A Small Broadband Folded-Loop Antenna With Disk-Loaded Monopole

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***Abstract*—A small broadband folded-loop antenna with a disk-loaded monopole is designed and measured. Its size is 0.08 $\lambda \times$ 0.1 $\lambda \times$ 0.1 λ at the center frequency of 1.5 GHz. The measured fractional bandwidth is 11.2% with the voltage standing-wave ratio (VSWR) less than 2. It has an omnidirectional radiation pattern of vertical polarization in the horizontal plane.**

***Index Terms*—Broadband, disk-loaded monopole, fold-loop, small antenna.**

I. INTRODUCTION

WITH the raised demand for small wireless devices, different small antennas have been widely explored. There are many techniques to reduce the antenna size. For example, high-permittivity substrates are used to reduce the resonant frequency of microstrip antennas, or top-loading technique is used to extend the current path, hence reducing the resonant frequency of antennas [1]. Other examples are folding technique, meander-line [2], inductive or capacitive loading elements [3], [4], and so on.

When applying these techniques, the antenna efficiency and the impedance bandwidth are usually reduced because more energy tends to be retained around the smaller antennas [5]. Recently, bandwidth enhancement techniques have been studied—for example, inducing mode coupling between adjacent elements [6], [7], adding vertical lines to a meander line [8], using dual meander sleeves [9]–[11], and so on.

In this letter, a folded loop with a disk-loaded monopole is proposed, which has an enlarged impedance bandwidth by merging two resonant modes of the folded loop and the disk-loaded monopole, respectively. The design considerations and geometry of the proposed antenna are described in Section II, simulated and measurement results are presented and discussed in Section III, followed by the conclusion.

II. DESIGN CONSIDERATIONS

The Q-factor of a small antenna with dimension a is about $Q \simeq 1/(ka)^3$ [5], and the impedance bandwidth is roughly proportional to $1/Q$, which implies that smaller antennas have narrower impedance bandwidth. In this letter, the bandwidth is extended by coupling two resonant modes with similar radiation characteristics. Fig. 1 shows the geometry of the folded-loop antenna with a disk-loaded monopole, which is fed by a 50-Ω coaxial cable. Fig. 2(a) shows the layout of the unfolded loop. The side view and top view of the antenna are shown in Fig. 2(b) and (c), respectively.

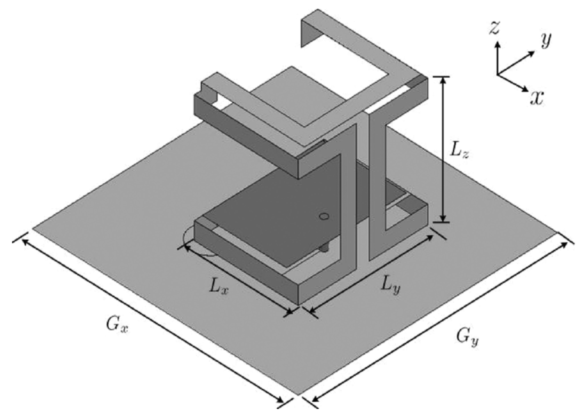

Fig. 1. Geometry of the proposed antenna.

Both the disk-loaded monopole and the folded loop have omnidirectional radiation pattern of vertical polarization in the horizontal plane. By properly adjusting the gap width g between the disk and the parasitic patches, the resonant modes of both structures are coupled to increase the overall impedance bandwidth.

III. RESULTS AND DISCUSSIONS

Around the center frequency of 1.5 GHz, the electric length of the folded-loop is about one wavelength, and that of the disk-loaded monople is about one-quarter wavelength. Fig. 3 shows the measured and simulated return loss of the proposed antenna using HFSS. The antenna takes a cubic space of $16 \times 20 \times 20$ mm^3, mounted on a horizontal ground plane of size 126×130 mm^2. The 10-dB bandwidth is about 168 MHz, or 11.2% in fractional bandwidth. Reasonable agreement between measurement and simulation results is observed.

Fig. 4 shows the comparison of simulated return losses with and without the disk-loaded monopole. Without the disk-loaded monopole, the fractional bandwidth of the folded-loop alone is about 4.4%. By inserting the disk-loaded monopole, another resonant mode appears, and the bandwidth is increased to 11.2%. The total length of the folded loop is 201 mm, about 0.94 wavelength at 1.4 GHz. The reduction of resonant length may be explained by the proximity coupling due to the folding. Similarly, the total length of the disk-loaded monopole is 40 mm, about 0.207 wavelength at 1.875 GHz. The strong capacitive coupling

