

Design of Dual Band Notch UWB Monopole Antenna Using Dual-Arm Spiral Resonator

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Abstract—An ultra wideband (UWB) monopole antenna with dual band-notch characteristic is proposed. Dual arm spiral resonators (DASR) are placed on both sides of the feed line to create band notches at 5.25 and 5.8 GHz for the upper and lower WLAN bands respectively. First the antenna is optimized individually for both upper and lower WLAN band-notch behaviors then embedded together for dual band-notch characteristic. The measured results ensure that two band notches are achieved, and the antenna can be used for UWB applications without any interference from WLAN band.

1. INTRODUCTION

Since the Federal Communication Commission (FCC) approved the frequency band from 3.1 GHz to 10.6 GHz for ultra-wideband (UWB) technology [1], a new era is open for fast wireless transmission. As a key component of UWB system, UWB antenna attracted many researchers of both academia and industry, because of its application in high data-rate wireless communication, imaging systems, high-accuracy radars, and in medical applications. However, antenna designs for UWB communication face many challenges which include electromagnetic interference (EMI) of WLAN band (5.15–5.35 GHz and 5.725–5.825 GHz). These sub-bands may affect the performances of UWB devices. Therefore, it is necessary for UWB antenna to suppress these narrow frequency bands. In the literature, various methods have been proposed to reject these sub bands, and the most common method is to etch slot either on radiating patch [2,3] or on feedline [4] and over ground plane [5–7]. Attaching parasitic strip with the radiating patch or ground plane are other alternatives used by many researchers [7–10]. Metamaterial structures such as complement split ring resonator (CSRR) and electromagnetic band gap (EBG) structures are also used to generate band-notched characteristic [11, 12].

However, most of the reported antennas reject the entire 5–6 GHz frequency band, which is much wider than the needed. Therefore, the useful spectrums are wasted. Also four EBG cells have been used to get the single band notch in [12], so to get the dual band notches we need to increase the number of EBG cells and hence the size of the antenna. Various EBG structures have been introduced in literature for different microwave applications [12–17]. In this paper, we present a dual band-notch monopole antenna with dual arm spiral resonators (DASR) to get the band-notch characteristic.

The proposed structure gives a better performance than the structure reported with four EBG cells [12]. The DASR are optimized using transmission line model (Figure 1(a)), and its return loss characteristic is shown in Figure 1(b). The two DASR of different dimensions are placed near the feedline to notch lower WLAN (5.15–5.35 GHz) and upper WLAN (5.725–5.825 GHz) bands. The CST Microwave Studio 2012 software is used for the design and optimization of antenna.

Received 17 January 2014, Accepted 4 March 2014, Scheduled 13 March 2014

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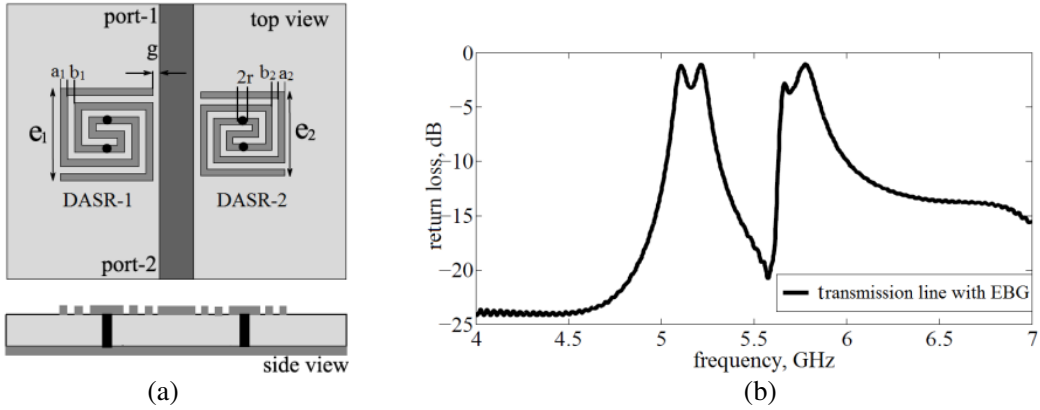


Figure 1. (a) Transmission line model and (b) return loss characteristic.

