Smart RFID Based Design for Inventory Management in Health Care

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KEYWORDS	ABSTRACT
Gerber Files, Radio Frequency Identification; Printed Circuit Boards; Main Controller; Integration Engine; Par levels	*Radio Frequency Identification (RFID) is used to identify the characteristics of an object wirelessly using radio waves. The purpose of this technology in this study is mainly focused on healthcare for inventory management and theft control replacing the manual logs. The storage and tracking of high-cost inventory items is developed. Automatic reordering and billing interfaces are designed for the inventory falling below the par levels. iRISupply and iRIScope are the two RFID systems developed to reduce the inventory costs, expired item costs and to improve the inventory management with easy reporting system.*

1. Introduction

The goal of this project is to design a SMART inventory Management System with Radio Frequency Identification.

Information of the object is captured and stored on an item called RFID tag, affixed to the object. An RFID tag consists of a microchip attached to a radio antenna. The microchip stores information of the product on the tag. Information like unique identification numbers, lot number, manufacturers and other information about the product.

Data stored on the RFID tag is retrieved through the use of a reader. The reader has one or more antennas that emit radio waves and receive signals back from the tag. Once the reader receives the information from the tag, it then passed in digital form to a computer system. This is accomplished utilizing Radio Frequency (RFID) technology to manage the inventory levels and for patient tracking. Through the process of transmitting object data from tag to a reader, RFID enables the communication of information in a timely and accurate manner. More significantly, it improves

the operational processes within healthcare system by creating a safe, efficient system and a higher quality of care [1]. Medical errors continue to increase and administrative processes, such as billing and inventory management, become more problematic and are often overlooked due to the complexities and fast-paced environment in many hospitals.

This explains the main processes using RFID technology in medical cabinets. Medical industries and hospitals are in need of a device that monitors the supplies and expensive equipment such as pacemakers, stents, drugs etc [4]. iRISupply is designed to meet the needs of the medical industries and reduce the inventory cost by eight to twelve percent.

Fig. 1. iRISupply- RFID solution

iRIScope provides an easy-to-use solution that automates the workflows of nurses and technicians, responsible for endoscope utilization and reprocessing. In turn, through the workflow automation department leadership is provided critical information to optimize the utilization of these expensive assets [1]. There are many kinds of cabinets with multiple configurations, designed to meet various needs in the medical departments. Typical system configuration consists of three to five cabinets. Depending on the storage needs, more cabinets can be added. These are called "the multiple systems." Inventory management systems are designed to provide integration between all the cabinets and the network.

The control cabinet consists of a touch screen with a keyboard that provides the details of the cabinets control activity. In addition, it also gives access to the many compartments in order to view the status of the cabinet. Using cabinets is quick, easy and secure. Cabinets scan and manage inventory [2]. The supplies in the cabinet use RFID tags and with the RFID technology, tags are scanned and shown on the transaction list.

These cabinets identify three things: what items are taken by whom and at what time. They even identify, when the items were returned. The supply knowledge software provides real time inventory reports with the inventory replenishments [4]. This software is a graphical link to the supply server. For a fully automated solution, the Integration Engine (IE) is connected to the hospital inventory systems. This will enable the IE to automatically place orders when supplies fall below the user defined levels.

2. Hardware Development

This section reports the design methodology of the cabinet. We explain both the hardware and software developments for the iRISystems classified as iRISupply and iRIScope. The design of these systems plays a major role for their functioning using RFID. iRIScope is an innovative endoscope tracking system designed to help surgical specialty care providers improve the storage utilization and reprocessing of flexible endoscopes. Through a patient-centric design the solution helps to:

1. Increase patient safety by preventing equipment cross-contamination and reducing risk for proliferation or transmission of infection.
2. Improve care quality by enhancing compliance to protocols for equipment cleaning
3. Re- processing and utilization.
4. Optimize asset management by tracking equipment utilization and mitigating risk of equipment theft damage or misuse.

