Near-field antenna for RFID smart shelf in UHF

Wonkyu Choi *, Jeong-Seok Kim, Ji-Hoon Bae, Gilyoung Choi and Jong-Suk Chae
Electronics and Telecommunications Research Institute (ETRI)
Tel : +82-42-860-4999 , Fax : +82-42-869-1457 , E-mail : wkchoi@etri.re.kr

Abstract

This paper presents the design of a near-field reader and tag antennas in UHF that can be used for various smart shelves. The tag antenna is designed by introducing an "S"-shaped or "┼"-shaped slot to the circular patch and the reader one is a rectangular slot array fed by a microstrip line. These antennas operated in UHF near-field are more reliable in many RFID applications where reading distance is not the major factor. Electric coupling concept between the reader and tag antenna is employed for near-field communication.

Introduction

Radio frequency identification (RFID) has been widely used in supply chain and logistics applications in identifying and tracking goods. A near-field UHF RFID has recently received a lot of attention as a possible solution for item-level tagging (ILT), the biggest market of RFID, where HF RFID has traditionally been used. The existing UHF RFID of far-field concept has several advantages compared to HF RFID but performance of UHF RFID is more susceptible to objects nearby tags. In addition to that, UHF RFID may unintentionally detect some other tags in far-field region since the field region is not localized. So we think that UHF RFID is more suitable for pallet- and case-level tagging, long range applications, than item-level. However near-field concept in UHF is well established and is already used in a few areas of UHF RFID. UHF near-field RFID is increasingly popular for item-level tagging because the tag can be detected more consistently on various objects such as bottles of water, garments, DVDs, and small items [1-3]. ILT RFID has special requirements making it different from other categories of RFID like pallets and cases. That is, tags must be small and be read among a number of closely spaced items. Near-field UHF RFID means that the tag chip of standard Gen2 and reader system are used in the same way as far-field communication but the antennas for a tag and reader are designed to communicate by near-field coupling using electric or magnetic field. The near-field RFID antenna is a key factor for UHF item-level tagging systems. The near-field reader antenna is optimized to read near-field tags placed on products with various packaging options. In this paper, the UHF near-field antennas of a reader and tag are designed and these are used for the application of an RFID smart shelf for wine management.

Design of the tag and reader antenna in near-field UHF

This paper introduces the design and performance of the tag and reader antenna in near-field UHF which can be utilized for an RFID smart shelf for wine management. The geometry of the near-field tag antenna is shown in Fig. 1. Generally an RFID tag chip may have complex impedance different from 50Ω, that is, the tag chip impedance is a complex combination of small resistance and large capacitive reactance. The tag antenna is designed by introducing an "S"-shaped or "┼"-shaped slot

978-1-4244-3647-7/09/$25.00 ©2009 IEEE

to the circular patch formed on a thin film in order to have definite inductive reactance. Hence the designed tag antenna is conjugate-matched with the tag chip to tune at 911MHz. Fig. 2 illustrates the design concept of the slot array of the near-field reader antenna for a smart shelf. The reader antenna is composed of a dielectric substrate with the ground plane in which several pairs of slots are etched for radiation and the feeding network on the other side of it. Voltage and current standing wave exist along the microstrip line with open-circuited by means of the incident wave and the reflected one and exhibit maxima and minima. This manifests a variation in the magnitude of the voltage and current along the line. Fig. 2 illustrates the current standing wave along the line left open-circuited. The first maximum current distribution occurs at the position $\lambda_g/4$ apart at the open-circuited and maxima of current are periodically placed n * ($\lambda_g/2$) apart from the first one. Where n is positive integer and λ_g is the wavelength in the microstrip line.

