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PIN Diodes Slotted Microstrip Antenna as Frequency Reconfigurable Antenna

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1. Introduction

Reconfigurable antenna have become attractive options to be used in various advanced wireless communication applications, such as SDR (Software Defined Radio), MIMO (Multiple Input Multiple Output) and CR (Cognitive Radio). Reconfigurable antennas are multi-functionality antennas which can change the operating frequency, radiation pattern or polarization without changing the whole antenna structure. To achieve reconfigurability properties of operating frequency, the effective length of the antenna has to be changed dynamically using different kind of RF switches, such as PIN diodes, FETs, varactor diodes, and RF-MEMS switches [1].

In the previous published report [2]-[6], the switches on the reconfigurable antenna are designed using copper strips as a model of ideal switches. This technique was done to prove the concept that varying the slot length can be used to change the resonant frequency in a certain frequency range. However, using copper strips as ideal switches will eliminate the issue of designing DC biasing lines onto antenna. In practice, RF switches has to be used instead of copper strips.

This paper presents a slotted microstrip antenna as a frequency reconfigurable antenna by using PIN diodes to alter the operating frequency. The PIN diodes are turned *on* and *off* by DC biased signal, therefore, biasing line network has to be designed carefully to minimize the impact on antenna performance. The PIN diodes, biasing lines, lumped circuits and other components of the antenna were modeled in computer simulations to predict the antenna performance. The design, simulation, and measurement are discussed in this paper.

2. Antenna Design

The basic antenna structure is based on our previous work [6]. The antenna consists of rectangular patch, ring slot, and ten switches as shown in Fig. 1. The dimension of the antenna are listed in Table 1. Ten PIN diodes as electronic switches are then implemented to change the antenna operating frequency. Each PIN diodes has to be activated independently, which means that when one or several PIN diodes is forward biased to become active, the other diodes have to be remain inactive.

The schematic diagram of biasing technique is depicted in Fig. 2. To ensure each PIN diodes can be forward biased independently, each diode has to have independent biasing line. The capacitor is placed to block DC current so that the bias current does not influence the other diodes. The problem of using this technique was the ring slot has only 2 mm in width, so it was difficult to place all the lumped circuits (RF choke inductor, DC blocking capacitor, and PIN diode) on the slot. In addition, the biasing lines which lies over the antenna will degrade the antenna's performance. The frequency response of this antenna is unstable due to the existence of biasing lines.

The biasing technique was modified as shown in Fig. 3. The antenna is fragmented by implementing several thin slots. This slot will isolate the DC current from one biasing line to another, thus, the bias voltages of one PIN diodes will not bias the adjacent PIN diodes. The ten switches can be activated independently. The DC blocking capacitor is applied on the thin slots to block DC current but allowing the RF current to pass through the fragmented antenna. The RF choke inductor is used to avoid RF current induction to the biasing lines. The values of DC blocking capacitor and RF choke inductor were obtained from extensive parametric study by computer simulation.

3. Simulation and Measurement Results

In computer simulation, these ten PIN diodes, DC blocking capacitor, RF choke inductor are modeled using the resistance, inductance, and capacitance (RLC) model. The PIN diodes are modeled as capacitors in the *off* state and resistors in the *on* state. The datasheet of the PIN diode, BAP51-02 [7], provides the value of the capacitance and the resistance which are in the range of 0.2pF – 0.55pF and 1.5Ω – 9Ω, respectively. Its value depends on reverse voltage or forward current applied. As a result of extensive parametric study, it has been obtained that the PIN diode is modeled as capacitance with 0.2pF in *off* state and resistance with 1.5Ω in *on* state. The value of RF choke inductor is 1μH and the capacitor is 10nF. We used entirely 11 DC blocking capacitors, 10 RF choke inductors and 10 PIN diodes on the antenna.

Fig. 4 shows the comparison of S_{11} performance on *off* state between antenna with biasing line circuit as seen on Fig. 3 and the conceptual antenna as seen on Fig. 1. It is shown that there is slight change in resonance frequency about 4.97%. The simulated results for several combination of active switches is presented in Fig. 5 and summarized for $S_{11} < -10$dB in Table 2. It is shown that the operating frequency can be reconfigured accordance to combination of *on* switches. The ten switches will give us 1024 combinations, but only 14 combinations presented in this paper.

The antenna prototype based on the designed model has been fabricated and it is depicted in Fig.6. Moreover, Fig. 7 shows the measurement results of the antenna performance with different configuration of active switches. The measurement results exhibit the reconfiguration of operating frequency when various combination of *on* switches is applied. However, the measured results is different from the simulated results due to soldering imperfection in antenna fabrication.

