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The Investigation of PIN Diode Switch on Reconfigurable Antenna

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Abstract— **The investigation and simulation of PIN diode as a switch on reconfigurable antenna are described in this paper. The simulation of the PIN diode model is constructed on CST Simulation tools with the integration of single patch antenna. The radial stub biasing circuit is used for fabrication with the antenna. Three different locations of PIN diode with radial stubs biasing circuit are investigated and analyzed. The result shows the separation of biasing circuit and antenna give a better performance in term of return loss and current distribution.**

Keywords- PIN Diode Switch, Microstrip antenna, Reconfigurable

I. Introduction

The reconfigurable antennas have received a great deal of attention for their applications in wireless communication in recent years. Compared to conventional antennas, reconfigurable antennas provide the ability to dynamically adjust various antenna parameters such as operating frequency [1-2], polarization [3], radiation pattern [4], and two or more parameters [5] in single antenna. The first approach on designing the reconfigurable antenna may employ the electronic, mechanical or optical switching [6]. However, the efficiency and the reliability makes the electronic switching more frequently used compared to others. The electronic switching includes the PIN diodes, FET transistor, varactor diodes or RF MEMS switches.

As reported in [7], the MEMS switches have advantages in term of isolation and insertion loss compared to the PIN diodes and varactor diodes. Meanwhile, the RF PIN diodes have low rate of loss and low cost to be employed with reconfigurable antenna, but it needs to be connected with forward bias direct current when in the ON state which will degrade the power efficiency and antenna's performance. This paper provides an investigation of the PIN diode circuit representation that obtained from the Computer Simulation Software (CST). A single square patch antenna with inset fed line is constructed on FR-4 substrate (ε_r = 4.5 and tan δ = 0.019) at frequency 3.0 GHz as simulated process of integration with PIN diode. In real cases, PIN diodes BAR 64 from Infineon [8] are used as a switch. Same as other microwave circuit likes amplifier, oscillator and mixer, the PIN diode also need biasing circuit to control the voltage and limits the current from entering the microwave circuits. In this paper, the locations of biasing circuit that can be used in reconfigurable antenna is also discussed.

II. Analysis of PIN Diode Representation

The PIN diode equivalent circuit is an important part in simulation of reconfigurable antenna in order to get the similar results with measurement. This section elaborates on the PIN diode that used in this antenna design using Computer Simulation Technology (CST) software. Two types of PIN diode representation are simulated and discussed which are using lumped element and PEC pad.

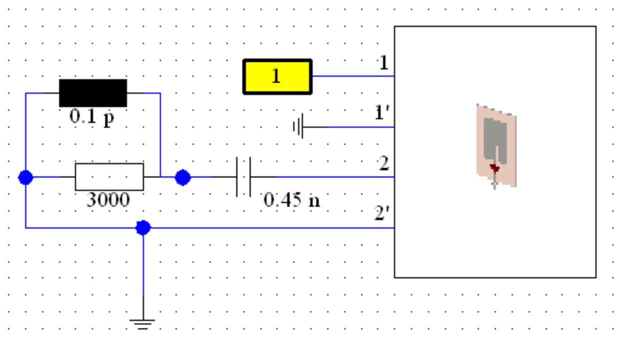

Figure 1. Schematic design of PIN Diode using CST Microwave studio.

TABLE I. Value of Lumped Element at Different Modes

PIN Diode Modes	*Resistor (Ω)*	*Inductor (H)*	*Capacitor (F)*
ON	3.5	1.0×10^{-11}	0.45×10^{-9}
OFF	3000	0	0.45×10^{-9}

Fig. 1 shows the schematic design of PIN Diode using CST Microwave studio that based on Microsemi [9]. The equivalent circuit of PIN diode for forward bias consists of a series combination of the series resistance (R_S) and a small Inductance (L_S). Series resistance is a function of the forward bias current (I_f) and this function can be found in PIN diode datasheet [8] while the small inductance depends on the geometrical properties of the package such as metal pin length and diameter. The value of inductance is optimized to get a minimum value that can reach the current to flow through the PIN diode as shown in Fig. 2. The minimum value of inductor is 1 x 10^{-9} H and below than that value, the current is blocked or the PIN diode is in OFF modes.