In using RFID as an enabling technology iRIScope provides an easy-to-use solution that automates the workflows of nurses and technicians, responsible for

endoscope utilization and reprocessing [5]. In turn, through the workflow automation department leadership is provided critical information to optimize the utilization of these expensive assets. Key features are identified below and with a product flyer providing a full system description:

1. Cabinet-based storage units provide secure, yet easy access to all endoscopes
2. Forced-ventilation within Cabinet units to dry endoscopes following reprocessing washes.
3. Ruggedized RFID tags affixed to endoscopes that withstand the chemicals pressure and action of reprocessing stations including ultrasonic agitations.
4. Reprocessing work stations that automate processes and data capture associated with cleaning protocols.
5. Automated rules and alerts delivered to email and handheld devices for cross-contamination risk or equipment status concerns (e.g. scope out of system exceeds 24 hours).
6. Web based reporting tools to support analysis of endoscope utilization reprocessing compliance instrument repair and operational indicators.

The iRISupply is an Effortless compliance which increases the productivity, enhances the quality of care and reduces cost. So it is truly effortless. No bar codes or no buttons to push. It is completely automatic and no manual operation is involved. Cabinets scan and manage inventory. These cabinets identify three things 1.what items are taken 2.by whom 3. At what time. They even identify when the items are placed back. The supply knowledge software provides with the real time inventory reports, as well as to track the inventory replenishments.

It is a graphical link to supply server, the heart of effortless compliance. For a fully automated solution the integration Engine (IE) is connected with the hospital integrated systems [5]. This will enable the IE to automatically place orders when the supplies fall below the user defined levels. iRISupply is an RFID enabled inventory management solution that supports the storage and management of high cost inventory items commonly used in areas such as cardiac and vascular catheterization labs interventional radiology suites and surgical specialty areas [3]. By using RFID technology iRISupply offers a 'Hands Free' approach to managing inventory in these busy often hectic clinical areas where time is of the greatest importance.

The average hospital spends as much as 36 percent of its total purchasing dollars on supplies for operating rooms catheterization and other interventional labs but captures on average only about 75 percent of all charges related to those supplies according to the Healthcare Financial Management Agency (HFMA) [6]. With the cost of medical devices increasing dramatically combined with their shortened shelf life, the need for hospitals to more carefully and accurately

track their inventory is imperative.

Key component of the iRISystem is iRISupply™, an RFID-enabled modular inventory management cabinet system that is installed in operating rooms catheter labs EP labs interventional radiology and wherever the tracking of critical hospital supplies is required. Each cabinet automatically tracks and reorders each item according to user-defined levels and through iRISense™, associates the removal or replacement of each item with a particular clinician and patient and can automatically alert clinicians when items are about to expire or if they have recalled product on their shelves [10]. The scalable server and Mobile Aspects integration services link this information to patient tracking financial and billing systems ensuring that all patient charges are captured.

By eliminating the common problems associated with manually intensive approaches that use paper stickers, barcode scanning or button pushing iRISupply enables an increased level of automation and accuracy by removing the burdensome tasks, typically completed by clinical staff. Common benefits experienced by organizations implementing the technology include:

1. Improved Charge Capture Accuracy
2. Eliminated Product Expiration Costs
3. Reduced Time Spent Managing Inventory
4. Optimized On-Hand Inventory Levels and
5. Improved Product Recall Management.

3. Hardware Design for Reliability and Safety

The hardware of the iRISupply consists of PCB designing of the boards and antennas used in the cabinet. These PCB's are designed with the Eagle application. Secure controlled storage units are accessible only by authorized users. The authorized users have an RFID tag on their ID and when the ID is scanned on the scanner attached to the cabinet, it detects the user and the status of the Cabinet. A touch screen console is designed to provide quick and easy end user interaction. Adjustable shelving to accommodate a variety of packaging sizes and shapes is provided in the Cabinet. Re-configurable Cabinets to adapt to changes in inventory mix. Dynamic shelving organization and location as all items are located through RFID. Lighting inside the Cabinets to enhance visibility to all items within storage is provided by the light boards designed with LED's.

