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Resonator Type for the Creation of a Potentially Reconfigurable Filtering Band in a UWB Antenna

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Abstract—In this letter, a novel frequency-reconfigurable monopole antenna with several switchable states including an ultra-wideband (UWB) state, filtering narrowband states, and a tunable filtering band state is presented. The antenna, which supports most applicable overlook narrowband frequencies between the 2–6 GHz, can be used in multiradio wireless systems. Moreover, the proposed antenna, which can avoid UWB interference and has narrowband functionality, has good potential for use in cognitive radio.

1. INTRODUCTION

Frequency diversity is particularly beneficial for wireless communication systems if multiple operational systems and reuse are required. This results from the emergence of the new wireless links which require that the antenna operates in different frequency bands or changes its radiation pattern or polarization. As a result, reconfigurable antennas which are able to change their characteristics have attracted a great deal of attention.

The development of narrowband wireless communication systems which can be operated in a frequency bands near each other requires the antenna to reject unwanted frequencies. Some frequency bands must be rejected in UWB operation in order to avoid the interference with other nearby frequencies. In UWB communication systems, there are a variety of different narrowband systems, such as WLAN (2400–2484 MHz; 5150–5350 MHz; 5725–5825 MHz), and WiMAX (2500–2690 MHz; 3400–3690 MHz; 5250–5825 MHz).

Various printed monopole antennas with a single or dual band-notch function have recently been proposed [1–5]. Adopting an electrical and mechanical method as well as active elements may provide reconfigurable antennas in terms of frequency band [6], polarization [7], pattern [8] and multi-application [9] in some UWB antennas. These elements are used to obtain alterable notched-bands. For this purpose some designs include RF MEMS [10], PIN diodes [11], microfluidic [12] and varactor diodes [13].

Therefore, a UWB antenna with resonant cell is proposed in this paper. The filtering frequency covers the 5.4–6.1 GHz range. This antenna uses two PIN diodes embedded in a resonance cell at the ON state to obtain the full UWB band (3.1–10.6 GHz). Filtering is provided by the varactor diode inserted in the middle arm of the resonance cell to regulate the capacitance; the filtering frequency is then electrically variable. The advantage of the proposed antenna, compared to recently published research [14, 15], is improved beam pattern, controlled by inserting the resonance cell on the transmission line affected by the radiation pattern.

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2. ANTENNA STRUCTURE

The configuration of the proposed microstrip antenna design comprises a Rogers RT/duroid 5880 substrate of planar size $30 \times 30\,\mathrm{mm}^2$. The substrate is of thickness 0.8 mm and permittivity 2.2 as depicted in Figure 1. A small resonance cell is located between the transition line and is connected at the end of the microstrip feed line. A ground plane has a semi-corner on top and is printed below the microstrip feed line. The dimensions of the proposed antenna as shown in Figure 1 are (all measurements in mm): $W = 30$, $L = 30$, $W_1 = 15$, $W_2 = 3$, $W_3 = 0.75$, $W_4 = 1.35$, $W_5 = 0.3$, $L_2 = 6.5$, $R = 7$, and $G = 0.5$.

To provide frequency reconfigurability, a switchable structure of slots is used on the ground transition line. This structure, which acts as a coplanar waveguide resonance cell filter, is designed to repress frequencies outside the desired band. The devised slot on the transmission line changes the inductance and capacitance of the input impedance of the antenna. This causes a shift in resonant frequency of the structure, which is controllable by changing the varactor diode capacitance.

The next step in simulation of this antenna after designing the coplanar waveguide resonance cell for creating the narrowband rejected band is to find a suitable position to embed the PIN diodes and varactor diode across the designed coplanar waveguide resonance cell. This is accomplished by using two PIN diodes and one varactor diode. Moreover, for each PIN diode and varactor diode, a 100 pf dc blocking capacitor was placed in the slot to create RF connection of the PIN diode and also to isolate the RF signal from dc. For biasing each of these active devices, a 0.7 V supply is applied to the metal strip isolation area. Resultantly, the filtering band switched by turning on the PIN diodes, and the resonant cell connected to the transition plane becomes a part of it.

