A Method to Reduce the Back Radiation of the Folded PIFA Antenna with Finite Ground

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Abstract **─** A novel method, named the resistors and inductors loading, is proposed in this paper to reduce the back radiation of the folded PIFA antenna with finite ground. With different loading schemes (i.e., resistors loading, inductors loading, and resistors and inductors loading), variable reduced back radiation and gain can be achieved. However, there is a compromise between the gain and back radiation and it can be chosen based on the specified applications. A prototype with resistors loading is fabricated and measured to verify the proposed design. Measured results agree well with the simulated results.

Index Terms - Back radiation, folded PIFA antenna, and resistors and inductors loading.

I. INTRODUCTION

Microstrip antennas have been widely used in modern mobile and wireless communication systems because of their significant advantages, such as the light weight, low profile, and low cost. Conventional microstrip antennas, operating at their fundamental mode (TM_{10} or TM_{01}), have an electrical length of about half wavelength and it is too large for many applications operating at lower frequencies such as portable UHF RFID reader antennas. Some techniques have been proposed to miniaturize the antenna size, such as the meandered patch, with high dielectric constant, PIFA antennas, meander PIFA antenna, the capacitive loading, the folded strip antenna, and the folded shorted-patch antenna [1-5]. However, the size of the ground plane is not considered in all of these methods, which can significantly affect the performances of the microstrip antenna. It is apparent that if the size of the ground plane is small, the gain will decrease and the back lobe will increase. As the size of the ground plane reduces, the currents on the edge of the ground plane increase and these currents result in a deceased front-to-back ratio of a patch antenna [6]. So the total size of the mcirostrip antenna should be determined by the size of the ground plane rather than the patch. Though some methods have been proposed recently to improve the front-to-back ratio of microstrip antennas [6, 7], a large ground plane is still employed. In [8], back radiation of the antenna is reduced by the resistors loading with a lower antenna gain.

A novel method, named the resistors and inductors loading, is proposed in this paper to improve the front to back ratio of the antennas with compact ground plane. The folded PIFA antenna is employed here to reduce the antenna size [4]. Compared with the method depicted in [6, 7], back radiation is reduced significantly in the proposed design while a compact ground plane is still remained. As can be seen, there is a compromise between the gain and the back radiation with different inductors and resistors loading schemes and it can be chosen according to the specified applications, so the proposed antenna in this paper have more freedom than the antenna presented in [8] and this antenna can also be considered as a reconfigurable antenna.

II. CONFIGURATIONS OF THE PROPOSED ANTENNA

A conventional folded PIFA antenna is shown in Fig. 1 and the dimensions of the antenna are shown in Table 1. It works at the UHF RFID band and the centre frequency of 915 MHz. This

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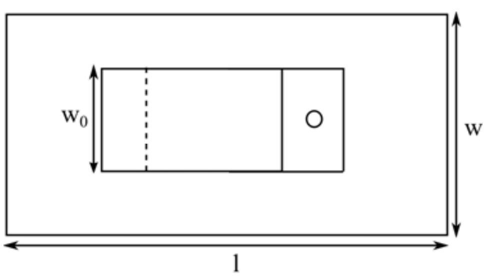
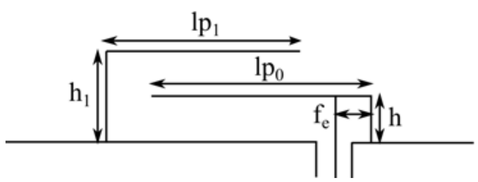
antenna suffers large back radiations because of the small ground size. A novel configuration is proposed in this paper to reduce the back radiation of the antenna. As shown in Fig. 2 (a), four inductors and resistors are loaded on the ground plane. Back radiation of the proposed antenna can be largely reduced by tuning values of the loaded inductors and resistors. The operating frequency of this antenna is determined by lp_0 and lp_1, as shown in Fig. 2 (b). The dimensions of the proposed antenna and the optimized values of the loaded elements are all shown in Table 2. Figure 2 (c) demonstrates the simulated model of the proposed antenna.

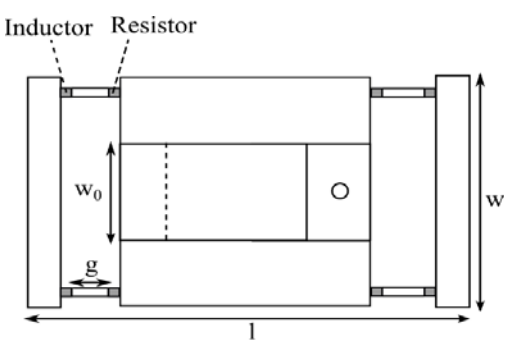


(a)



(b)

Fig. 1. The original configuration: (a) front view and (b) cross-section of the proposed antenna.