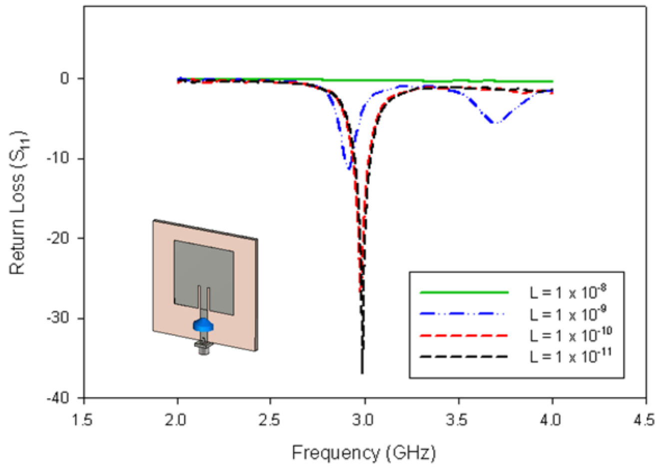

Figure 2. Return loss of the antenna at different value of inductor.

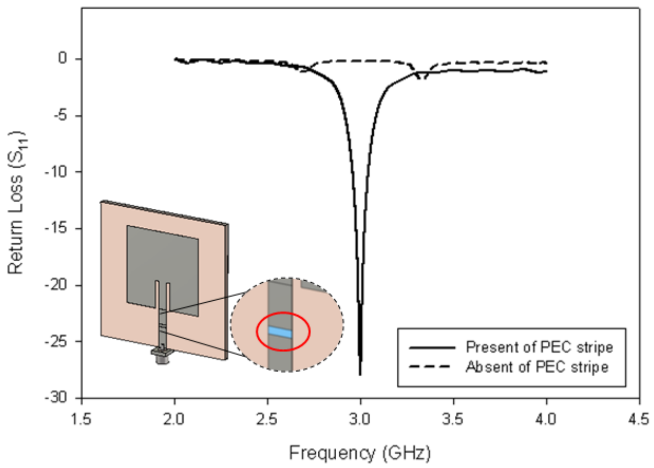

Figure 3. Return loss of the antenna while present and absent of PEC stripe at the antenna.

The other type of PIN diode representation in simulation process is by using a PEC pad. It is represented as an open or short of the transmission line as shown in Fig. 3. The ON state is represented by presenting the 3mm x 1mm metal stripe and the absence of the metal strip represents the OFF state. This type is easier than the lumped element circuit because the simulation is faster and more accurate. This principle of operation has also been used by other researchers as reported in [1-2]. The ON state is indicated by presenting the PEC stripe to allow the signal from port 1 passed through to the radiating element and the return loss is -28 dB at 3.0 GHz. While the OFF state is indicated by removing the PEC stripes and the return loss is -0.6 dB at 3.0 GHz.

III. Analysis of PIN Diode Location on Patch Antenna

The bias networks are important devices in any active microstrip circuit to supply the specific bias voltage and current. In this project, the antenna uses the radial stub and DC line as a biasing network for the PIN diode. This can be found in amplifiers, oscillators and frequency multipliers. Radial stubs provide a well-defined point for radial wave excitation due to their narrow coupling aperture. Fig. 4 shows the example of radial line stub that can be used as a bias network for biasing a PIN diode. A bias network consists of a capacitor that acts as a DC block and RF bias line with radial stub to form a low pass filter at point A. At this point, only a low frequency from DC source is passing through to activate the PIN diode while it is blocked by capacitor from interrupting the RF source. However, choosing a suitable location of biasing network is a critical decision to make in order to maintain the antenna's performance. Three locations of biasing circuit are discussed to activate the PIN diode, which are

i. at the transmission line of patch
ii. at the middle of length patches.
iii. at the back of antenna

