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Engineering Laboratory Inventory Management System using Cloud and RFID Technology: Conceptual Approach in KDU University College

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Abstract. As quality standards are an integral part of the higher educational system; this project's focus is on computerizing inventory management quality processes by using cloud architecture and radio frequency identification (RFID) technology dominantly to ensure accountability on University's valuable assets as well as ensuring engineering laboratory consistency of performance on teaching and learning process. Radio Frequency Identification, which is a "contactless technology" has gain popularity due to its ability to scan multiple devices at a rapid pace, user friendly to end-user and has add-on security values. Due to these characteristics, RFID is considered to be the potential successor of barcode and may complement or replace barcode. This study presents a two prong approach: first optimizing advancement of internet of technology in creating an efficiency database that renders a secure and efficient inventory asset management system; secondly innovatively notify the laboratory staff of calibration and maintenance work schedule of each test and measurement equipment; In this project, system software and prototype are used which crucially involve RFID tag and reader. The RFID tag contains each individual devices' information which will be transmitted via a long distance radio frequency to a cloud storage. This prototype will enable the assigned technical staff to have ready access to all technical specification information of the equipment more specifically its maintenance schedule and next calibration date. A real time notification will be propagated via a SMS mechanism to the technical support staff in the event it detects movement of equipment out of the engineering laboratory. Hence, significantly enhancing the effectiveness of the system in adhering to compliance of quality process requirements.

INTRODUCTION

Over recent years, a number of institution of higher engineering education have been adopting a quality process to improve the laboratory inventory management system. The process is to instigate appropriate and effective improvement effort on engineering laboratories to meet regulatory requirements, including local accreditation regulations, adequate support of teaching and learning and to monitor functionality and utilization of test and measurements, thereby ensuring engineering laboratory consistency of performance. The engineering laboratory of School of Engineering, KDU UC gains huge investment yearly to equip itself with essential test and measurement equipment that are considered to be the part of University's valuable assets. Thus, the drive to create an effective and technologically innovative system for documentation and recordkeeping, and ensuring the traceability of test and measurement equipment.

Leveraging on the development of the Internet of things, the study's focus is on computerizing inventory management quality processes by using cloud architecture and radio frequency identification (RFID) technology. This entails automated database system [1] to be created in tracking the School's laboratory inventory assets based on the radio frequency identification (RFID) technology [2]. In fact, RFID has gain increased attention recently for its use on remote storage and retrieval of data for many applications such as warehouses, production shop floors, logistics companies, distribution centers and retailers [3-6].

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Radio Frequency Identification, which is a “contactless technology” comprise of a small chip and an antenna. The small chip is embedded with information's of test and measurement equipment’s technical specification and calibration status. Thus, providing a suitable and systematic mode of tracking as well as movement of test and measurement equipment in real time from its designated area.

The current practice in School of Engineering uses the traditional inventory management system whereby the assets are identified manually primarily on paper based communications. The reliance on paperwork and data entry depends on the staff’s efficiency. Thus, viewed as a tedious and time consuming method in tracking the laboratory equipment as part of fulfilling the established quality process requirement. Hence, the RFID technology serves to revolutionize tracking and monitoring of test and measurement equipment in an automated manner; as a practical solution to the continuous quality improvement effort on inventory control and management.

Currently, two automated data collection technologies [7] exist in the market, namely, barcodes and RFID systems. The integration of RFID technology and wireless communication technology makes it superior to the bar code technology. Table 1 reflects the comparison of the barcode and RFID technology. A single tag is attached to an object can be automatically recognized, tracked, and traced from anywhere to shelf with RFID reader. The ultra-high frequency (UHF) RFID [8] frequency bands operates over a long range spectrum of 860–960 MHz. Over the past few years, significant improvements were gathered with respect to RFID usage, critically better performance identification, decreased set up cost of equipment and international standard usage around the world using UHF band.

TABLE 1. Comparison of Barcode and RFID (Gareth T.T 2007)

Barcode	RFID
Require line of sight to be read	Can be read without line of sight
Can only be read individually	Multiple tags can be read simultaneously
Cannot be read if damaged or dirty	Can identify a specific item
Can only identify the type of item	New information can be over-written
Cannot be updated	Can be automatically tracked removing human error
Require manual tracking and therefore are susceptible to human error	

However, importantly it provides high reading speed, multiple accesses capability, anti-collision and small antenna compare to low frequency (LF) or high frequency (HF) band RFID systems. For an example, RFID reader able to track the loaded vehicles [9-10] (or conveyers) with multiple goods or products by attaching tag on them. This RFID tag contains ID which is able to track the time departure and location data In fact, other information can be added into the tag.