On the other hand, this antenna can be optimized for other applications with an electrically controlled filtering band at parts of the UWB for the elimination of some cognitive wireless radio

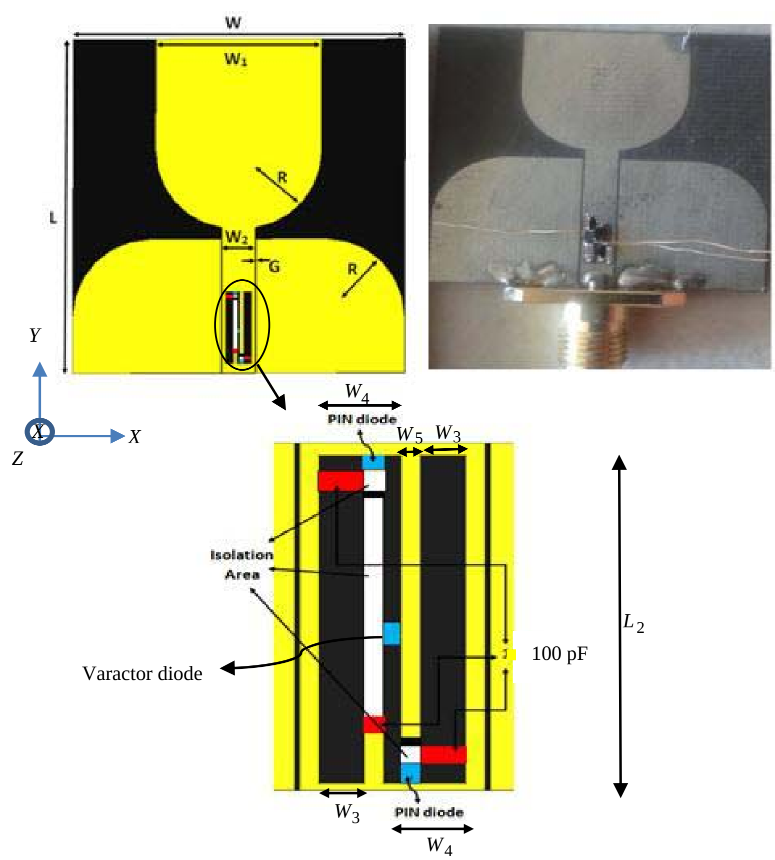

Figure 1. Photograph of the fabricated antenna with resonance cell, PIN diodes and varactor diode.

frequencies. The varactor diode is modeled as a resistor/capacitor combination in different states. The varactor diode is located at specific positions and is used to increase the capacitance of the slot.

We carefully control this varactor diode when both of the PIN diodes are in their OFF state. The center frequency of the filtering frequency band can be decreased by increasing the diode varactor capacitance at 5.71 GHz to 3.15 GHz.

In order to be independently DC-biased, the varactor diode is placed along the slot.

3. MEASUREMENT AND DISCUSSION

The proposed reconfigurable antenna has been simulated using High Frequency Structure Simulator (HFSS) software. Also, the antenna shown in Figure 1 is implemented, and measurements are performed. A photograph of the fabricated antenna is shown in Figure 1.

The return loss characteristic of the proposed antenna is shown in Figure 2. The three modes of operation of this antenna, which is the maximum magnitude for operating frequency, is −10 dB. When both of the PIN diodes are switched to the OFF state, a single filtering band covering 5.15 to 6.15 GHz is achieved. On the other hand, when the switch is in the ON state, the antenna operates over the 3.1 GHz and 10.6 GHz bands. Simulation and measurement of this mode is shown in Figure 2(a).

