Design of the Novel Band Notched UWB Antenna with the Spiral Loop Resonators

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Abstract — In this paper, a novel configuration of circular ultra-wideband (UWB) antenna with band rejection characteristic is presented. In order to obtain this characteristic, the spiral loop resonators resonating at the rejection frequency are located in both sides of the circular radiating patch. This novel structure provides the band-notched characteristic without the degradation of the UWB antenna performance itself. Furthermore, the notched band can be easily tuned by adjustment of resonator dimension because the size of the spiral loop resonators controls the corresponding resonance frequency. This prototype antenna has been fabricated on a substrate, Rogers 4003, with the thickness of 0.8 mm and relative permittivity of 3.38. The fabricated UWB antenna covers the frequency band from 3.1 to 11.23 GHz ($S_{11} \leq -10$ dB), and the band rejection characteristic appears near at 5.8 GHz band to which the wireless LAN service is assigned. And the far-field radiation patterns of the proposed antenna show omnidirectional and stable over the whole frequency band, which prospects the deployment in the UWB system. The measured results agree well with the simulation by the Microwave Studio of CST. This novel technique utilizing the spiral loop resonators might be useful to the planar antennas requiring the band rejection characteristics.

1. INTRODUCTION
The ultra-wideband (UWB) antennas have been widely adopted in communication systems of commercial and military domains. Because of its attractive features, such as low cost, small size, and easy fabrication, the printed ultra-wideband antenna has been a topic of intense research over the last ten years. The UWB communication uses the spectrum from 3.1 GHz to 10.6 GHz, unfortunately, WLAN 802.11a/n also uses the collision spectrum from 5.15 GHz to 5.825 GHz. Thus, there should be a way of avoidance to get out of interference between UWB and WLAN communication systems. For many years, various UWB antennas with a notch function have been developed to overcome this annoying mutual interference problem by resorting to a various shape slot patch and slot ground [1–4]. Recently, several research groups have attempted to reject the unwanted WLAN frequency bands using the metamaterial resonator such as the SRR (split ring resonator) or the CSRR (the negative image of SRR) structure [5–7]. Because the metamaterial resonator can be considered as an electronically small resonator with a very high Q, it has been used to be respective structure in constructing filters requiring a sharp notch or pass of a certain frequency band. In this paper, the spiral loop resonator (SLR) different in structure from the SRR and CSRR has been utilized, although the basic mechanism is the same to both type.

The characteristics of the SLR for the size reduction of antenna and metamaterial insulator have been already studied by several groups [8–10]. They have established the major theory and illustrated a large portion of experimental results on the SLR as a metamaterial resonator. However, there are few investigations on the interference protection method based on the SLR. Due to lack on these studies, our presentations are likely to be focused to this topic in terms of the known SLR principle.

In this article, a novel design method of the printed ultra-wideband antenna with unwanted band notched characteristics is proposed. By adjusting and tuning on the length of SLR, the desired band rejection performance can be obtained.

2. ANTENNA DESIGN
The geometry of the proposed unit cell of the SLR is shown in Figure 1. The spiral loop acts as an inductor, coupling energy from an incident time-varying magnetic field to produce a current loop in the spiral. There is a distributed capacitance and inductance between the loops of the spiral, and the interaction between the spiral inductance and spiral capacitance causes the resonant behavior.
So, the design method of the SLR is similar to the design of SRR and CSRR. According to the published literature on the CSRR analysis, $S$-parameter of basic resonator cell on 50Ω microstrip transmission line are simulated by the electromagnetic simulator firstly, which allows to decide the size of resonator by observing the stop band frequencies [11–13]. To apply the same method to SLR, a model of complementary SLR loaded on the microstrip transmission line and the resultant $S$-parameter are shown in Figures 2(a) and (b), respectively. Figure 2(a) is mounted on RO4003 (thickness $h = 0.812\,\text{mm}$, $\varepsilon_r = 3.38$ and $\tan\delta = 0.0027$) substrate, and optimized by using the CST Microwave Studio (MWS) simulation software. To the unit cell of resonator, the outer length of resonator is $L_1 = 3.3\,\text{mm}$, spiral loop has a constant line width $w = 0.4\,\text{mm}$, and the rest of values are $c = 0.4\,\text{mm}$, $d = 0.7\,\text{mm}$. These physical parameters of the simulated resonator on microstrip
transmission line have the band stop characteristic at the attenuation pole of 6 GHz in rejection band. As a simulation finding, many resonance frequencies are observed when the length of the SLR is adjusted. A series of this step is useful to the design of the proposed antenna. Figures 3(a) and (b) show the geometry of the prototype UWB antenna without the SLR and the proposed band notched UWB antenna, respectively. As shown in Figure 3(a), two sets of the SLRs are stuck on both sides of circular radiating patch. And design of the proposed antenna is based on a traditional UWB antenna with the circular shape patch and the CPW fed as shown in Figure 3(b), and two antennas have the same size and same shape except for resonator of band notched UWB antenna. These UWB antennas have a size of 38 × 38 mm$^2$ and are fed by a microstrip line of length $(L_2 + Sl) = 9.1$ mm, and width $Wl = 2.84$ mm, which is connected with an SMA connector. And two feed lines with a gap $Sg = 0.27$ mm on each side form a coplanar waveguide (CPW) fed transmission line of the characteristic impedance $Z_0 = 50 \Omega$. A circular radiating patch has a radius $R = 10.5$ mm, and the distances of gap between other elements (the ground plane and SLRs) are $Sl = 0.3$ mm, $gl = 0.1$ mm. On the same side of the dielectric substrate (Rogers RO 4003, $h = 0.812$ mm), the ground plane with two rectangular notches ($Tl = 1$ mm, $Tw = 1.5$ mm) are used. These antennas are simulated by the same simulation software of the Microwave Studio.

3. RESULT AND DISCUSSION

Figure 4 shows the photographs of the fabricated band notched UWB antenna. Its performance is measured by the Anritsu 38397C network analyzer. The simulated result and measured results are shown in Figure 5, and are in good agreement between them. According to the measured return loss curves on the general UWB antenna and the proposed band notched UWB antenna, it covers

![Figure 4: The fabricated band notched UWB antenna.](image1)

![Figure 5: Comparison of simulated results and measured results.](image2)

![Figure 6: Measured radiation patterns for the proposed band notched UWB antenna. (a) E-plane, (b) H-plane.](image3)
the band (3.1 GHz ∼ 10.6 GHz) assigned for the UWB communication applications. And measured notched bands (reference level $S_{11} = -10$ dB) are 5.91 GHz ∼ 6.15 GHz and 240 MHz bandwidth. The return loss plotted in Figure 5 indicates that the SLR is operated only at the notched band, and it ensures that adjustment of the outer length of SLRs can tune a notched band to the goal. Figure 6 represents the radiation patterns of $E$-plane and $H$-plane at 4 GHz, 6 GHz and 8 GHz. The pattern seen in Figure 6 reveals that the receiving power level is relatively low at notched band 6 GHz and the pattern of the other bands is omnidirectional and remains stable. And furthermore, it says that the application of SLRs can eliminate the 6 GHz frequency band involved in the original UWB antenna structure.

4. CONCLUSION

This paper presents a new technique on how to impose the band rejection property to the prototype UWB antenna. To this end, the SLRs were inserted into the both sides of the radiating patch of the UWB antenna. Especially, the synthesis approach on a traditional UWB antenna to add the complementary SLR has been attempted to achieve the band rejecting property. This technique shows an easy fabrication, cost down merit, and attractive means for the UWB antenna oriented applications.

REFERENCES