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Reconfigurable Planar inverted F Antenna for Cognitive Radio & Mobile Systems

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Abstract. This paper proposes a method of controlling the operation of the frequency reconfigurable planar invert F antenna (FRPIFA antenna) by FPGA. In order to tune the antenna operating frequency, the operation of PIN diodes – electronic switches are carried out through switches present in the FPGA board rather than a predefined code, which provides high flexibility for testing & performance. A very low return loss & hence low VSWR values is obtained. We were able to tune to frequencies as low as 766 MHz and frequencies as high as 8.4 GHz. It also covers the ISM band. This can be used in cognitive radio module as a reconfigurable antenna.

Introduction

THE rapid development of electronics and wireless communication has led to great demand for mobile devices that can operate using different standards such as GSM850 (824–894 MHz), GSM900 (880–960 MHz), GPS (1575 MHz),DCS (1710–1880 MHz), PCS (1850–1990 MHz), UMTS (1920–2170 MHz) and wireless local-area network (LAN) (2400–2484 MHz). In addition, the average consumer also demands smaller form factors for their mobile devices. These two requirements have triggered research on the design of compact PIFA and multiband reconfigurable antennas.

Reconfigurable antennas offer multiple functions by dynamically changing their properties such as operating frequency, polarization, radiation pattern, and a combination of all these factors. In recent years, there has been particularly growing effort in the development of frequency reconfigurable antennas [1]. These antennas can be classified according to their reconfiguration techniques. Lumped-elements [2, 3], variable capacitors [4, 5], silicon photo switches [6, 7], MEMS (microelectro-mechanical) switches [8, 9] or PIN diodes [10, 11] are such techniques being often used when designing antenna.

The Planar Inverted-F antenna (PIFA) is increasingly used in the mobile phone market. The antenna is resonant at a quarter-wavelength (thus reducing the required space needed on the phone), and also typically has good SAR properties. The Planar Inverted-F Antenna is popular because it has a low profile and an omnidirectional pattern.

We have a PIFA of length L1, of width L2. The shorting pin (or shorting post) is of width W, and begins at one edge of the PIFA. The feed is at a distance D from the shorting pin. The PIFA is at a height h from the ground plane. The PIFA sits on top of a dielectric with permittivity εr as with the patch antenna. The impedance of the PIFA can be controlled via the distance of the feed to the short pin (D). The closer the feed is to the shorting pin, the impedance will decrease; the impedance can be increased by moving it farther from the short edge. The PIFA can have its impedance tuned with this parameter. The resonant frequency of the PIFA depends on W. If W=L2, then the shorting pin runs the entire width of the patch. In this case, the PIFA is resonant (has maximum radiation efficiency) when:

$$\text{If } W=L2,\ L1=\lambda/4 \quad (1)$$

In this paper, we propose a method of controlling the operation of the frequency reconfigurable antenna by an FPGA.

The PIN diode circuit is integrated onboard with reconfigurable antenna. The operation of PIN diodes is done by switches present in FPGA. Section I presents the frequency reconfigurable PIFA antenna. In Section II, the control system for PIN diode of the antenna is proposed and analyzed. The simulation and measurement results are respectively presented and discussed.

Antenna Design and Simulation

Geometric configurations of the antenna's patch. In this study, we use a reconfigurable antenna and we aim to illustrate the control system operation of the PIN diode using an FPGA. The architecture of the initially RPIFA with ten PIN diodes (Di) antenna is shown in Fig 1.The antenna structure consists of three layers; the bottom layer (72x48mm^2) is a ground plane that covers the entire substrate. The middle substrate is FR4 with dielectric constant 4.4, loss tangent 0.02 and a thickness of 0.8mm. The upper layer is the metal patch composed of a main I section, two surrounding E sections & two C section. This antenna is fed through a 50-coaxial cable.

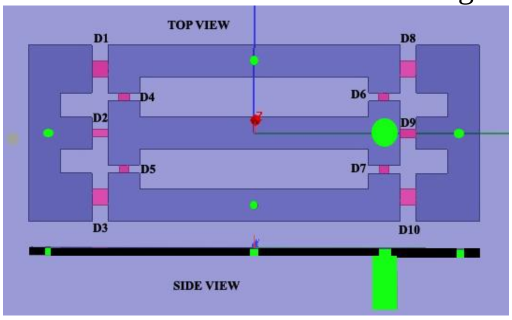

Fig 1. PIFA antenna with respective PIN diodes

The feeding position and the antenna dimensions are shown in Fig. 2. A side view of the antenna is also shown in Fig. 2.

