Miniaturization of an Ultra-Wideband Antenna with Two Spiral Elements

Seokjin Hong and Jaehoon Choi

ABSTRACT—In this letter, novel antennas with two spiral elements are presented for ultra-wideband application. The original antenna consists of a T-shaped microstrip feed line, two spiral radiating elements, and a ground plane with two circular slots. It measures 30 mm × 40 mm × 1.6 mm. Spiral elements are used to increase the lower bandwidth limit. To further reduce the size of the antenna, the original antenna is cut in half by using the symmetry of the surface current distributions. The proposed antennas feature omnidirectional radiation patterns and good gain flatness.

Keywords—Antenna, miniaturization, planar antenna, spiral antenna, ultra-wideband (UWB).

I. Introduction

An ultra-wideband (UWB) system is a very promising technology for short-range wireless communication with high data rates as it can take advantage of the large bandwidth allocated for UWB systems by the FCC in 2002 [1]. Designing a wideband antenna for use in a UWB system is a major challenge and has attracted the interest of many antenna engineers [2], [3]. In spite of broadband performance, the antennas proposed in [2] and [3] are not suitable for mobile handset application due to their large size and manufacturing difficulties. Among the newly proposed antenna designs, a spiral structure appears to be promising for wideband application due to its broadband impedance characteristic and compact size. Recently, various spiral antennas have been investigated because of their advantages. First, a spiral antenna can easily generate circular polarization (CP) without the use of other CP techniques [4], [5]. Second, multiband and/or wideband characteristics can be achieved using spiral geometry [6]-[8].

The antenna proposed in [7] has an operating bandwidth of around 66%. By controlling the capacitive coupling between the spiral patch and the strip line connected to the ground plane, wideband behavior is achieved. The antenna proposed in [8] satisfies the 10 dB return loss bandwidth from 6.85 GHz to 11.9 GHz using a balun for higher frequency band applications. However, these antennas do not fully satisfy the UWB bandwidth requirement even using an additional structure to broaden the bandwidth.

In this letter, planar antennas with two spiral elements covering UWB are presented. To widen the impedance bandwidth, a T-shaped microstrip feed line and two spiral elements are adopted. Furthermore, using the symmetry property of the structure, the antenna size can be reduced by half while keeping the impedance performance of the original antenna. The designed antennas were successfully implemented and experimental results are presented.

II. Antenna Design and Miniaturization

1. Antenna Design

The antenna depicted in Fig. 1 is printed on an FR4 substrate 1.6 mm thick with a dielectric constant of 4.4. The antenna is fed by a T-shaped microstrip line and consists of two spiral elements and a ground plane with two circular slots. The bottom width of the T-shaped microstrip line is 2.8 mm for 50 Ω characteristic impedance, while the top width of the microstrip line is 1 mm for 100 Ω characteristic impedance for wideband performance [9]. Two spiral elements are connected to the top of the T-shaped microstrip line. The spiral elements

Manuscript received Sept. 25, 2008; revised Nov. 17, 2008; accepted Dec. 17, 2008.

This research was supported by the MKE (Ministry of Knowledge Economy), Rep. of Korea under the ITRC (Information Technology Research Center) support program supervised by the IITA (Institute of Information Technology Assessment) (IITA-2008-C1090-0810-0019).

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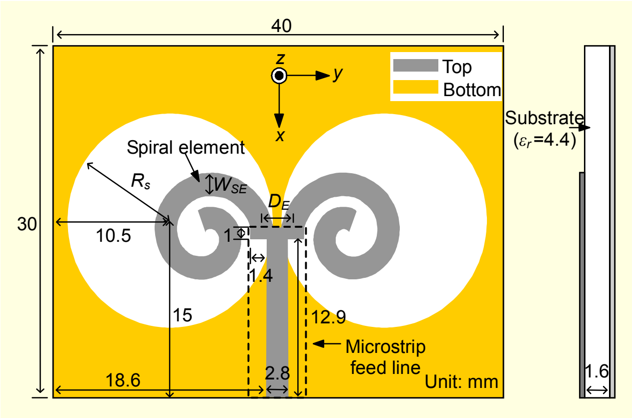

Fig. 1. Geometry of the UWB antenna. D_E=2.8 mm, W_{SE}=2.2 mm, R_S=9.2 mm, and number of turns=1.3.

and two slots on the ground plane are arranged symmetrically with respect to the *x*-axis. The two spiral elements and the microstrip feed line are printed on the top of the substrate while the ground plane is on the bottom. In this design, the number of turns and the width of the spiral element are the key control parameters for the impedance bandwidth in the lower frequency band.

