Chapter 5

Reconfigurable Antennas for UWB Cognitive Radio Communication Applications

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Additional information is available at the end of the chapter

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Abstract

In this chapter, reconfigurable antennas are reviewed for ultra-wideband (UWB) cognitive radio communication applications. The defected microstrip structure (DMS) has been reviewed and integrated into the UWB antennas to form the desired filtering antennas which can filter out unexpected narrowband signal interferences. Then, switches are incorporated into the filtering UWB antennas to construct the cognitive radio UWB (CR-UWB) antenna to make the antenna switch between the UWB antenna and band-notched UWB antenna. In these CR-UWB antennas, the DMSs are to give the desired notches while the switches are used for realizing the switchable characteristics. Several reconfigurable antennas and CR-UWB antennas are created and investigated. The results show that the designed CR-UWB antenna can switch between different modes, making it amazing for UWB, band-notched UWB, and multiband communication system applications.

Keywords: reconfigurable UWB antenna, cognitive radio, switchable antennas, frequency rejection antennas, filtering antennas

1. Introduction

With the development of the modern wireless communications, the demand for high data transmission rate and wide bandwidth has attracted much more attention in both academic and industrial fields [1–4]. Specially, a ultra-wideband (UWB) communication system covering a wide bandwidth, which ranges from 3.1 to 10.6 GHz, has been released by Federal Communications Commission (FCC) in 2002 for commercial UWB communications [5]. In sequel, a great number of UWB studies have been presented to build a practical communication system since the UWB system can provide high data rate and good resistance for multipath and jamming [6, 7]. To transmit and receive wireless signal, antennas are important and should be integrated into a wireless communication device. Then, UWB antenna designs have been widely investigated because a UWB antenna is one of the important components to create a UWB communication system.

Many UWB antennas have been put forward to carry out wide bandwidth in the past few years, which includes uniplanar and planar antennas [8–12]. In sequel, planar microstrip antennas have been extensively developed because of their low cost and easy fabrication. Then, a lot of UWB antennas have been presented with different structures and various feedings [11–13], such as coaxial feed, microstrip feed, and coplanar waveguide (CPW) feeds. Many UWB antennas are realized by using microstrip feeds which can provide a wide bandwidth. However, some of these antennas are complex in structure and others are still embarrassed in narrow bandwidth. Then, many bandwidth enhancement techniques have been reported to expand the bandwidth of the existing antennas [14, 15]. Furthermore, UWB antennas with CPW feedings have been widely studied to achieve wide bandwidths and good omnidirectional radiation patterns. Although these UWB antennas can well cover the entire UWB bandwidth, they may be interfered by the existing narrowband wireless communication systems such as wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) [16–19]. After that a great number of UWB antennas with band notched functions have been reported to give resistance to these potential interferences by using various notch techniques [16–19], including U-slot, C-slot, L-slot, and E-shaped slots. These etched slots on the ground plane or radiation patches might leaky electromagnetic waves which may affect the electromagnetic compatibility designs of wireless communication systems [16]. Then, some improved band-notched UWB antennas with stubs and resonators have been presented to overcome the drawbacks which are caused by the leaky electromagnetic waves [12, 20–24]. These band-notched UWB antennas can well filter out the unwanted narrowband interferences. However, it cannot provide a good service when an entire banded UWB antenna is desired for sensing demands. Thus, a multimode antenna is desired to fulfill the mentioned communication requirements. A reconfigurable antenna is a good candidate for providing multiple modes. In fact, the reconfigurable antennas have been widely studied and used in various communications [25–32], such as cognitive radio systems. Moreover, the reconfigurable techniques can also be used for designing a cognitive radio antenna by implementing the UWB operating mode, band-notched UWB mode, and multiple band mode [25–32].

Recently, the reconfigurable UWB antennas have been developed for cognitive radio (CR) communications [25–32]. In the CR communication systems, unlicensed users (secondary users) can access spectrum bands licensed to primary users at a spectrum underlay mode or spectrum overlay mode, which is illustrated in **Figure 1** [28]. In the underlay mode, the secondary users are limited under a very low transmission power which is less than 41.3 dBm/MHz for UWB users [26]. This approach can be realized by using impulse radio (IR) based UWB (IR-UWB) technology [26]. For the overlay mode, the secondary users detect the existing narrowband (NB) signals, such as those signals from WLAN and radio frequency identification (RFID), and provide immunity to the NB systems. This can be implemented by turning off corresponding subcarriers in orthogonal frequency division multiplexing UWB (OFDM-UWB), depending on whether any primary users exist or not in a special band [26–28].

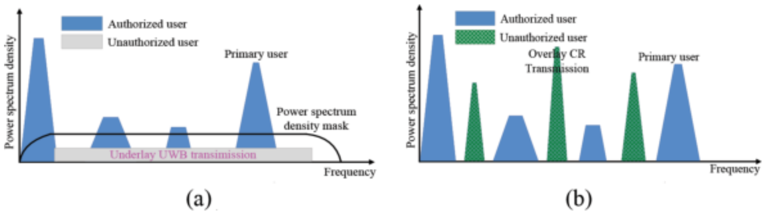

Figure 1. CR-UWB spectrum sharing modes. (a) Underlay. (b) Overlay.

In other words, the transmission spectrum of UWB radios can be sculpted in accordance with the presence of the primary users in the respective frequency bands [25–32]. Therefore, in CR-UWB systems, a CR antenna should cover the entire UWB band from 3.1 to 10.6 GHz with no notch bands for underlay applications and for detecting the licensed primary users and providing immunity to these users using band-notched technologies [25–32].

This chapter reviews the recent development of the CR-UWB antenna designs, including the defected microstrip structure (DMS)-based stop-band filter, band-notched UWB antenna and reconfigurable UWB antenna. First, DMS stop-band filter is briefly reviewed to give a discussion of the filtering UWB antenna designs. Second, the band-notched UWB antennas with stop-band filters are presented. Third, reconfigurable UWB antennas with multimodes are discussed to give an explanation to illustrate multiband and CR antenna designs. Finally, an example for developing CR-UWB antenna with wide bandwidth and multimode is introduced for multiband and CR communications.