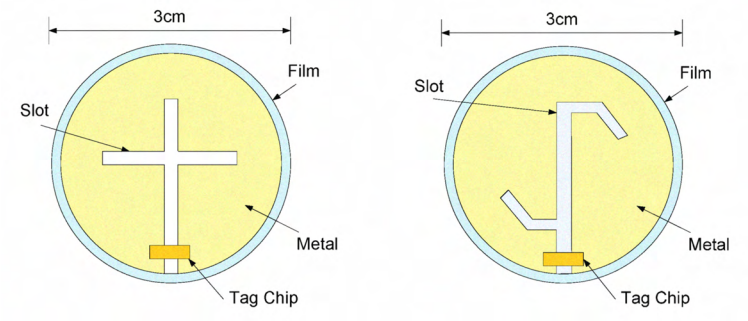

Fig. 1 Near-field tag antennas in UHF

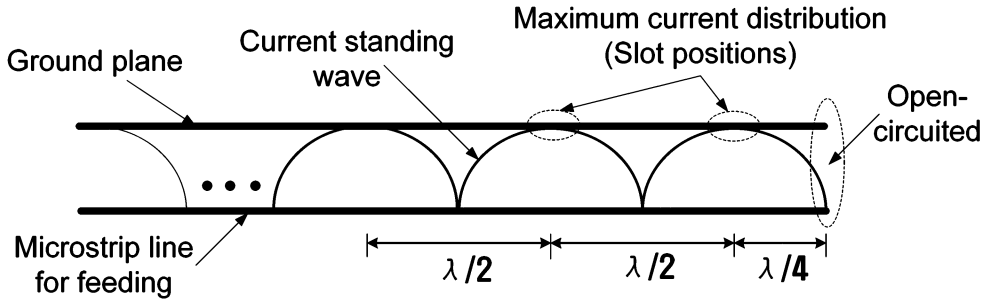

Fig. 2 Design concept of the antenna (Current standing wave in microstrip line)

Fig. 3 shows the near-field reader antenna which is electrically coupled with the tag antenna. The reader antenna consists of rectangular slots fed by a microstrip line left open-circuited. An approximate design technique for microstrip-fed rectangular slots is presented in [4]. Each pair of slots in the ground plane is formed at the positions for the current distribution to maximize, so the strong electric field occurs across the slots. All pairs of slots are spaced $\lambda_g/2$ apart since the distance between successive current maxima is $\lambda_g/2$. The line-length required for phase shift between adjacent pairs of slots is realized by making the maicrostrip line the meander-shape. Also the microstrip line for feeding is the combination of corporate and series feeds. All pairs of slots

are excited in phase with almost equal amplitudes by this feeding structure. Therefore the electric field appears in the near-field region of the reader antenna uniformly and wide. The proposed reader antenna can easily be redesigned modifying the length of the slots and the number of them. That is, the antenna has the good design flexibility. This feature of the antenna is greatly useful since the size and shape of the shelf in marts may be diverse.