An RFID reader [11] consists of antenna, RFID interrogator, processor and user interface. The antenna and interrogator work under mutual inductive in conjunction to gather and read the tag information, then send to the processor. The processor retrieves information from the tag and displays it on the interface such as LCD, cloud, WIFI, memories card, personal computer and other outputs. The RFID tag content of each individual device information will be attached to the lab equipment in the School of Engineering lab and transmit the information in real-time once it is taken out from the reader area.

As an initial stage, a web-based system is designed to document the information of the equipment such as the location, source and equipment maintenance schedule. The new system would enable able the laboratory staff to identify and record the inventory of test and measurement instruments via the long distance radio frequency identification (RFID) tag. The RFID tag contains information's of each test and measurement equipment’s technical specification and calibration status which can be read almost instantaneously. It will transmit the information in real-time in the event if any test and measurement equipment is moved away from the reader area or designated area without permission; thus, generating an alerting signal to the laboratory staff. The system is innovatively geared to notify the laboratory staff of deadline of calibration and maintenance work schedule of each test and measurement; thus, adheres to the quality process requirement without fail. Overall, the proposed new system able to significantly reduces labor costs, unnecessary documentation work and increase efficiency of maintenance task in meeting quality process requirements.

CURRENT LABORATORY ISSUES

This proposed project aims to provide an innovative approach in addressing issues faced by laboratory staff of School of Engineering, KDU University College; among others:

1. Failure to detect calibration date of test and measurement equipment on a timely manner.
2. Failure to check and track on vendors in terms of delayed service turn-around time.
3. Unaware of test equipment being moved from the designated area without permission
4. Failure in meeting compliance requirement of ISO procedure involving maintenance and calibration works.

Methodology

This proposed design project consists of (1) Multiple point access RFID system, (2) an embedded microcontroller Raspberry Pi for data acquisition and processing, (3) a Global System for Mobile communications (GSM) module, (4) a Remote Monitoring System (RMS), (5) a wireless ZigBee module and a personal computer (PC), as shown in Fig. 1.

Control Operation

The control operation is designed to operate under following 3 cases: Case 1: All the information of the instrument in term of the code and name are stored in RMS. Case 2: Microcontroller reads from the RMS on the deadlines of maintenance and calibration schedules and subsequently triggered an alert to notify the lab technician. Case 3: SMS and alarm will be triggered to the person in charge when instrument is moved away from the designated area

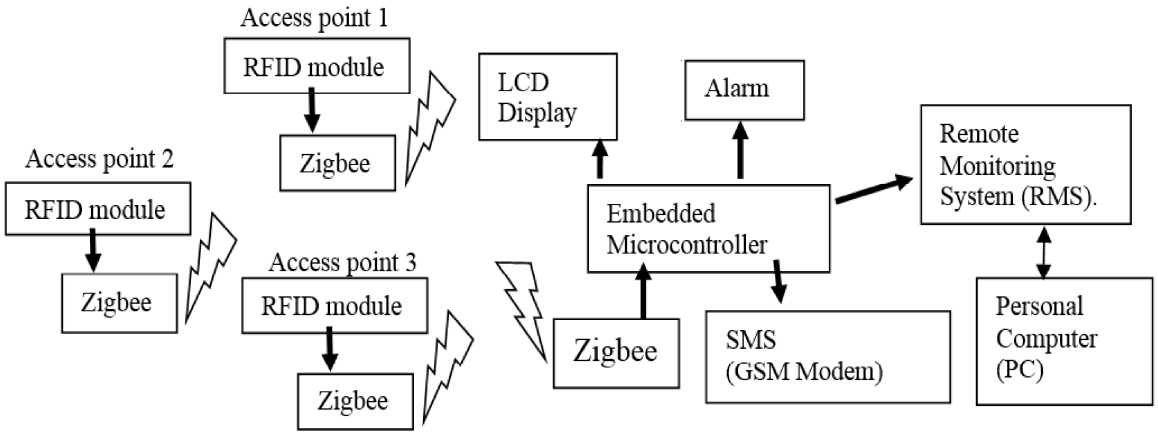

FIGURE 1. Engineering Laboratory Inventory Management Control System

RFID System

This RFID system is product identification tool that uses ultrahigh frequency (UHF) waves to capture information stored on a tag attached to an object. UHF waves are the waves having frequency in the range of 300 MHz to 3 GHz. It uses electrostatic and electromagnetic coupling and a variety of modulation and encoding techniques between chip and the reader for transferring data (anytime anywhere GSM network). RFID system involved RFID tag and reader. RFID tag is an IC chip that has unique electronic product code (EPC). It acts as a key to open a particular lock. RFID reader is a system uses to transmit and receive the data to the tag by radio waves. RFID system can be operated in either in low frequency (LF), high frequency (HF), or ultra-high frequency (UHF). RFID with ultra-high frequency (UHF RFID) will be implement in this project. UHF RFID provides a high reading speed, multiple accesses capability, anti-collision and small antenna compare to low frequency (LF) or high frequency (HF) band RFID systems. RFID printers are available in market from Zebra, such as ZD500R and R110xi4 (industrial RFID printer) (Fig. 2). Two (2)