2. Advances of UWB antenna designs

To provide a good service for CR-UWB communication system, a CR-UWB antenna is required to transmit and receive the desired signals [25–32]. The UWB communication system overlaps with the existing narrowband communication systems, such as WLAN, WiMAX, C-band, radio frequency identification (RFID), and X-band [16–19]. These communication systems occupy almost all the spectrum resources under the 10 GHz. Sometimes, we need to change the operation modes to meet multimode wireless communication and cognitive radio applications [25–32]. Thus, UWB antenna requires a signal selection scheme that can detect the presence of narrowband interferences [16–19, 25–32]. Then, the UWB antenna can provide effective notches to reject these potential interferences. One of the effective methods is to utilize CR-UWB technique. To construct a CR-UWB communication system, a CR-UWB antenna is desired to transmit and receive electromagnetic signals. Then, several CR-UWB antennas have been reported to meet the CR-UWB communication requirements [25–32]. However, the proposed CR antennas (CRAs) are complex in structure for dual port antennas [27, 29]. For the single UWB CRAs, the previous CRAs cannot be designed flexibly. Most of proposed single port cognitive antennas are designed using split-ring resonators (SRRs) in the radiation patch [26], which might leak electromagnetic wave that deteriorates the radiation patterns. Next, we will introduce a CR-UWB antenna design based on the band-stop filter techniques step by step.

2.1. Defected microstrip structure (DMS) band-stop filter

The DMSs have small size and can effectively give resistance to electromagnetic interferences (EMIs), which are carried out by etching various slots in the microstrip lines [33]. The DMSs can be used to filter out unwanted electromagnetic signals in a special frequency. Furthermore, the DMS is easy to fabricate and integrate into a microwave system and it can be effectively analyzed by using circuit theory [34]. A typical DMS, which is realized by etching a meander line slot on a 50-Ohm microstrip line, is shown in **Figure 2(a)** and its equivalent circuit model is given in **Figure 2(b)**. The performance of the DMS band-stop filter is shown in **Figure 3**. It is found that a stop band near 3.5 GHz is achieved, which can be used for filtering out the unexpected narrowband signals from the WiMAX communication system [34].

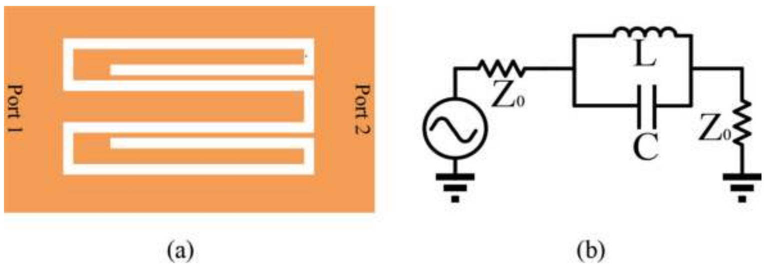

Figure 2. A typical DMS band-stop filter and its equivalent circuit. (a) DMS band-stop filter. (b) Equivalent circuits.

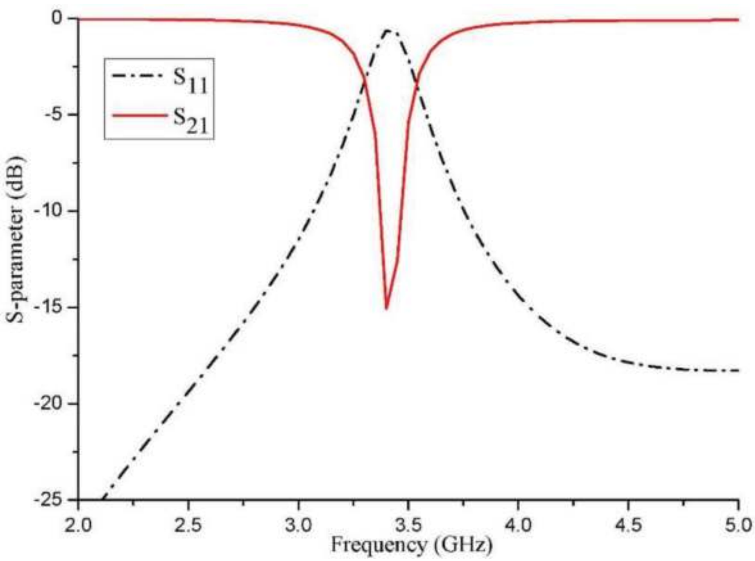

Figure 3. Performance of the DMS band-stop filter.

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Then, another meander line slot is etched on the DMS filter given in **Figure 1** to create the second stop band. The configuration of the stop-band filter with two stop bands is illustrated in **Figure 4**. Two meander line slots with different dimensions are used to generate the desired stop bands [34], respectively. The larger meander line slot is to produce the lower stop band, while the smaller meander line slot can provide the upper stop band. The performance of the filter with two stop band is described in **Figure 5**. Another stop band is obtained around 5.25 GHz to reject the unwanted signal from the WLAN band. The two stop bands are given by using different DMS cells and they are controlled independently. Thus, we can embed different DMSs into the 50-Ohm microstrip line to construct multiple stop bands.

From the above discussions, it is observed that the DMS can be used for designing various stop bands. Thus, DMS-based stop-band filter can be used in a wireless system to reject the narrow-band signals. However, it will increase the complexity and the size of the wireless device since

Figure 4. Configuration of the filter with two stop bands.

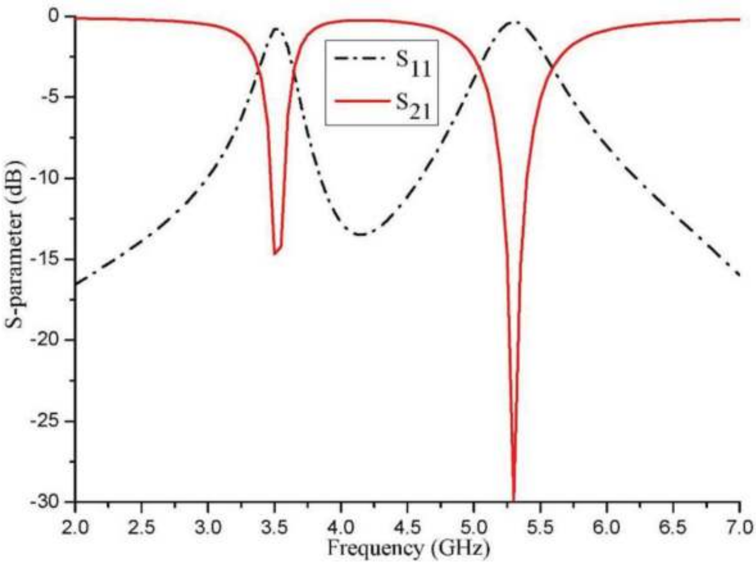

Figure 5. Behavior of the stop-band filter with two meander line slots.

it is usually added at the end of the antenna. Thus, band-notched UWB antenna can be realized by combining the stop-band filter and UWB antenna together to build a filtering UWB antenna.

