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Compact reconfigurable UWB antenna integrated with SIRs and switches for multimode wireless communications

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Abstract: A kind of reconfigurable wide slot UWB antenna integrated with stepped impedance resonators (SIRs) and ideal switches is presented. The proposed antenna 1 has dual notch band functions which are obtained by using two stepped impedance stub loaded SIRs. The three reconfigurable models are investigated and discussed. The measurement results with ideals switches demonstrate the performances of proposed reconfigurable antennas. The designed reconfigurable antennas can be suitable for future multi-mode wireless communications systems.

Keywords: wide slot antenna, UWB antenna, notch band antenna, frequency reconfigurable antenna, switchable antenna

Classification: Microwave and millimeter wave devices, circuits, and systems

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1 Introduction

With the rapid development of wireless communications, systems with high data rate, low cost and low power have attracted much attention in academia and industry. An ultra-wideband (UWB) system is a good candidate for these purposes and a lot of UWB antennas have been developed [1, 2, 3]. However, the UWB band overlaps with traditional narrow bands, such as WLAN and X-band [2]. Notch band UWB antennas are proposed to reduce the potential interference between UWB systems and narrow band systems [1, 2, 3]. However, the proposed antennas just work in the UWB mode or the notch band UWB mode. Recently, plenty of reconfigurable antennas are designed for multimode communication and cognitive radio systems [4, 5, 6].

In this letter, three compact reconfigurable wide slot UWB antennas with notch band characteristics and switchable functions for multi-mode wireless communication applications are presented. The notch band functions are achieved using two stepped impedance stub loaded stepped impedance resonators (SIRs). The reconfigurable characteristics are achieved using switches on SIRs. The operating mode can be reconfigured by switching SIRs. Two switchable methods are proposed to design the multimode antennas. The performances of the antennas are investigated and demonstrated in this letter. The design procedure and the measurement results are presented and discussed.

2 Antenna design

The configurations of the proposed antennas are shown in Fig. 1. Fig. 1 (a) illustrates the geometry of the proposed reconfigurable UWB antenna 1 with all switches ON. Antenna 1 is a dual notch band UWB antenna. The two stop bands are obtained using two SIRs, the upper SIR and the lower SIR. Antenna 2 shown in Fig. 1 (b) is a reconfigurable UWB antenna with switch 1 (SW1). By switching SW1 ON and OFF, antenna 2 can be used as a UWB antenna or dual notch band UWB antenna. Antenna 3 shown in Fig. 1 (c) is another reconfigurable UWB antenna with switch 2 (SW2) and switch 3 (SW3). By controlling the two switches ON and OFF, antenna 3 can work as a dual notch band UWB antenna/tri-band antenna, a notch band UWB antenna/dual band antenna, or a UWB antenna. A substrate with relative permittivity of 2.65, a loss tangent of 0.002 and a thickness of h=1.6 mm is used in antenna designs. The proposed reconfigurable antennas consist of a circular wide slot, a circular radiation patch, a upper SIR etched in circular radiation patch, a lower SIR embedded in CPW transmission signal strip line and a 50 CPW feed structure. The 50 CPW feed structure consists of the

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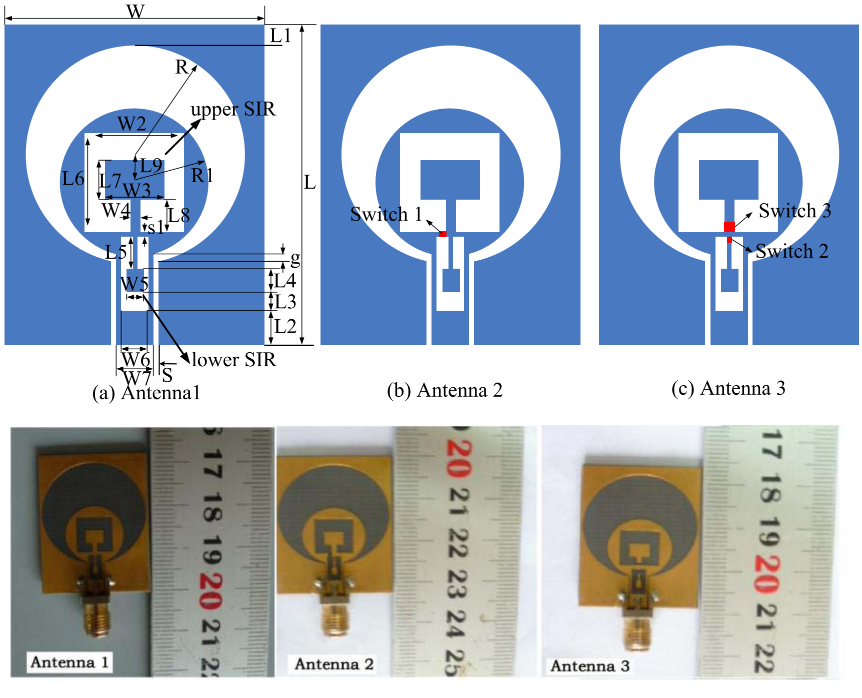

