

# Circularly polarized slot-array antenna for an RFID shelf in the UHF

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## Abstract

This paper presents a circularly polarized microstrip antenna which consists of slots series-fed by a microstrip line left open-circuited for RFID shelf applications in the UHF band. A circular polarization of the antenna is realized by a pair of orthogonal slots and a distance between the slots in which the distance is adjusted to excite each slot with two orthogonal electric-field components in phase quadrature.

**Keywords :** RFID, Antenna, Circular Polarization

## 1. Introduction

Radio frequency identification (RFID) has been widely used in supply chain and logistics applications in the identification and tracking of goods [1][2]. A considerable number of studies have been conducted on UHF RFID fields, especially tag antennas [3][4] and impedance evaluation method of a tag chip [5]. An UHF RFID has received a lot of attention as a possible solution for item-level tagging (ILT), which is the largest market for RFID. Generally we think that UHF RFID is more suitable for pallet- and case-level tagging which are long range applications than item-level tagging. However, recently the UHF-RFID smart-shelf system has been studied for item-level applications such as grocery products in the retail supply chain, large volumes of books in libraries, bottles in pharmaceutical industry and important documentation in offices. The RFID smart-shelf system helps us to keep adequate stock on the shelves and ensure product placement in desired locations at the appropriate time. The antenna is one of the key factors in RFID systems. The detection range and accuracy of an RFID system are directly dependent on the performance of the reader and tag antennas. Especially an RFID smart-shelf reader antenna can be subject to a wide range of environmental changes. A shelf may be empty or full and materials placed on a shelf may contain liquids or metals. In order to accommodate this varying configuration the reader antenna should be optimized to read stably tags placed on products with various packaging options in near-field zone. In this paper, a very simple and effective antenna design is proposed for the UHF-RFID smart-shelf complying with various itemized goods. The designed reader antenna is embedded into a shelf plate to monitor signals from tags placed on each product and is easily adaptable to different shelf sizes and types.

## 2. Design of the reader antenna

This paper introduces the design and performance of the reader antenna in the UHF which can be utilized for an RFID smart-shelf of an apparel application that need to detect a number of crowded items in a close range. The reader antenna in an RFID shelf should have a flexible design in its dimensions because shelves are so various in size and shape and the reading area of the antenna is also different depending on the applications. We designed a circularly polarized slot-array antenna for an RFID shelf in the UHF. Fig. 1 illustrates the design concept of the slot array of the reader antenna [6]. The antenna is composed of a dielectric substrate of thickness 0.79mm and relative permittivity  $\epsilon_r = 2.5$ , in which several pairs of orthogonal slots are etched in the ground plane for radiation, and the microstrip line is printed on the other side for feeding. A voltage and current standing wave exist along the microstrip line with an open-circuit through the superposition of incident and reflected waves, and the standing wave has periodic variations with

maxima and minima in the magnitude of the voltage and current along the line. Fig. 1 illustrates the current standing wave when the microstrip line was left open-circuited. The first maximum in the current distribution occurs at a position  $\lambda_g/4$  from the open-circuit end and other maxima of the current occur at points given by  $n*(\lambda_g/2)$  measured from the first maximum, where  $n$  is a positive integer and  $\lambda_g$  is the guide wavelength in the microstrip line. Fig. 2 shows the structure of the circularly polarized slot-array antenna designed. The antenna consists of the several pairs of the orthogonal slots series-fed by the microstrip line left open-circuited. Each pair of the orthogonal slots is placed at the current maxima positions along the open-circuited feed-line and the length of slots is about quarter wavelength at center frequency 911MHz. The distance “D” between a pair of orthogonal slots is adjusted to excite each slot with two orthogonal electric-field components in phase quadrature so a pair of slots is made to achieve circular polarization. Also the slots are offset-fed by the feed-line with the distances  $d_1$ ,  $d_2$  and  $d_3$  for both impedance matching and power control.

### **3. Simulated and measured results**

We designed the reader antenna in the UHF for smart shelf applications, especially apparel, that need to detect a number of crowded items in close range. The reader antenna is designed to radiate circularly polarized field in order to read stably tags attached to clothes, independent of tags' orientation. Fig. 3 shows the simulated and measured return-loss as a function of frequency. The axial-ratio at 911MHz and measured fractional return-loss bandwidth of less than -10dB are about 2dB and 13%, respectively. Fig. 4 shows the RFID shelf configuration into which the designed antenna is embedded at the bottom. As shown in Fig. 4, the shelf is designed to arrange shirts in 6 rows and 4 columns. Each pair of the orthogonal slots of the reader antenna placed at the bottom of the shelf is aligned with the center of a column of shirts stacked up to 4 steps. So tagged shirts can be read reliably without respect to how tags are positioned within the reader antenna's field because each pair of the slots emits circularly polarized electric-field. The RFID tag, ALN-9662 of Alien Technology, is attached to shirts on the shelf and the read range is about 30cm when a reader's output power is 25 dBm. A single reader can be used with multiple shelves using a standard electrically actuated RF switch to sequentially read each shelf. In this way, the output power of the reader, 25 dBm, is enough to read an arbitrary number of shelves.