4. Conclusion

This works presents the simulated and measured results of reconfigurable slotted microstrip antenna. It is shown in simulation that the operating frequencies can be tuned within 1.28 GHz to 2.92 GHz by using 14 combinations of active switches. Therefore, it has been proven that the reconfiguration of the operating frequencies can be achieved by changing the slot length on the antenna by turning *on* or *off* the switches in certain combinations.

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Table 1. The dimension of the antenna [6]

Lg	Wg	Lp	Wp	Ls
77.2 mm	87.9 mm	34.2 mm	44 mm	22 mm

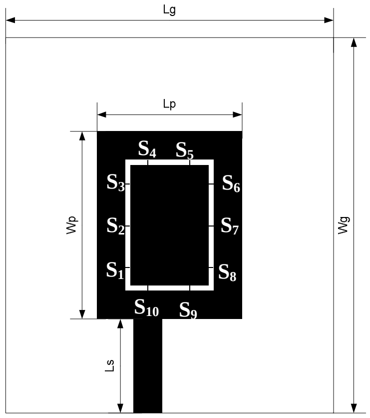

Fig 1. the schematic of designed antenna without biasing lines and position of the switches on the slot[6]

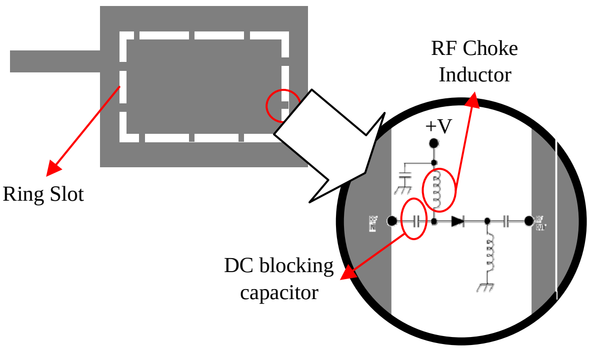

Fig 2. The schematic diagram of biasing technique.

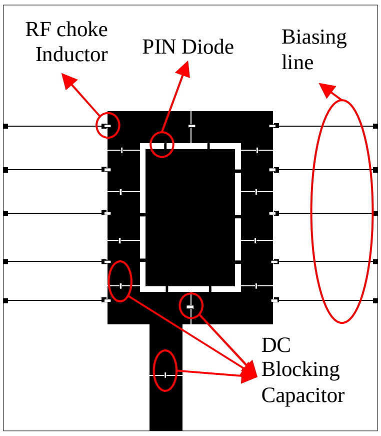

Fig 3. The schematic diagram of modified biasing technique.

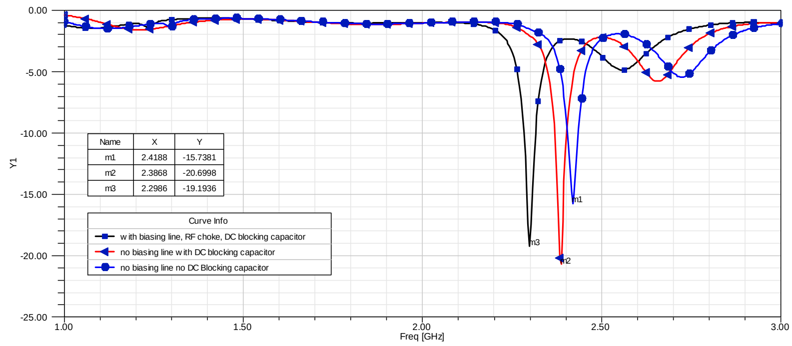

Fig 4. The comparison of *off* state simulated S_{11} between conceptual antenna (Fig. 1) and antenna with biasing line network (Fig.3)

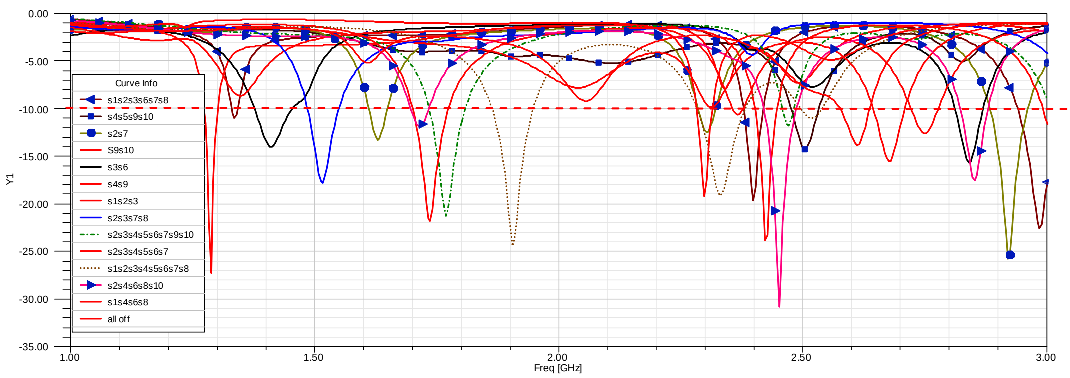

Fig 5. Simulated results of the changing of antenna's operating frequency due to various combination of *on* switches.