Another application is available after inserting a varactor diode in the resonant cell. When the OFF state for two PIN diodes was obtained by tuning the voltage of the varactor diode, the filtering band shifted as shown in Figures 2(a) and (b) for two different voltages ranging from 20 to 9 V. According to the measured result, we can see a wide tuned filtering band that can be observed from 5.69 GHz to 3.38 GHz. In this case, the PIN diodes light up every time the proposed antenna can be used for UWB systems. Table 1 is a summary of the proposed reconfigurable antenna as verified by the results of Figure 2.

The simulated electric field distribution in the reconfigurable antenna for the two different electric field distributions is shown in Figure 3. In Figure 3(a), in the filtering band, current is centralized at the electrical short circuit that corresponds to a minimum electric field. This causes the antenna to operate with low impedance in the filtering band. This low impedance leads to the desired high attenuation and impedance mismatching near the filtering band. Figure 3(b) shows the PIN diodes in ON state at 5.8 GHz, where the filtering band fades, and the antenna works in UWB applications.

The radiation pattern performance for the antenna presented above is included next. Simulated normalized relative power patterns, i.e., E-plane and H-plane patterns for the microstrip radiator, are shown in Figures 4(a) and (b) and are compared in their ON/OFF states at 5.8 GHz. A fairly

Table 1. Performance summary of the proposed reconfigurable antenna.

Mode	Experience	Device	Return Loss Results Figure	Varactor diode (Value)	PIN diodes	Center of Filtering band (GHz)
State 1	Measured	Two PIN diodes	Figure 2(a)	-	OFF	5.69
		Varactor Diode (V)	Figure 2(b)	$V = 20\,\mathrm{V}$		3.78
		And Two PIN diode	Figure 2(c)	$V = 9\,\mathrm{V}$		3.38
State 2	Simulated	Two PIN diodes	Figure 2(a)	-	OFF	5.71
		Varactor Diode (pf)	Figure 2(b)	$C = 0.3\,\mathrm{pf}$		3.64
		with Two PIN diode	Figure 2(c)	$C = 0.4\,\mathrm{pf}$		3.42
State 3	Measured	Two PIN diodes	Figure 2(a)		ON	-
		Varactor Diode (V)	Figure 2(b)	$V = 20\,\mathrm{V}$		
		with Two PIN diode	Figure 2(c)	$V = 9\,\mathrm{V}$		
State 4	Simulated	Two PIN diodes	Figure 2(b)		ON	-
		Varactor Diode (pf)	Figure 2(b)	$C = 0.3\,\mathrm{pf}$		
		with Two PIN diode	Figure 2(c)	$C = 0.4\,\mathrm{pf}$		

