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A WIDEBAND STACKED SHORTED ANTENNA FOR MINIATURIZED ACTIVE RFID TAGS

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Abstract—A novel and simple antenna applicable to active RFID tags is designed. The designed antenna has been skillfully integrated with the active RFID tag circuit. The antenna consists of two parts. One part comprises stacked shorted patches and a ground plane. The other one is an active tag circuit mounted on the bottom of the antenna. By using the offset shorting posts technique, the proposed antenna can achieve an enhanced operating bandwidth with a small size. The measurement results reveal that the antenna has return loss less than −10 dB within the bandwidth of 42 MHz (from 914 MHz to 956 MHz), which totally covers the 5 MHz bandwidth from 920 MHz to 925 MHz (The band is also allowed for passive RFID) requirement for active RFID in China.

1. INTRODUCTION

Nowadays, Radio Frequency Identification (RFID) is an extremely important technology of automatic identification. It is being used in a

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wide range of applications [1–3], such as electronic toll collect (ETC), vehicle access, electronic article surveillance (EAS), animal tagging, supply chain tracking, warehouse management, and security systems. An RFID system consists of readers (also called interrogators) and tags (also called transponders). Readers broadcast queries to tags in their wireless transmission ranges for information contained in tags, and tags reply with required information such as identification (ID) numbers.

There are two main types of RFID tags in use: passive and active ones. Passive tags are powered by the electromagnetic field generated by the reader's antenna. While active tags use an internal battery as a power source, which are widely used in cars, buses and trucks because of their long reading rang and reliability [4]. The antenna, as a key part of the active tag, enables the tag to send and receive the signal, and has been widely investigated [5–8]. The inverted-F [5, 6], folded monopole [7] and loop antenna [8] have been designed for tags and had good performance. However, they are not suitable for direct integration with the circuit of active tags.

In this paper, a dual-resonant stacked shorted patch antenna with the offset shorting posts for bandwidth enhancement is introduced, which is integrated with an active RFID tag circuit skillfully. The offset shorting posts technique consists of two shorting posts. One shorting post connects the driven patch to the ground plane, and the other connects the parasitic patch to the driven patch. In addition, the two shorting posts have a distance in horizontal direction. The antenna consists of two parts. One part comprises stacked shorted patches and a ground plane, which are printed on a dielectric substrate. In [9–13], stacked shorted patch antennas have been investigated. The proposed antenna in the current paper is dual-resonant and has a much smaller size than the one in [13]. The other part is an active RFID tag circuit mounted on the bottom of the antenna. To evaluate the antenna performance, this paper illustrates the return loss and radiation patterns.

2. ANTENNA DESIGN

The configuration of the proposed antenna is shown in Fig. 1. The antenna consists of two parts. One part is comprised of three layers of conductor (one finite-size ground plane and two radiating patches) mounted on RF4-substrate ($\varepsilon_r = 4.4$, $\tan\delta = 0.02$). The other part is the active RFID tag circuit, which is below the ground plane ($30 \times 60\,\mathrm{mm}^2$) with a height of $h_1 = 1.6\,\mathrm{mm}$. A shorted driven patch of $27 \times 27\,\mathrm{mm}^2$ is placed above the ground plane at spacing of

$h_2 = 1.6\,\mathrm{mm}$. The shorted driven patch is fed by a feeding probe which is through a hole of diameter $d_1 = 2.4\,\mathrm{mm}$ on the ground plane. The feeding probe has a diameter of $d_2 = 1\,\mathrm{mm}$. To enhance the bandwidth, a parasitic patch with a dimension of $27 \times 27\,\mathrm{mm}^2$ is placed right above the driven patch with the placing of $h_3 = 1.6\,\mathrm{mm}$ and connected to the driven patch by a post. The two shorting posts are of diameter $d_3 = 1\,\mathrm{mm}$, and the distance between the shorting posts is $d = 1.1\,\mathrm{mm}$.

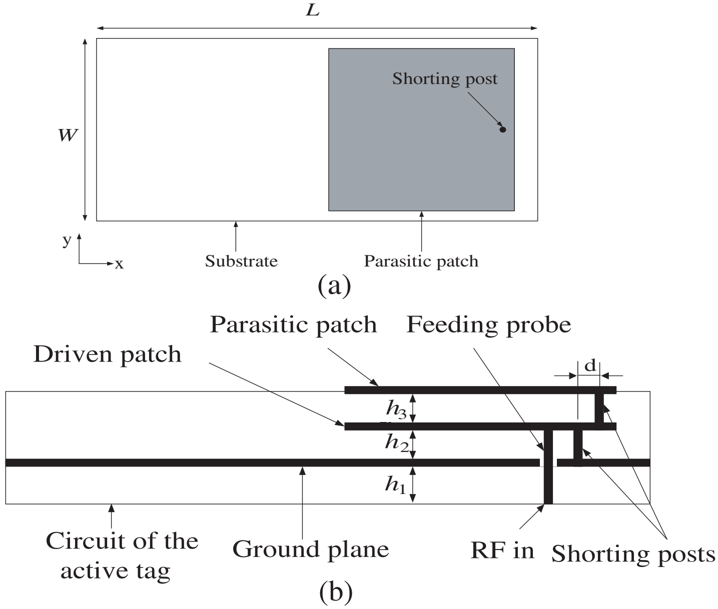


Figure 1. Configuration of the proposed antenna. (a) Top view. (b) Side view.