RFID readers (AD082X-long distance integrated reader) can be mounted on the wall above the entrance in the engineering laboratory as shown in Fig.3.

Figure.2: Zebra RFID printer. (a) ZD500R. (b) R110xi4 (Zebra Technologies)

The Two (2) RFID readers are connected to long distance integrated reader. It is to make sure the tag is being read at any angles. Once the tag is read, the information will send to the ZigBee and then to the cloud server. There are many types of tag available in the market such as jewellery tag, wristband tag, windshield tag, anti-metal tag, screw tag, laundry tag, NFC tag, NFC sticker, vehicle tag, key fob tag, disc tag, animal tag and others.

The Embedded Microcontroller

A microcontroller is the heart of the system. It reads the data from the RFID chip and updates the data to a remote monitoring system. Industrial buzzer will be triggered and a SMS will send to the person in charge when the RFID module is triggered. Raspberry Pi microcontroller system will be used in this project. It is a credit-card-sized general-purpose computer which has rich peripherals to interface with various sensors or outside world. Raspberry Pi 3 as

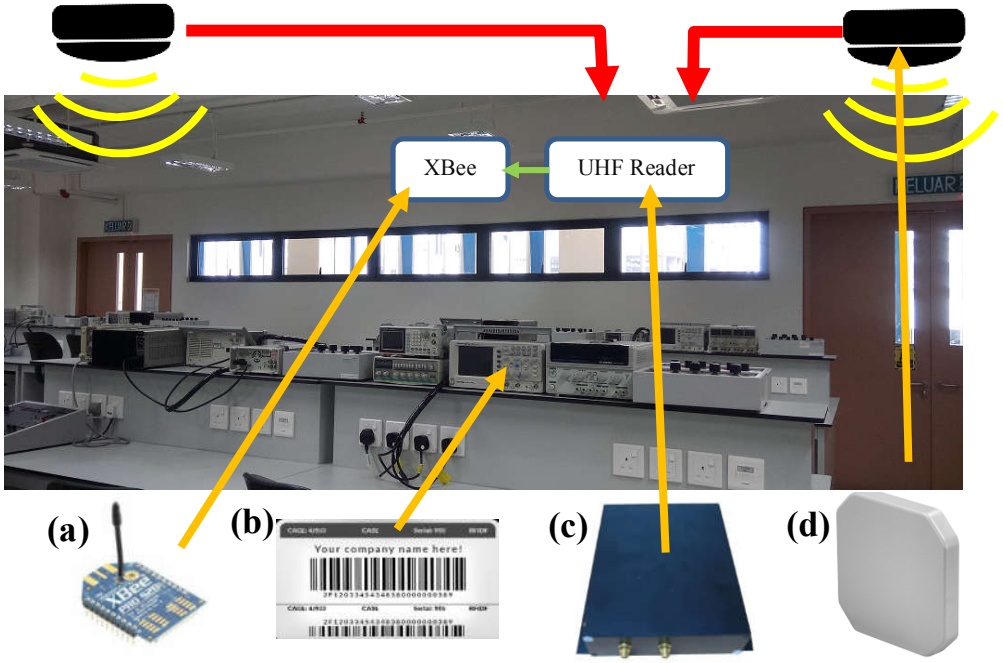

Figure 3: RFID system installation at engineering laboratory (a) XBee Module (b) RFID Tag (c) 2 channels UHF reader S006 [MDT INNOVATIONS SDN. BHD.] (d) RFID Antenna Laird S9025PL/S8655PL [MDT INNOVATIONS SDN. BHD]

shown in Fig. 4, with a quad-core ARM Cortex-A53 processor, is fully capable of handling dedicated industrial automation tasks. It provides cost effective full feature performance ideal for IoT (Internet of Thing). Compare to Arduino, Raspberry Pi is more capable in performing multiple tasks and encrypting data for storage. It is easily

connecting to the internet which will be helpful for the data collected from RFID to be sent to the Remote Monitoring System.