Fig. 1. Geometry of proposed reconfigurable antennas: (a) reconfigurable antenna 1; (b) reconfigurable antenna 2; (c) reconfigurable antenna 3; (d) prototypes of the three antennas

CPW transmission signal strip line with a signal strip width W7=3.6 mm, and the gap between the CPW ground plane and transmission signal strip with width S=0.2 mm. In this letter, three antennas have same dimensions. Three ideal switches are used for evaluating proposed reconfigurable antennas. The presence of a metal bridge represents ON states and the absence of a metal bridge represents OFF states [6].

3 Numerical and experimental results and discussions

According to the design description mentioned above, the proposed reconfigurable UWB antennas have been optimized using HFSS. During the optimization, the SW1 was replaced by a microstrip line with length of 0.9 mm and width 0.7 mm. The ideal SW 2 was a microstrip line with length of 1 mm and width 0.4 mm. SW 3 was substituted by a 1.25 mm×0.4 mm microstrip line. The optimized dimensions of the proposed reconfigurable UWB antenna are as follows: L=32 mm, W=24 mm, L1=1.9 mm, L2=3 mm, L3=1.8 mm, L4=1.5 mm, L5=2.5 mm, L6=8 mm, L7=3 mm, L8=2 mm, L9=4.6 mm, W2=8 mm, W3=4 mm, W4=0.4 mm, W5=1.4 mm, W6=2.7 mm, W7=3.6 mm, S=0.2 mm, s1=0.7 mm, R=11.6 mm, R1=6.6 mm, and g=0.5 mm. In this letter, the notch band characteristics of antenna 1 and switch functions of antenna 2 and antenna 3 are investigated and discussed herein. Fig. 2 shows the VSWR characteristics of the proposed reconfigurable UWB antennas. It can be seen from Fig. 2 (a) that the two notch bands are generated

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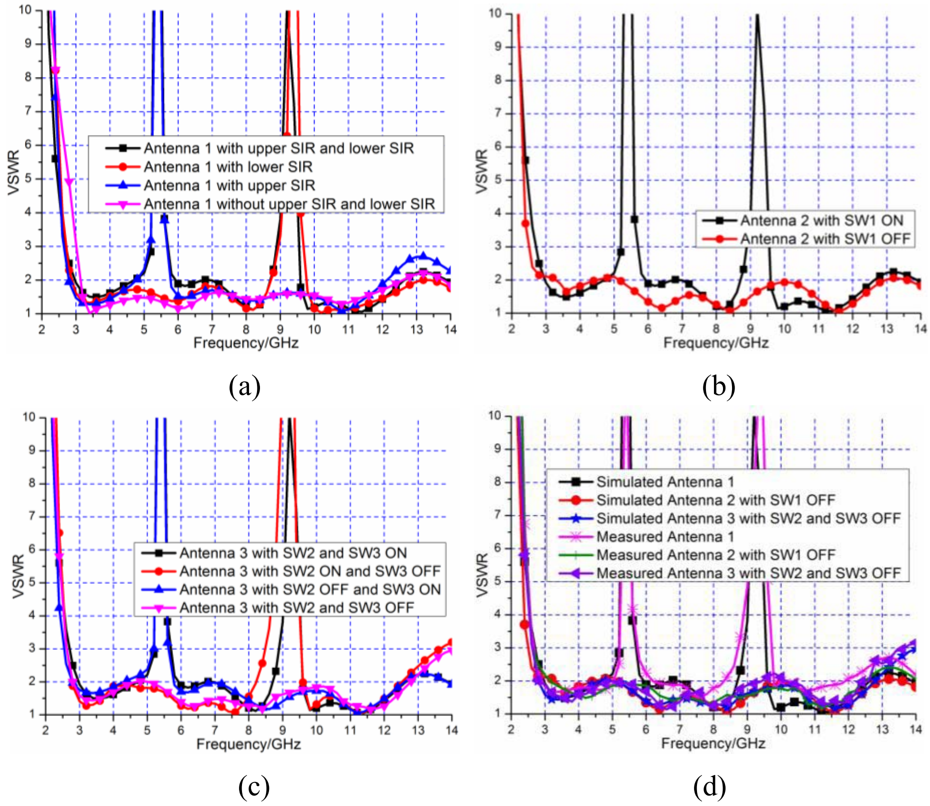

