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Silver Ink Patch Antenna for Passive RFID

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1. Introduction

Metallic objects strongly degrade the performance of a conventional radio frequency identification (RFID) tag antenna by affecting its impedance and radiation pattern. When a general dipole-type antenna is mounted near a metallic object, current will be induced on both the antenna surface and the metallic surface due to the RFID reader's radiation. The metallic surface acts as an image part of the original antenna, which has a negative influence on the tag antenna's scattered field and makes the tag unreadable for normal ranges [1]. In order to enable an RFID tag to work near metallic objects, special attention must be paid to the structural design of the antenna.

In general, there are two approaches to design an RFID tag antenna for metallic objects. One way is to utilize the metallic object itself in order to construct the antenna, such as in [2], where an RFID tag is formed by cutting a slot into metallic foil. The other approach is to design a general tag antenna which is able to be mounted on any metallic surface. The microstrip antenna (MSA) possesses this unique advantage. Several proposed RFID tag antennas for metallic objects, such as planar inverted-F antenna (PIFA), U slot inverted-F tag antenna [3-4] are examples of this type. The MSA has a low profile planar configuration and can be made to be conformal to the host surface. With a conducting ground plane, a microstrip patch antenna can be designed to operate in the vicinity of metal. These advantages make them preferable for numerous military applications and with compact design they are also used in personal mobile communication.

As an electronic identification technology to compete with rock-bottom pricing barcodes, the cost involved is one of the main issues holding back the widespread adoption of RFID. A traditional MSA has generally been constructed using good conducting materials, such as copper or aluminium and low-loss substrate in order to achieve relatively high radiation efficiency, but the high cost involved has proved to be a significant limitation to its application in the RFID field. In order to reduce the cost of an MSA, some low price material, such as foam, has been used as the substrate [5]. However, no cheaper alternative solution has been proposed for the conducting parts. Recently the concept of printing antennas utilizing commercial printing techniques has received a great deal of attention due to the requirement for low cost, high volume RFID tags. In the printing technique, the ink's colour pigment is replaced by small silver particles, making the printed ink-traces electrically conductive and the use of this technique can significantly reduce the cost of the tag antenna. Although the printed trace is not as conductive as copper, conventionally simple RFID tag antennas printed using silver based ink have proved to be very effective [6]. Unlike a conventional dipole-type antenna, the MSA is a structure with two conducting layers and thus is more sensitive to the ohmic loss.

In this paper, the performance of silver ink printed microstrip patch antenna for passive RFID application is investigated. Two compact patch structures working at 869MHz are presented where the conducting parts of the patch antenna are printed with silver ink utilizing the flexographic printing machine and the cardboard is adopted as the substrate. The performance parameters, such as impedance and the read range of these two printed patch antennas are measured with no material behind the structures and when backed up by a finite metallic plate. Their performance is evaluated by means of comparisons with the same antenna structures made of copper.

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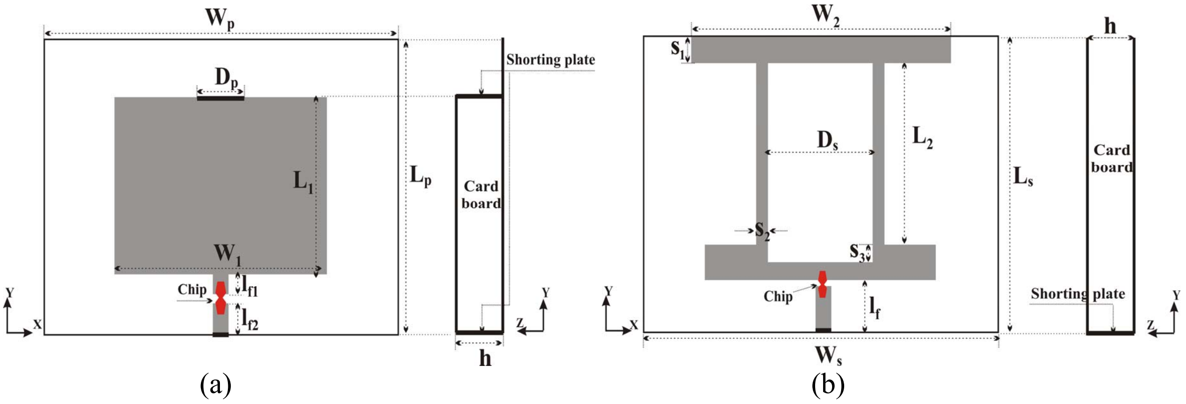


Figure 1: Geometrical Structures of (a) Shorted and (b) Slot Microstrip Patch Antenna

