A Compact Dual Spiral Line Loaded Monopole Antenna

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I. INTRODUCTION

Increased consumer demand for small handheld transceiver units has propelled the rapid development of compact and broadband antennas for wireless communication, and many antenna structures have been proposed to satisfy these requirements. Recently, it has been shown that the bandwidth of a small antenna can be improved by using a mutual coupling between two radiators located in a very close proximity [1-4]. In this paper, we present a small dual spiral line loaded monopole antenna on a vertical ground plane with a broad bandwidth and omni-directional radiation pattern. The proposed antenna has an impedance bandwidth of 12.3% for VSWR<2 with a center frequency at 1.10 GHz and small physical dimensions of 12 mm x 12 mm x 12 mm.

II. ANTENNA STRUCTURE

The geometry of the proposed antenna is depicted in Fig. 1. The antenna is composed of two spiral line loaded monopoles. Each spiral line is etched on a 12 x 12 mm^2 substrate with a dielectric constant of ε_{r1}=3.38 and a thickness of t_1=0.203 mm. The upper spiral line is located at height h from the top edge of the ground plane. The upper spiral line is connected to the vertical ground plane with a shorting pin that has diameter ϕ_1. The antenna is excited with a microstrip line through a probe pin with diameter ϕ_2 that is connected at the end of the lower spiral line located at height h_f from the top edge of the ground plane. The length and width of the lower spiral line are l_f and w_f, respectively. The outer and inner line widths of the upper spiral are w_1 and w_2, respectively, and the gap between them is g. The shorting pin and probe pin are separated by distance d. The antenna is constructed on a 40 x 55 mm^2 vertical ground plane, the substrate of which has a dielectric constant of ε_{r2}=3.38 and a thickness of t_2=0.508 mm.

III. ANTENNA CHARACTERISTICS

The key to reducing antenna size is known to be maximization of the current path of the conductor [4]. Therefore, a spiral line is a good candidate structure for obtaining such characteristic. The characteristics of the proposed antenna are investigated using a full-wave electromagnetic simulator, Microwave Studio by CST. The proposed antenna can be considered to

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comprise two monopoles, i.e., a shorting pin with the upper spiral line monopole and a probe feed with the lower spiral line monopole. Therefore, we can expect the antenna to support a dual resonant mode.

Figure 2(a) shows the return loss characteristics with respect to the gap of the upper spiral strip line. As the gap increased from 0.6 to 1.1 to 1.6 mm, the lower resonance frequency decreased from 1.07 to 1.04 to 1.0 GHz. The higher resonance frequency remained at around 1.17 GHz. As the gap of the spiral increases, so does the inductance of the upper spiral line. Therefore, the resonance frequency of the shorting pin with the spiral line decreased, shifting to a lower frequency. Figure 2(b) shows the return loss characteristics with respect to the diameter of the shorting pin. As the diameter of the shorting pin increased from 0.2 to 0.7 to 1.2 mm, the lower resonance frequency increased from 1.02 to 1.04 to 1.05 GHz, respectively; however, the higher frequency remained around at 1.17 GHz. The inductance of the shorting pin decreases with increases to the diameter of the shorting pin. Therefore, the resonance frequency of the shorting pin with the spiral line increased, shifting to a higher frequency. From these results, it can be seen that the shorting pin with the upper spiral line monopole provided the lower resonance frequency. Figure 2(c) shows the variation of the antenna's return loss with respect to the length of the lower spiral line. As the length of the lower spiral increased from 59.3 to 61.3 to 63.3 mm, the higher resonance frequency decreased from 1.20 to 1.17 to 1.14 GHz, respectively. The lowest resonance frequency remained around at 1.04 GHz. From this result, it can be seen that the probe pin with the lower spiral line monopole provided the upper resonance frequency. Figure 2(d) shows the return loss characteristic with respect to the distance between the probe feed and the shorting pin. Since the total dimensions of the monopoles do not change with changes to the distance between the two pins, the lower and higher resonance frequencies remained around their original values. 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=0.7 mm, ϕ_2=1.0 mm, h=12 mm, h_f=9.1 mm, l_f=61.3 mm, w_f=0.8 mm, l_s=73.9 mm, w_1=1.2 mm, w_2=0.9 mm, g=1.1 mm, d=4.1 mm, a=3.4 mm, b=1.4 mm. The impedance bandwidth of the optimized antenna is 136 MHz for VSWR<2 at the center frequency of 1.10 GHz. The calculated radiation patterns of the antenna at 1.1 GHz are shown in Figure 3. The radiation patterns show a good omni-direction characteristic.

