Frequency Switchable Metamaterial Inspired Antenna for Software Defined Radio (SDR) Applications

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Abstract

In this paper, we propose a frequency switchable metamaterial antenna for software-defined radio (SDR) applications. Metamaterial's zeroth-order resonance enables antenna size reduction. It is able to electronically switch a resonant frequency between 1.8 GHz and 2.3 GHz. More than 74 % of radiation efficiency is achieved at each frequency.

Keywords : frequency reconfigurable antenna, metamaterial, zeroth-order resonance (ZOR)

1. Introduction

In the last 20 years, mobile communication systems have shown a tremendous growth. Recently, software-defined radio (SDR) architecture is spotlightened as an emerging solution [1]. While an RF processor is implemented in hardware in a conventional radio communication system, it can be replaced in software in a SDR system. Therefore, a multi-standard terminal can be achieved without an abundance of hardware components. Especially, a reconfigurable antenna is essential for the SDR system where the antenna configuration is controlled through the antenna control unit (ACU) [2].

In this paper, a frequency reconfigurable antenna is proposed based on the metamaterial transmission line (TL). Metamaterial's zeroth-order resonance enables the antenna size to be compact [3]. A narrow bandwidth is a drawback of a metamaterial. This drawback is overcome by a co-planar waveguide (CPW) configuration [4]. The frequency tuning capability is achieved by integrating PIN diodes between the signal line and ground planes on the CPW.

2. Antenna Design

The zeroth-order resonance (ZOR) is realized by a composite-right/left-handed (CRLH) TL. At the ZOR frequency, the resonant condition is independent of the antenna's size so that a compact antenna can be achieved. The equivalent circuit model of the CRLH TL is shown in Fig. 1. For an unbalanced CRLH TL, the series (ω_{se}) and shunt (ω_{sh}) resonant frequencies are given by

$$\omega_{se} = \frac{1}{\sqrt{L_R C_L}} \text{ rad/s} \tag{1}$$

$$\omega_{sh} = \frac{1}{\sqrt{L_L C_R}} \text{ rad/s.} \tag{2}$$

Especially, the ZOR frequency results from the shunt resonant frequency for an open ended structure. The ZOR frequency of the proposed antenna is determined by the shunt inducatnce (L_L) and the shunt capacitance (C_R) between patch and CPW grounds. The L_L, is realized by lumped elements (chip inductors) and the gap between the patch and CPW ground represents C_R. Therefore, this frequency can be controlled by varying L_L or C_R. In this paper, variable L_L is chosen instead of changing C_R. Two stubs with different inductance values are in parallel inserted and include switches. PIN diodes are used for switches. Based on the applied voltages, one stub is chosen and its ZOR is determined from the selected inductance.

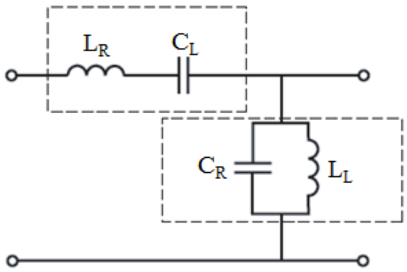


Figure 1: Equivalent circuit model of a general CRLH TL.