2. ANTENNA DESIGN

The proposed planar band-notch antenna consists of radiating patch on the top of substrate and a partial ground plane on the bottom as shown in Figure 2. The radiating patch is of rectangular shape with a dimension of $W_P \times L_P$ and tapered by 51° at bottom corners to increase the percentage bandwidth (Figure 2(a)). The ground plane (Figure 2(b)) consists of a partial ground plane of length L_g with three equal slots of width (W_s) and length (L_s). These slots are etched out to improve the impedance matching between the feed line and radiator. The antenna is fed by microstrip line of width W_f and length L_f to achieve a 50Ω characteristic impedance.

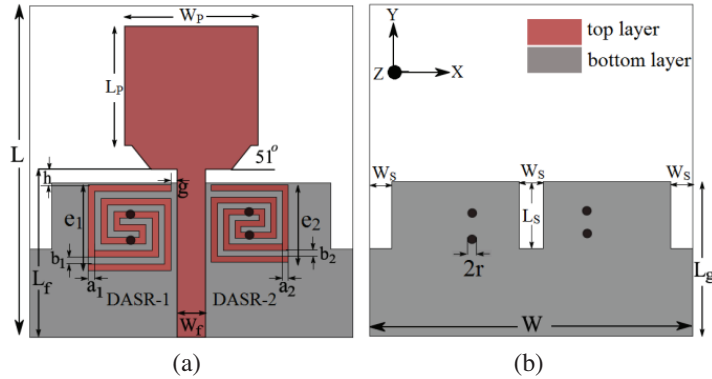


Figure 2. Geometry of the proposed antenna. (a) Front view and (b) back view.

For dual band-notch characteristic at lower (5.2 GHz) and upper (5.8 GHz) WLAN bands, the UWB antenna is optimized individually with DASR and then embedded together as shown in Figure 2. Figures 3(a) and (b) show the geometry of lower and upper WLAN band notched UWB antenna. For lower WLAN band notch characteristic, DASR-1 of width (a_1) and spacing (b_1) is placed near the feedline at a distance of h from radiating patch, with gap g from feedline as shown in Figure 3(a). However, for upper WLAN band-notched characteristic, DASR-2 of width (a_2) and spacing (b_2) is placed on the other side of the feedline with gap g and at a distance h from the radiating patch as shown in Figure 3(b). Both DASR-1 and DASR-2 are shorted to ground using two vias of diameter $2r$ to provide a better resonance. DASR are optimized for the desired band by varying width and spacing of spirals, while keeping the via dimension same. This can be understood from the impedance equations of parallel resonant LC (1).

$$Z = j\omega L / (1 - \omega^2 LC) \quad (1)$$

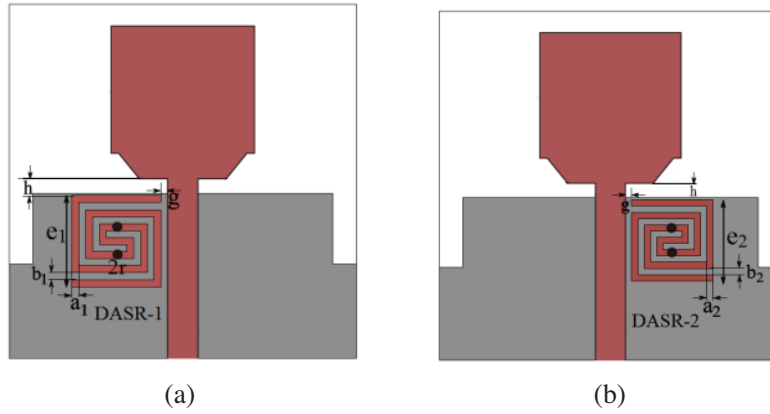


Figure 3. Geometry of antenna for (a) upper WLAN band notch behavior and (b) lower WLAN band notch behavior.