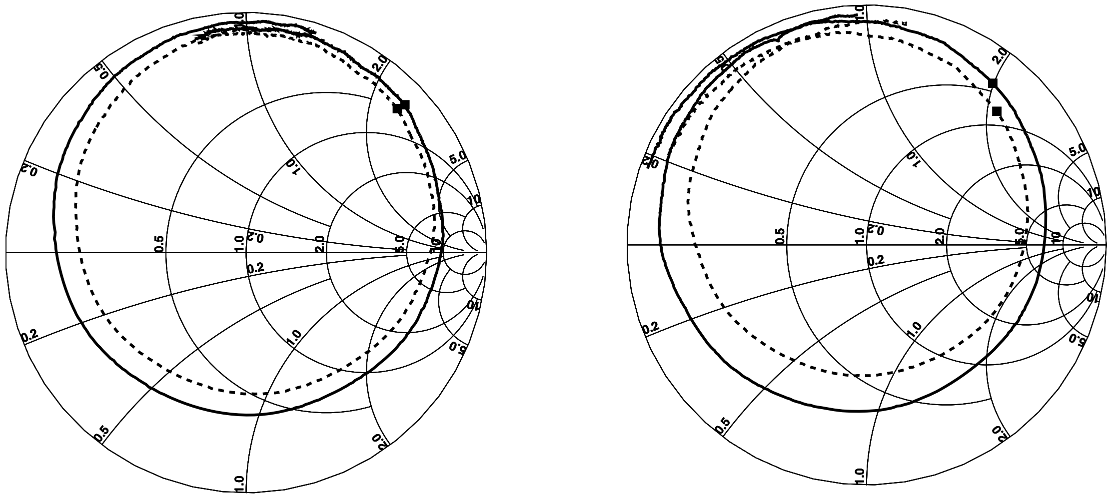
2. Antenna Design

The size of the regularly shaped MSA operating in the UHF band is quite large as its resonant length is inversely proportional to the frequency. Therefore, conventional MSA configurations must be modified for RFID application. It is demonstrated that by using a shorting plate or by cutting slots, compact patch antennas can be achieved [7]. In Figure1 (a), a shorting plate is added to the middle of one radiating edge (the top edge). The antenna's resonance frequency is controlled by tuning the width D_p of the shorting plate, where the resonance frequency decreases with the decreasing D_p. In order to facilitate the chip mounting, a segment of microstrip line is connected to the radiating patch and a slot is cut along the feed line for the placement of an RFID chip. One end of the feed line is directly connected to the ground plane by means of a small piece of copper tape and the shorting plate is achieved by wrapping a segment of copper tape through a slot which is cut along the radiating edge, through the substrate and to the ground plane. It is possible to substitute the small pieces of copper tape by staples in an industrial process.

The shorted MSA is a compact antenna but the disadvantages it then suffers from involve poor gain and degradation in the radiation pattern. An alternative way to reduce the resonance frequency of the MSA is to increase the patch length of the surface current by cutting slots in the radiating patch. Generally, size reduction is achieved by adopting a C-shaped or H-shaped slot or a ring MSA [7]. In order to make the antenna more compact, both the H-shaped slot and ring are adopted in this case, resulting in the geometry shown in Figure 1 (b). Slots are respectively cut in the middle and along the two non-radiating edges of the patch. As the shorted MSA, a segment of microstrip line is used to feed the slot patch and the RFID chip is placed across the gap between the feed line and patch. The connection between the feed line and the ground plane is achieved by the same method as that for the shorted MSA. In both cases, cardboard is utilized as the substrate and the thickness is approximately 2.8mm. These two presented patch antenna structures possess advantages regarding both construction and chip mounting.

3. Results and Discussion

The ground plane, radiating patch and feed line are printed on a plastic film with a thickness of 80μm by using the flexographic printing machine FlexiProof 100 from RK print [8] and the printer runs using the silver based ink CFW-102X from Precisia LLC [9]. In order to achieve a good sheet resistance, the antennas are printed in three consecutive layers, creating a total layer thickness of approximately 10-15 μm. After being cured at 120°C for 20 minutes, a DC sheet resistance of 70mΩ/□ is obtained. The plastic films holding the printing trace are glued to both sides of the cardboard. Repeated impedance and read range measurements determines the geometrical parameters: W_p=100mm, L_p=L_s=75mm, D_p=12mm, W_1=60mm, L_1=45mm, l_{f1}=5mm, l_{f2}=9mm, W_s=110mm, W_2=80mm, L_2=38mm, D_s=27mm, l_f=10mm, s_1=12mm, s_2=2.5mm, s_3=9mm.



(a) (b)

Figure 2: Measured Input Impedance of (a) Shorted and (b) Slot Patch Antennas.

In order to evaluate the influence of the limited conductivity of the silver ink printed conductors on the antennas performance, another two copper antennas are constructed with the same structure by replacing the printed plastic film by 70 µm thick copper film. The input impedance of the printed and copper patch antennas are measured using an unbalanced probe by means of an Agilent vector network analyzer E5070B and the results are displayed in Figure 2. Figure 2 (a) shows the impedance traces of the shorted patch antennas and Figure 2 (b) shows those involving the slots. The solid lines represent the impedance traces of copper antennas and the dashed lines are those of the printed ones. The measured frequency range is from 500MHz to 1500 MHz and the square shaped marks represent the impedance values at 869MHz. In the Smith chart it can be seen that the radius of the impedance trace circles of the printed antennas in both cases are smaller than those of the copper ones, which represents more conduction loss. It is also observed that the radius difference is more obvious for the slot patch antenna than for the shorted one which is mainly due to the difference in the antenna structure.