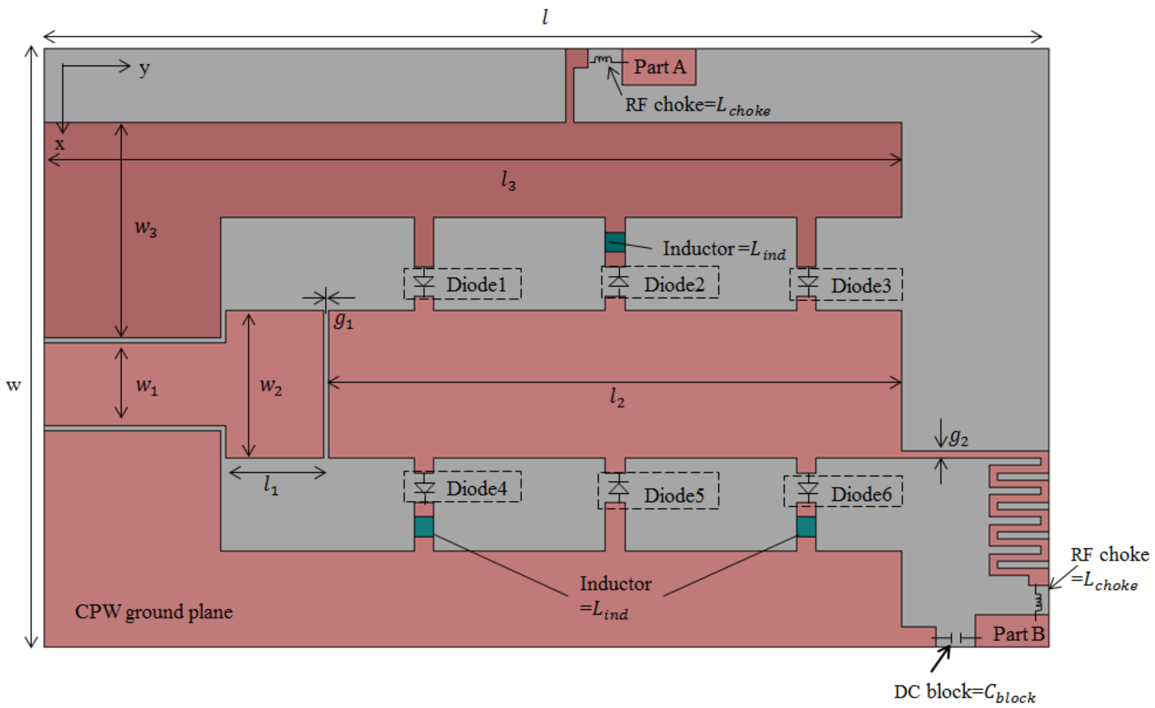


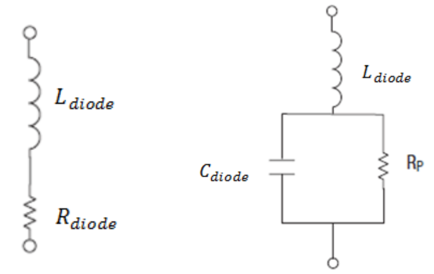
Figure 2: Geometry of the proposed switchable antenna.

The top view of the proposed antenna configuration is illustrated in Fig.2. It consists of three unit cells and each unit cell has two shorted stubs. One stub has a single PIN diode and chip inductor in series while another stub has only a single PIN diode. In the first stub, the anode of the diode is connected to the patch on the CPW. The cathode of the second stub's diode is connected to the patch on the CPW. The voltage at the part A is supplied to the ground on the CPW and the voltage at the part B is supplied to the patch on the CPW. When the part A is at a high voltage and the part B is at a low voltage, the diodes #1, #3, #5 turn on. When the part A is at a low voltage and the part B is at a high voltage, the diodes #2, #4, #6 turn on. Therefore, the shunt inductance can be dramatically changed by varying voltages at the part A and B.

3. Simulation and Experimental Results

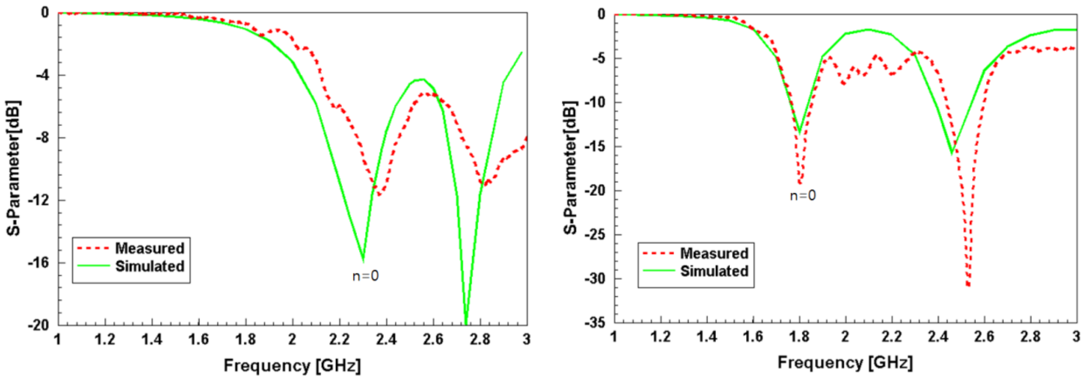
The proposed switchable ZOR antenna is fabricated on a 1.6 mm-thick RT/Duroid 5880 substrate with a dielectric constant of 2.2. Diodes loaded on shunt transmission line are SMP1345-079LF provided by Skyworks. The RF equivalent circuit of the diode is shown in Fig.3 for both the

ON and OFF states. The diode's components are L_{diode}=0.7nH, C_{diode}=0.18pF and R_{diode}=2Ω, respectively. The value R_p is higher than the reactance of the capacitance, C_T, and is less significant. These components are considered in all the simulations in order to fully characterize their effects on the antenna performance. In Fig. 4, the simulated and experimental s-parameter results are compared depending on the supplied bias voltages.



(a) (b)

Figure 3: RF equivalent circuit model of PIN diode. (a) on-state, (b) off-state.



(a) (b)

Figure 4: Measured and simulated return loss for the switchable antenna

(a) The state 1 and (b) the state 2.