2. Simulation Results

A parametric study was carried out using the Ansoft HFSS [10] to optimize the design. The simulated results for various numbers of turns (N_T) are plotted in Fig. 2(a). It is clear that the impedance bandwidth increases as N_T increases. Figure 2(b) shows the effect of the width (W_{SE}) of the spiral element on the return loss characteristic. As the width of the spiral element widens, the bandwidth broadens. From Figs. 2(a) and (b), it is noted that N_T and W_{SE} are the two key factors for lower impedance matching. By adjusting the size of the spiral element, good impedance matching over the UWB can be achieved. Figure 2(c) shows the return loss characteristics for various distances (D_E) between the two spiral elements. Results indicate that impedance matching for frequencies between 4.5 GHz and 5.5 GHz is sensitive to this parameter.

3. Antenna Miniaturization

The proposed original antenna (shown in Fig. 1) has a symmetrical structure. The symmetrical plane along the *x*-axis can be regarded as a perfect magnetic plane due to the symmetric distribution of surface current and magnetic field distributions [11]. The original antenna size can be further reduced by half as shown in Fig. 3 without significant performance degradation.

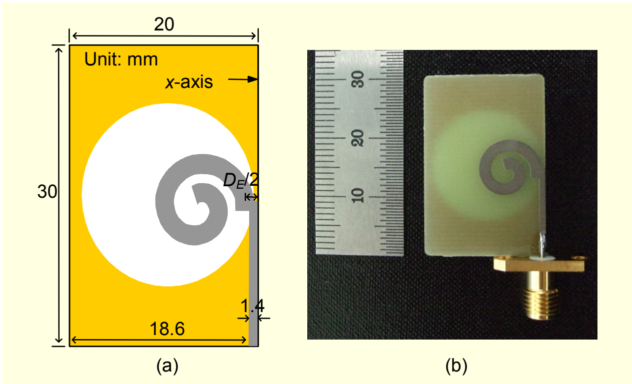

Fig. 3. Structure of the miniaturized UWB antenna: (a) miniaturized antenna and (b) fabricated antenna (other dimensions are the same as in Fig. 1).

III. Results

After optimization of antenna parameters, the proposed antennas were fabricated and the return loss characteristics were measured using an Agilent 8719ES network analyzer. Figure 4 shows their measured and simulated return loss. The measured results agree well with simulated ones over the frequency band of interest. The measured 10 dB return loss impedance bandwidth of the original antenna ranges from 3.11 GHz to over 11 GHz, while that of the miniaturized antenna ranges from 3.12 GHz to over 11 GHz. The measured radiation patterns for the *x*-*y* and *y*-*z* planes are shown in Fig. 5. The original and miniaturized UWB antennas show similar

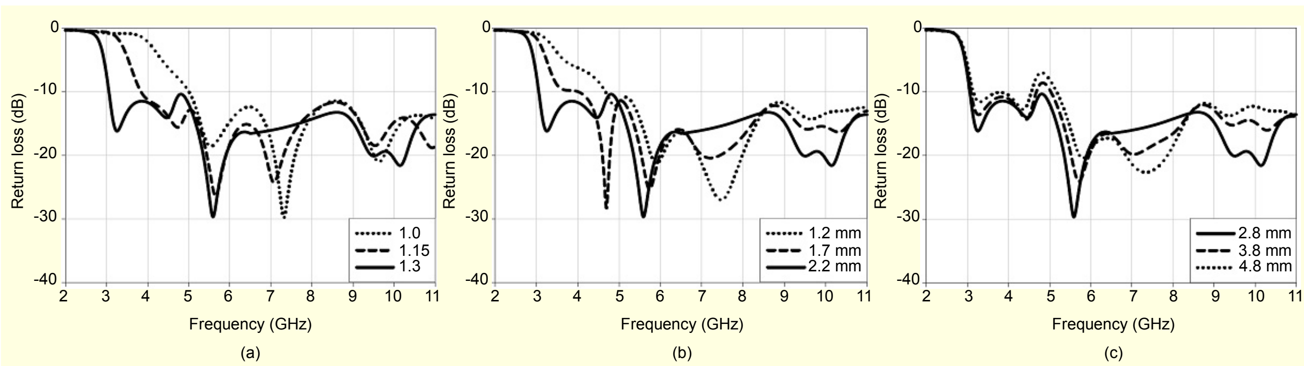

Fig. 2. Return loss for various antenna parameters: (a) N_T, (b) W_{SE}, and (c) D_E.