2.2. Filtering UWB antenna

Here, the DMS stop-band filters are integrated into the microstrip feeding signal strip line to form filtering UWB antenna [34]. An example of the UWB antenna is shown in **Figure 6(a)**. The UWB antenna, which is printed on a substrate with a relative permittivity of 2.65, constants of a tapper patch, a ground plane, and a microstrip feeding signal strip line. The antenna can cover the entire UWB band ranging from 3.1 to 10.6 GHz with a voltage standing wave ratio (VSWR) <2 or a reflection coefficient <−10 dB. To prevent the potential interference from the WiMAX communication system at 3.5 GHz, a DMS cell is incorporated into the microstrip feeding signal line to create the filtering UWB antenna given in **Figure 6(b)**. In comparison with the UWB antenna shown in **Figure 6(a)**, there is an extra DMS cell in the feed transmission line.

The impedance characteristics of the UWB antenna and the filtering UWB antenna are demonstrated in **Figure 7**. **Figure 7(a)** shows the reflection coefficient (S11) and VSWR of the UWB

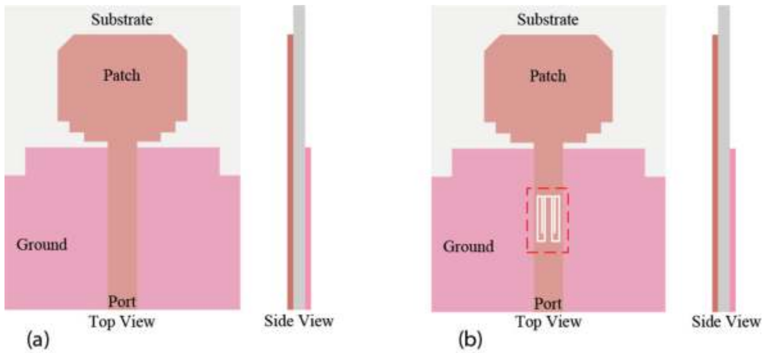

Figure 6. UWB antenna and filtering UWB antenna. (a) UWB antenna. (b) Filtering UWB antenna.

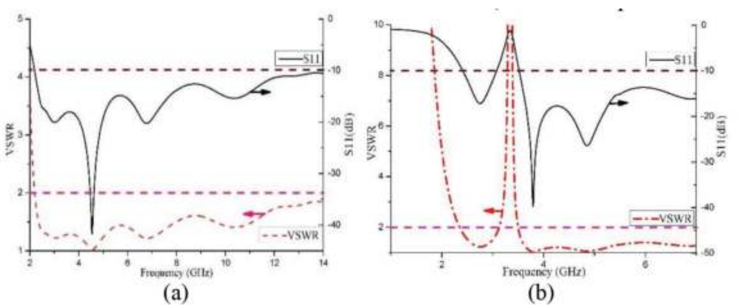

Figure 7. Impedance bandwidth of the UWB antenna and filtering UWB antenna. (a) Impedance of the UWB antenna. (b) Impedance of the filtering UWB antenna.

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antenna, while **Figure 7(b)** presents the S11 and VSWR of the filtering UWB antenna. It can be seen from **Figure 7(a)** that the UWB antenna has a bandwidth of 147.5%, which covers the entire UWB band released by FCC. By incorporating a meander line slot into the transmission signal line of the UWB antenna, a notch is produced within the UWB band. The notch can well filter out the interferences from the 3.5 GHz WiMAX band. Also, the notch depth and bandwidth can be adjusted by changing the dimensions of the meander line slot. In this case, the stop-band filter and the UWB antenna are integrated together, which may reduce the size of the devices.

Then, another meander line slot is used for generating the second notch to filter out another narrowband interferences [26]. To better understand the independence of the notch bands, a UWB antenna with two meander line slots is created and its configuration is given in **Figure 8(a)**. These meander line slots are sequentially integrated into the feeding signal line. The VSWR and S11 are illustrated in **Figure 8(b)**. It is observed that a notch at 5.2 GHz is obtained by using the second meander line slot. Therefore, the two notch bands can be controlled by the meander line slots. As we know, these UWB antennas can well filter out the unwanted narrowband signal interferences. However, a new UWB antenna should be designed if the narrowband communication is necessary. Thus, a reconfigurable UWB antenna might be useful to switch between the UWB communication and band-notched UWB communication systems.

2.3. Reconfigurable UWB antenna

Since the CR-UWB antenna may change the modes between the band-notched UWB and UWB communication systems, a reconfigurable UWB antenna with a bandwidth of 2.38–7 GHz is presented to provide the desired switchable characteristics. Three switches, namely, switch-1 (SW1), switch-2 (SW2) and switch-3 (SW3), are incorporated into the band-notched UWB antenna to make the antenna reconfigurable. The reconfigurable antenna is shown in **Figure 9(a)** and its performance is given in **Figure 9(b)**. It is found that three switches are integrated into the meander line slot to control its resonance. By switching the switches ON and OFF, the resonance of the meander line slot can be well controlled. In this simulation, the presence of a

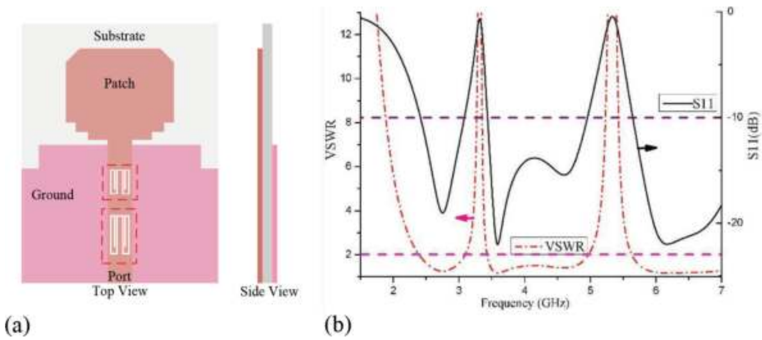

Figure 8. Dual-notch band UWB antenna and its performance. (a) Dual-notch UWB antenna. (b) Performance of the dual-notch UWB antenna.