For the state 1, high voltage (5V) is applied at the part B and the part A is grounded. For the state 2, high voltage (5V) is applied at the part A and the part B is grounded. At the state 1, the ZOR frequency is 2.3 GHz while it is 1.8 GHz at the state 2.

Figures 5(a) and (b) show the simulated radiation patterns on the Y-Z (E-plane) and X-Z (H-plane) planes at 1.8GHz. Figures 5(c) and (d) show the simulated radiation patterns on the E-plane and H-plane at 2.3GHz. The simulated efficiencies at 1.8GHz and at 2.3GHz are 74.2% and 75.5%, respectively. In addition, the peak gains are -3.45dBi and -2.62dBi respectively.

4. Conclusion

In this paper, we propose a frequency switchable matamaterial-inspired antenna for SDR applications. Because of metamaterial's zeroth-order resonance, the proposed antenna is able to reduce antenna size compared with conventional antennas. Acceptable bandwidth is achieved thanks to the CPW configuration. The ZOR frequency is successfully switched between 1.8GHz and 2.3GHz while keeping good radiation performances. More than 74 % of radiation efficiency is achieved at each frequency. The resonant frequency can be simply determined by the chip inductor's values. Therefore, the proposed antenna provides better design feasibility.

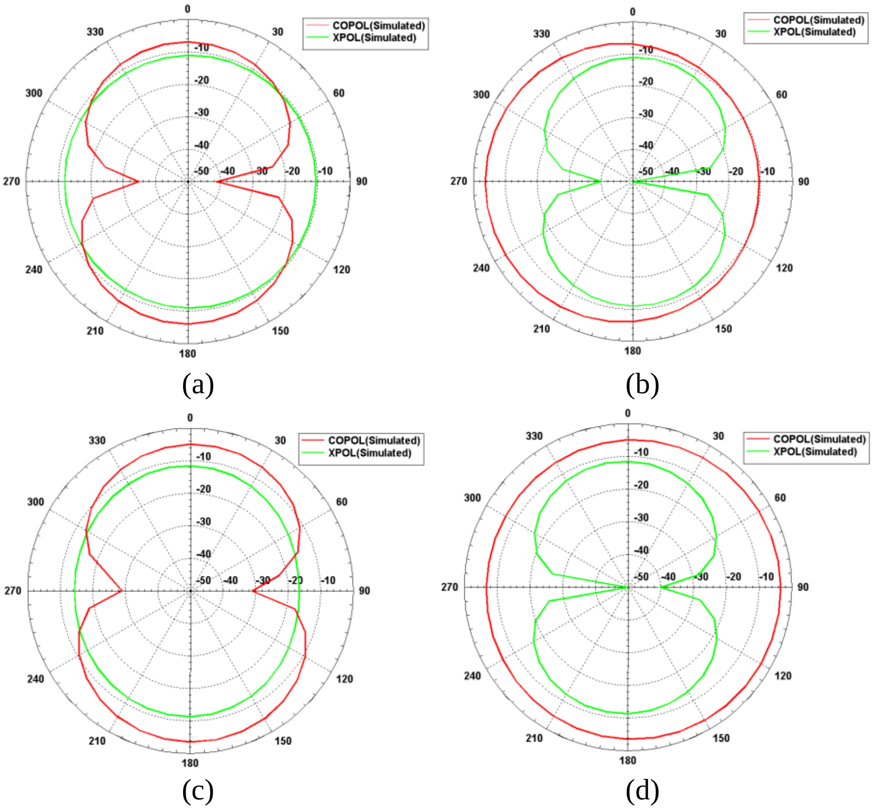


Figure 5: Simulated radiation patterns (a) y-z plane (E-plane) at 1.8GHz, (b) x-z plane (H-plane) at 1.8GHz, (c) y-z plane (E-plane) at 2.3GHz, (d) x-z plane (H-plane) at 2.3GHz.

References

[1] J. Mitola, "The software radio architecture," IEEE Commun. Mag., vol.33, no.5, pp.26-38, May.1995.

[2] J. T. Aberle, S.-H. Oh, D. T. A, and S. D. Rogers, "Reconfigurable antennas for portable wireless devices," IEEE Antennas and Propagation Magazine, vol.45, no.6, Dec.2003.

[3] A. Lai, Kevin. M. K. H. Leong, and T. Itoh, "Infinite wavelength resonant antennas with monopole radiation pattern based on periodic structures," IEEE Trans. Antennas Propag., vol.55,no.3, pp. 868-875, Mar.2007.

[4] T. Jang, J. Choi, and S. Lim, "Compact coplanar waveguide (CPW)-fed zeroth-order resonant antennas with extended bandwidth and high efficiency on vialess single layer", IEEE Trans. Antennas Propag, vol.59, no.2, pp.363-372, Feb.2011.

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