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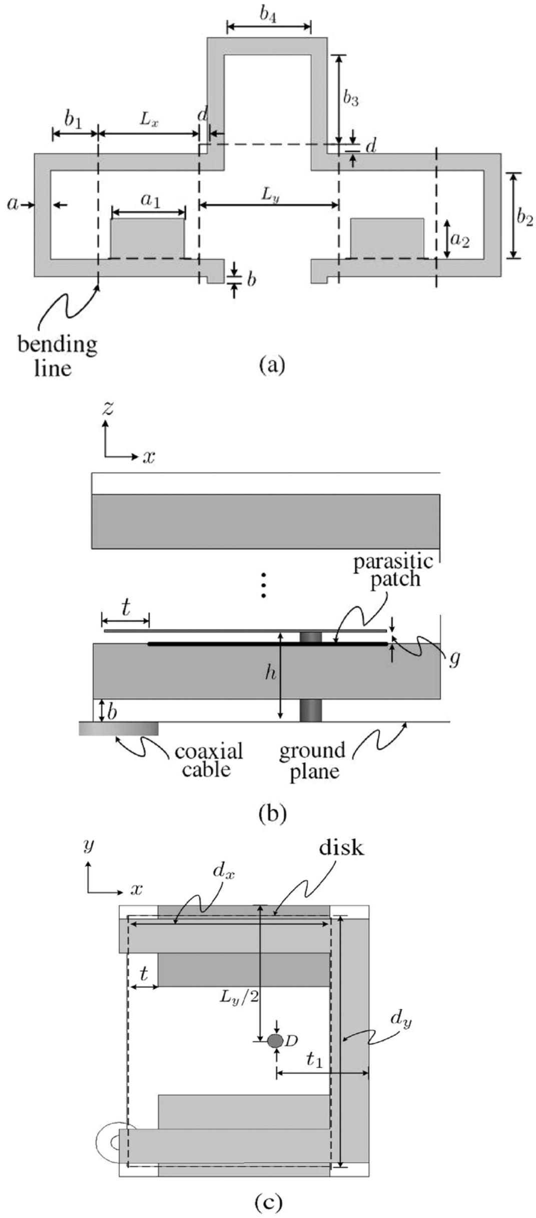


Fig. 2. (a) Layout of unfolded loop. (b) Side view and (c) top view of the proposed antenna.

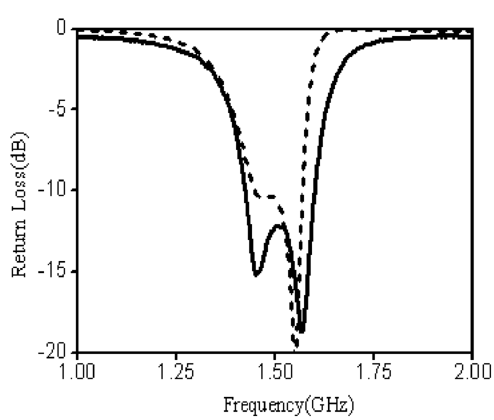


Fig. 3. Measured (——) and simulated (– – –) return loss, $L_x = 16$, $L_y = 20$, $L_z = 20$, $G_x = 126$, $G_y = 130$, $a = 2.5$, $a_1 = 11$, $a_2 = 6$, $b = 1$, $b_1 = 6.5$, $b_2 = 13$, $b_3 = 13.5$, $b_4 = 13$, $d = 1$, $t = 2$, $t_1 = 6$, $h = 4$, $g = 0.5$, $D = 1$, $d_x = 13$, $d_y = 18.5$, all in millimeters.

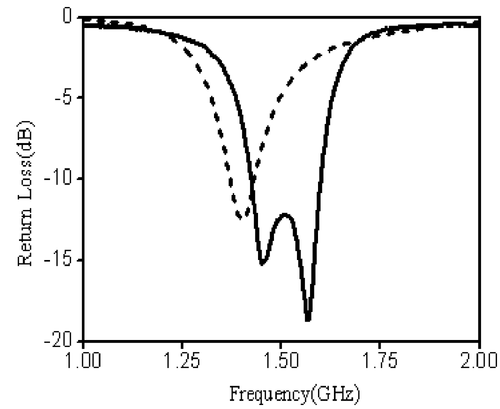


Fig. 4. Comparison of simulated return loss with (——) and without (– – –) disk-loaded monopole. Parameters are the same as in Fig. 3.

