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Design of a Dual Spiral Line Loaded Monopole Antenna for Cellular and RFID Bands

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I. Introduction

Wireless communication and identification technology are currently developing very rapidly. In particular, antennas embedded in handheld transceiver units for voice and data communications with radio frequency identification (RFID) capability are gaining popularity for a number of applications [1, 2]. Compact size, robustness, aesthetics, broad bandwidth, and omni-directional radiation characteristics are inherent requirements for such internal antenna designs. Spiral configurations have shown their advantage with respect to reducing antenna size [3, 4], but tend to have narrow bandwidths. Recently, however, it has been shown that the bandwidth of a compact spiral antenna can be improved by using mutual coupling between two spiral radiators located in very close proximity [5]. This paper presents a compact dual spiral line loaded monopole antenna for cellular and RFID applications. The proposed antenna measures $8 \times 36 \times 12$ mm^3 with a 40×70 mm^2 vertical ground plane, which is a typical size for cellular phones. The bandwidth of an antenna with a voltage standing wave ratio (VSWR) < 2 is about 17% (820 ~ 972 MHz), which covers the cellular (824 ~ 894 MHz) and ultra high frequency (UHF) RFID (908.5 ~ 914 MHz) bands in Korea. Good omni-directional radiation patterns are also obtained.

II. Antenna structure

Figure 1 shows the geometry of the proposed antenna. The antenna is modeled in a stack configuration and comprised of two rectangular spiral strip lines. Each spiral line is printed on an 8×36 mm^2 substrate with a dielectric constant of ε_{r1}=3.38 and a thickness of t_1=0.203 mm. The upper and lower spirals are located at heights h and h_f from the top edge of the vertical ground plane, respectively. The upper spiral line is connected to the ground plane with a shorting pin that has a diameter of ϕ_1. The antenna is excited with a microstrip line through a probe pin with a diameter of ϕ_2 that is connected at the end of the lower spiral line. The width, gap, and length of the upper spiral line are w_s, g_s, and l_s, respectively, whereas those of the lower spiral line are w_f, g_f, and l_f. The shorting and probe pins are separated by distance d. The antenna occupies a volume of $8 \times 36 \times 12$ mm^3 with a 40×70 mm^2 ground

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plane. The substrate for the ground plane has a dielectric constant of ε_{r1}=3.38 and a thickness of t_2=0.508 mm.

III. Antenna characteristics

The antenna characteristics with respect to the frequency response of each spiral line loaded monopole were investigated using the full-wave electromagnetic simulator Microwave Studio by CST. A dual resonance mode is expected due to the electromagnetic coupling between the two monopoles, *i.e.*, the shorting pin with the upper spiral line monopole and the probe feed with the lower spiral line monopole.

Figure 2(a) shows the return loss characteristics with respect to the length of the upper spiral strip line. As the length increased from 99 to 100.5 to 102 to 103.5 mm, the lower resonance frequency decreased from 854 to 838 to 822 to 784 MHz, respectively. Nevertheless, the higher resonance frequency remained around 968 MHz. Figure 2(b) shows the return loss characteristics with respect to the length of the lower spiral line. As the length of the lower spiral line increased from 82.5 to 84.5 to 86.5 to 88.5 mm, the higher resonance frequency decreased from 991 to 979 to 968 to 952 MHz, respectively, while the lower resonance frequency remained around 822 MHz. These results demonstrate that the shorting pin with the upper spiral line monopole regulated the lower resonance frequency and the probe feed with the lower spiral line monopole regulated the higher resonance frequency.

Figure 2(c) shows the variation of the return loss of the antenna with the distance between the probe feed and shorting pin. As the total dimensions of the monopoles do not change with changes in the distance between the two pins, the lower and higher resonance frequencies remained near their original values. In addition, the change in the distance between the two pins caused a change in the coupling between the two spiral radiators. Figure 2(d) shows the variation of the return loss of the antenna with the change in the height of the probe connected to the lower spiral strip line. As the height of the probe feed increases, the total length of the probe feed with the lower spiral line monopole increases. This causes the higher resonance frequency to decrease, while the lower resonance frequency remained near its original value. Therefore, the frequency behavior of the antenna can be manipulated with the design parameters so that its impedance variation is small over a wide frequency range.

The optimized antenna has the following design parameters: ϕ_1=ϕ_2=0.5 mm, h=12 mm, h_f=6 mm, w_f=w_s=1.5 mm, g_f=g_s=1.75 mm, l_f=86.5 mm, l_s=102 mm, and d=5.5 mm. The impedance bandwidth of the optimized antenna is 152 MHz for VSWR<2 at a central frequency of 896 MHz. The calculated radiation patterns of the antenna at 896 MHz are shown in Figure 3. The radiation patterns show good omni-directional characteristics.

