Design of a UWB Antenna with Band-Notch Function

Zeng Fanli · Jaewon Lee · Chulhee Kim · Jaehoon Choi

Abstract

In this paper, a compact wideband antenna with a band-notch function is proposed. It operates over the UWB band with a band-stop characteristic. To increase the impedance bandwidth, a ring-shaped radiator is used. By attaching a circular stub to the ring-shaped radiator, the band-notch performance is obtained. The proposed antenna operates over a frequency range from 2.7 GHz to 11 GHz to satisfy the 10-dB return-loss requirement and provides band-stop performance in the frequency band from 5.15 GHz to 6.1 GHz. Experimental results reveal that the proposed antenna exhibits good radiation performance and is suitable for UWB applications.

Key words : Band Notch, Circular Stub, Ring Radiator, UWB, WLAN.

Ⅰ. Introduction

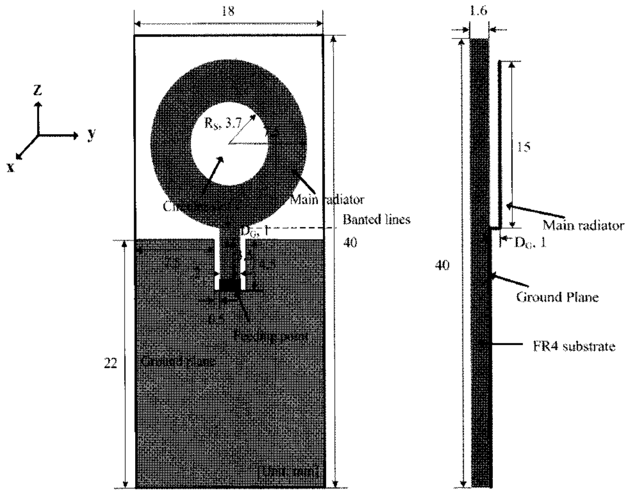
Since the release by the Federal Communications Commission(FCC) of a wide spectrum for an ultra-wideband(UWB) system in 2002[1], UWB technology has received considerable attention. UWB systems have been widely considered as an alternative to conventional wireless systems due to their advantages, such as portable size, low power consumption, and high data rate. Due to the attractive performance of UWB systems in providing wide bandwidth and a reasonable radiation pattern, planar monopole antennas[2]~[5] have been investigated for wireless UWB systems. Among them, circular monopole antennas[3]~[5] have simple structure and wideband characteristics. However, since the allocation of the 5-GHz frequency band to WLAN(5.15 GHz to 5.825 GHz) services, a band-stop filter in UWB systems has been necessary to avoid interference between UWB and WLAN services. To avoid the increasing complexity of the UWB system due to the use of a band-stop filter, UWB antennas with a band- stop function have been investigated using slots of various shapes[6],[7], tuning stubs[8], spurline[9], and parasitic elements[10].

In this paper, we propose a compact UWB antenna that uses a circular stub in order to achieve the band-stop characteristic. Wideband performance is obtained by choosing a ring radiator connected to a circular stub to provide band-notch functionality. The antenna is mounted on the top portion of the ground plane. Critical parametric analysis, measured and simulated return-loss characteristics, and radiation patterns are presented.

Ⅱ. Antenna Design

2-1 Wideband Antenna Design

Fig. 1 shows the configuration of the proposed antenna, which consists of a circular radiator with a circular slot and a circular-shaped stub. In the antenna design, the circular slot is inserted into the main radiator to obtain the wideband characteristic. The antenna and ground plane are fabricated on the FR4 substrate with a dielectric constant of 4.4 and thickness of 1.6 mm. A 50 Ω feed line and circular main radiator are attached to the top of the substrate. The length of the feed line is fixed at 3.5 mm, which is about $\lambda/8$ at 10.6 GHz(the



(a) Front view (b) Side view

Fig. 1. Geometry of the proposed UWB antenna.

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highest frequency of a UWB band). The main radiator is bent and separated by a distance of D_G from the substrate, as shown in Figs. 1(a) and 1(b). The dimensions of the antenna are 40×18×2.6 mm. The dimensions of the ground are fixed at 22×18 mm, which is the system ground size of a typical USB dongle device. Fig. 2 shows the simulated return- loss characteristics for various radii(R_S) of the circular slot from 2.7 mm to 4.7 mm. It is clear that the impedance matching depends largely on the inner radius of the ring-shaped radiator.