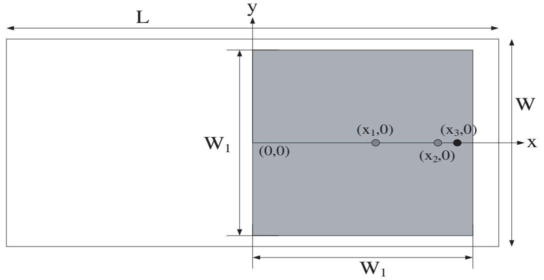
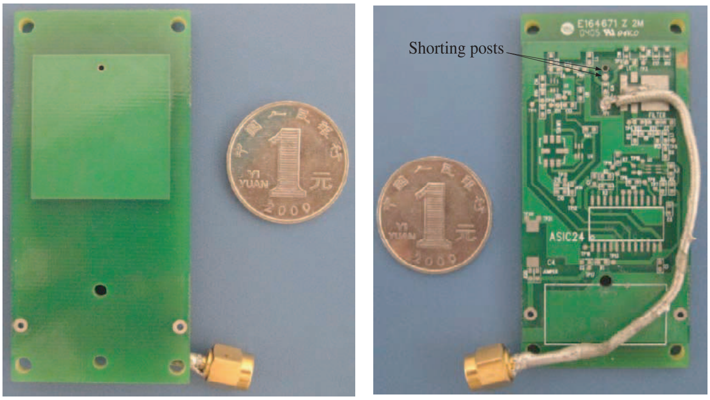


Figure 2. Antenna detailed dimensions ($h_1 = h_2 = h_3 = 1.6\,\mathrm{mm}$, $W = 30\,\mathrm{mm}$, $L = 60\,\mathrm{mm}$, $W_1 = 27\,\mathrm{mm}$, $x_1 = 20.55\,\mathrm{mm}$, $x_2 = 24.48\,\mathrm{mm}$, $x_3 = 25.58\,\mathrm{mm}$).



(a) (b)

Figure 3. Photograph of the proposed antenna. (a) Top view. (b) Bottom view.

With the aid of simulation by Ansoft High Frequency Structure Simulator (HFSS.11), which is based on the finite element method (FEM), the antenna is optimized. The detailed dimensions are shown in Fig. 2.

To optimize the bandwidth, we must control the coupling between the driven patch and parasitic patch. The coupling depends on the distance between the radiating edges of the patches and the unloaded quality factors of the patches [9]. In this paper, the distance between the two shorting posts (d) can affect the coupling significantly. When the parameter d is optimized to 1.1 mm, the resonance frequencies of two patches are suitably close to each other to yield a broad bandwidth. A single shorting post is also employed here for each patch to achieve a minimum size of the stacked patch antenna. The radiating patches, ground plane, feeding probe and two shorting posts are all made of copper. A prototype of the proposed antenna was fabricated, as shown in Fig. 3.

3. RESULTS AND DISCUSSION

The antenna was measured in an anechoic chamber using the Satimo StarLab far field measurement system and Agilent 8722D vector network analyzer. Fig. 4 shows the measured and simulated return losses of the antenna against frequency. The measured -10 dB return loss bandwidth is 42 MHz (914–956 MHz), and the simulated one is 43 MHz (912–955 MHz). The discrepancy between the measured and simulated results is due to fabrication and mechanical tolerances. Fig. 4