IV. Conclusions

We have presented a dual spiral line loaded monopole antenna on a vertical ground plane. The antenna has a 152 MHz impedance bandwidth (820 ~ 972 MHz) for VSWR<2 at a central frequency of 896 MHz. The proposed antenna covers both the cellular and UHF RFID bands in Korea and is suitable as the internal antenna of a handheld transceiver unit because of its thin configuration, broad bandwidth, and good omnidirectional radiation characteristics.

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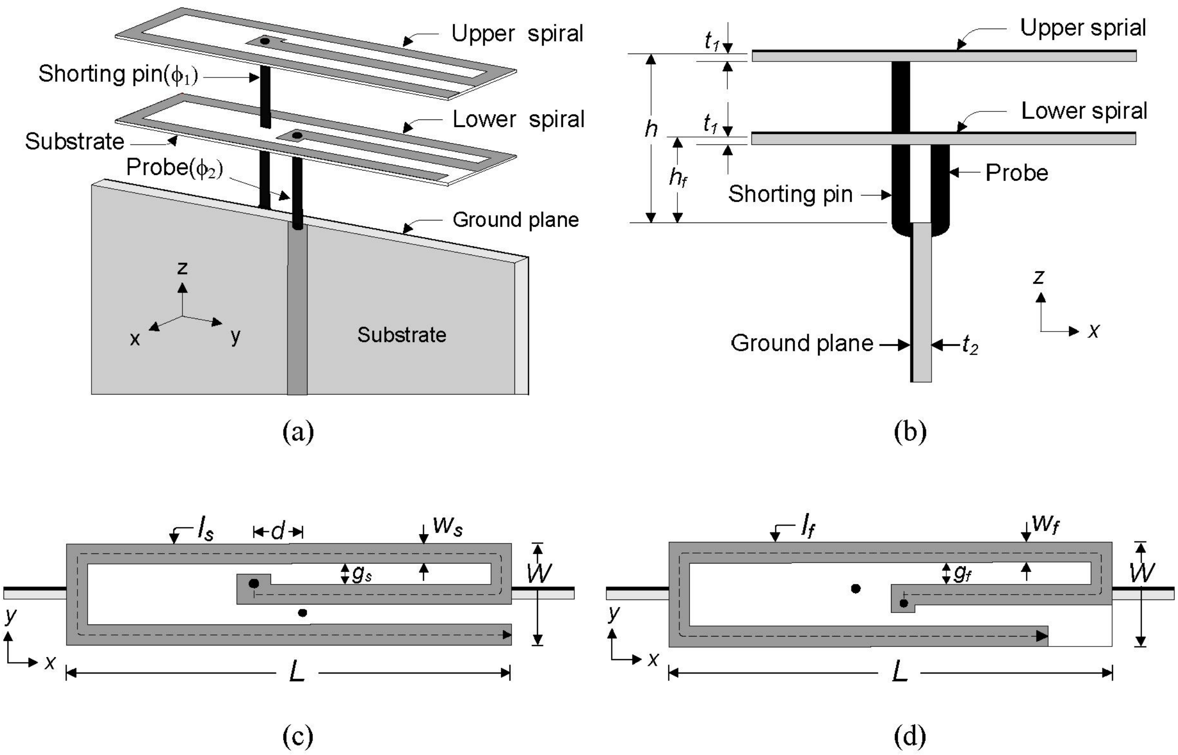

Fig. 1. Structure of the proposed antenna: (a) 3-dimensional view, (b) side view, (c) top view of the upper spiral line, (d) top view of the lower spiral line.