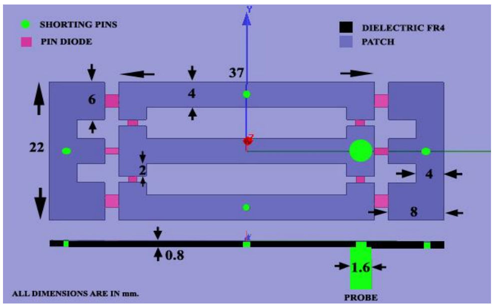

Fig 2. PIFA antenna with dimensions

When ten PIN diodes are disconnecting, an antenna with I-Shape microstrip patch is obtained as illustrated in Figure 3. This mode has 800 MHz bandwidth around 5.6 GHz & also resonates in 8.1 GHz.

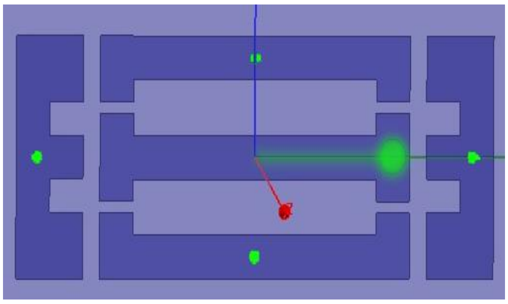

Fig 3. I shaped patch

When the PIN diode D1, D3, D8, D9 & D10 are connecting, an antenna with different shape microstrip patch is realized as presented in Figure 4.

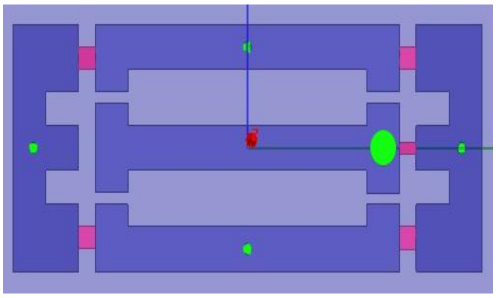

Fig 4. Complex shaped patch

Simulation on HFSS software. The simulation was performed on HFSS. It is one of several commercial tools used for antenna design, and the design of complex RF electronic circuit elements including filters, transmission lines, and packaging. The PIN diodes used are micro-semi MPP4203. In order to model and simulate the ON/OFF states of PIN diodes, we used a PEC pad of area 0.3x0.9mm^2. Simulation results (S11 parameter) of RPIFA antenna are shown in Figure 5.

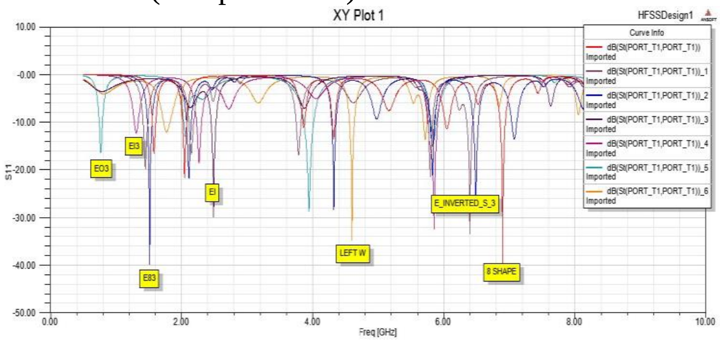

Fig 5. S11 parameter of various modes

Table 1. Some modes corresponding to status of switches

Diode(D1)	D2	D3	D4	D5	D6	D7	D8	D9	D10	Shape
0	0	0	0	0	0	0	0	0	0	I
0	0	0	0	0	0	1	0	0	0	U
0	0	0	0	0	1	0	0	0	0	PI
0	0	0	0	0	1	1	0	0	0	O
0	0	0	0	1	0	0	0	0	0	W
1	0	1	0	0	0	0	1	1	1	EO3
0	1	0	0	0	0	0	0	0	0	EI
Di=0: OFF, Di=1: ON, i=1-10										

Table 1 shows diode configuration for some significant modes. It also mentions the shape of the patch. Table 2 mentions the resonant frequency bands for some significant modes along with the corresponding patch shape. The EO3 shape focuses on 766 MHz, E I shape focuses on ISM band. Very low return loss results are obtained from 8 shape, E83 shape & left W shape. The gain plot for case where all switches are ON are given in Fig 6. The radiation pattern is given in Fig 7.

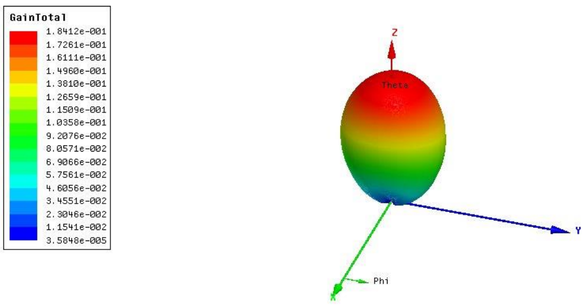

Fig 6. Gain plot for case where all diodes are ON at 2.4882GHz.

