 k-
Parallel Capacitance (*Cp*)	0.02 pF

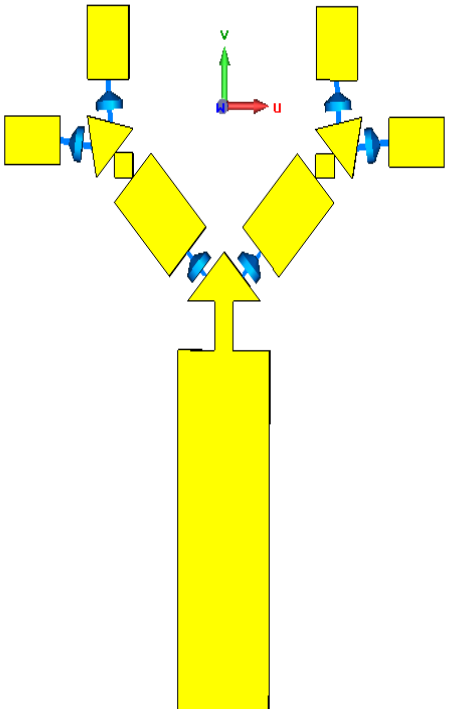

Fig. 3 Design for fractal Tree antenna in CST Microwave Studio Suite

Above fig. 3 shows the design of antenna using 6 Pin diodes. As above fig shows that 6 Pin diodes are deployed in the antenna having their RL series circuit for ON state and RLC parallel circuit for OFF state. The equivalent circuits and their values of the are given in table no. 1.

III. Simulation Results.

The design fractal tree antenna using PIN diode has been simulated using CST Microwave Studio. By changing the diodes condition i.e. ON state and OFF State of diodes which are deployed in the antenna we are reconfiguring the characteristics of the antenna so that we have different operational multi frequency and radiation pattern. Following fig. 4 and fig .5 shows the S_{11} and VSWR graph respectively.

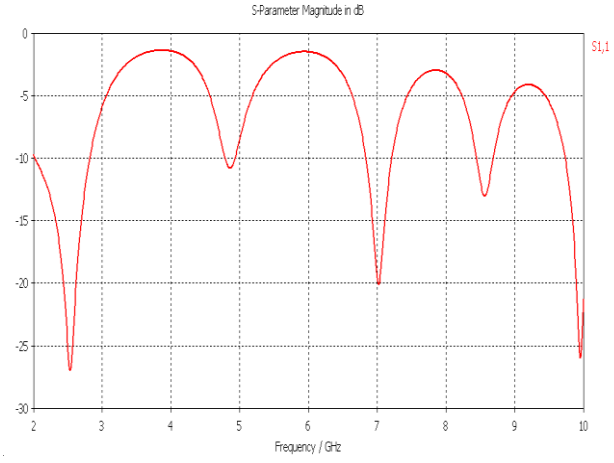

Fig. 4 S_{11} Parameter graphs.

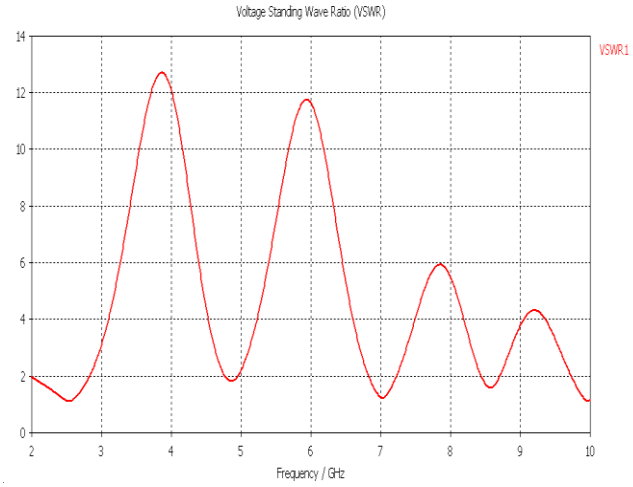

Fig. 5 VSWR graphs.

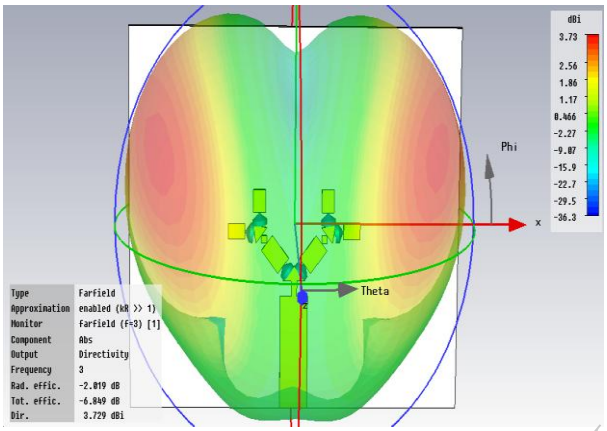

Fig. 6 radiation pattern at 3GHz frequency graphs.