Fig. 2. VSWR characteristics of proposed reconfigurable UWB antennas: (a) Notch band characteristics of antenna 1; (b) Switch functions of antenna 2; (c) Switch characteristics of antenna 3;(d) Measured VSWRs of proposed antennas

using two SIRs. The lower notch band is produced by the upper SIR and the higher notch band is created by the lower SIR. Antenna 1without two SIRs is a UWB antenna having a wide bandwidth ranging from 2.8 GHz to 12.5 GHz. Switch characteristics of antenna 2 are shown in Fig. 2 (b). Antenna 2 has two notch bands with SW1 ON. Antenna 2 with SW1 OFF is a UWB antenna covering whole UWB band. So, Antenna 2 can work as a dual notch band UWB antenna or a UWB antenna by controlling SW1 ON and OFF. The switch characteristics of antenna 3 are shown in Fig. 2 (c). Reconfigurable antenna 3 with SW2 and SW3 ON is a dual notch band UWB antenna or a tri-band antenna. When one of the two switches is ON and the other switch is OFF, antenna 3 is a notch band UWB antenna or a dual band antenna. Antenna 3 with two switches OFF is a UWB antenna having an impedance bandwidth of 128%. To evaluate the proposed reconfigurable antennas, antenna1, antenna 2 with SW1 OFF, and antenna 3 with SW2 and SW3 OFF are fabricated and shown in Fig. 1 (d). The measured VSWRs of the antennas are obtained by using Anritsu 37347D vector network analyzer and are shown in Fig. 2 (d). From Fig. 2 (d), the measured results agree well with the simulated results which help to verify the accuracy of the simulation. The differences between the simulated and measured values may be due to the errors of the manufactured antennas and the SMA connector to

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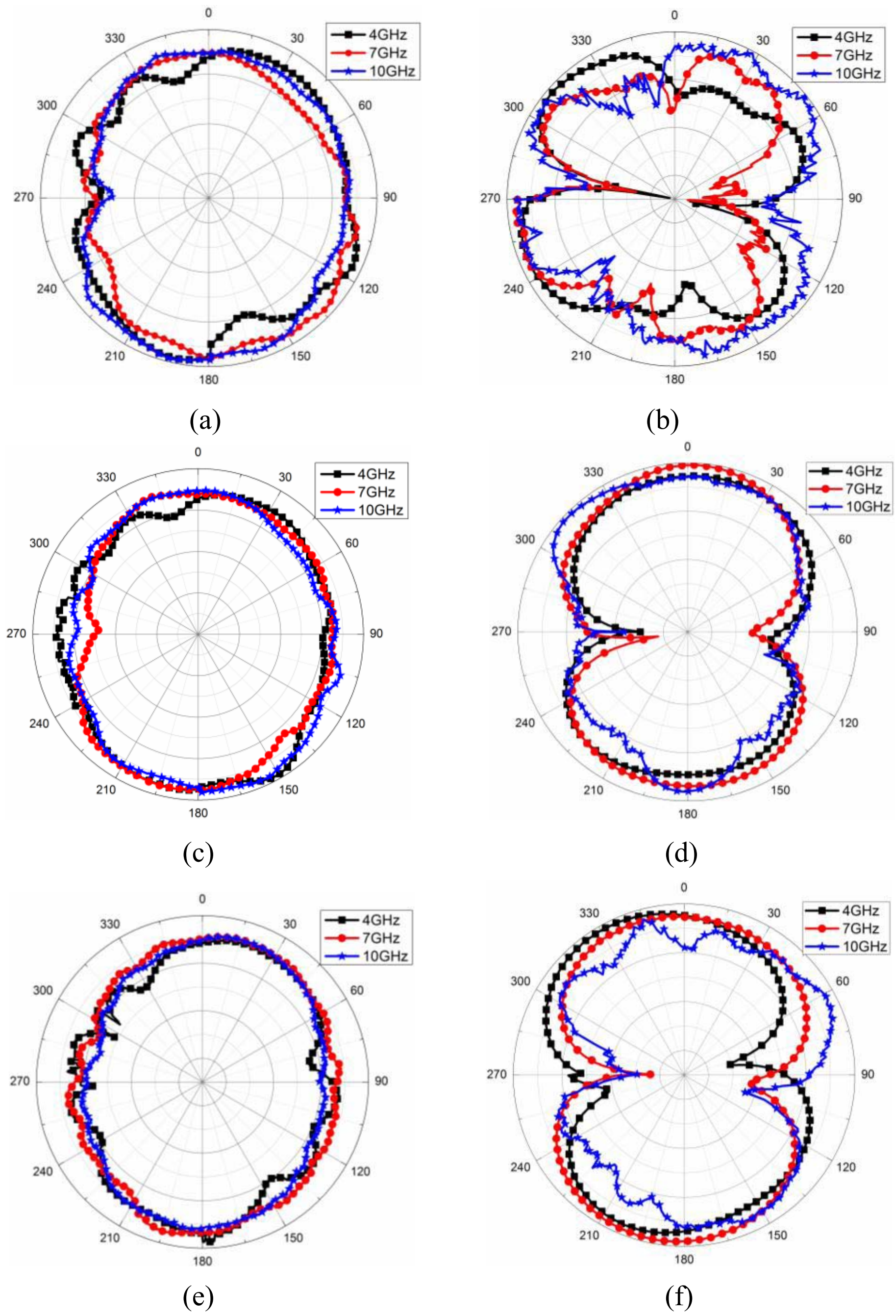