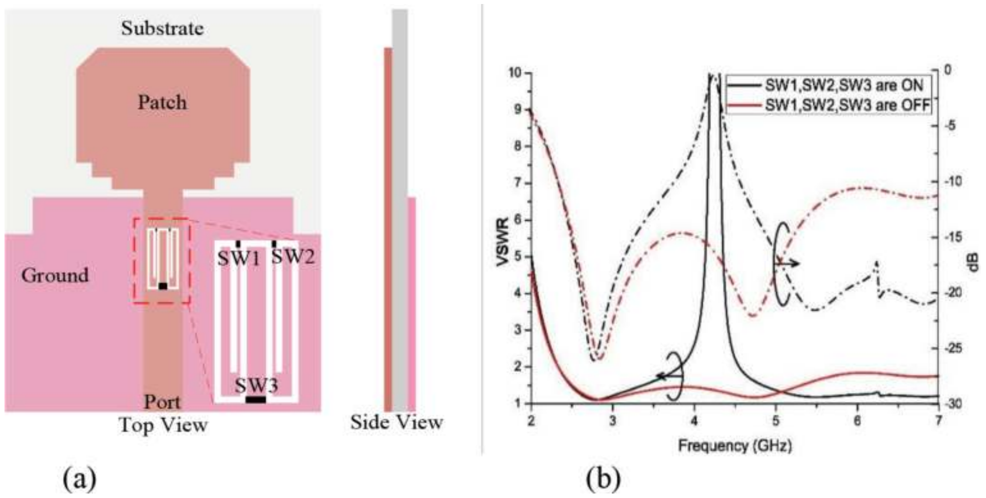

Figure 9. Reconfigurable UWB antenna. (a) Reconfigurable UWB antenna. (b) Behavior of the antenna.

metal bridge represents the ON state, while its absence represents the OFF state [26–30]. From **Figure 9(b)**, the antenna is a band-notched UWB antenna when all the switches are ON. A notch at 4.2 GHz is generated by the meander line slot. Moreover, the antenna is also a dual-band antenna. When all the switches are turned OFF, the antenna is changed to be a UWB antenna which has a bandwidth of 49.2%. Thus, the antenna can operate at least two modes for meeting the UWB and band-notched UWB communication requirements.

3. CR-UWB antenna

Based on the UWB antenna, band-notched UWB antenna, DMS stop-band filter design, switch techniques, and reconfigurable antenna design concept, CR-UWB antenna design will be introduced in detail. To obtain much more operation modes, three meander line slots are used for constructing the CR-UWB antenna. In this design, three meander line slots are etched in the microstrip transmission signal line, which is a DMS-based stop-band filter. Then, switches are integrated into these meander line slots to control their resonances. Here, the CR-UWB antenna design and analysis are given step by step.

To create a multiple mode CR-UWB antenna, a triple band DMS stop-band filter is designed. It is realized by etching three DMS cells in a 50-Ohm microstrip line, which is shown in **Figure 10**. It is observed that the three DMS cells are all meander line slots with different dimensions. Furthermore, these DMS cells can also be obtained by using spur slots, T-shaped slots, or their combinations. The performance of the triple stop-band filter is demonstrated in **Figure 11**. We can see that there are three stop bands operating at 3.3, 5.25, and 6.8 GHz, which can be used for preventing the potential interferences from 3.3 GHz WiMAX, 5.25 GHz WLAN, and 6.8 GHz RFID systems. Furthermore, the center frequencies of the three stop bands can be adjusted

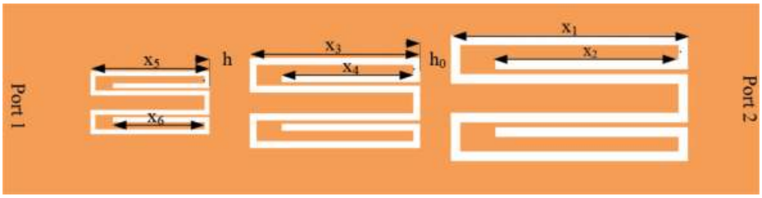

Figure 10. Geometry of the tri-band stop-band filter.

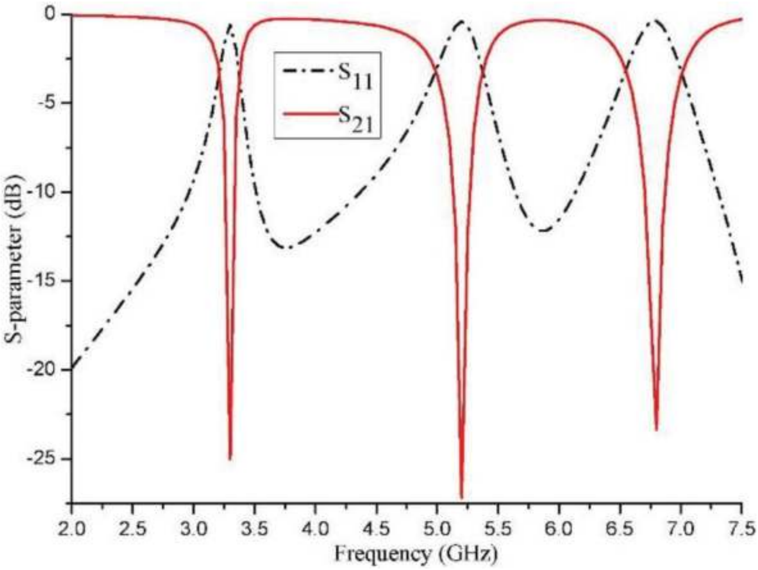

Figure 11. Performance of the tri-band stop-band filter.

by selecting the dimensions of these meander line slots, which are given in **Figure 12**. X_1, X_3, and X_5 control the length of the DMS resonators. With the increment of the X_1, the center frequency of the lowest stop-band shifts from high frequency to low frequency because the increased X_1 expands the resonance length of the right DMS cell. In this case, the center frequency of the middle stop band keeps constant. However, the center frequency of the highest stop band has a little shift when X_1 is 7.4 mm. Similarly, parameters X_3 and X_5 can well control the center frequencies of the middle and highest stop bands, respectively. However, X_3 and X_5 have slight effects on the other stop bands. Thus, the stop band can be adjusted by properly selecting the dimensions of these meander line slots.