Fig. 2. Reader module

Easy-to-learn intuitive work flows that significantly speeds end user adoption and proficiency. Item-level product tracking including lot number serial number and expiration date [7]. Automated expiration notifications and alerts through cabinet console and via e-mail. Product query and identification tools to support incidents of product recall are available. Ability to interface with external systems to communicate patient charges and inventory replenishment are being done. Powerful access to data is also available through iRISynergy reporting tool.

4. Hardware Design of Printed Circuit Boards.

The design and circuitry are discussed while designing the boards. Joining the diverse line of RFID readers and the Intermec RFID antennas including antennas, specifically designed for fixed applications as well as vehicle mount applications. The shock and vibration can far exceed average industry specifications. Intermec RFID antennas provide the vital link between reader and tag serving as the conduit that moves data back and forth. The antenna in an RFID tag is a conductive element that permits the tag to exchange data with the reader. Passive RFID tags make use of a coiled antenna that can create a magnetic field using the energy provided by the reader's carrier signal.

4-1. RFID Antenna

A system for reading RFID tags of articles within a cabinet includes a repositionable shelf. The repositionable shelf includes an antenna assembly having three antenna pairs. Each antenna pair has a loop antenna [8].
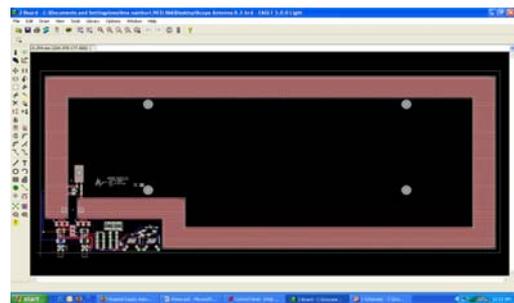

Fig. 3. Design of Antenna board

The antenna pairs are on a PC board. The PC board includes an RJ45 connector which provides both power to the antenna assembly as well as a communication interface for the antenna assembly. The RJ45 connector could be used to provide the RF signals from the antenna to a reader. The system could also include a repositionable divider for placement perpendicular to the repositionable shelf. The repositionable divider also includes a loop antenna and a eight antenna [7]. The mentioned problems are overcome by a moveable and reconfigurable storage device, using an RFID antenna system utilizing multiple instances of a eight antenna in combination with a loop antenna.
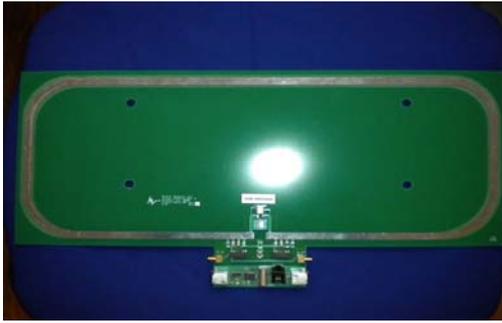
Fig. 4. PCB of RFID Antenna

In a preferred embodiment, the loop antenna and the Figureure eight antenna are arranged about a common axis, referred to as the X-axis. The Figureure eight antenna is placed symmetrically within the loop antenna.

Currents created in one part of the Figureure eight antenna, due to coupling with the loop antenna are offset by equal and opposite current, created in another portion of the Figureure eight antenna. Similarly, currents created within the loop antenna due to coupling with one portion of the Figureure eight antenna, are countered by equal and opposite currents created by coupling with another portion of the Figureure eight antenna. Thus, nulls created by the coupling between the Figureure eight antenna and the loop antenna are substantially reduced [8]. Since the nulls between the two antennas are minimized, it is possible to place the two antennas in relatively close proximity, thereby allowing the near-field coverage of the two antennas to be maximized.