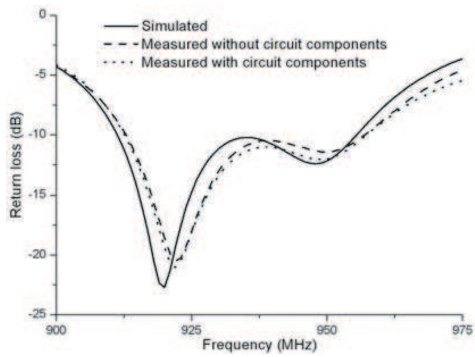
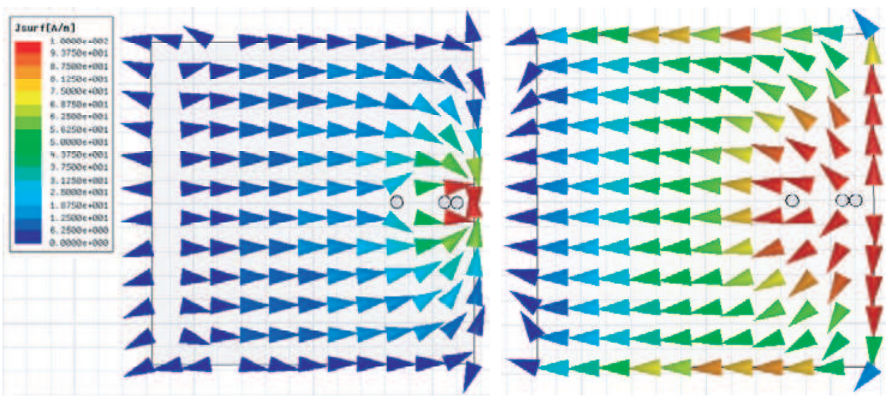


Figure 4. Measured and simulated results of the return loss.



(a) (b)

Figure 5. Simulated surface current distributions of two patches at 920 MHz. (a) Driven patch. (b) Parasitic patch.

also shows little difference of the return losses between the antennas integrated with and without circuit components. This is because the ground plane between the antenna and circuit components shields the effect of the circuit components.

Figures 5(a) and (b) show the current distributions on the driven and parasitic patches at 920 MHz, respectively. The currents on the two patches flow to the opposite direction except the left edges, which are the radiation edges of the antenna. The distance d of the shorting posts is a key parameter. It can be seen from Fig. 6 that the parameter d can significantly affect the performance of the proposed antenna. This fact reveals that the offset shorting posts technique is an effective way to attain dual-resonant property, which leads to an enhanced impedance bandwidth of the proposed antenna.

Figure 7 exhibits the effect of ground plane on the performance of the antenna. It is observed that the operating band is shifted down as the ground plane width W increases. Furthermore, the effect is more notable at lower frequencies. Greater W increases the antenna size, thus shifting down the operating band, whereas it enhances the gain in the meantime. In practical design, the width of the ground plane is optimized to 30 mm to meet the circuit design requirement of the active RIFD tag. However, the ground plane length L has little effect on the performance of the proposed antenna.

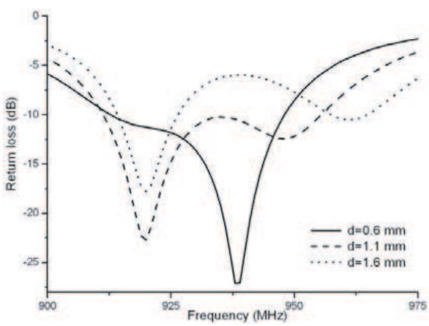


Figure 6. Simulated return loss for different d.

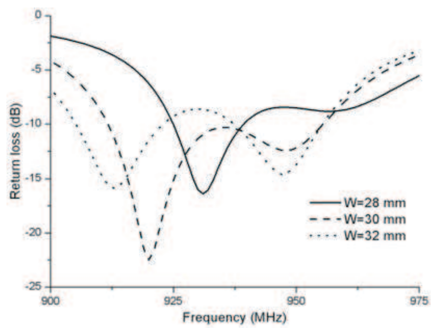
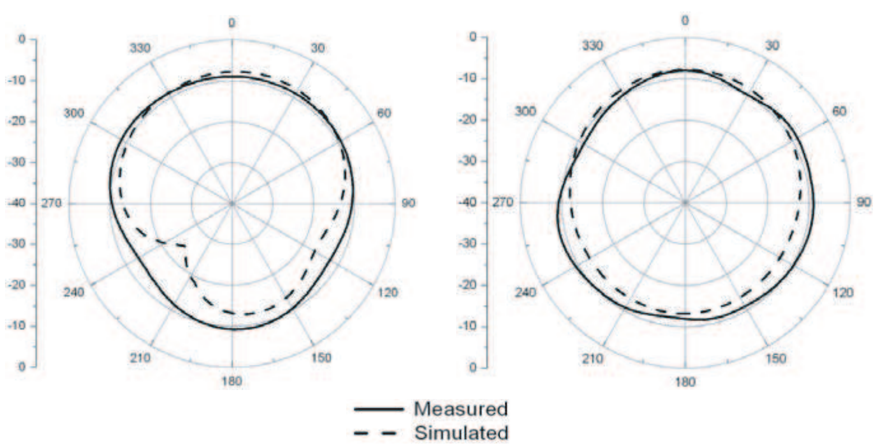


Figure 7. Simulated return loss for different W.



(a) (b)

Figure 8. Measured and simulated radiation patterns. (a) x-o-z plane. (b) y-o-z plane.

