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Research and Design of Library Smart Bookshelf Based on Passive UHF RFID Technology

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Abstract. An intelligent Library Smart Bookshelf (LSB) based on the emerging UHF passive RFID technology is currently being designed in order to replace a traditional bar-code system at the university's library. Objectives of the design include maximization of tag readability, localization of tagged items in the smart bookshelf, reduced spill-over energy to nearby shelves. Different types of shelf antennas were used and tested including evanescent-type antennas as well as far-field antennas. The antennas were designed, simulated, built, and tested in a realistic environment. HFSS were used to evaluate radiation parameters and illustrate the radiation effects of near-field and far-field antennas in the presence of the cabinet and library users. The project will provide practical management system convenient and practical, market prospects.

Keywords: Passive UHF RFID, Tag, Antenna, Radiation Parameters.

Introduction

Radio Frequency Identification (RFID) is a growing technology with a plethora of useful applications in major sectors of the economy ranging from the health care [1] and pharmaceutical industry to retailing, transportation and logistics [2]. The project at hand is dealing with the design, implementation, and deployment of a pilot RFID system for the university's library. The main idea is to use the passive RFID technology at UHF frequencies in order to develop an intelligent low-cost Library Management System (LMS) that reduces labor and running cost and improves productivity at workplace [3]. The general objectives of the ongoing project include: a) replacement of traditional time-consuming processes for checking books in and out of the library; b) automation of labor-intensive and time-consuming stock-taking processes; c) improvement of productivity at workplace by eliminating tedious and paper-bound processes traditionally followed during inventory taking; d) reduction of library running cost due to a more productive and highly efficient working environment; e) reduction of thefts and of the number of missing or misplaced items; etc.

In order to achieve the aforementioned general objectives of the project, the research team has undertaken the task to design and build: a) a smart RFID bookshelf interfaced with computer technology via a Graphical User Interface (GUI) which is user-friendly, portable, and versatile; b) a check-out counter where the library user can check out books through the use of an RFID enabled system which is fully interfaced with the existing library database system; c) a book-return counter or drop box where a library user is able to return books without the help of a librarian; d) a portal RFID enable system which is activated when a non-properly checked-out book is about to exit the library entrance.

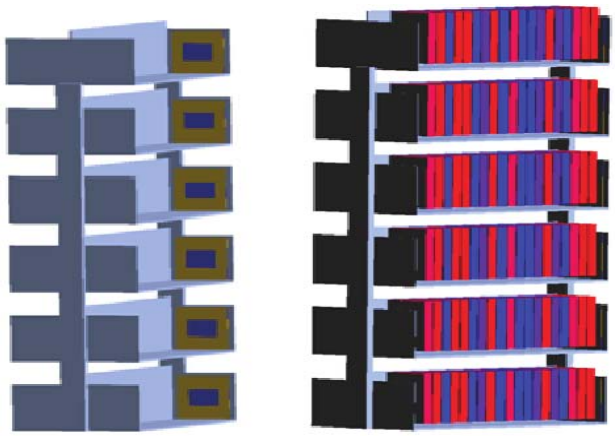
In this paper, we focus our efforts primarily on the design and evaluation of a smart cabinet developed using existing state-of-the-art passive UHF RFID systems interfaced with computer technology (laptops, tablets, and smart-phones) via a user-friendly and portable GUI[4]. A properly designed antenna is installed on each shelf of the cabinet allowing maximum readability of RFID tags placed somewhere in the interior of the books. Either a far-field or a near-field antenna can be used.

A far-field antenna has a larger range allowing reading of tags from a relatively large distance (4-7 m) depending on the tag type, reader's sensitivity, antenna input power, and environment. A near-field antenna has a shorter range-measured in tens of centimeters-thus allowing readability of tags in the near vicinity of the antenna [5]. Design of far-field antennas is easy and straight-forward; however, there is significant spill-over of energy to nearby shelves creating tag localization problems

and undesirable readings. In addition, it generates excessive radiation toward unsuspected library users in the vicinity of the shelves. On the contrary, near-field antennas are extremely difficult to design and have a very short readability range creating tag identification problems of books on the shelves. In the current work, we decided to test two well-known and previously published antennas a near-field micro-strip line and a far-field rectangular patch antenna in terms of coverage on the shelf as well as in terms of the Specific Absorption Rate (SAR) for nearby library users. An optimum solution is the one that provides adequate coverage and low SAR readings [6].

Proposed RFID Enabled LMS

Problem Setup. In this paper, we will focus primarily on the radiation characteristics of the smart cabinet assuming certain types of shelf antennas. A typical cabinet is illustrated in Figure 1. Each of these shelves consists of a shelf antenna positioned either at the bottom of the shelf, the back of the shelf, the back of the shelf, or even the side-wall of the shelf. Such antennas are either near-field antennas or far-field antennas. The objective is to allow 100% readability of the books in the particular shelf without reading other books from nearby shelves.