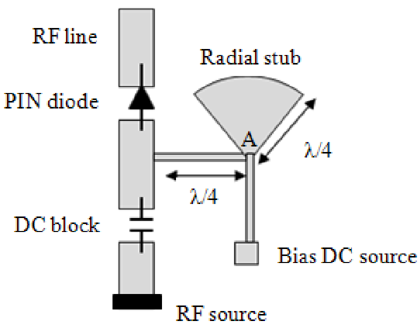

Figure 4. Bias network configuration using radial line stub

Fig. 5 shows the single patch antenna with biasing circuit consists of a quarter wave length radial stub and DC line. The biasing circuit is located in the middle of transmission line in order to study the effects of current distribution and return loss of the antenna. The DC signal is connected to the positive terminal of PIN diode via the biasing circuit. The simulated current distribution of the antenna is presented in Fig. 6(a). From this figure, it is show that the radial stub biasing circuit did not disrupt the current flow at the transmission line. Hence, it can be considered that the biasing circuit is not radiated since the maximum current distribution is observed. Further analysis of the antenna shows that the return loss is very deep which -18 dB for simulated and -40 dB for measured result. It revealed that only minimum signal transmitting power was reflected back.

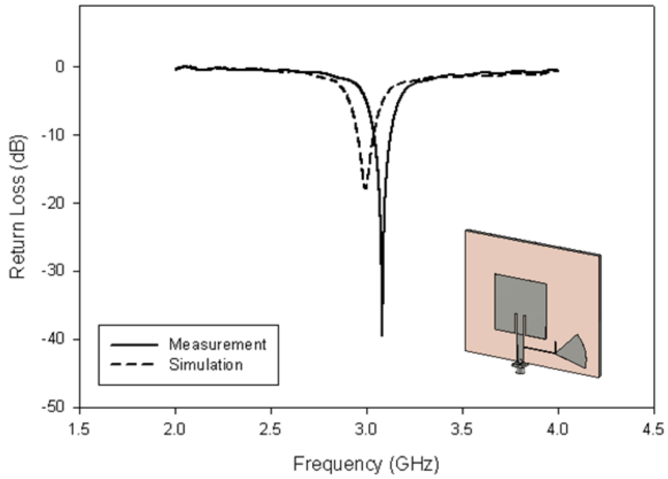

Figure 5. The antenna with biasing circuits at transmission line with return loss results.

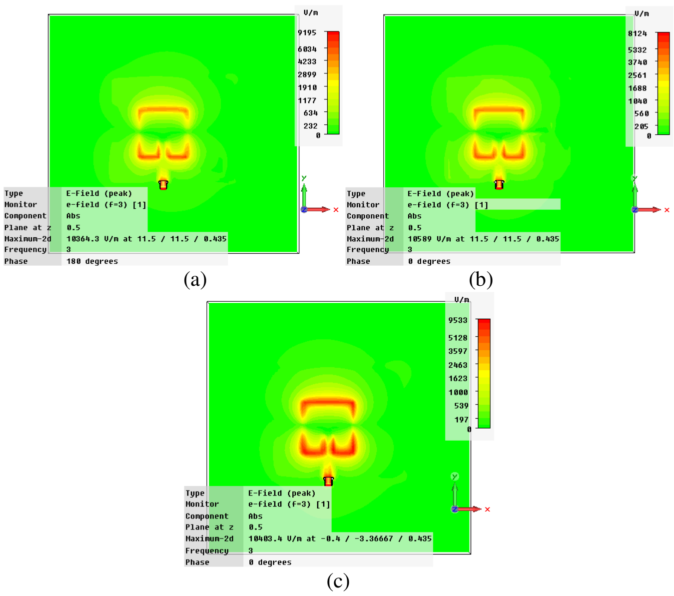

Figure 6. The simulated current distribution (a) biasing circuits at transmission line (b) biasing circuits at the middle of antenna (c) biasing circuits at the back of the antenna