To further improve the accuracy and detection of the antenna assembly, an additional antenna is arranged such that the axis about which it is aligned, referred to as the Y-axis, is aligned generally perpendicular to that of the X-axis [8]. Additional antennas having axes parallel to the X-axis and perpendicular to the Y-axis may also be provided. Additional instances of the combination of a loop antenna with a Figureure eight antenna placed in the same plane as the initial combination and having an axis parallel to the X-axis provide even greater accuracy. The resultant antenna assembly has few nulls and allows for highly accurate detection and reading of RFID tags.

The antenna assembly can be manufactured on a single printed circuit (PC) board by placing multiple instances of the loop antenna within the Figureure eight antenna on one side of the PC board. The other side of the PC board includes antennas arranged so that their axes are parallel to the Y-axis.

In the current embodiment, the antenna assembly has a layer with several coplanar antennas on side of the PC board. The first antenna layer has a loop antenna enclosing a first Figureure eight antenna. A second Figureure eight antenna is positioned within the perimeter of the first loop of the first Figureure eight antennas. Within the second Figureure eight antenna is a second loop antenna. A third Figureure eight antenna

is positioned within the perimeter of the second loop of the first Figureure eight antenna.

To improve the accuracy of the PC board, the width of the antenna elements of the first antenna pair is larger than the width of the antenna elements of the second antenna pair or the third antenna pair, thereby providing that the inductance of each of the antennas is approximately the same. Since the inductance of the antennas is approximately the same, the same size tuning capacitors for each antenna can be used.

The resultant system has high accuracy detecting RFID tagged items placed on the shelf. Additionally, the shelves are easily movable, allowing a Cabinet or shelf system to be adaptable so as accommodate a variety of articles. These and other objects, advantages, and features of the invention will be more fully understood and appreciated by reference to the description of the current embodiment and the drawings.

The fabrication of antennas with recycled materials but with good performance is possible by using the classical formulation from textbooks. Several antenna designs built with materials found at home are shown and their performance is measured with professional equipment to assess an acceptable agreement between simulations and measurements [13].

Practical design and fabrication of antennas made with used materials and operating at Wi-Fi bands will surely stimulate students of basic topics of antennas to fabricate and test their own designs. Most of them are designed to operate into a 50 ohm load because, that is the standard quantity that the industry is following for measuring high frequency electrical power. Transformation of the resistive and capacitive components of the plasma to 50 ohms is done [13], thus matching the load impedance to generators impedance.

4-2. Main Controller
The Main Controller performs the function of communication, control and command scheduling onboard the ROV. It is a PC 104 architecture-based rugged computer with Intel 386 as its core processor. It has a stack comprising power supply a motherboard and a multi-serial card [11].

Fig. 5. PCB of Main Controller

It connects to the various payloads through a common interface depending on the role for which it is being deployed [12]. The main controller is pre-programmed with an ID for enabling address-based communication required for collaborative control over multiple ROVs. Main controller is designed to control all the Printed Circuit Boards (PCB) in the Cabinet. It is also connected to the computer CPU to control and monitor the operations of the Cabinet. It has 3 DIP switches, 3 transistors in parallel. There are 4 outputs which are connected to RF Antenna, LOW-PASS FILTER, CPU, Light Board.

5. Gerber Files

A Gerber File is a file format used by printed circuit board manufacturing machines to layout electrical connections such as traces vias and pads (the component "footprints" on the PCB). In addition the file contains information for drilling and milling the completed circuit board. These files are generated by PCB layout software and are sent to manufacturing companies where they are uploaded to the applicable machines for each step of the PCB production process [8]. When making an actual printed circuit board based on the data made from CAD the data of Gerber form are used in many cases. Gerber data are the data formats which a photograph plotter maker's Gerber Scientific Instrument Company created. All the information (the position of a hole a size thickness of a line etc.) for automating manufacture of a printed circuit board is numerically expressed with Gerber data. Gerber form is standardized as CAD output data of a printed circuit board.