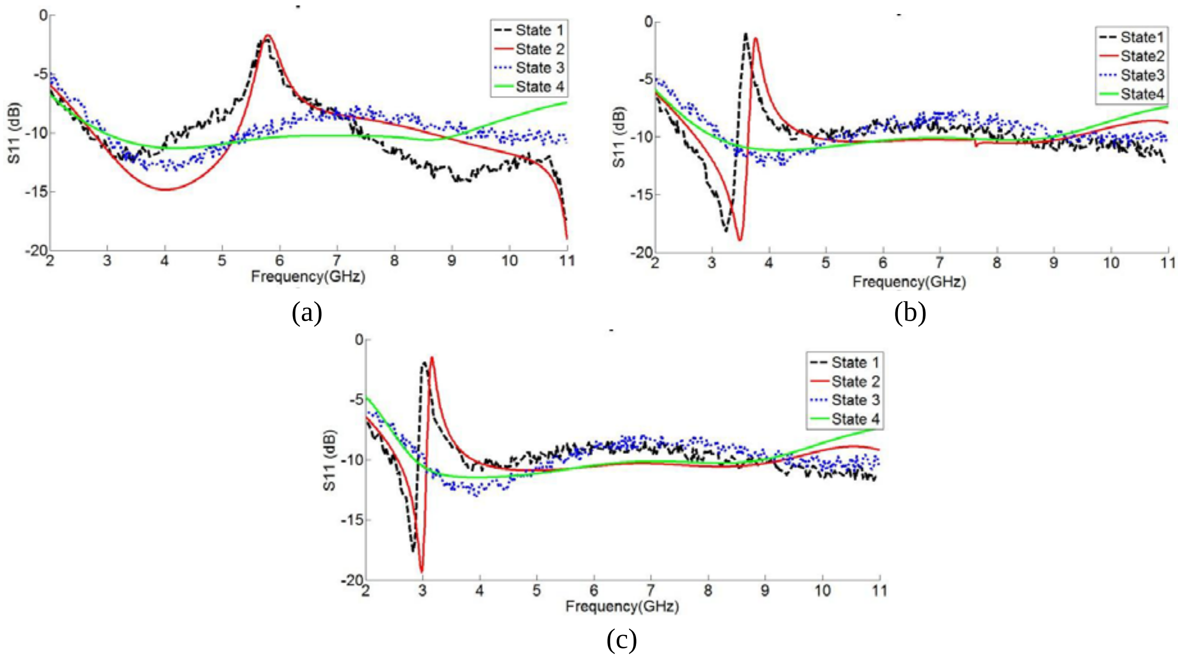

Figure 2. Measured and simulated return loss of the reconfigurable antenna (according to the Table 1).

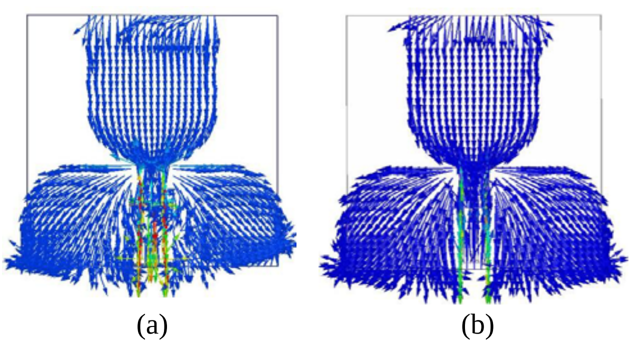

Figure 3. Electric field distribution at 5.8 GHz with two PIN diodes. (a) PIN diodes OFF state. (b) PIN diodes ON.

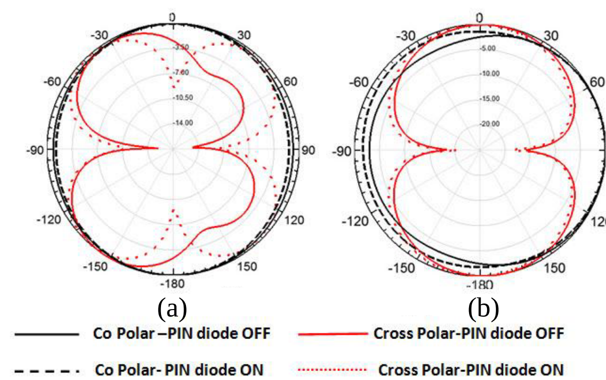

Figure 4. Radiation patterns of the antenna at 5.8 GHz. (a) E-plane. (b) H-plane.

omnidirectional pattern is achieved for the E-plane, while for the H-plane it shows a deteriorated omnidirectional pattern for the OFF state of the PIN diode.

4. CONCLUSION

An adjustable filtering band antenna with frequency reconfigurability has been presented. PIN diodes enable to switch the narrowband filtering states to turn on the notch band frequency at the ON state. Further, by adding another device, a varactor, we can adjust the center frequency of the filtering band from 5.8 to 3.1 GHz. This property can be used in different wireless systems, such as antenna applications in radar, electronic warfare, jamming technology, etc. These CPW filters are very compact and can be integrated within the structure of an antenna without taking any extra space. The integration of these electrically controlled filter bands with antennas results in valuable frequency agility. These results strongly approve the recently published papers [16–18]. Good agreements between simulated and measured results are obtained for the S-parameters of the filters and their respective antennas.

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