An Alien chip with measured impedance $Z_c \approx 30\text{-}j100\Omega$ at 869MHz is placed across the slot along the feed in order to constitute an RFID tag. The chip is attached to a strap, which contains metallic pads in order to more readily facilitate the attachment of a very small microchip to the antenna structure. The read range in the front direction of these four tags when there are no metallic objects nearby and when they are mounted at the centre of a metallic plate is obtained by placing the tag in an open air read range with an RFID reader from SAMSys Inc [10] and the results are shown in Table 1. It can be seen that without any objects nearby, the read range of the slot patch antennas are better than the shorted ones and this can be related to three antenna parameters difference: polarization, gain and reflection at the terminal of the chip. The first two factors are mainly determined by the antenna structure and the last one depends on the impedance match between the antenna and RFID chip. In the Smith Chart, it can be seen that the impedance values of the slot patch antennas at 869MHz are more close to the conjugate impedance value of the RFID chip than those of the shorted ones. Therefore, the power reflection from the RFID chip is weaker for the slot patch antennas. For both patch antenna structures, the read range when they are mounted on a metallic plate with size of 305×165mm is better than when there are no metallic objects nearby. The range enhancement is also rather better for the shorted patch antenna than for the slot one. The read range of the copper antennas are only slightly better than those for the printed ones and this is probably mainly due to the more impedance displacement to the conjugate impedance value of the RFID chip. Since the geometrical parameters for the antenna are determined for the printed patch antennas, the input impedance will offset those for the originals when applying the same geometrical parameters to the more conductive copper antennas. This then degrades the impedance match between the antenna and the RFID chip.

Table 1: Measured Read Range in the Front Direction of the Patch Antenna

Antenna type	Without metallic objects nearby	When mounted on a metallic plate with size of 305×165mm
Shorted microstrip patch antenna (copper)	2.2m	3.3m
Shorted microstrip patch antenna (printed)	2.0m	2.8m
Slot microstrip patch antenna (copper)	2.5m	2.8m
Slot microstrip patch antenna (printed)	2.3m	2.4m

4. Conclusion

Two compact microstrip patch antennas are designed for evaluating the performance of the printed patch antenna. The conducting part is printed using silver ink and cardboard is adopted as the substrate. Although the radiation efficiency of the printed patch antenna is reduced because of a greater conduction loss in comparison to that for the copper one, it is shown that in the front direction of the patch antennas an operational distance of more than two metres is achieved under good impedance match between the antenna and the RFID chip. It is possible to read this at an even greater distance when it is mounted on a metallic object. This low cost RFID solution for metallic object detection provides the possibility of integrating RFID tags into cardboard packages by printing ink directly onto cardboard boxes at the manufacturing site, where the ground plane is inside and the patch is outside the cardboard boxes. The electrical shorts between the patch and the ground plane can be implemented by means of an ordinary stapling machine. This technique uses cardboard box material itself as the MSA substrate and makes RFID tags insensitive to the cardboard boxes contents.

References

[1] P. R. Foster and R. A. Burberry, “Antenna problems in RFID systems,” IEE Colloquium on RFID technology, pp. 3/1-3/5, 1999.

[2] L. Ukkonen, M. Schaffrath, L. Sydanheimo and M. Kivikoski, “Analysis of integrated slot-type tag antennas for passive UHF RFID,” IEEE Antennas and Propagation Society Int. Symp., pp. 1343-1346, 2006.

[3] M. Hirvonen, P. Pursula, K. Jaakkola and K. Laukkanen, “Planar inverted-F antenna for radio frequency identification,” Electron. Lett., Vol. 40, No. 14, pp. 848-850, 2004.

[4] H. Kwon, B. Lee, “Compact slotted planar inverted-F RFID tag mountable on metallic objects,” Electron. Lett., Vol. 41, No. 24, pp. 1308-1310, s2005.

[5] H.-W. Son, G.-Y. Choi and C.-S. Pyo, “Design of wideband RFID tag antenna for metallic surfaces,” Electron. Lett., Vol. 42, No. 5, pp. 263-265, 2006.

[6] P. V. Nikitin, S. Lam, K. V. S. Rao, “Low cost silver ink RFID tag antennas,” IEEE Antennas and Propagation Society Int. Symp., Vol. 2B, pp. 353-356, 2005.

[7] G. Kumar, K. P. Ray, Broadband microstrip antennas, Artech House, USA, pp. 205-227, 2003.

[8] RK Print Coat Instruments Ltd., www.rkprint.com, accessed 061130.

[9] Precisia, LLC, acquired by Efi Jetrion in 2006, www.precisia.net, accessed 2006-12-18.

[10] Sirit Inc, http://www.sirit.com/samsys, accessed 2007-03-12.