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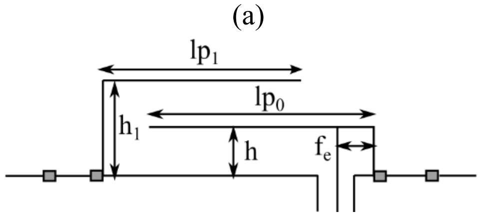

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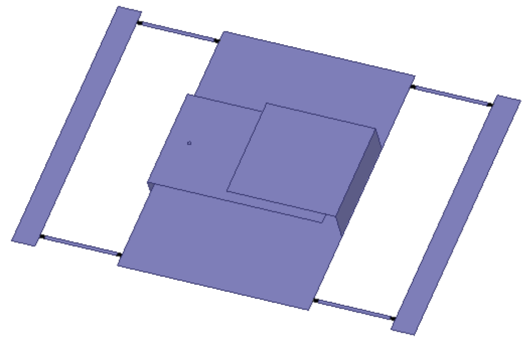


(c)

Fig. 2. Configuration of the proposed structure (a) front view, (b) cross-section, and (c) simulated model of the proposed antenna.

Table 1: Dimensions of the original patch.

l	120 mm	lp_0	52 mm
w	80 mm	lp_1	32.5 mm
h	5 mm	f_e	9 mm
h_1	10 mm	w_0	30 mm

Table 2: Dimensions and values of the loading elements of the proposed patch.

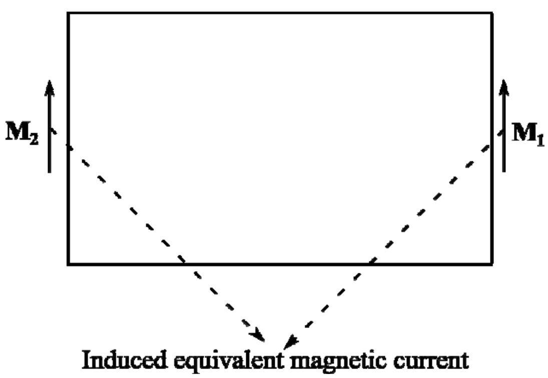
l	120 mm	lp_0	52 mm
w	80 mm	lp_1	32.5 mm
h	5 mm	f_e	6.5 mm
h_1	10 mm	g	24.5 mm
R	50 Ohm	w_0	30 mm
L	7 nH		

III. EXPLANATION AND SIMULATION OF THE PROPOSED ANTENNA

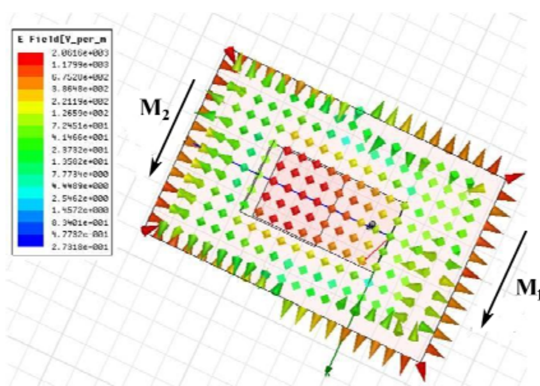
The working principle of the proposed antenna is discussed in this section. The induced equivalent magnetic currents (**M_1** and **M_2**) [9] on the edges of the finite ground plane, as shown in Fig. 3 (a), contribute not only to the antenna gain but also to the back radiation. Because of the size of the ground plane of the original antenna, which is only 0.39 λ_0 × 0.24 λ_0, which is even smaller than a conventional air substrate microstirp antenna, it is apparent that the induced equivalent magnetic current can be very large due to the small ground size. As shown in Fig. 3 (b), because of the large electric field on the edges of the ground plane, the induced equivalent magnetic currents will be very large, which are obtained according to the formula,

$$\mathbf{M} = -\mathbf{n} \times \mathbf{E}\,. \tag{1}$$

Inductors and resistors are loaded on the ground plane in this paper to reduce the back radiation of the traditional fold PIFA antenna. As shown in Fig. 4 (a), the induced equivalent magnetic currents $\mathbf{M_1}$, $\mathbf{M_2}$, and $\mathbf{M_3}$ can be considered as a three-element antenna array. By controlling the amplitude and phase of $\mathbf{M_1}$, $\mathbf{M_2}$, and $\mathbf{M_3}$, the field produced by them will cancel each other in some directions and the back radiation can be reduced. Simulated electric field distribution on the edge of the ground plane of the proposed antenna is shown in Fig. 4 (b). Here, the resistors are used to control the amplitudes of each element while the inductors and gaps are used to control the phases of each element.