IV. CONCLUSION

We have presented a dual spiral line loaded monopole antenna on a vertical ground plane. The antenna has a 136 MHz impedance bandwidth for VSWR<2 at the center frequency of 1.10 GHz. The antenna has small overall dimensions of 12 mm x 12 mm x 12 mm. It has been shown that antenna size can be reduced significantly by using the spiral line as a loading element on a monopole.

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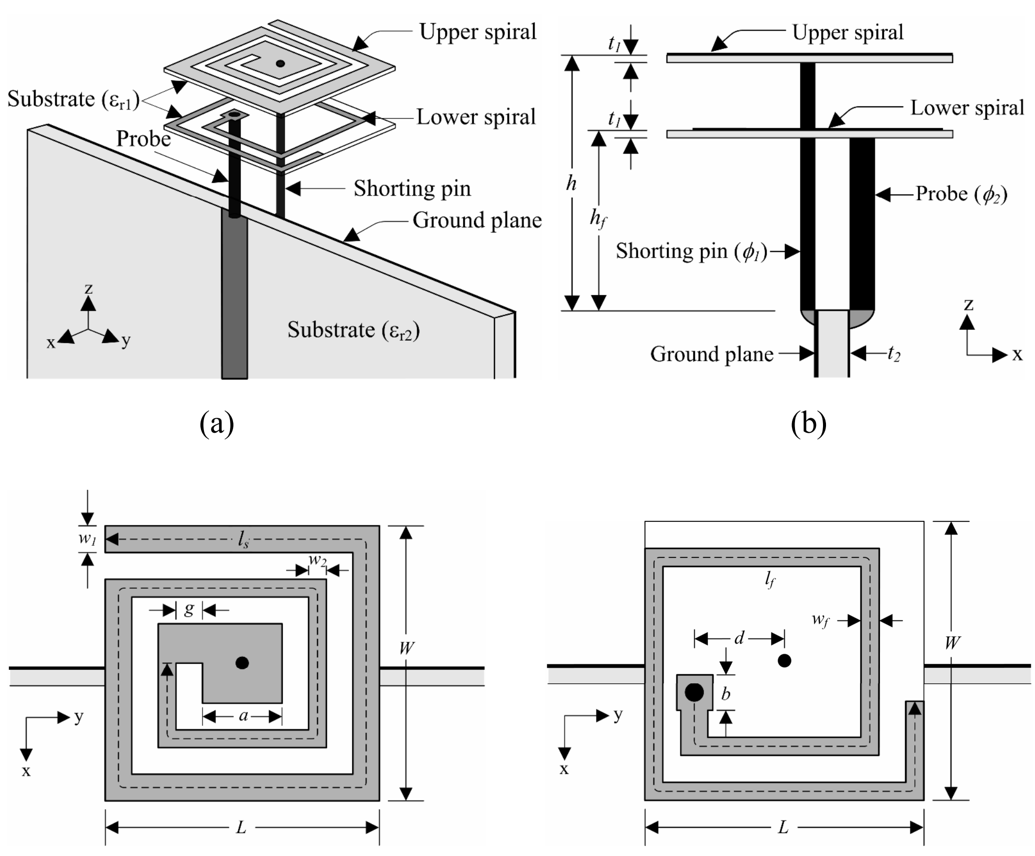

(a) (b)

(c) (d)

Fig. 1. Proposed antenna structure: (a) 3-dimenstional view, (b) side view, (c) top view of the upper spiral line, (d) top view of the lower spiral line.