The second configuration of biasing circuit is shown in Fig.7 where the biasing circuit is located at the middle length (L) of the patch. The theory about the patch antenna shows that the radiating slot of the square/rectangular patch is located at the edge width (W) of the patch. The maximum radiation can be observed at this region while the minimum radiation is at the lengthwise edge of patch. Hence, in order to reduce the disruption of the current distribution, the biasing circuit is placed at the middle of patch's length. Fig.6 (b) shows the simulated current distribution of the antenna. From that figure, it shows that the current distribution at the patch was not disrupted by the biasing circuit. Hence, it can be considered that the biasing circuit was not radiated since the maximum current distribution is seen along the width of patch. The return loss of this configuration is -22 dB for simulated and -17 dB for measured result.

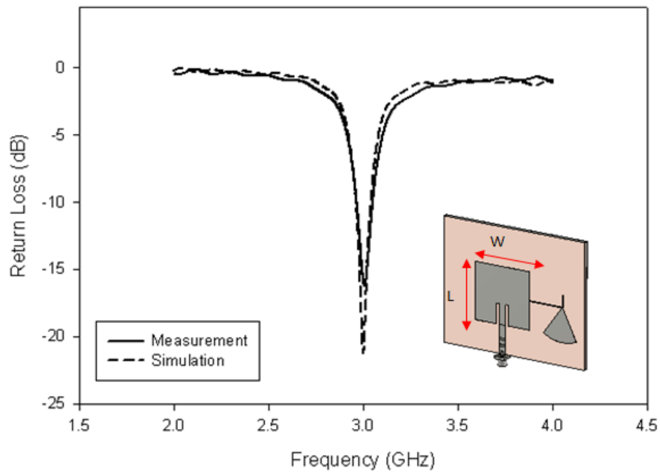

Figure 7. The antenna with biasing circuits at the middle of antenna with return loss results.

The structure on Fig. 8 shows the third configuration of biasing circuit on the single patch antenna. The biasing circuit is placed at the back of the antenna on a different substrate plane and connected to the transmission line through the copper via. The structure is constructed in order to form a tidy design and to avoid destruction to the radiation pattern. The maximum current density is shown at the front radiating elements while very low current density is radiated at the back of antenna. This radiation might be given an effect to the back lobe of the radiation pattern. However, the antenna is still resonating at a frequency of 3.0 GHz with a return loss of -17 dB (simulated) and -32 dB (measured) as shown in Fig. 8.

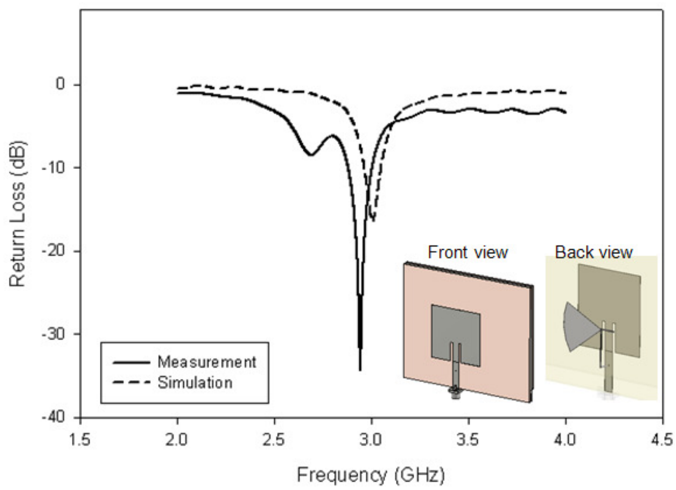

Figure 8. The antenna with biasing circuits at the back of the antenna with return loss results.

IV. Conclusion

The simulated of PIN diode representation using CST simulator have been proposed. However, these representations may be differed with other PIN diode manufacturer. Three positions of PIN diode and biasing circuits are discussed, in which the position at the back of the antenna could not effect the antenna's current distribution and produced a better return loss. These proposed PIN diode representation and their positions could be used in reconfigurable antenna and other s microwave circuit.

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