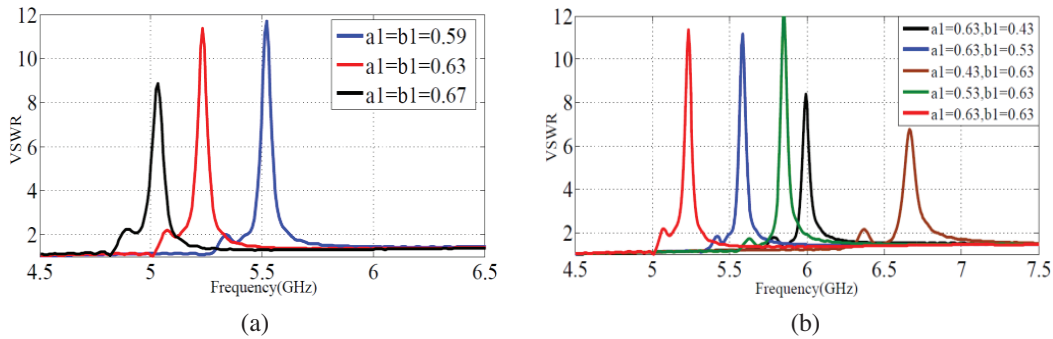


Figure 4. (a) Optimization of lower WLAN band notch behavior when (a) $a_1 = b_1$ and (b) $a_1 \neq b_1$.

Table 1. Optimized dimensions of fabricated antenna in mm.

L	W	W_f	L_f	L_g	W_p	L_p	W_S	L_s
32	32	2.8	16.2	14.9	13.2	11.5	2.2	6.4
E_1	E_2	b_1	b_2	a_1	a_2	g	h	r
8.12	7.47	0.63	0.57	0.63	0.57	0.6	1.6	0.35

where resonant frequency is given by,

$$\omega_0 = 1/\sqrt{LC} \tag{2}$$

Figure 4 shows the variation in a_1 and b_1 for the optimization of DASR-1. Figure 5 shows the variation in a_2 and b_2 for the optimization of DASR-2. From Figures 4(a) and 5(a), we can notice that as the width and spacing increase the resonant band shifts towards lower frequency. This can be understood from Eqs. (1)–(2) that as the width and spacing increase the overall size of DASR increases which leads to larger capacitance and inductance. Thus the resonant frequency decreases with increase in inductance and capacitance. The effect of variation in width and spacing in different combinations, over notched band, is also examined as shown in Figures 4(b) and 5(b). It is clear from Figure 5(b) that as width or spacing decrease while keeping the other constant, the resonant band shifts toward higher frequency. Reducing the width and spacing decreases the overall size of DASR, which leads to a lower capacitance. The final optimized dimension for the antenna is listed in Table 1 and printed on FR4 substrate of dielectric constant 4.4 and thickness 1.6 mm.

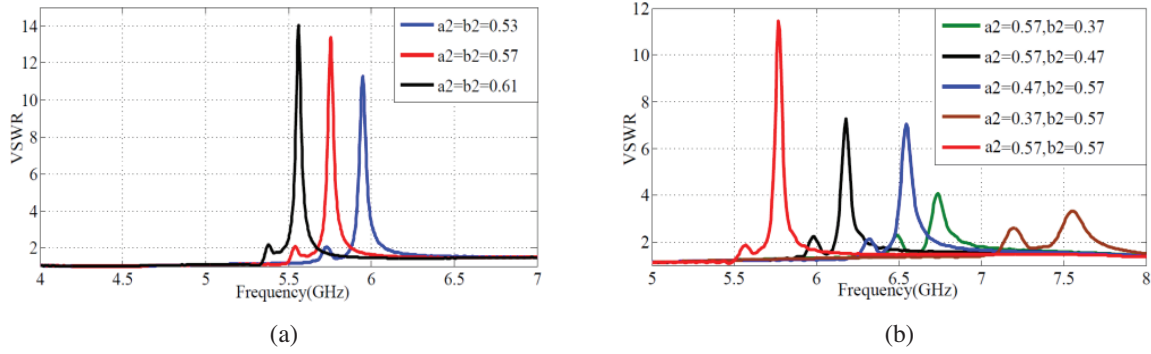


Figure 5. Optimization of upper WLAN band notch behavior when (a) $a_2 = b_2$ and (b) $a_2 \neq b_2$.

