Multi-loop Antenna for High Frequency RFID Smart Shelf Application

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Introduction

The past two years have witnessed an explosion of interest in radio-frequency identification (RFID) and supporting technologies, primarily due to their rapid expanding use in tracking grocery products through the supply chain. RFID technology is expected to improve automation, inventory control, and checkout operations in stores, factories, and warehouse. Currently, supermarkets and other retailers across the world are planning large-scale item-level deployments of the RFID systems for consumer goods. Leading retailers such as Wal-Mart, Marks & Spencer, Tesco, Metro, Coles Myer and Mitsukoshi etc. are implementing RFID solutions for their supply chain management. The increasing demand spurs the development of so-called "RFID Smart Shelf". Besides for retail application, smart shelf is also expected to be applied in libraries to manage large volumes of books and other media, in pharmaceutical industry to track and monitor the tagged bottles, and in offices to manage important documentation.

A typical RFID smart shelf as shown in Fig. 1 comprises three main parts: antenna system, multiplexer and reader/writer. The system can detect and identify tagged items in range and read their identification, to map the position of detection to an absolute position on the shelf, communicates the retrieved IDs and their positions to an external system by user request.

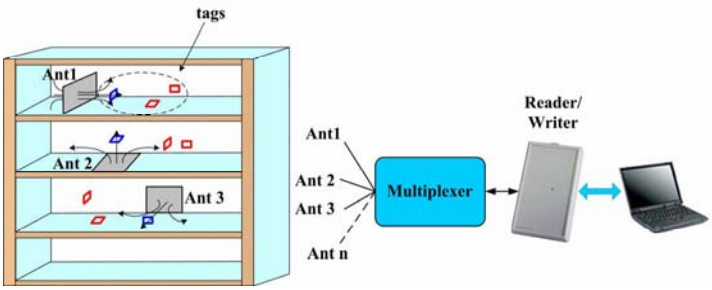


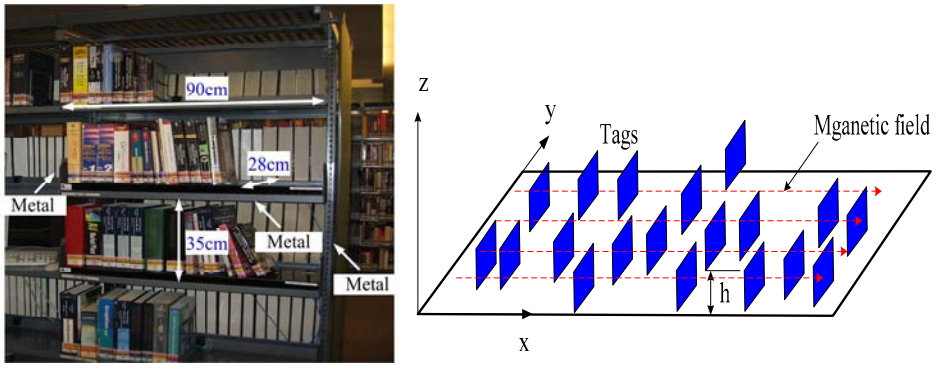
Fig. 1 Typical RFID smart shelf configuration

For item-level tracking and management in short distance, near-field coupling is the most straightforward approach because of the limited detecting range. The reported RFID smart shelves are operating at high frequency (HF @13.56MHz) [1, 2, 3, 4, 5]. Although the application of UHF (860MHz to 960MHz) RFID smart shelves has been of interest recently, no UHF RFID smart shelf prototype

has been reported till now. In this paper, we will address the antenna for HF RFID smart shelf application, a patent-pending multi-loop antenna is presented to generate uniform field distribution in an interrogation region located around the antenna. The proposed antenna has been successfully used to configure a HF RFID smart shelf system in Singapore National Library for real time tracking and locating of the books.

Antenna Design Considerations

Antenna design is the key factor for RFID smart shelf system. The detection accuracy is directly dependent on antenna's performance. In addition, optimized low-cost antenna design will benefit the system with better detection accuracy, reduced antenna fabrication cost, simple system configuration and implementation cost reduction. Fig. 2 shows a book shelf in library. Each shelf comprises 4 metal tiers. The dimensions of each tier are 90 cm (length) x 28 cm (width). The separation between two tiers is 35 cm. The books tagged with Phillps I-CODE 1 RFID tags are placed vertically on the metal racks.



(a) (b)

Fig. 2 Book shelves in library, (a) books in the shelf; (b) positioning of the tags.

Consider that most of books in the shelf are positioned vertically (as shown in Fig. 2a), i.e. the tags are oriented in the y-z plane and parallel to each other. The dimensions of the tags are 50mm × 50mm. The distance, h, is measured between the metal shelf and the bottom of the tag. The antenna is required to be properly configured to generate magnetic field along the x-axis to read the parallel tags with specified detection accuracy (≥ 95%).

There are various antenna designs and configurations for the application. Conventional single loop antenna can be vertically placed in the shelf to detect the books; vertical placement configuration is the most straight forward way as the parallel tags are in best orientation to get maximum magnetic flux. The disadvantage of the vertical placement single loop antenna include: (a) detecting range is limited, at least two antennas are needed to cover one tier (90cm long), therefore system complexity and cost is increased; (b) mounting antennas on the shelf rack needs some mechanical modification to the book shelf, hence

increasing system implementation cost; (c) interference between the antennas in adjacent tiers / shelves is serious and very hard to control, which severely degrades the detecting accuracy.