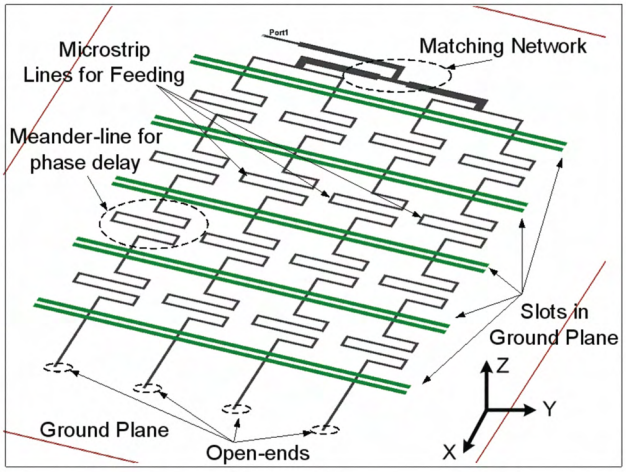

Fig. 3 Near-field reader antenna in UHF

Simulated and measured results

We designed the near-field tag and reader antenna in UHF for smart shelf applications that need to detect a number of crowded items in close range. This paper shows the smart shelf for wine management of various ILT applications. The designed tag is affixed to the bottom of a wine and the reader antenna shown in Fig. 3 is into the shelf. The reader antenna for the smart shelf must strongly and uniformly have near-field distribution over a specified range without dead zones. Fig. 4 presents the simulated and measured return-loss bandwidth and Fig. 5 shows the electric near-field distribution of the reader antenna. The measured bandwidth for S_{11}<10dB is 16 MHz from 905 to 921MHz and the electric near-field, i.e. E_x is uniformly distributed in the reading zone of 41cm by 32cm in which the E_x is the electric field in the virtual plane 3cm apart from the antenna.

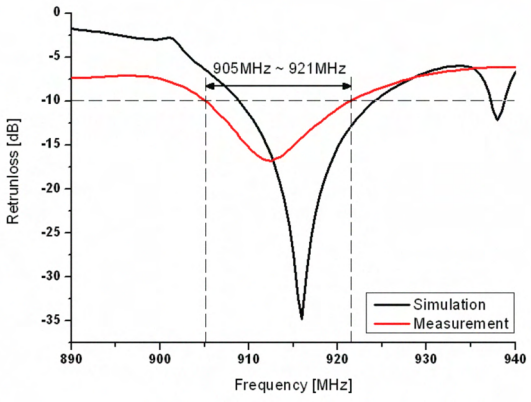

Fig. 4 Bandwidth of the reader antenna

We designed the smart shelf in which the designed reader antenna is embedded and tested the read performance of the shelf on which 20 bottles of wine are placed. The designed smart shelf offers the good reading stability without null zone.

Conclusion

This paper presents the design of the near-field reader and tag antennas in UHF that can be used for various smart shelves, the wine shelf particularly. The reader antenna embedded in the shelf offers uniform near-field distribution over a specified range, 41cm x 32cm, without dead zones and has design flexibility to easily change the size and shape of the antenna depending on the shelf configuration. We obtain the detailed information of the wine and the environments in which it travels picking it up on the shelf.

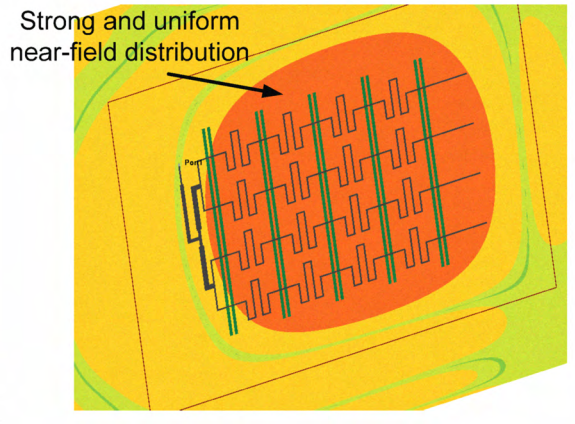

Fig. 5 Near-field distribution of the reader antenna

References

[1] P. V. Nikitin, K. V. Rao, and S. Lazar, "An overview of near field UHF RFID," *IEEE International Conference on RFID*, pp. 167-174, Mar. 2007.

[2] J. Choo, J. Ryoo, I. Park, J. Hong, and J. Lee, "A novel multi-loop tag for near field communication in UHF band," *Proceeding of Asia-Pacific Microwave Conference*, pp. 1-4, Dec. 2007.

[3] A. Shameli, A. Safarian, A. Rofougaran, J. Castaneda, and F. De Flaviis, "A UHF near field RFID system with fully integrated transponder," *IEEE Trans. Microw. Theory Tech.*, vol. 56, pp.1267-1277, May 2007.

[4] Akhavan, H. G., and D. Mirshekar-Syahkal, "Approximate model for microstrip fed slot antennas," *Electron. Lett.*, Vol. 30, No. 23, Nov. 1994, pp. 1902-1903.