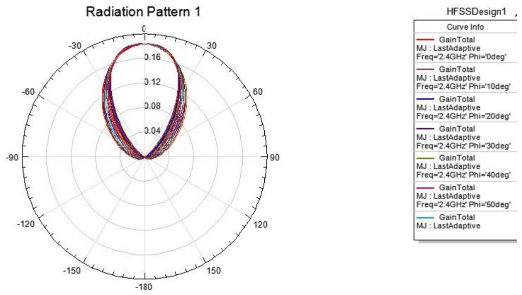

Fig 7. Radiation pattern for case where all diodes are ON at 2.4882GHz

Table 2. Some modes with their resonant bands

SHAPE	FREQUENCY(GHz)
I	5.6
8	1.57;2;3.86;4;6;6.9
E83	1.5,2.1;4.3;5.86;6.5;7.1
EO3	.766;2;4;5.8;8.4
EI	2.4;5.7(ISM)
S	3.6;5.7;6.4
W	1.8;4.6;5.7

Antenna Control System

Control system solutions. Altera Cyclone IV GX FPGA Development Kit[12] is used to control the PIN diode switching. FPGAs contain programmable logic components called "logic blocks", and a hierarchy of reconfigurable interconnects that allow the blocks to be "wired together"—somewhat like many (changeable) logic gates that can be inter-wired in (many) different configurations. Logic blocks can be configured to perform complex combinational functions, or merely simple logic gates like AND and XOR. The FPGA board is shown in Fig 8. The entire control system is shown as block diagram in Fig 9.

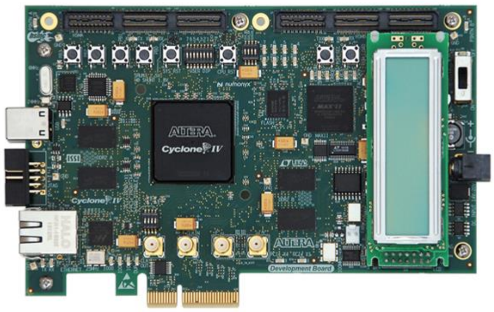

Fig 8. Altera Cyclone IV GX FPGA Development Ki

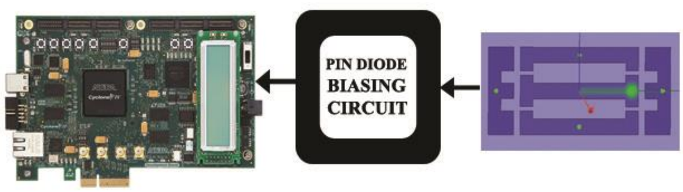

Fig 9. Block diagram of the entire system.

Pin diode Biasing Circuit. Pin diodes are given proper biasing while interfacing with FPGA. The circuit is shown in Fig 10.

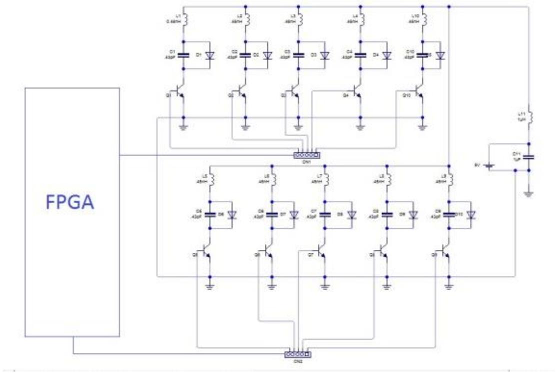

Fig 10. PIN diode biasing circuit

Conclusion

A novel method to control the reconfigurability operation of antenna is presented. The control system for RPIFA antenna has been designed. The antenna provides a high degree of flexibility. But we select some combinations only as other patterns are redundant. The operation of PIN diodes – electronic switches are carried out through switches present in the FPGA board rather than a predefined code which provides high flexibility for testing & performance. Very low return loss upto -40dB has been achieved. Use of PIFA has lead to size reduction. Reconfigurability has been made possible from 766MHz to 8.4GHz which is a very significant improvement over all other similar reconfigurable antenna of its kind[13], [14], [15], [16]. Manufacturing of the antenna is also very easy.

Scope of Improvement

In this bandwidth tuning is not mentioned. Hence control over bandwidth can be made possible by suitable change in physical parameters. Also gain obtained is low which can be mitigated by trying out different dielectric medium. Fine tuning of sub bands can be made possible using Varactor diodes in suitable positions [4]. Also the performance of the antenna will depend on the mode chosen. Hence mode selection can be made more efficient by using neural network or genetic based or fuzzy based algorithms.

Acknowledgements

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