Fig. 6. CAM Processor

CAM processor is used to generate the Excellon drill data. While creating the Gerber files for PCB manufacturing, CAM processor is required to create a drill file. To create this, Go to File->Open->Job to open the "_excellon AD.cam" CAM job file. This step needs the previously generated rack file "*.drl" for it to work. Click "Process Job" to generate the "*.drd" drill output file. In addition, a "*.dri" information file is generated.

6. Test and Results

Testing is performed in two parts hardware and software. Hardware testing is done for boards on the physical cabinet. Software testing is done for the application and reporting system that controls the cabinet. Hi-pot, antenna Standing Wave Ratio, Accuracy scan tests are performed once the hardware is ready. A "short" on a board would be a connection where there should not be one; an "open" is between two points that should be connected but are not. For small- or medium-volume boards, flying-probe and flying-grid testers use moving test heads to make contact with the copper/silver/gold/solder lands or holes to verify the electrical connectivity of the board under test.

After the printed circuit board (PCB) is completed, electronic components must be attached to form a functional printed circuit assembly, or PCA (sometimes called a "printed circuit board assembly" PCBA). In through-hole construction, component leads are inserted in holes. In surface-mount construction, the components are placed on pads or lands on the outer surfaces of the PCB [8]. In both kinds of construction, component leads are electrically and mechanically fixed to the board with a molten metal solder.

There are a variety of soldering techniques used to attach components to a PCB. High volume production is usually done with machine placement and bulk wave soldering or reflow ovens[12], but skilled technicians are able to solder very tiny parts (for instance 0201 packages which are 0.02 in. by 0.01 in.) by hand under a microscope, using tweezers and a fine tip soldering iron for small volume prototypes. Some parts are impossible to solder by hand, such as ball grid array (BGA) packages.

Often, through-hole and surface-mount construction must be combined in a single assembly because some required components are available only in surface-mount packages, while others are available only in through-hole packages [13]. Another reason to use both methods is that through-hole mounting can provide needed strength for components likely to endure physical stress, while components that are expected to go untouched will take up less space using surface-mount techniques [9].

After the board has been populated it may be tested in a variety of ways:

1. While the power is off, visual inspection, automated optical inspection. JEDEC guidelines for PCB component placement, soldering, and inspection are commonly used to maintain quality control in this stage of PCB manufacturing.
2. While the power is off, analog signature analysis, power-off testing.
3. While the power is on, in-circuit test, where physical measurements (i.e. voltage, frequency) can be done.
4. While the power is on, functional test, just checking if the PCB does what it had been designed for.

To facilitate these tests, PCBs may be designed with extra pads to make temporary connections. Sometimes these pads must be isolated with resistors. The in-circuit test may also exercise boundary scan test features of some components [12]. In-circuit test systems may also be used to program nonvolatile memory components on the board.

In boundary scan testing, test circuits integrated into various ICs on the board form temporary connections between the PCB traces to test that the ICs are mounted correctly. Boundary scan testing requires that all the ICs to be tested use a standard test configuration procedure, the most common one being the Joint Test Action Group (JTAG) standard.

Boards are subjected to bare board testing and then fitted in the metal cabinets. By using Radio frequency and design of iRISupply offers a "hands free" approach to managing inventory in these busy and often hectic clinical areas where time is of the greatest importance. Data stored on the RFID tag is retrieved through the use of a reader.

The reader has one or more antennas that emit radio waves and receive signals back from the tag [11]. Once the reader receives the information from the tag, it then passes the information in digital form to a computer system.

7. Conclusions

This paper describes the use of Radio Frequency Identification for simplifying the healthcare management. iRISupply is the system designed for tracking the inventory and patients. Hardware design was developed to store the inventory that was controlled by the application.

Reporting system of the inventory is simple and user friendly.

Tagging the products with RF tags was done with Synergy software. Overall, the system is simple with patient interface and reporting system.

Future enhancements for tagging procedures are being planned to reduce the time for tagging each product. Also, scan times of the antennas need to be reduced to improve systems speed.

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