Fig. 3 illustrates the simulated return-loss characteristics at various distances(D_G) between the main radiator and ground plane. As shown, the impedance bandwidth reaches its maximum at D_G=1 mm, at which the impedance bandwidth becomes about 8 GHz(from 2.72 GHz to 10.98 GHz). One can conclude that the parameters R_S and D_G are the factors that determine the upper operating frequency, impedance bandwidth and impedance matching.

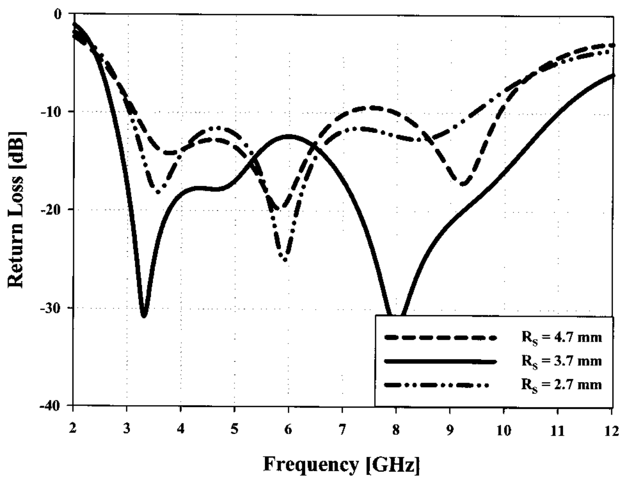


Fig. 2. Return loss characteristics for various values of R_S(D_G is fixed at 1 mm).

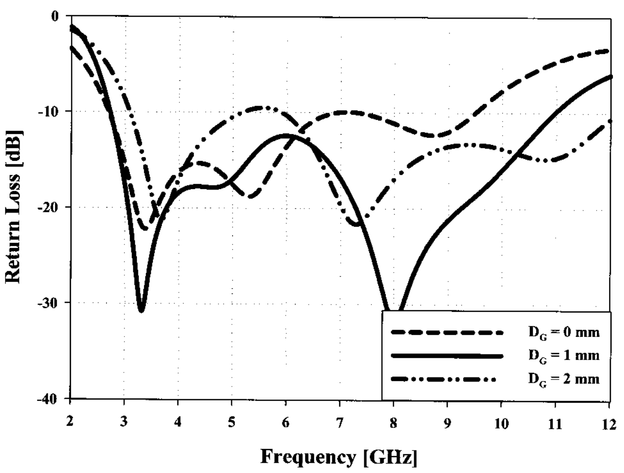


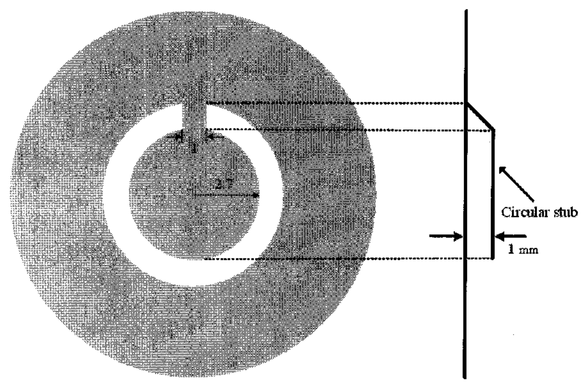
Fig. 3. Return loss characteristics for various values of D_G(R_S is fixed at 3.7 mm).

2-2 Design of a Wideband Antenna with Band-stop Characteristic

To obtain the band-stop performance, the circular stub is attached to the main radiator, as shown in Fig. 4. The circular stub generates additional surface currents, which are flowing in a direction opposite to that of the main radiator, as shown in Fig. 5. The field radiated by this opposite current will cancel that of the main radiator. Fig. 6 shows the return-loss characteristics for the various radii of the circular stub. The stop-band frequency is controlled by changing the radius of the circular stub.

Ⅲ. Measured Results

A picture of the fabricated antenna is shown in Fig. 7.



(a) Detailed view (b) Side view

Fig. 4. Detailed configuration of the main radiator with circular stub.