The tri-band stop-band filter can be analyzed based on Butterworth low-pass filter theory which can calculate the circuit parameters of the DMS-based filters. The equivalent circuit model of the low-pass filter and the DMS cell is given in **Figure 13**. Here, g_0, g_1 and g_2 are normalized values, and g_0 is internal resistance, and g_1 and g_2 can be found from a **Table 1**.

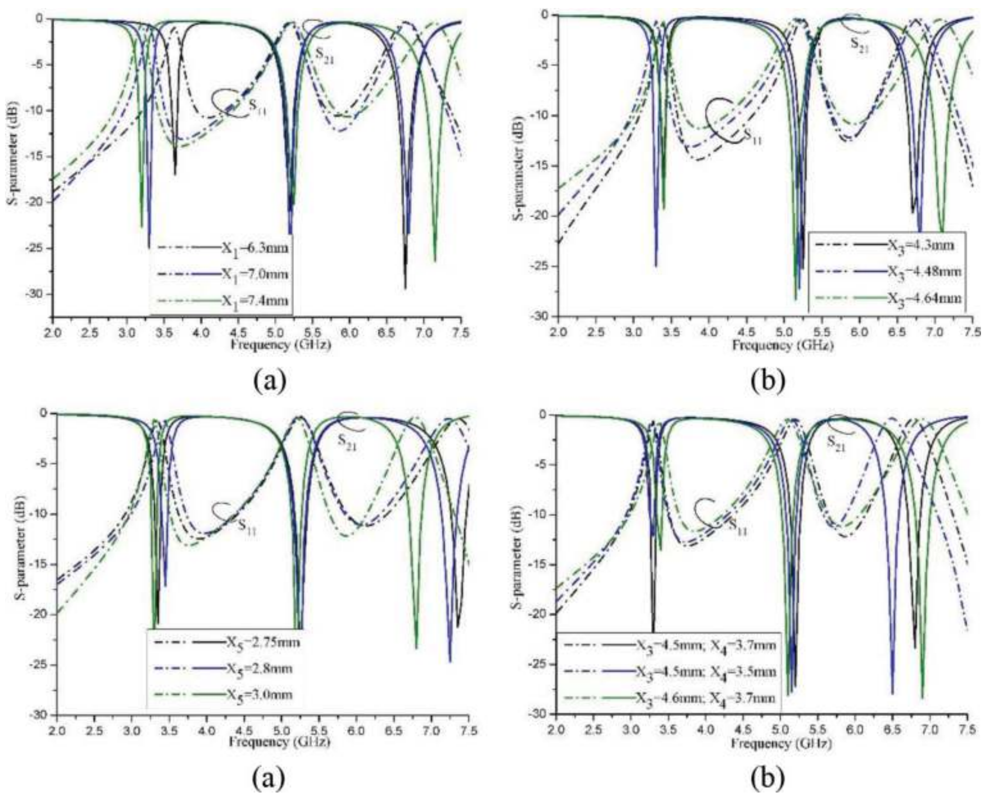

Figure 12. Parameter effects on the behavior of the tri-band stop-band filter. (a) X_1. (b) X_3. (a) X_5. (b) X_3 and X_4.

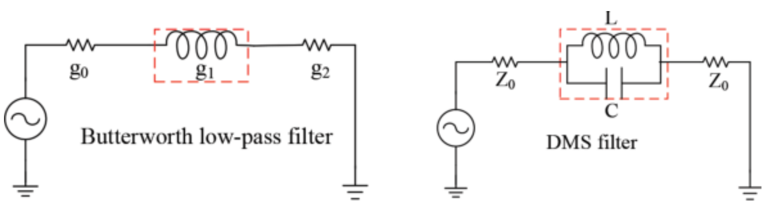

Figure 13. Equivalent circuit of the Butterworth low-pass filter and DMS filter.

Z_0 is characteristic impedance. Then, the reactance of the Butterworth low-pass filter and the DMS-based filter can be obtained Refs. [33, 34]

$$X_L = \omega' Z_0 g_1 \tag{1}$$

$$X_{LC} = \left[\omega_0 C\left(\frac{\omega_0}{\omega}\right) + \frac{\omega}{\omega_0}\right]^{-1}, \tag{2}$$

Modes	SG1	SG2	SG3	Highest notch	Middle notch	Lowest notch
1	OFF	OFF	OFF	–	–	–
2	OFF	ON	OFF	–	4 GHz	–
3	OFF	OFF	ON	–	–	3.3 GHz
4	OFF	ON	ON	–	4 GHz	3.3 GHz
5	ON	OFF	OFF	5.5 GHz	–	–
6	ON	ON	OFF	6 GHz	4.5 GHz	–
7	ON	OFF	ON	5.5 GHz	–	3 GHz
8	ON	ON	ON	2.4 GHz	4 GHz	5.5 GHz

Table 1. Modes of the CR-UWB antenna.

where ω' is normalized angle frequency, ω_0 is the resonance frequency of the DMS cell and it is obtained from

$$\omega_0 = 1/\sqrt{LC} \tag{3}$$

Based on the circuit theory and the equivalent theory, we have

$$X_{LC}/_{\omega=\omega_C} = X_L/_{\omega'=1} \tag{4}$$

From Eqs. (1) and (4), we get Refs. [33, 34]

$$C = \left(\frac{\omega_C}{Z_0 g_1}\right)\frac{1}{\omega_0{}^2 - \omega_C{}^2}, \tag{5}$$

$$L = \frac{1}{4\pi^2 f_0{}^2 C} \tag{6}$$

where f_0 and f_c are the pole frequency and -3dB cut-off frequency. Since the tri-band stop-band filter is realized based on three cascaded DMS filters with different dimensions, the transmission network, including the capacitance and inductances, can be obtained

$$CP_i = -\frac{1}{2\pi f_{Ti} X_{(i+1),i}}, i = 1, 2, \tag{7}$$

$$LS_i = \frac{X_{ii} - X_{(i+1),i}}{2\pi f_{Ti}} + \frac{L_i}{(f_{Ti}/f_{0i})^2 - 1}, i = 1, 2, 3, 4, \tag{8}$$

where f_{0i} is the i-th pole frequency, f_{Ti} is the transmission poles between the pole frequencies, X is the imaginary part at f_{Ti}. Based on the theory above, the equivalent circuit model of the tri-band stop-band filter is obtained and is given in **Figure 14**. The values of the parameters are L_1 = 0.297 nH, C_1 = 7.839 pF, L_2 = 0.265 nH, C_2 = 3.541 pF, L_3 = 0.183 nH, C_3 = 3.003 pF, L_{s1} = 0.434 nH, L_{s2} = 0.01 nH, C_{p1} = 0.417pF, Ls3 = 0.852 nH, L_{s4} = −0.085 nH, C_{p2} = −0.08 pF.