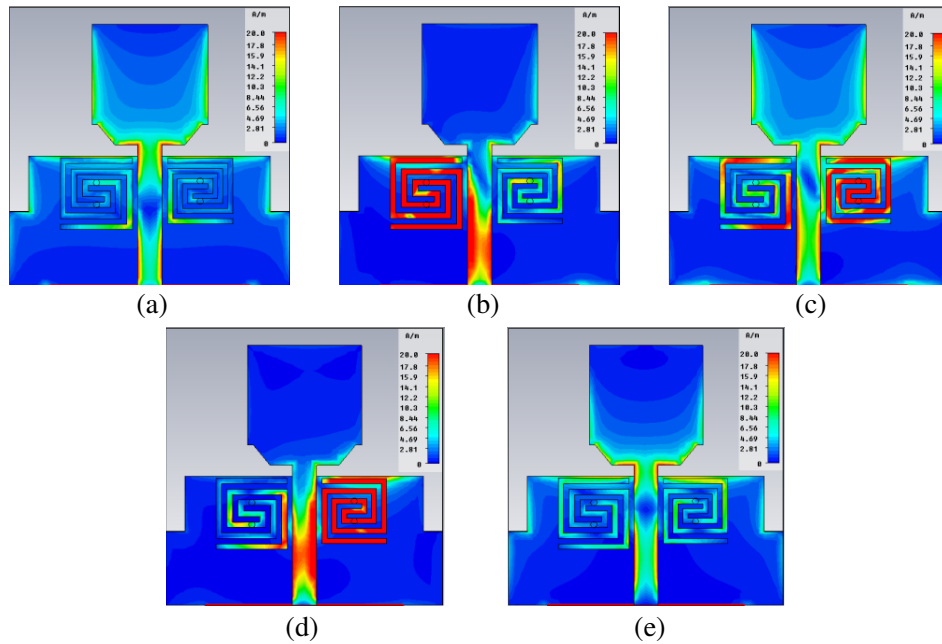


Figure 6. Surface current distributions at (a) 4 GHz, (b) 5.2 GHz, (c) 5.5 GHz, (d) 5.8 GHz, (e) 7 GHz.

3. RESULTS AND DISCUSSION

For understanding the operational mechanism of the proposed antenna with dual band-notched functions, simulated current distributions at 4, 5.2, 5.5, 5.8 and 7 GHz are shown in Figures 6(a), (b), (c), (d) and (e), respectively. It can be observed from Figures 6(a), (c) and (e) that the current distributions on DASR-1 and DASR-2 are weak at 4, 5.5 and 7 GHz, and most of the current flows through the radiating patch, resulting in radiation on these frequencies. However, the current distribution at 5.2 GHz is mainly concentrated over the DASR-1, while the negligible current flows through radiating patch and DASR-2 as shown in Figure 6(b). Figure 6(d) shows that the current distribution at 5.8 GHz is high over DASR-2 and very weak on radiating patch and DASR-1. It indicates that the two DASR are operating as band reject filter.

The simulated and measured VSWR of the proposed band-notched UWB antenna are shown in Figure 7(a). It can be observed that the designed antenna covers a wide bandwidth from 3.34–10.54 GHz except the notched bands from 5.07–5.32 GHz and 5.67–5.9 GHz. Therefore, without wasting the useful band from 5.35–5.75 GHz, the proposed antenna can reject interference from any wireless system. The simulated radiation efficiency of the antenna without DASR is compared with the proposed antenna as

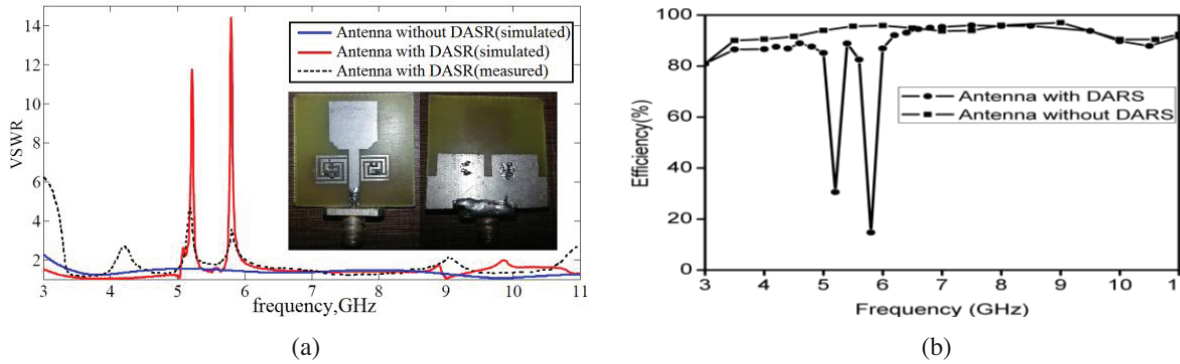


Figure 7. (a) Simulated and measured VSWR of the proposed antenna, (b) antenna efficiency.