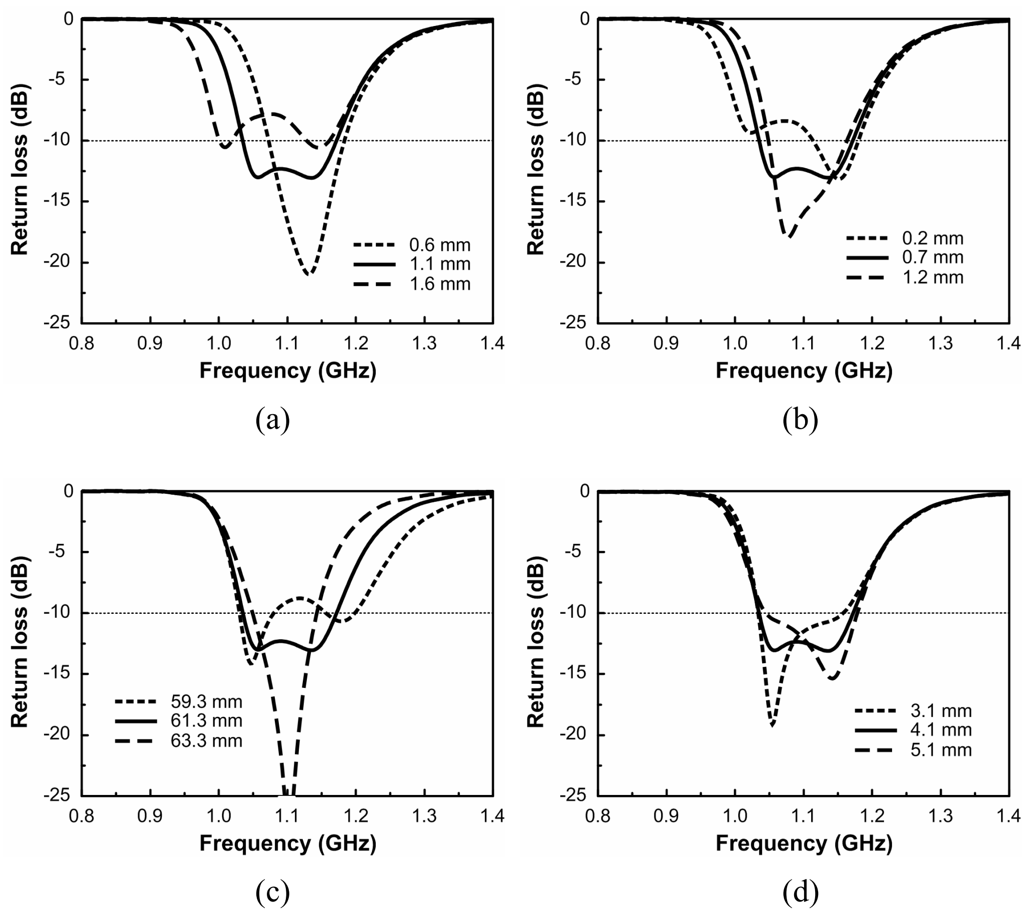

Fig. 2. Variation of return loss with respect to various design parameters: (a) upper spiral line gap, (b) diameter of shorting pin, (c) lower spiral line length, (d) distance between probe feed and shorting pin.

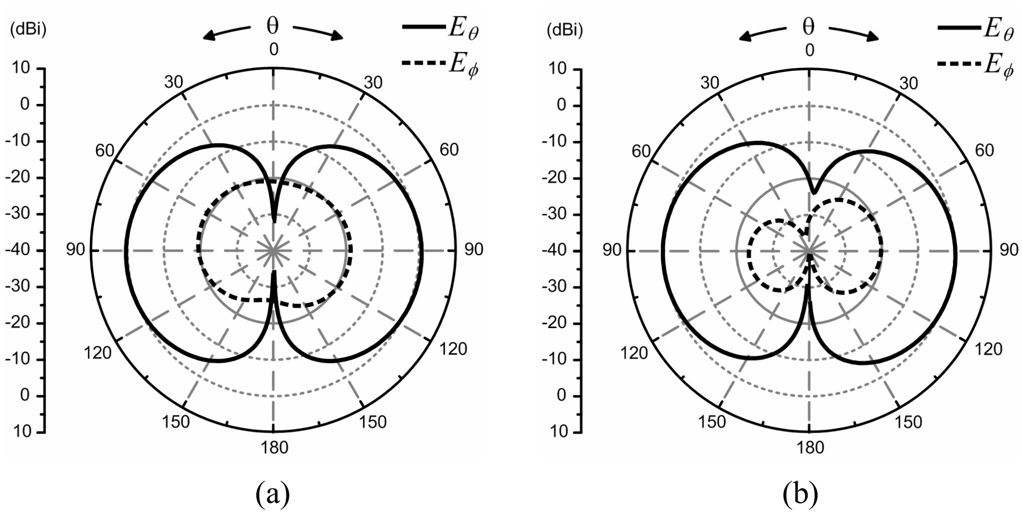

Fig. 3. Computed radiation pattern at 1.10 GHz: (a) x-z plane, (b) y-z plane.