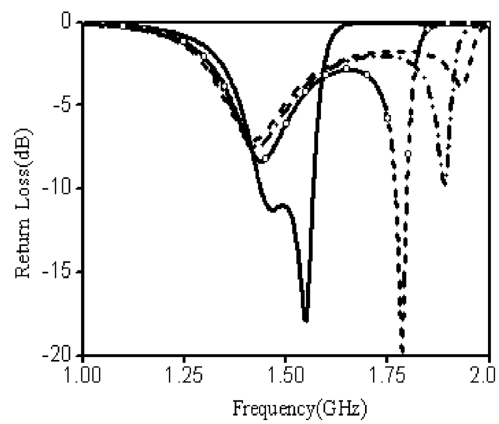


Fig. 5. Simulated return loss with different gap sizes between disk and the parasitic patches. ——: $g = 0.5$ mm. – – –: $g = 2$ mm. — · —: $g = 1.5$ mm. —o—: $g = 1$ mm. Other parameters are the same as in Fig. 3.

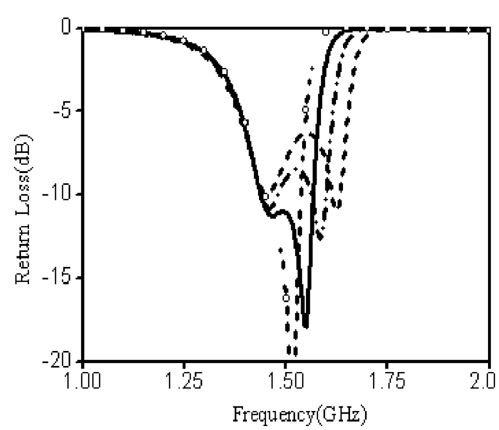
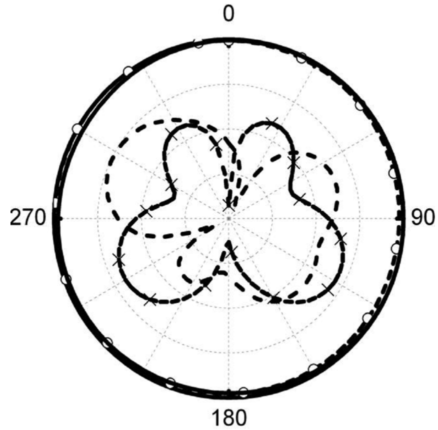


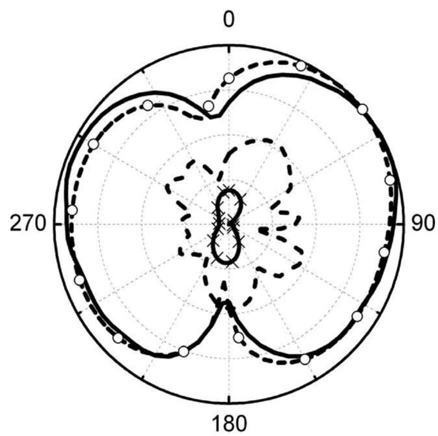
Fig. 6. Simulated return loss with different patch sizes. ——: $a_2 = 6$ mm. – – –: $a_2 = 5$ mm. — · —: $a_2 = 5.5$ mm. —o—: $a_2 = 6.5$ mm. Other parameters are the same as in Fig. 3.

between the folded loop and the disk-loaded monopole may explain why the second resonant frequency is reduced from 1.875 to 1.55 GHz.

Fig. 5 shows the simulated return loss versus the gap size between the disk and the parasitic patches. With a smaller g, the second resonant frequency is decreased because the capacitive coupling becomes stronger and the effective length of the



(a)



(b)

Fig. 7. Radiation pattern at 1.5 GHz. (a) xy plane. Numbers indicate ϕ (in °), with $\phi = 0$ in the x-direction. (b) xz plane. Numbers indicate θ (in °), with $\theta = 0$ in the z-direction.——: measured E_θ. – – –: measured E_ϕ. –o–: simulated E_θ. $- \times -$: simulated E_ϕ. On radials, 10 dB per division. All parameters are the same as in Fig. 3.

disk-loaded monopole is extended. The optimum gap size is about $g = 0.5$ mm.

Fig. 6 shows the simulated return loss versus the patch size. When a_2 is increased, the overlapping area between the parasitic patch and the disk increases, and the second resonant frequency decreases. The optimum size is about $a_2 = 6$ mm.

Fig. 7 shows the measured and simulated radiation pattern at 1.5 GHz. The E_θ pattern in the xy plane is nearly omnidirectional, and the measured peak gain is about 0.7 dBi. The cross polarization is about 10 dB lower than the copolarization.

IV. Conclusion

The bandwidth of a small folded-loop antenna is almost doubled by merging its resonant mode with another one of a disk-loaded monopole. The size of the antenna is about 0.08 $\lambda \times$ 0.1 $\lambda \times$ 0.1 λ at the center frequency of 1.5 GHz, and its fractional bandwidth is 11.2% with VSWR less than 2. The radiation pattern in the xy plane is nearly omnidirectional.

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