Table 2. Summary of various operating frequencies and bandwidth for $S_{11} < -10$dB by varying *on* switches combinations.

No	*On* Switch Combinations	Frequency band (GHz)		Bandwidth		freq at S_{11} min
		f_{low}	f_{high}	Abs (MHz)	%	
1	S_1 S_2 S_3 S_6 S_7 S_8	2.3828	2.4188	36	1.50	2.3988
2	S_4 S_5 S_9 S_{10}	2.4749	2.5311	56.2	2.25	2.503
3	S_2 S_7	2.8838	2.9599	76.1	2.61	2.9198
		2.2826	2.3226	40	1.73	2.3066
		1.6092	1.6493	40.1	2.46	1.6333
4	S_9 S_{10}	1.2725	1.3006	28.1	2.18	1.2886
5	S_3 S_6	1.3768	1.4569	80.1	5.67	1.4128
		2.8116	2.8677	56.1	1.97	2.8437
6	S_4 S_9	2.7194	2.7756	56.2	2.04	2.7555
7	S_1 S_2 S_3	2.6433	2.7074	64.1	2.39	2.6794
8	S_2 S_3 S_7 S_8	1.485	1.5491	64.1	4.23	1.517
9	S_2 S_3 S_4 S_5 S_6 S_7 S_9 S_{10}	1.7335	1.8096	76.1	4.30	1.7695
		2.4589	2.483	24.1	0.97	2.4749
10	S_2 S_3 S_4 S_5 S_6 S_7	1.7014	1.7735	72.1	4.15	1.7375
		2.4028	2.4469	44.1	1.82	2.4228
11	S_1 S_2 S_3 S_4 S_5 S_6 S_7 S_8	1.8617	1.9499	88.2	4.63	1.9058
		2.2826	2.3828	100.2	4.30	2.3307
		2.495	2.5431	48.1	1.91	2.523
12	S_2 S_4 S_6 S_8 S_{10}	1.6974	1.7335	36.1	2.11	1.7134
		2.4188	2.487	68.2	2.78	2.4509
		2.8236	2.8798	56.2	1.97	2.8517
13	S_1 S_4 S_6 S_8	2.5752	2.6393	64.1	2.46	2.6112
14	All swiches *off*	2.2826	2.3146	32	1.39	2.2986

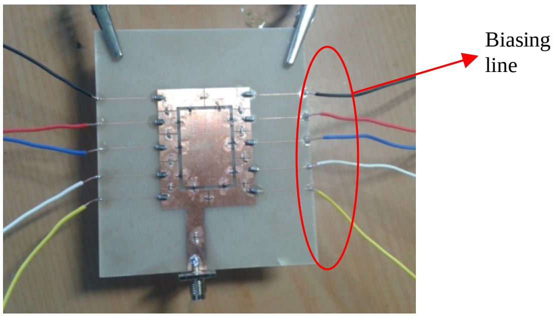

Fig 6. Fabricated antenna.

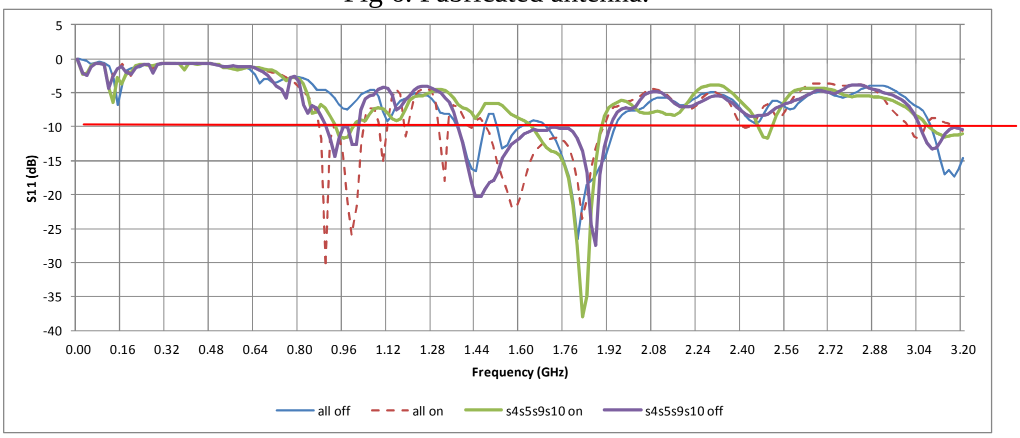

Fig 7. measured results of the changing of antenna's operating frequency due to various combination of *on* switches.