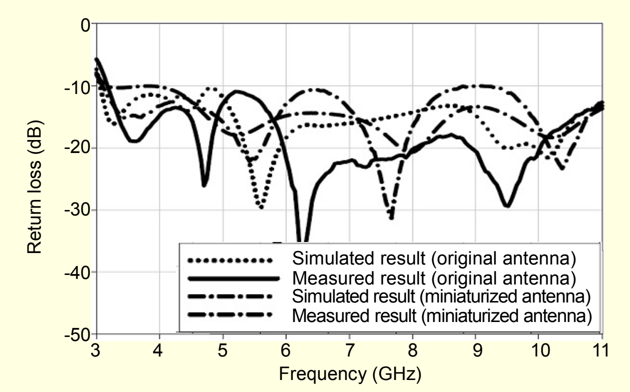

Fig. 4. Measured and simulated return loss of the proposed antennas.

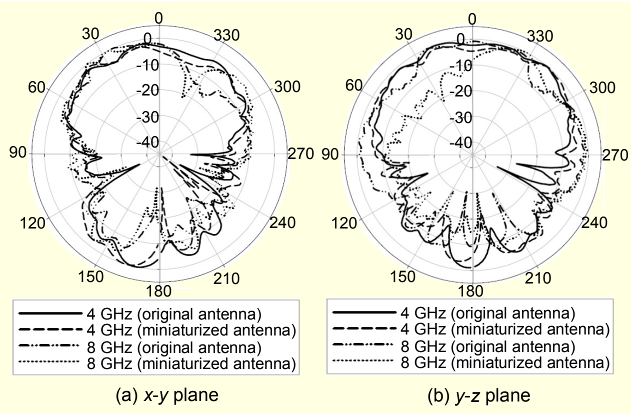

Fig. 5. Measured radiation patterns.

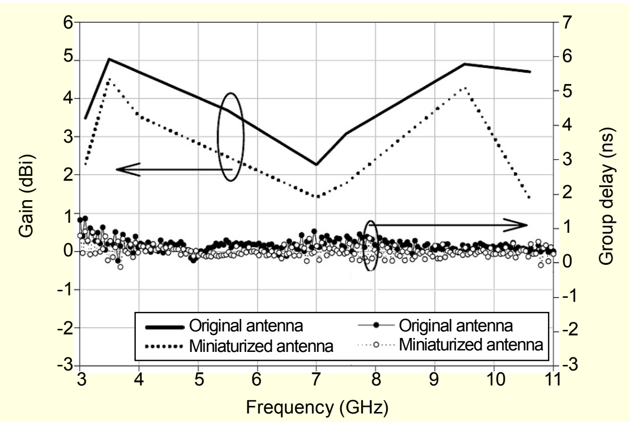

Fig. 6. Measured antenna gain and group delay characteristics.

co-polarization radiation patterns. The radiation patterns for both antennas are good enough for mobile applications. The measured gains of the realized antennas are shown in Fig. 6. The figure indicates that the proposed antennas have good gain flatness; however, the miniaturized antenna exhibits slightly lower gain in the operating band due to the size reduction. Furthermore, the variation of group delay is less than 0.8 ns and 1 ns for the original and miniaturized antennas, respectively. These characteristics indicate that the proposed antennas are suitable for UWB impulse radio systems.

IV. Conclusion

New and simple ultra-wideband antennas were proposed. Spiral elements with a T-shaped microstrip feed line were adopted to widen the bandwidth of the original structure. To further reduce antenna size, the original antenna was cut in half using the symmetry property. Thus, a miniaturized antenna measuring 30 mm × 20 mm × 1.6 mm was obtained. The proposed antennas feature suitable radiation patterns for mobile applications with good gain flatness. Satisfactory antenna performance with a simple structure and small size makes the proposed miniaturized antenna a good candidate for UWB wireless communication applications.

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