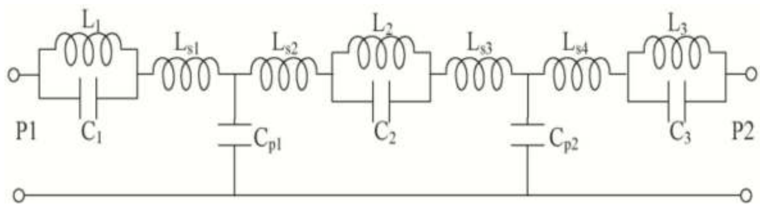

Figure 14. Equivalent circuit model of the tri-band stop-band filter.

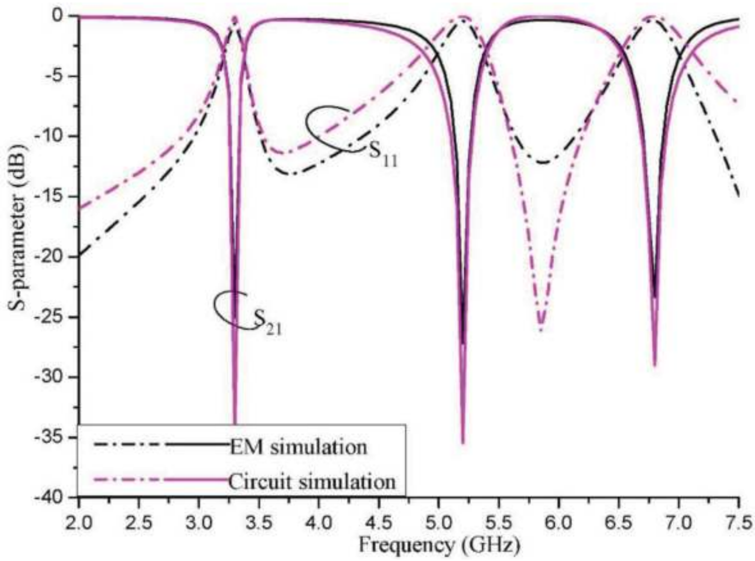

Figure 15. Comparisons of the tri-band stop-band filter.

The result of the circuit simulation is described in **Figure 15**. It is found that the circuit simulation agrees well with the EM simulation. Thus, the tri-band stop-band filter can be calculated based on circuit theory, which render it easy to understand and design. There is some fluctuation between the EM and circuit simulations, which can be corrected by carefully adjusting the values of the equivalent circuit.

Then, we use the designed tri-band stop-band filter to construct a triple band-notched UWB antenna. The stop-band filter is directly integrated into the feeding signal strip line to generate the desired three notches by properly choosing the dimensions of the DMS cells. The configuration of the band-notched UWB antenna with triple notches is shown in **Figure 16(a)**. It is observed that three DMS cells are sequentially etched on the transmission signal line and tapered structures are used to enhance the bandwidth of the UWB antenna. The impedance bandwidth of the tri-band band-notched UWB antenna is depicted in **Figure 16(b)**. The antenna has three notches at 2.8, 4, and 5.25 GHz to give resistance to the unwanted narrow-band signals. To further under the performance of the tri-band band-notched UWB antenna,

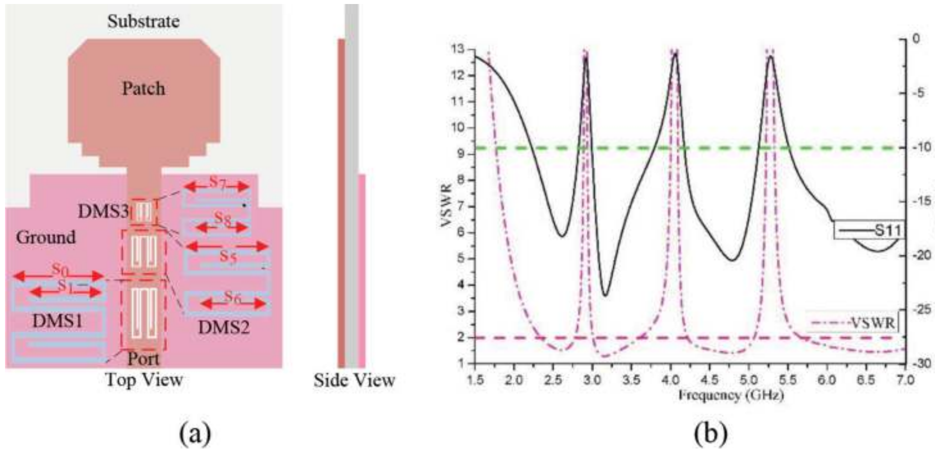

Figure 16. Tri-band band-notched UWB antenna. (a) Geometry. (b) Impedance bandwidth of the antenna.

the parameters of the meander line slots are investigated. **Figure 17(a)** shows the design process of the tri-band band-notched UWB antenna. It is found that the antenna without any DMS cells is a UWB antenna which can provide a wide bandwidth. The antenna has a notch at 3.5 GHz when only DMS1 is integrated into the transmission signal line. As both DMS1 and DMS2 are incorporated into the feeding signal strip line, the antenna can generate two notches at 3.5 and 5.25 GHz, respectively. When the MDS1, DMS2, and DMS3 are used in the UWB antenna, the antenna has three notches at 2.8, 4, and 5.25 GHz. Since the size of the antenna and the feeding transmission signal line are limited, the coupling of these DMS cells might affect the resonance center frequencies. Thus, the lowest notch moves to low frequency. However, these notches are produced by independent DMS cells. **Figure 17(b)** shows the effects of S_0 on the impedance of the tri-band band-notched UWB antenna. It is observed that the lowest notch shifts from high frequency to low frequency when S_0 increases from 6.7 to 7.1 mm because the resonance length is expanded by the increased S_0. However, the center frequencies of the middle and the highest notches are also affected since the cascaded DMSs produce some couplings which may affect the circuit parameters. Similarly, the effects of the parameters S_3 and S_5 are discussed in **Figure 17(c)** and **(d)**, respectively. By properly selecting the S_3 and S_5, the center frequencies of the corresponding notches can be well adjusted to meet the practical engineering applications. Thus, these notches can be controlled by choosing the dimensions of the DMS1, DMS2, and DMS3.