(a) (b)

Fig1. CAD model of a typical smart cabinet without books (a) and with books (b)

Another objective is to avoid excessive radiation toward the library user due to spill-over energy. For this reason, we considered to examine two types of antennas: a) a simple micro-strip line terminated by a matched load which was recently proposed by Medicos [7] and b) a linearly polarized far-field patch antenna designed for the UHF RFID frequency band. Both these antennas are illustrated in Figure 2.

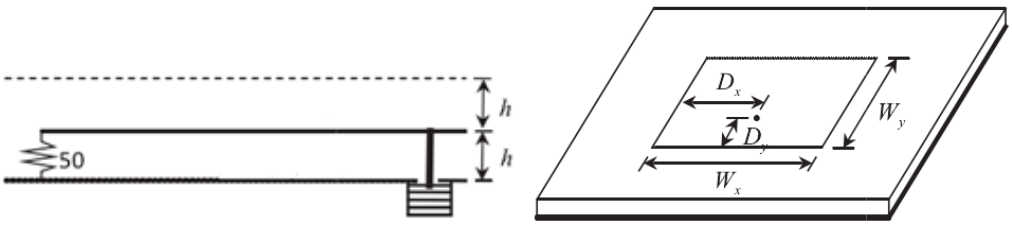
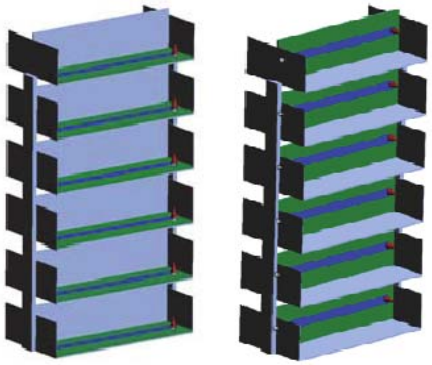


Fig2. (a) The micro-strip line (b) Linearly polarized patch antenna

The micro-strip line generates an evanescent field in the transverse plane whereas the voltage and current waves are propagating undisturbed in the longitudinal direction. This type of antenna can be placed either on the bottom of the shelf, as shown in Figure 3(a), or at the back of the shelf, as shown in Figure 3(b).



(a) (b)

Fig3. (a) Micro-strip line mounted on the bottom of the shelf; (b) Micro-strip line mounted at the back of the shelf.

Numerical human models . Two different simulation scenarios were studied. In the first scenario the human model is facing the cabinet at a distance of 10cm, whereas in the second case the human model is nearly touching (5mm away) the cabinet with its arm. Simulations were performed with or without the presence of books. Return loss of patch antenna versus frequency, as shown in Figure 4.

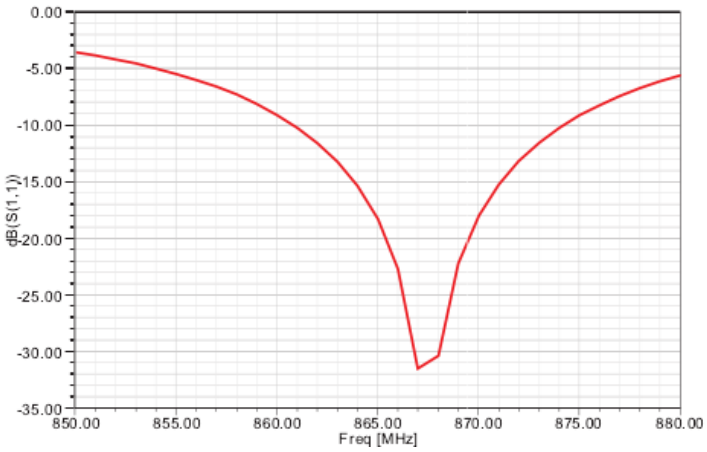


Fig4. Return loss of patch antenna versus frequency.

Simulation Results Analysis

The evaluation of the library system proposed in this paper is based on two factors. Firstly, we examine the spill-over of the energy to the nearby shelves and secondly the maximum exposure to human models from the antennas.

Spill-over electric field. In order to assess the spill-over, we have compared in dB the maximum E-field in nearby shelves with the maximum E-field in the space of scanned shelves. Table 1 contains this comparison for each antenna.

Table1. Relative value of maximum electric field observed in non-scanned nearby shelves

Antenna type/case	**Spill-over E-field（dB）**
Patch antenna	-28.5
Patch antenna (no books)	-29.5
Microstrip horizontal	-30.6
Microstrip horizontal (no books)	-38.9
Microstrip vertical	-31.9
Microstrip vertical (no books)	-38.8

Summary

In this work, we have shown that it is possible to design a smart library cabinet taking into account both its efficiency in books scanning, as well as its compliance with environmental factors, like human exposure.

The numerical results indicate that using a micro-strip antenna placed at the back of the cabinet shelves results in reduced spill-over electric field in the space of non-scanned shelves. This configuration is also the second best in terms of energy absorbed in the body of library users, whereas the patch antenna leads to the lowest exposure.

Acknowledgments

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