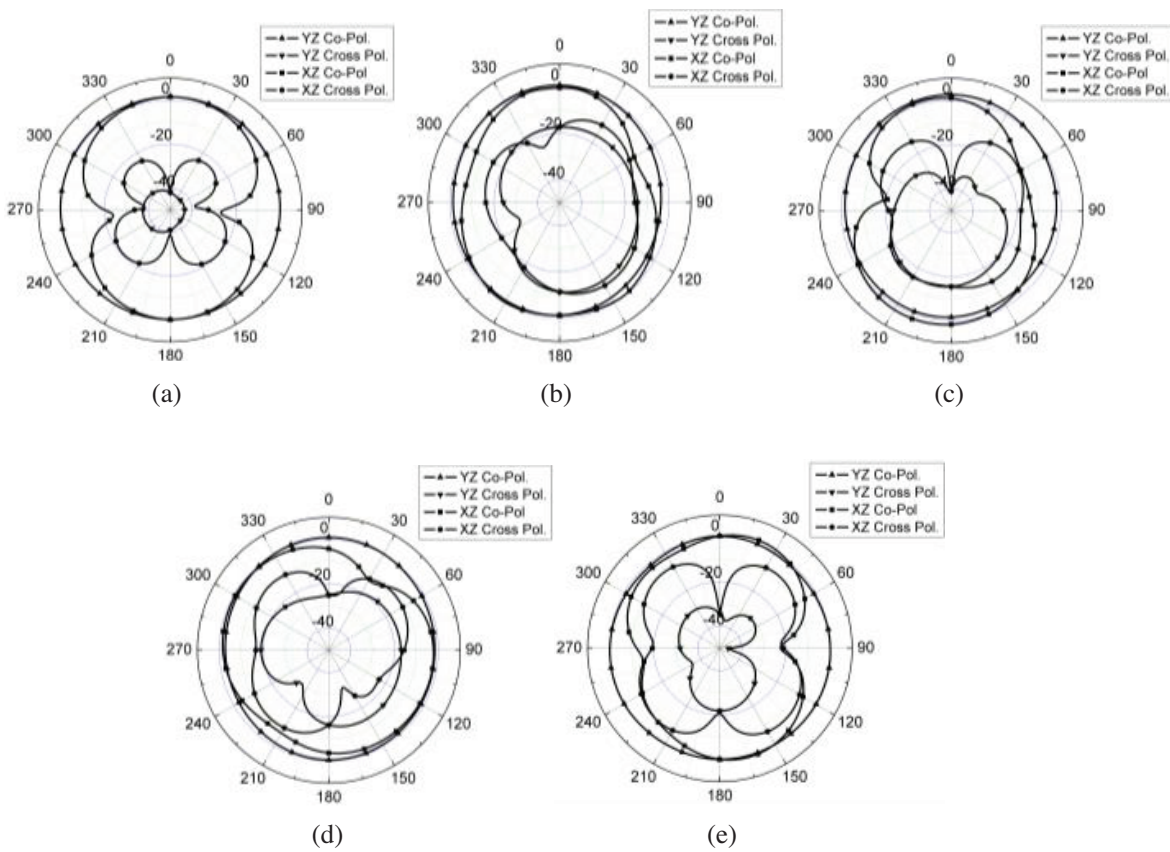


Figure 8. Simulated radiation patterns at (a) 3.5 GHz, (b) 5.2 GHz, (c) 5.5 GHz, (d) 5.8 GHz, (e) 7.5 GHz.

shown in Figure 7(b). It is observed that with DASR, antenna efficiency is reduced by 2%.