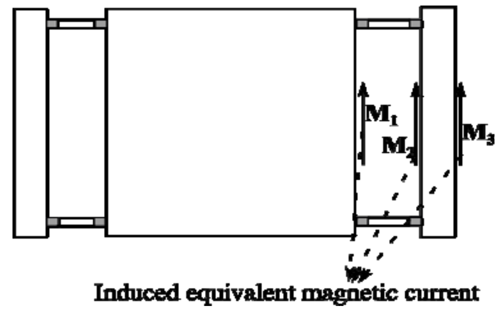


(a)

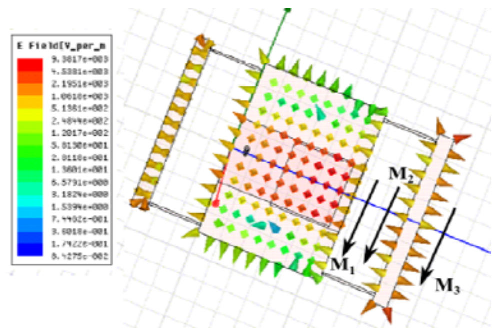


(b)

Fig. 3. Conventional folded-short patch antenna, showing induced equivalent magnetic currents on the ground plane: (a) induced equivalent magnetic currents and (b) simulated electric filed distribution.



(a)



(b)

Fig. 4. Proposed folded-short patch antenna, showing induced equivalent magnetic currents on the ground plane: (a) induced equivalent magnetic currents and (b) simulated electric filed distribution.

The proposed antenna is simulated using an in-house full-wave electromagnetics solver based on the EFIE (Electric Field Integral Equation) and the magnetic frill source. The simulated radiation patterns with and without loadings are shown in Figs. 5 and 6, respectively. More details about the gain, the back radiation, and the front-to-back ratio are shown in Table 3. The optimized dimensions of the gap and values of inductors and resistors are shown in Table 2. They are obtained by the trial-and-error method.

Table 3: Performance comparison with different loading.

	Gain	Back Radiation	Front-to-Back Ratio
Original	4.65 dB	-0.51 dB	5.16 dB
R loading	3.86 dB	-11.42 dB	15.28 dB
L loading	5.08 dB	-5.61 dB	10.69 dB
R and L loading	3.41 dB	-26.23 dB	29.64 dB

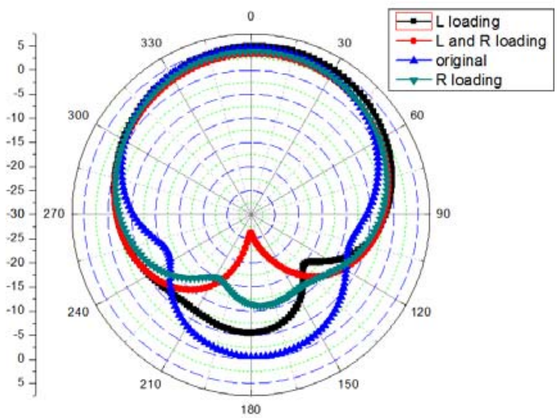


Fig. 5. Radiation pattern of E plane at 915 MHz.

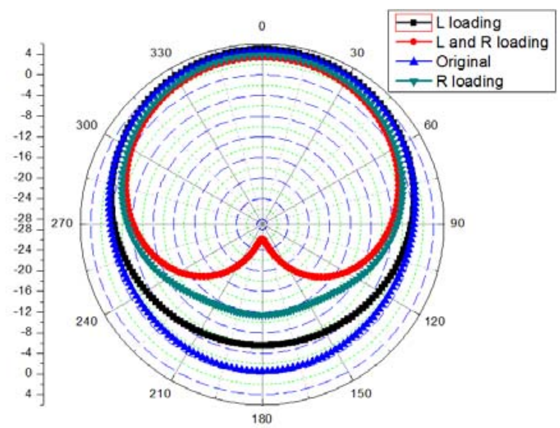


Fig. 6. Radiation pattern of H plane at 915 MHz.

Table 3 shows that if both resistors and inductors are loaded, the back radiation is reduced significantly. The front-to-back ratio is 29.64 dB, which is 24.48 dB higher than the conventional one. However, the gain deceases slightly. It is 1.24 dB lower than the conventional one because of the resistive loss. If only inductors are loaded on the ground plane, the front-to-back ratio is enhanced by 5.53 dB and the gain increases slightly. Meanwhile, if only resistors are loaded on the ground plane, the front-to-back ratio is enhanced by 10.8 dB, while the gain decreases, which is also because of the resistive loss. By slightly changing the feeding position (f_e), all the antennas can be matched to 50 Ohms easily. The S_{11} without loading or with different loadings schemes is shown in Fig. 7.