Above S_{11} parameter shows the results when 2 diodes are in ON state and other is in OFF state. That time we got 2 frequencies i.e. 2.5 GHz and 7 GHz. Also the VSWR in those frequencies are 1.2 and 1.1. Also the fig. 6 shows the radiation pattern.

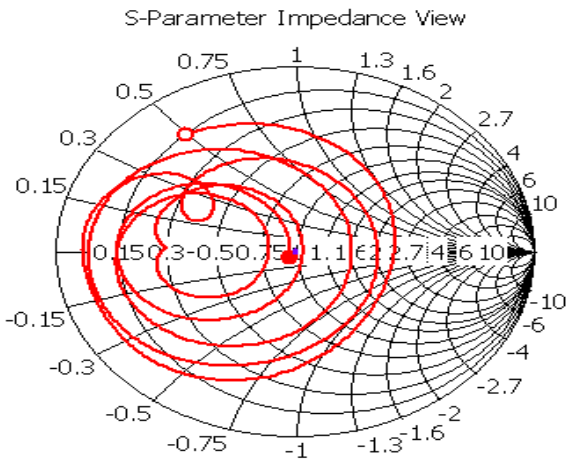

Fig. 7 Impedance of the Antenna using 6 PIN diodes.

Table. 2 Pin diode working frequencies

Mode	ON State Diodes	Resonant Frequency (GHz)
I	D1,D2,D3,D4 ,D5,D6	8.3, 9.9
II	D1, D2	2.5, 7
III	D3, D4	3, 5.9, 7.5
IV	D1, D2 , D3, D4	2.2, 5.5 ,7.6

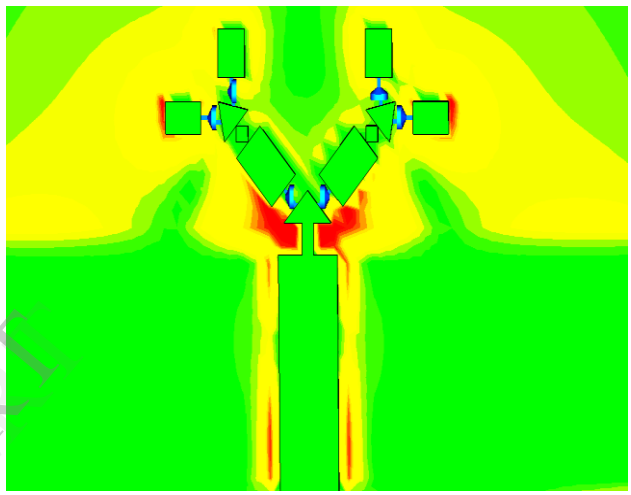

Fig. 8 Software antenna simulation.

Above table 2 shows the operating frequencies of the respective diodes when they are on at that time. When all diodes are in ON state that time the operating frequencies are 8.3 GHz and 9.9 GHz. When diode D1 and D2 are in ON state and all other diodes are in OFF state that time operating frequencies are 2.5 GHz and 7 GHz. When Diode 1 to 4 are in ON state and diode 5 and 6 are in OFF state at that time operating frequencies are 2.2 GHz, 5.5 GHz, 7.6 GHz. The above antenna is basically for covers some service bands such as: WiMAX (2.400{2.483) GHz, m-WiMAX (3.4{3.6) GHz and WLAN (5.15{5.825) GHz and operates some other frequencies between 2 GHz to 10 GHz. In fig.6 and fig 8, radiation patterns sequentially are shown while diodes are ON state between source to trunk and trunk to branch is showing separately for each trunk-branch couple. It can be seen that while the trunk is becoming ON or OFF state with branch, radiation direction is changing with 90 degree since there are 90 degree angles between trunks.

IV. Conclusion

In this paper a multiband frequency reconfigurable is studied by using fractal tree antenna which is controlled by 6 PIN diodes and their equivalent circuit. The effects of the biasing lumped elements on the antenna performance are discussed based on the simulation results by using CST microwave

studio suite 2013. PIN diodes reconfiguration causes frequency shift in the resonance frequency of the antenna and radiation pattern can be controlled by changing PIN diodes state ON or OFF states of the respective PIN diodes which is deployed in this antenna.

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