### **4. Conclusions**

This paper presents the design of the reader antenna in the UHF band that can be used for RFID smart shelves in apparel and its performance is confirmed using the apparel shelf fabricated for the test. The reader antenna with three pairs of orthogonal slots is embedded in the shelf plate and reads stably the tags attached to 24 clothes on the shelf independent of the orientation of the tags. The designed reader antenna has great design flexibility to easily change the size and shape of the antenna depending on the shelf configuration. Although the proposed concept can be generalized to other RFID shelf applications in the UHF, this paper focuses on RFID shelf in apparel.

### **Acknowledgments**

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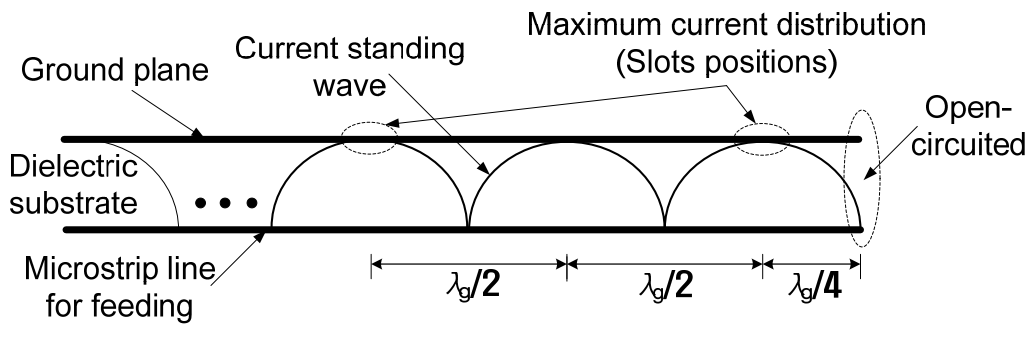


Figure 1: Design concept of the antenna using current standing wave in microstrip line.

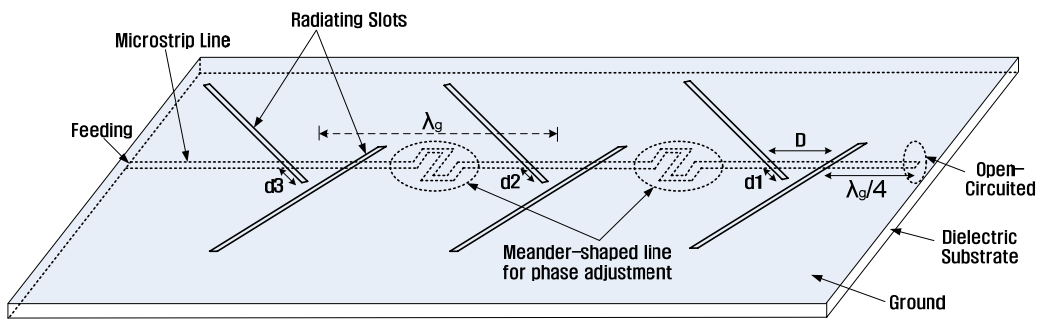


Figure 2: Circularly polarized slot-array antenna for RFID shelf in the UHF

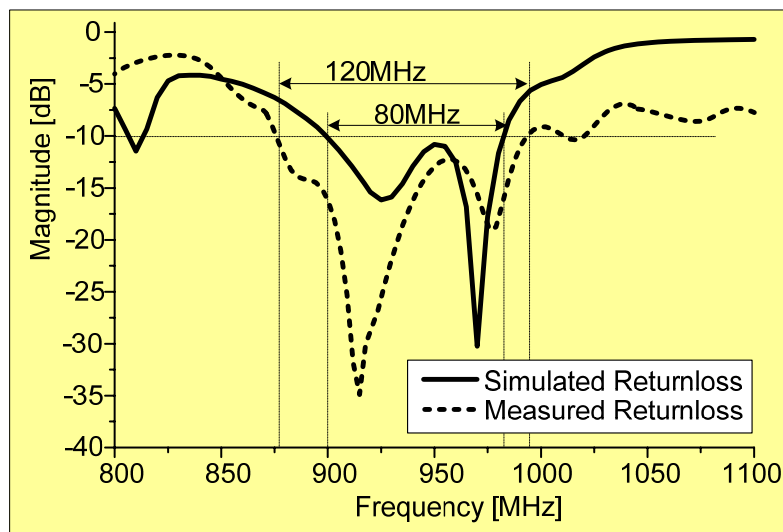


Figure 3: Simulated and measured return-loss bandwidth



Figure 4: Designed RFID shelf configuration in apparel

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