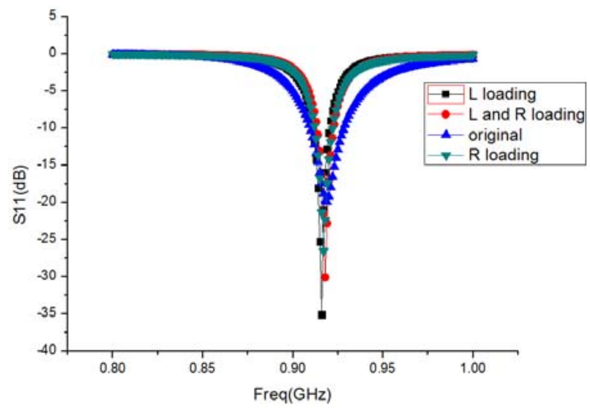


Fig. 7. Simulated S_{11} of the proposed antennas.

From the analysis above, it is found that there is a compromise between the antenna gain and the back radiation with different loading schemes. By changing the values of the loaded components, different antenna gain and back radiation can be obtained and it depends on specified applications.

IV. EXPERIMENTAL RESULTS

To verify the performance of the proposed antenna, a prototype of the design with resistors loading only was fabricated and measured. The fabricated prototype is shown in Fig. 8. Four 50 Ohm resistors are loaded on the ground plane to reduce the back radiation. The measured S_{11} and radiation patterns are shown in Figs. 9 and 10, respectively. Both of them have a good agreement with the simulated results.

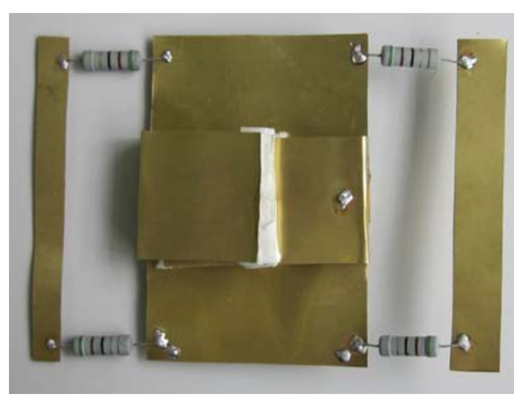


Fig. 8. Photograph of the fabricated prototype.

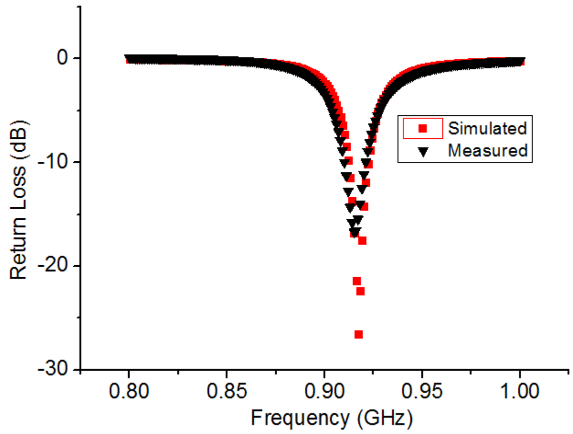


Fig. 9. Measured $|S_{11}|$ of the proposed antenna with resistors loading only.

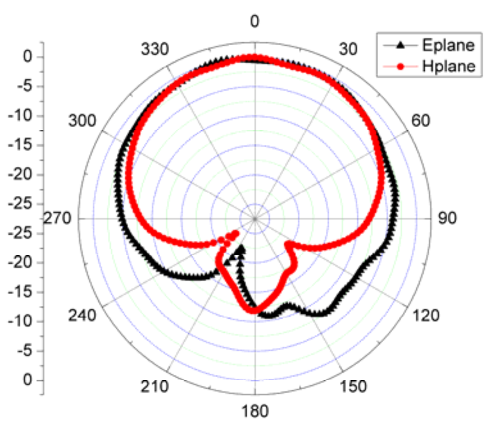


Fig. 10. Measured radiation pattern of the proposed antenna with resistors loading only.

VI. CONCLUSIONS

In this paper, the ground plane of the folded PIFA antenna is loaded with resistors and inductors to reduce the back radiation. By the resistors and inductors loading, the back radiation is reduced dramatically, which is 25.72 dB lower than the conventional counterpart, while the antenna gain decreases slightly. However, there is a compromise between the gain and back radiation. Different inductors and resistors loading schemes can be chosen according to the specified applications. For example, if the back radiation is of greater concern, resistors and inductors loading should be employed. If the antenna gain is more emphasized, the inductors loading should be chosen.

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