To better understand the triple band-notched UWB antenna, the equivalent circuit model is extracted and given in **Figure 18(a)**. The parameter values are R_1 = 1.0 Ohm, L_1 = 58.804 nH, C_1 = 0.05 pF, R_2 = 59.0 Ohm, L_2 = 0.01 nH, C_2 = 1.509 pF, R_3 = 141.25 Ohm, L_3 = 0.5 nH and C_3 = 5.25 pF. The results are shown in **Figure 18(b)**. It is found that the circuit simulation is same as the EM simulation which helps to verify the effectiveness. There is some difference between the EM and circuit results which can be corrected by properly choosing the values of the circuit parameters.

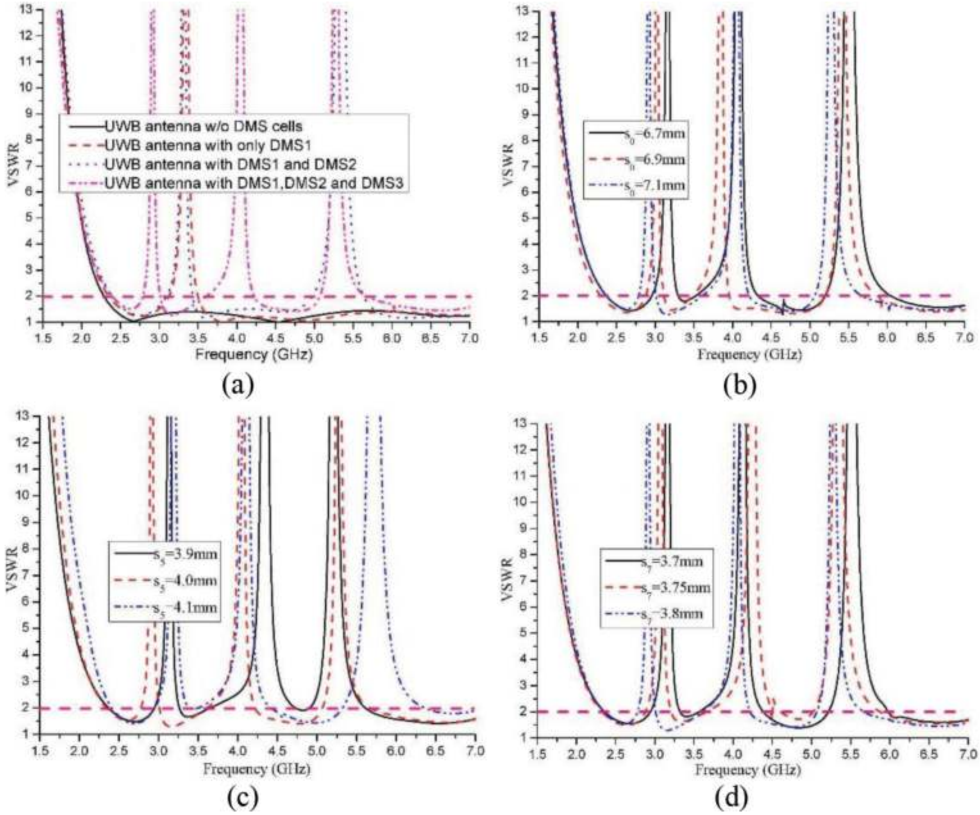

Figure 17. Tri-band band-notched UWB antenna. (a) Design process of the antenna. (b) S_0. (c) S_5. (d) S_7.

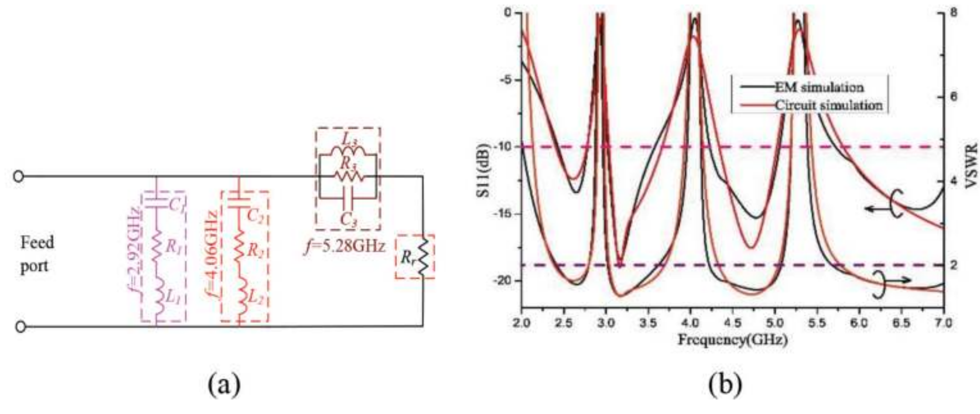

Figure 18. Equivalent circuit and the results of the triple band-notched UWB antenna. (a) Equivalent circuit model. (b) Impedance characteristics of the antenna.

Finally, nine switches are incorporated into the triple band-notched UWB antenna to carry out a CR-UWB antenna. The configuration of the CR-UWB antenna is shown in **Figure 19**. We can see that nine switches, namely, switch-1 (SW1), switch-2 (SW2), switch-3 (SW3), switch-4 (SW4), switch-5 (SW5), switch-6 (SW6), switch-7 (SW7), switch-8 (SW8), and switch-9 (SW9), are used for realizing the CR-UWB antenna. In the design, the SW1, SW2 and SW3 are named as switch group 1 (SG1), and the SW4, SW5 and SW6 are denoted as switch group 2 (SG2), and the SW7, SW8 and SW9 are formed to be switch group 3 (SG3). All the switches in each group are turned ON or turned OFF instantaneously.