Fig. 3. Radiation patterns of proposed reconfigurable antennas (a) H-plane of antenna 1; (b) E-plane of antenna 1; (c) H-plane of antenna 2 (SW1 OFF); (d) E-plane of antenna 2 (SW1 OFF); (e) H-plane of antenna 3 (both switches OFF); (f) E-plane of antenna 3 (both switches OFF);

CPW-fed transition, which is included in the measurements but not taken into account in the calculated results. So, the proposed reconfigurable antenna is a multimode antenna which can work as a dual band notch UWB antenna/tri-band antenna, a notch band UWB antenna/dual-band antenna and UWB antenna. In this letter, antenna 2 just uses one switch to change the working statuses as a dual notch band UWB antenna or a UWB antenna.

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Antenna 3 can achieve all the proposed modes by controlling two switches SW2 and SW3 ON/OFF. In addition, the proposed reconfigurable antennas can also reduce or avoid the potential interference between UWB systems and narrow band systems by controlling the states of the switches.

The measured radiation patterns at 4 GHz, 7 GHz, 10 GHz are shown in Fig. 3. From Fig. 3, we can see that antenna 1, antenna 2 with SW1 OFF, and antenna 3 with two switches OFF can give nearly omni-directional characteristics in the H-plane and dipole-like patterns in the E-plane. The E-plane radiation patterns of antenna 1 have a little distortion. This is caused by the two SIRs which leak electromagnetic waves. The leaked electromagnetic waves deteriorate the radiation patterns. The E-plane radiation patterns of fabricated antenna 2 and antenna 3 have a lot distortion at 10 GHz. However, the proposed reconfigurable antennas still satisfy the omni-directional requirement of wideband communication applications.

The peak gains of the proposed reconfigurable antennas are achieved by comparing to a double ridged horn antenna and shown in Fig. 4. From Fig. 4, stable gain of antenna 1 can be obtained throughout the operation band except the notched frequencies. As is desired, two sharp gains decrease in the vicinity of 5.5 GHz and 9 GHz. The gains drop deeply to −6.1 dBi at the lower notch band and −4.6 dBi at the higher notch band. Antenna 2 with SW1 OFF and antenna 3 with SW2 and SW3 OFF have similar gains in the operation band. The increased gains in the high frequency may be attributed to the deteriorated E-plane radiation patterns.

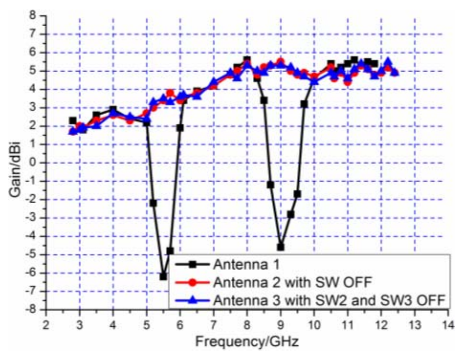

Fig. 4. Gains of the proposed reconfigurable antennas

4 Conclusion

A kind of reconfigurable UWB antennas using two SIRs and switches is proposed and studied numerically and experimentally. The notch band characteristics are obtained using two SIRs. Two reconfigurable antennas based on the proposed dual notch band UWB antenna 1 is achieved by employing one switch on antenna 2 and two switches on antenna 3. By controlling the switch ON and OFF, the proposed reconfigurable UWB antenna can work in UWB mode, dual notch band UWB mode/tri-band mode, and notch band UWB mode/dual band mode. The proposed antennas have small

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size of 32 mm×24 mm. Measured and simulated results show that the proposed reconfigurable antennas have good omni-directional radiation patterns, switchable characteristic, and good notch band characteristic. The proposed reconfigurable antenna can be suitable for multi-mode wireless communications applications.

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