The simulated co- and cross-polarization patterns of proposed antenna at 3.5, 5.2, 5.5, 5.8 and 7.5 GHz in XZ and YZ plane are shown in Figures 8(a), (b), (c), (d) and (e). Magnitude of the cross-polar component increases with the increase in frequency, and at the notch frequency cross-polarization level is high and almost the same as co-polar component. Hence the gain of the antenna reduces to a lower level at the notch band. Measured co-polarized radiation patterns in XZ and YZ planes at 3.5, 5.5 and 7.5 are shown in Figures 9(a), (b) and (c). It can be noticed that the antenna exhibits nearly omnidirectional radiation pattern in H-plane and a dipole-like radiation pattern in E-plane. The simulated and measured gains of the proposed antenna are shown in Figure 10(a). It can be observed

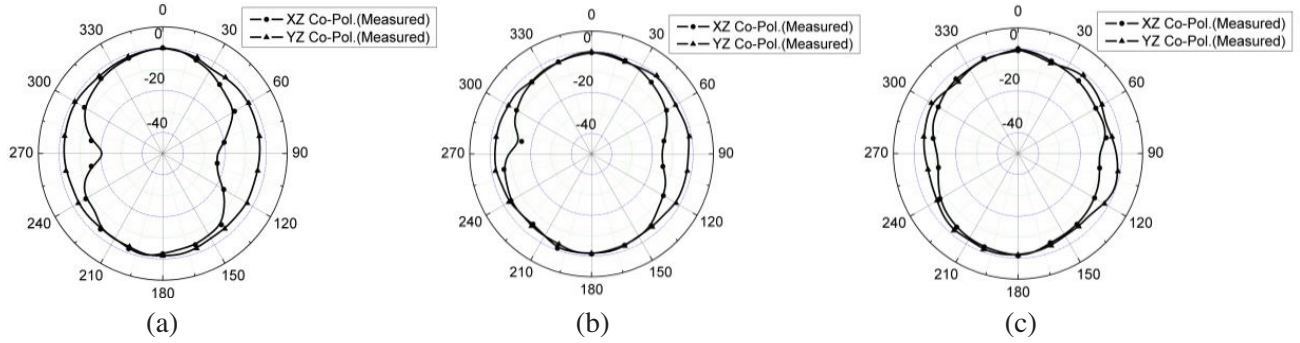


Figure 9. Radiation patterns (measured) at (a) 3.5 GHz, (b) 5.5 GHz and (c) 7.5 GHz.

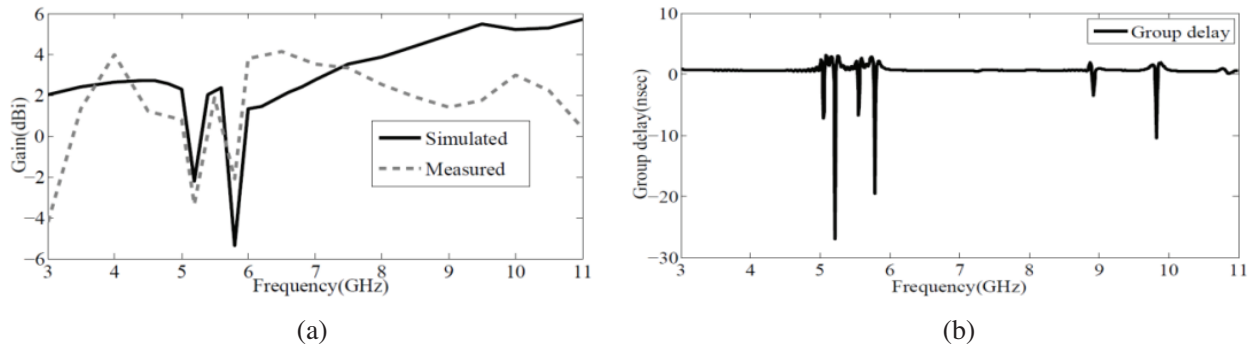


Figure 10. (a) Gain characteristic and (b) group delay characteristic.

that the realized gain is below 0 dBi between 5.07–5.32 GHz and 5.67–5.9 GHz with minimum value of -3.8 dBi at 5.2 GHz and -2.1 dBi at 5.8 GHz. A good agreement between the simulated and measured results is achieved. The little disagreement is mainly caused by the fabrication error as well as the environments of the measurement. The simulated group delay of the antenna is shown in Figure 10(b). The variation of the group delay is within 2 ns across the whole band except the notched band.

4. CONCLUSION

A monopole UWB printed antenna with dual band-notched characteristic for the lower and upper WLAN bands has been presented and discussed. The two compact DASR (DASR-1 and DASR-2) are placed on both sides of the feedline to create band notch at 5.2 and 5.8 GHz. The current distributions over notched bands are used to explain the working mechanism of the proposed antenna. Good agreement between simulated and measured results ensures that the proposed DASR can be used for band-notch applications.

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