Horizontal placement antenna which is placed on the shelf rack is preferable. The advantages of using horizontal placement antenna are: (a) one antenna is needed to cover one tier, which reduce the number of antennas and multiplexers; (b) no modification is required to the shelf and it is easy to retrofit, thereby reducing system implementation cost; (c) less interference between the antennas in the shelves. However it is a big challenge to design the horizontal placement antenna: (a) It is very difficult to generate uniform horizontal (x-axis) magnetic field distribution over the whole tier; (b) the metal rack has a serious effect on the loop antenna, which weakens the magnetic field significantly and degrades the reading range.

Antenna Configuration and Results

The main magnetic field flux of a horizontal placement single loop antenna in x-y plane will be along the y-axis over the centre area of the antenna, the tags fall in the area with much weak horizontal magnetic filed will not be detected. It is obviously that single loop element cannot offer the required magnetic field distribution to cover the whole tier. A patent-pending multi-loop antenna (shown in Fig. 3) is presented for this purpose.

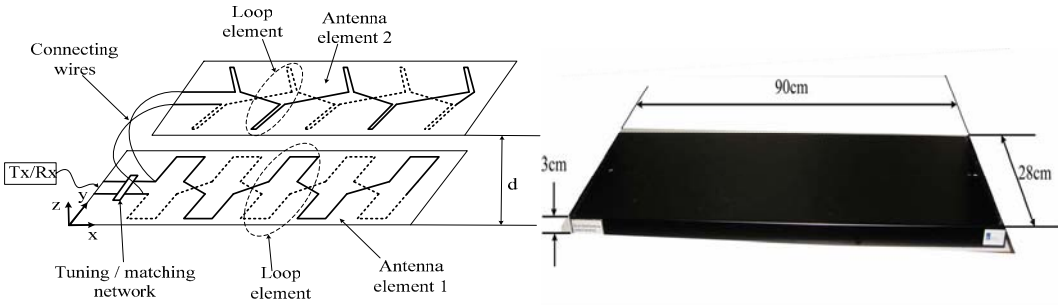


Fig. 3 Patent-pending multi-loop antenna prototype for HF RFID smart shelf application, (a) antenna configuration; (b) antenna prototype with casing.

The proposed multi-loop antenna comprises two antenna elements which are composed of a plurality of loops. The antenna elements are separated by a substrate with a thickness of d. By selecting the shape, size and location of the loops, the magnetic field produced by the loops can compensate each other to achieve uniform field distribution in an interrogation region located around the antenna array. The loop elements are configured to make the current direction either clockwise or anti-clockwise, and the current direction with respect to each adjacent loop to be in phase opposition. A tuning/matching network is to tune the antenna to 13.56MHz and achieve good impedance matching between the antenna and the 50 ohms feed line. The measured return loss and field distribution of the

proposed antenna are illustrated in Fig. 4 and Fig. 5. The results of the detecting accuracy of the books are summarized in table 1.

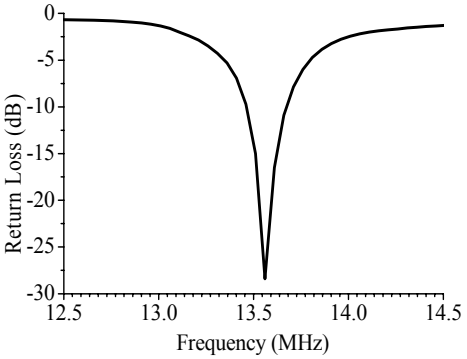


Fig. 4 Measured return loss

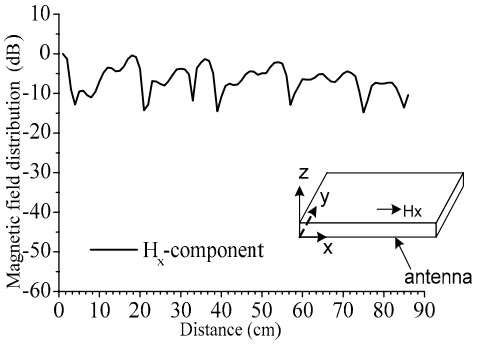


Fig. 5 Measured field distribution

Table 4.1 Tested detection accuracy for patent-pending horizontal placement antenna.

No. of books	Height of tag (h, mm)	Detected books	Detection accuracy (%)*
40	0	40	100.0
	12	40	100.0
	25	38	95.0

*The minimum thickness of testing books for testing is 1cm; the detection accuracy may degrade if the books are less than 1cm thick because of the detuning effect between tags.

Conclusion

This paper has presented a patent-pending multi-loop antenna for HF (13.56MHz) RFID smart shelf applications. The proposed antenna prototype has been able to generate magnetic field with uniform magnitude for a larger interrogation region. In addition, the low profile structure makes it very easy for implementation and not necessary for any modification to the shelf. Hence, the system installation cost has been reduced significantly. The patent-pending multi-loop antenna has been used for RFID smart shelves which are implemented in library for book management with achieved detection accuracy of 95-100%.

References:

[1]http://www.panasonic.com/industrial/other/other_components_input_devices_rfid_smartshelf.htm
[2]http://ubiks.net/local/blog/jmt/archives3/004327.html
[3]http://www.teco.edu/projects/smartshelf/
[4]http://www.tagsysrfid.com/html/rfid-news-250-2-1.html
[5] http://www.exploit-tech.com/news/newsDetail.asp?UID=75