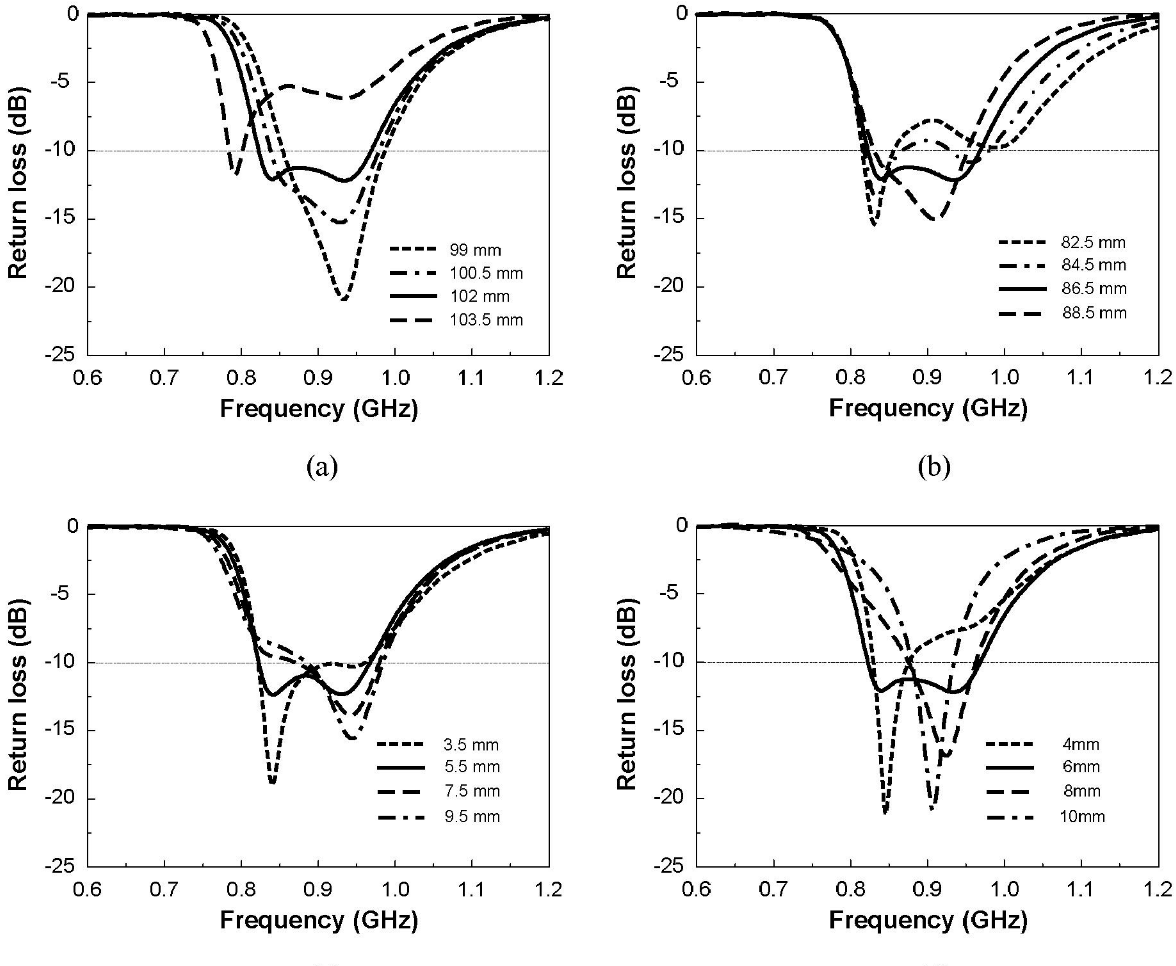

Fig. 2. Variation in the return loss with respect to various design parameters: (a) upper spiral line length, (b) lower spiral line length, (c) distance between the probe feed and shorting pin, (d) probe height

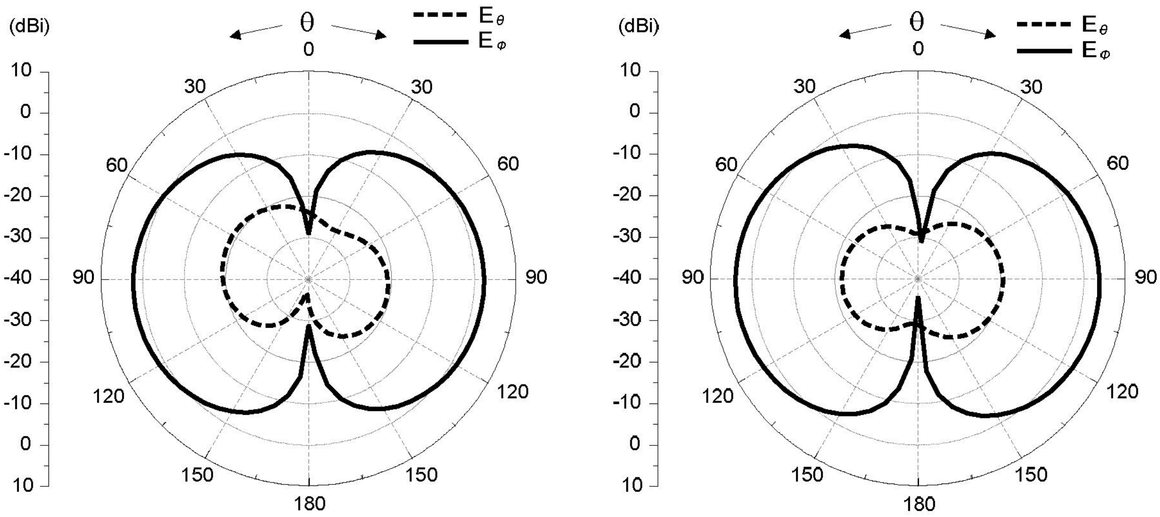

Fig. 3. Computed radiation pattern at 896 MHz: (a) *x-z* plane, (b) *y-z* plane.