The operating modes of the CR-UWB antenna are shown in **Figure 20**. It is found that there are 8 operating modes by using the three group switches. In the simulation, the presence of a metal

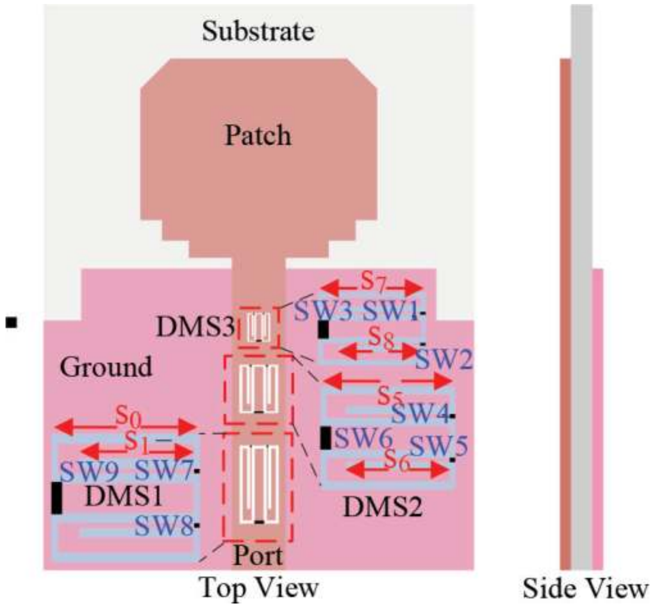

Figure 19. Configuration of the CR-UWB antenna.

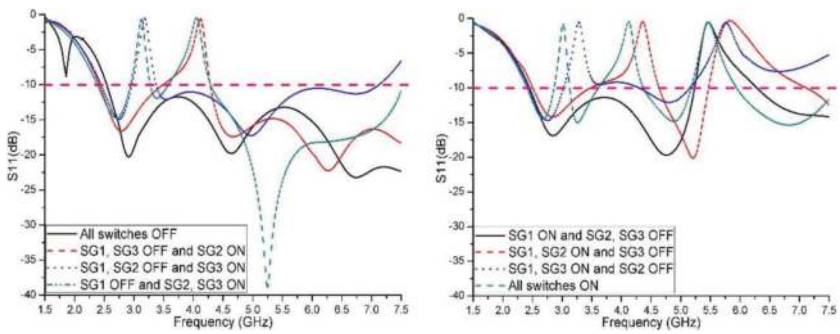

Figure 20. Operating modes of the CR-UWB antenna.

bridge represents the ON state, while its absence represent OFF state. The operating modes are given in **Table 1**. When the CR-UWB antenna works in mode 1, it is a UWB antenna which can be used in underlay mode in a very low power. In this case, the IR-UWB technology can be used to transmit and receive desired signals. Furthermore, it can also be used as a sensing antenna in CR communication systems. As the CR-UWB antenna operates at mode 2 to mode 8, it is a UWB antenna with different notches. In these cases, the CR-UWB system can be implemented by using OFDM-UWB technology to switch ON/OFF the different carries to make the antenna to prevent the unwanted narrowband signals. Thus, the designed antenna can be used for various CR-UWB communication systems to sense and to prevent interferences. It can also switch between the overlay and underlay modes by change the antenna operating modes. In addition, the CR-UWB antenna can be used for UWB, band-notched UWB and multiband communication systems.

The radiation patterns of CR-UWB antenna in mode 4 and mode 5 are shown in **Figure 21**. It is found that the CR-UWB antenna has omnidirectional radiation patterns in the H-plane and it

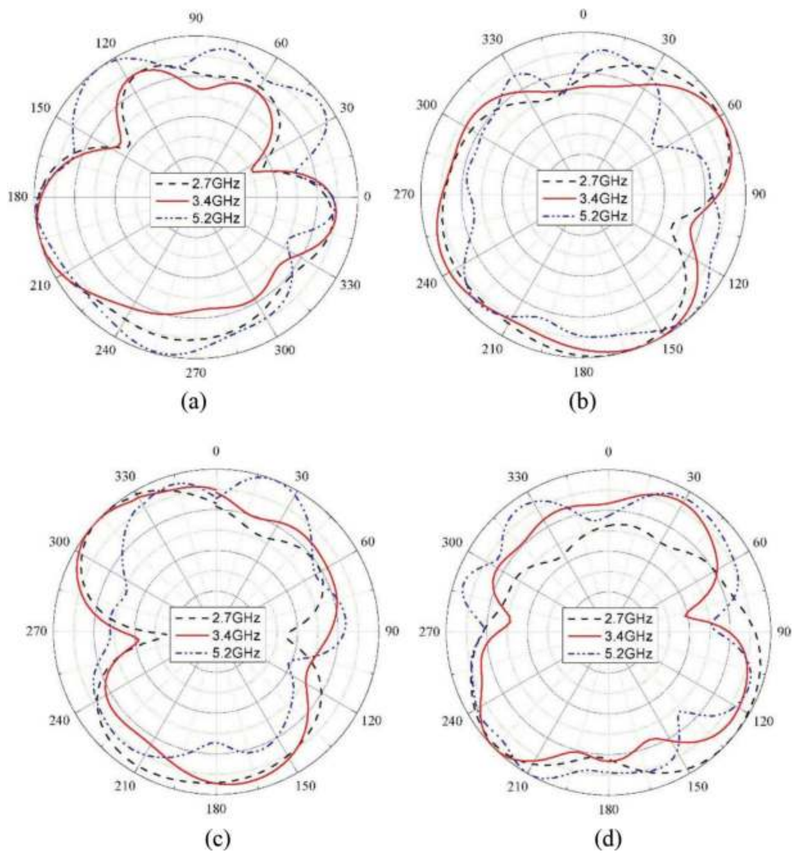

Figure 21. Radiation patterns of the CR-UWB antenna. (a) E-plane of mode 4. (b) H-plane of mode 4. (c) E-plane of mode 5. (d) H-plane of mode 5.

can provide eight-like radiation patterns in its E-plane, which render the CR-UWB antenna suitable for multiple mode communication requirements. The radiation patterns in other modes are similar as the mode 4 and mode 5.

4. Conclusion

In this chapter, UWB antennas for CR communication have been reviewed. The DMS-based stop-band filter, UWB antenna, band-notched UWB antenna and reconfigurable UWB antenna have been discussed to construct a CR-UWB antenna. The CR-UWB antenna has been realized by integrating desired DMS-based stop-band filters and radio frequency switches into a UWB antenna. The DMS-based filters were used to create the notches to filter out the unwanted narrowband interference signals, while the switches control the reconfigurable modes of the antenna. The antenna is designed step by step and it is analyzed in detail. The results showed that the CR-UWB antenna can be used to switch between different modes and it can be used as UWB antenna, band-notched UWB antenna and multiband communication systems.

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