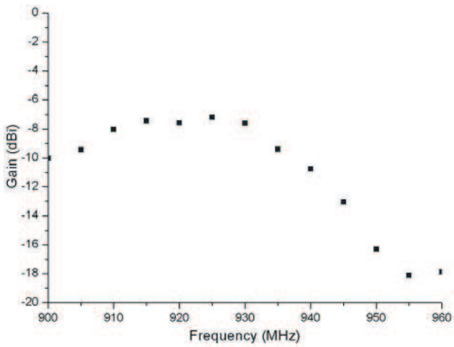


Figure 9. Measured gains for the proposed antenna.

The far-field radiation characteristics for the proposed antenna with the optimum value of $d = 1.1\,\mathrm{mm}$ were studied. Because the active RFID tags need to be attached to items with large area such as metal walls of a container, the radiation patterns are measured and simulated with metal ground. Fig. 8 shows the radiation patterns in the x-o-z and y-o-z planes at 920 MHz. Fig. 9 shows the measured gains in terms of the frequencies for the proposed antenna. It can be observed that the maximum gain is $-7.19\,\mathrm{dBi}$ at 925 MHz.

4. CONCLUSION

A dual-resonant stacked shorted patch antenna with the offset shorting posts for bandwidth enhancement has been designed for active RFID tags. The antenna is integrated with an active RFID tag circuit skillfully. The experimental results reveal that the proposed antenna features wide bandwidth and compact size. Furthermore, the parametric studies have addressed the effects of the distance of the shorting posts and the size of the ground plane on the performance of the antenna. The information derived from the study will be helpful for antenna engineers to design and optimize the antennas for active RFID tags.

REFERENCES

1. Chen, S.-L., S.-K. Kuo, and C.-T. Lin, "A metallic RFID tag design for steel-bar and wire-rod management application in the steel industry," *Progress In Electromagnetics Research*, Vol. 91, 195–212, 2009.
2. Lazaro, A., D. Girbau, and R. Villarino, "Effects of interferences in UHF RFID systems," *Progress In Electromagnetics Research*, Vol. 98, 425–443, 2009.

3. Hua, R. C. and T. G. Ma, "A printed dipole antenna for ultra high frequency (UHF) radio frequency identification (RFID) handheld reader," *IEEE Trans. Antennas Propag.*, Vol. 55, No. 12, 3742–3745, Dec. 2007.
4. Almanza-Ojeda, D. L., A. Hernandez-Gutierrez, and M. A. Ibarra-Manzano, "Design and implementation of a vehicular access control using RFID," *Electronics and Photonics, 2006. MEP 2006. Multiconference*, 223–225, 2006.
5. Choi, W., H. W. Son, J. H. Bae, G. Y. Choi, C. S. Pyo, and J. S. Chae, "An RFID tag using a planar inverted-F antenna capable of being stuck to metallic objects," *ETRI Journal*, Vol. 28, No. 2, Apr. 2006.
6. Hirvonen, M., P. Pursula, K. Jaakkola, and K. Laukkanen, "Planar inverted-F antenna for radio frequency identification," *Electronic Letters*, Vol. 40, No. 14, Jul. 2004.
7. Ryn, H. K., S. Lim, and J. M. Woo, "design of electrically small, folded monopole antenna using C-shape meander for active 433.92 MHz RFID tag in metallic container application," *Electronic Letters*, Vol. 44, No. 25, Dec. 2008.
8. Ng, M. L., K. S. Leong, and P. H. Cole, "A small passive UHF RFID tag for metallic item identification," *International Technical Conference on Circuits/Systems, Computers and Communications*, 10–13, Chiang Mai, Thailand, Jul. 2006.
9. Waterhouse, R. B., J. T. Rowley, and K. H. Joyner, "Stacked shorted patch antenna," *Electronic Letters*, Vol. 34, No. 7, 612–614, Apr. 1998.
10. Ollikainen, J., M. Fischer, and P. Vainikainen, "Thin dual-resonant stacked shorted patch antenna for mobile communications," *Electronic Letters*, Vol. 35, No. 6, 437–438, Mar. 1999.
11. Mishra, A., P. Singh, N. P. Yadav, J. A. Ansari, and B. R. Vishvakarma, "Compact shorted microstrip patch antenna for dual band operation," *Progress In Electromagnetics Research C*, Vol. 9, 171–182, 2009
12. Fujimoto, T. and K. Tanaka, "Stacked square microstrip antenna with a shorting post for dual band operation in WLAN applications," *Proceedings Asia-Pacific Microwave Conference*, 1979–1982, 2006
13. Lee, G. Y., T. Z. W. Chiou, and K. L. Wong, "BroadBand stacked shorted patch antenna for mobile communications handsets," *Proceedings of Asia-Pacific Microwave Conference*, 232–235, 2001.