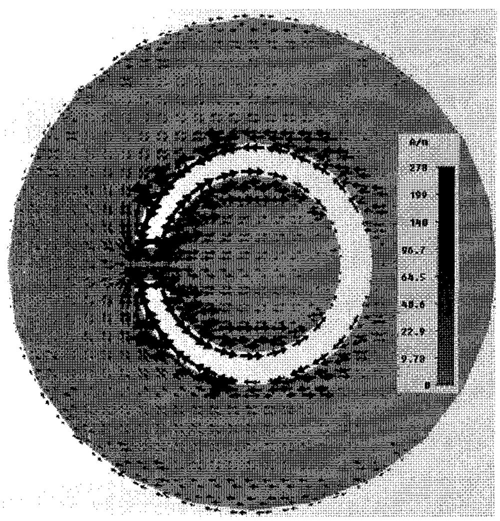


Fig. 5. Surface current distributions at 5.6 GHz.

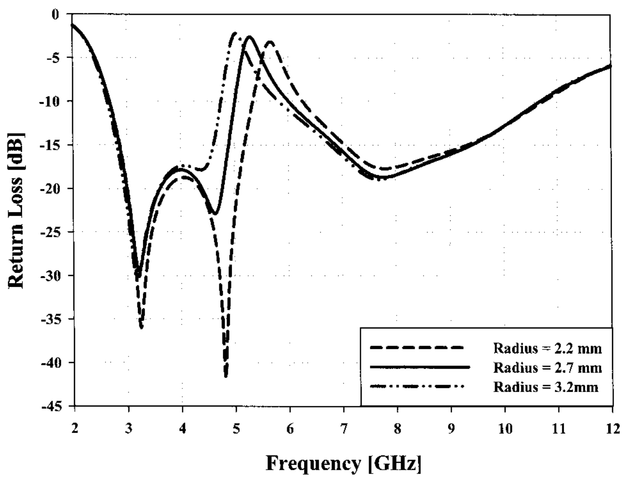


Fig. 6. Calculated return loss characteristics for various radii of the circular stub.

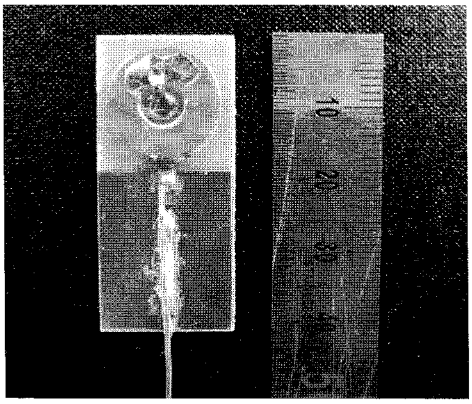


Fig. 7. Photograph of the fabricated antenna.

The impedance performance of the proposed antenna was measured using the HP 8719 ES network analyzer. Fig. 8 shows the measured return-loss characteristics with and without the circular stub. When the circular stub is absent, the 10-dB return-loss bandwidth is about 8 GHz(2.6 GHz to 10.65 GHz). When the circular stub is present, the impedance bandwidth is 8.3 GHz(2.7 GHz to 11 GHz), including the stop-bandwidth of 0.95 GHz(5.15 to 6.1 GHz).

The measured radiation patterns for the UWB antenna with and without the circular stub in x-y, y-z, and z-x planes are plotted in Fig. 9. These radiation patterns show that the proposed antenna behaves quite similarly to typical printed monopoles.

Fig. 10 shows the measured gain of the proposed antenna with and without a stub. The gain drops sharply around 5 GHz, as expected. The gain variation is about 2.98 dB, except for the stop-band.

Fig. 11 shows the measured group delay characteristic of the proposed UWB antenna. In the UWB system, the phase of the radiated field should vary linearly with the frequency. That is, a stable group delay response is desirable. The group delay, τ_g, is defined[11] as

$$\tau_g = -\frac{\partial\phi}{2\pi\partial f} \quad (1)$$

where ϕ is the far-field phase and f is the frequency.

In order to obtain the group delay characteristic, two identical antennas were connected to a network analyzer (Agilent's 8719ES, which converts the frequency domain data into the time domain using a chirp-Z Fourier transform with time domain option)[12]~[14]. The distance between the two antennas was 300 mm due to the low-output powers of the network analyzer and the identical face-to-face arrangement of the antennas. It can be observed from this result that the group delay variation of the proposed antenna is less than 0.72 ns, except for the stop-band frequency. In the vicinity of the stop-band, the group delay variation greatly exceeds 1 ns, which can deteriorate phase linearity.

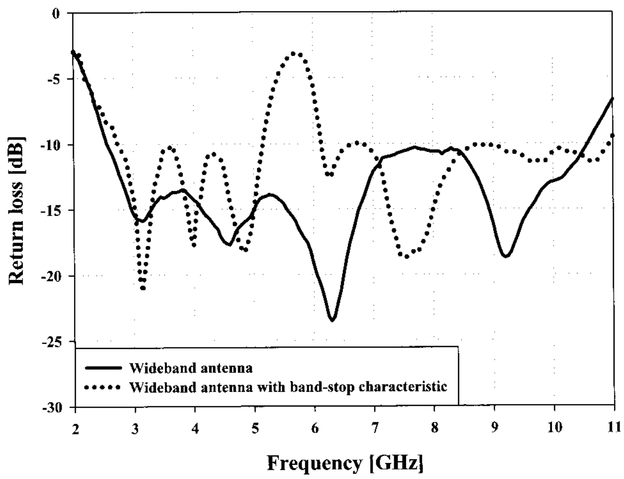


Fig. 8. Measured return loss characteristics with and without the circular stub.

Ⅳ. Conclusion

A wideband antenna with a band-stop function for the WLAN service(5.15 GHz to 5.825 GHz) has been proposed. The antenna consists of a circular radiator with a circular slot and a circular stub. The overall dimensions of the antenna are 40×18×2.6 mm. The impedance bandwidth of the designed antenna is 8.3 GHz(2.7 GHz to 11 GHz), including a stop- bandwidth of 0.95 GHz (5.15 GHz to 6.1 GHz). The measured gain variation is about 2.98 dB, except for the stop-band. The overall antenna characteristics are sufficient for UWB application.

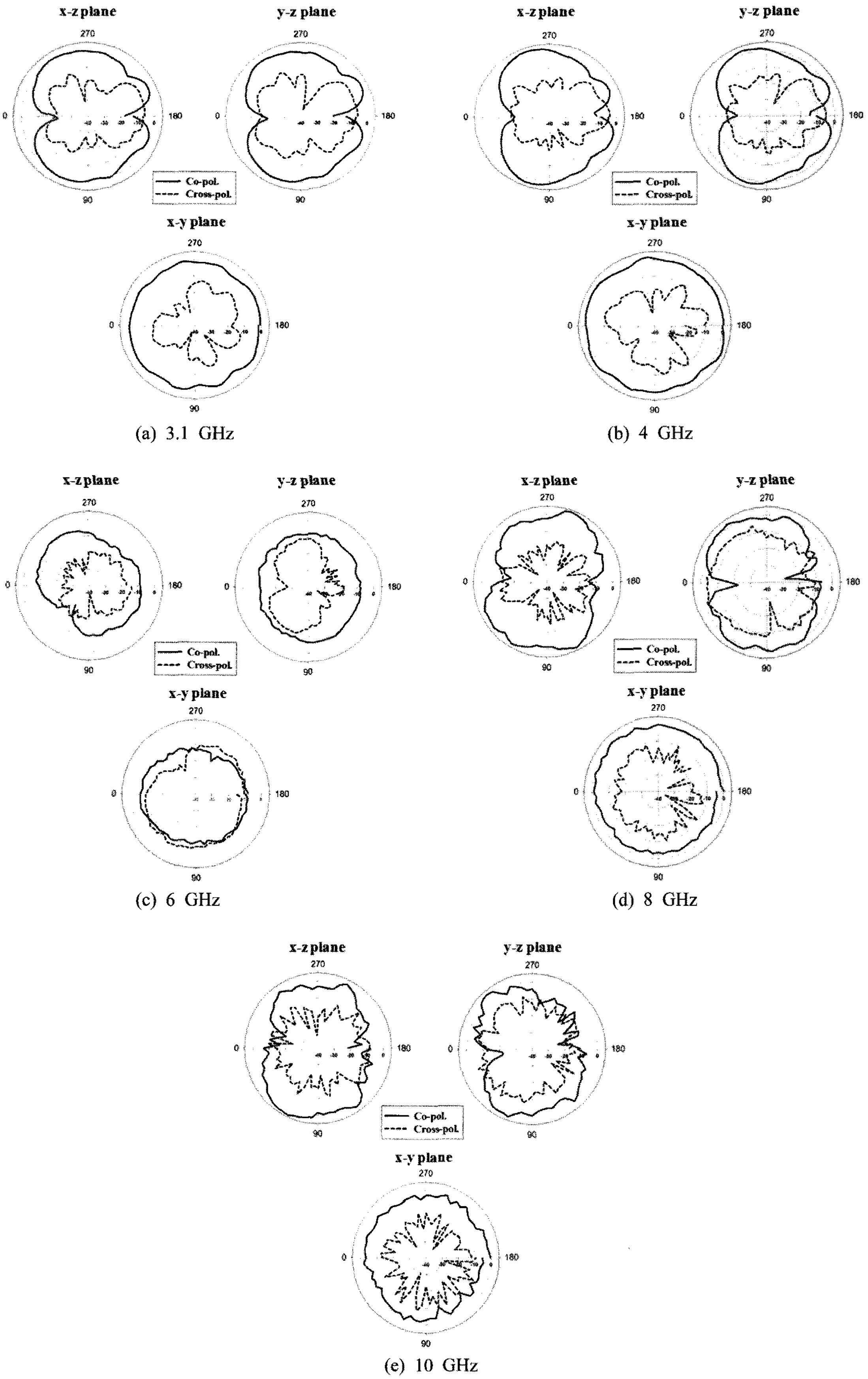


Fig. 9. Measured radiation patterns of the proposed antenna.

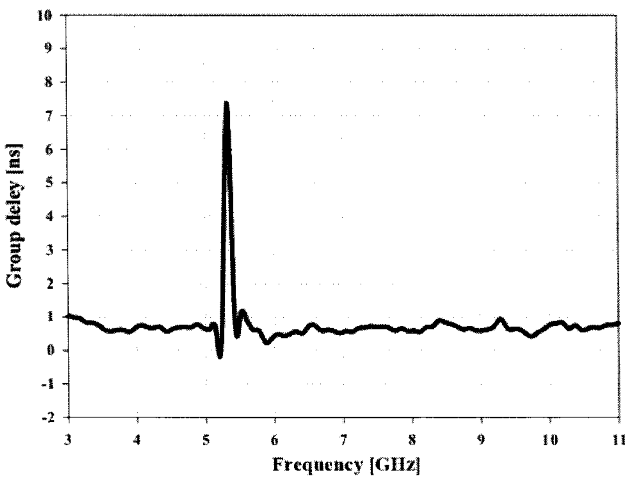


Fig. 10. Measured antenna gain characteristics for the proposed antennas.

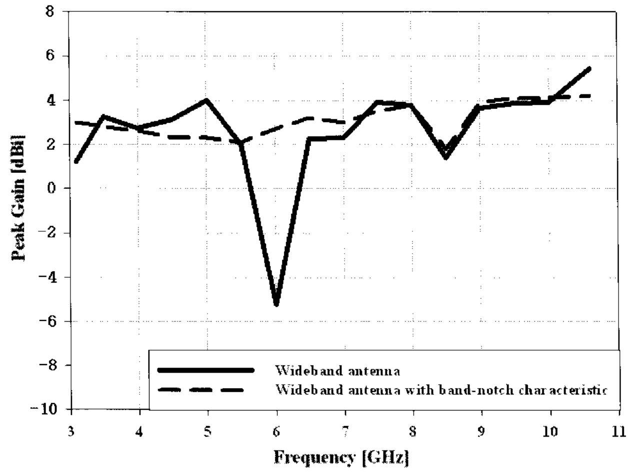


Fig. 11. Measured group delay characteristics.

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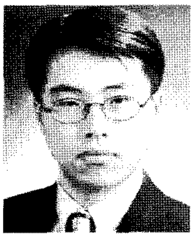

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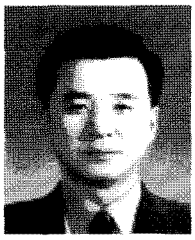

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