GSM (Global System for Mobile communications) module

GSM is a second-generation digital mobile telephone standard using a variation of Time Division Multiple Access (TDMA). GSM module (GSM-SIM900A-MOD) is a wireless devices that are designed for communication with microcontroller. It requires a SIM (Subscriber Identity Module) card to activate the communication with the network. Then, it will send an SMS through the microcontroller when system is triggered. Microcontroller will send AT commands through UART communication protocol and communicate with GSM modem.

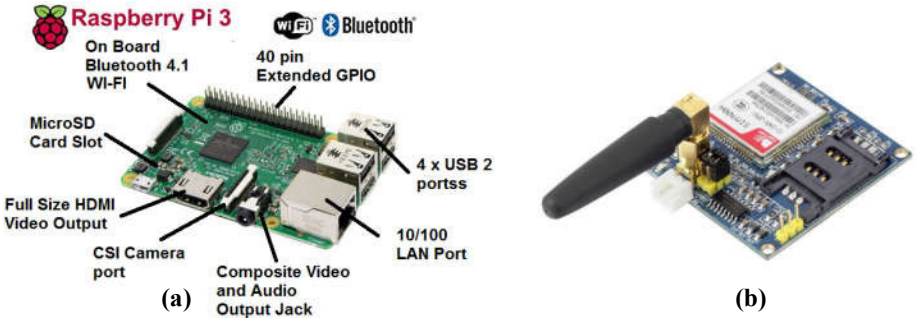

Figure 4: (a) Raspberry Pi 3 (b) GSM-SIM900A-MOD (adapted from QQtrading)

Remote Monitoring System

Remote Monitoring System is the database to store all the data fields like Instrument ID code, name of the instrument, calibration due date, and maintenance schedule due date. The system is designed to be smart to be able to send information with regards to calibration due date and maintenance schedule due date to lab technician. Furthermore, it is coded with the capability of triggering an alert system when the instrument is removed from the designated area

This remote monitoring system involves two sections which are client and server section. Client section consists of Raspberry Pi 3, RFID, ZigBee and GSM module. When the RFID is triggered, a message will be sent to the pre-defined mobile number. The time and date of triggered will also be sent to the server by the Hypertext Transfer Protocol (HTTP) request message. Furthermore, Raspberry Pi controller will send request to obtain the maintenance and calibration due date from the server from time to time. Lab technician will be acknowledged by SMS three months before the due dates.

In server section, the time and date sent from client section will be stored in the MySQL database [12]. The web server script is written with HTTP. Besides capturing the time and date of the triggered, a table consists of the due dates related to the calibration and maintenance is displayed for remote monitoring and scheduling of calibration or maintenance dates.

ZigBee

ZigBee [13] has network topologies: star topology, mesh topology and combination of star and mesh topology as shown in Fig. 3. Therefore, it can be used to create an access point for data collection. ZigBee is operating in 2.4GHz band under IEEE 802.15.4-based specification. It is used to create a personal networks for wireless communication. It is widely used in monitoring and control application especially towards Internet of Things (IoT) application.

Alarm

The output of the module includes the message alarm, audible alarm and the message display on LCD. The message alarm will only send to the pre-defined mobile number. And the audible alarm and indicator light will be place at the open area near to the lab staff office. An industrial audible alarm with SEP Series is chosen because it is able to give an 110dB output. It is used to alert the lab technician if any instrument is moved out from the lab without authority. The indicator light come along with buzzer alarm (Modal: ONN-M4 from Alibaba). Red colour will turn on and remain when an equipment take out from the lab without permission, while the green colour will turn on and sound-a-bet for a short duration when equipment take out from lab with permission. The permission will set from the system by a person in charge.

RESULTS AND INSTALLATION LAYOUT

Floor plan of engineering laboratory

The complete layout design and installation of RFID system in Engineering Laboratory is shown in Fig. 5. Eight (8) labs and a technician office are going to implement the RFID system. There are system lab, electronics design lab, engineering simulation lab, communication lab, mechanical lab, project lab, power system lab and power machine lab. The RFID reader will be installed at the entrance in all the labs. All the readers need a ZigBee module with serial port. When a passive tag is detected, information in the tag will be read and send to RFID reader and then send to the ZigBee through the UART communication port. The data will be read by the ZigBee (receiver) in the technician office. The data will updated into the cloud server using raspberry pi 3. Users able to access into the ZigBee or cloud server to do modification or extra data for analysis.

Wireless workflow of engineering laboratory

A wireless communication in between the engineering lab and the cloud is shown in Fig. 6.The concept set up is based on the innovation in the Internet of Things (IoT). A sub-GHz wireless light switched [14] has been successfully adopted for the smart home lighting control.

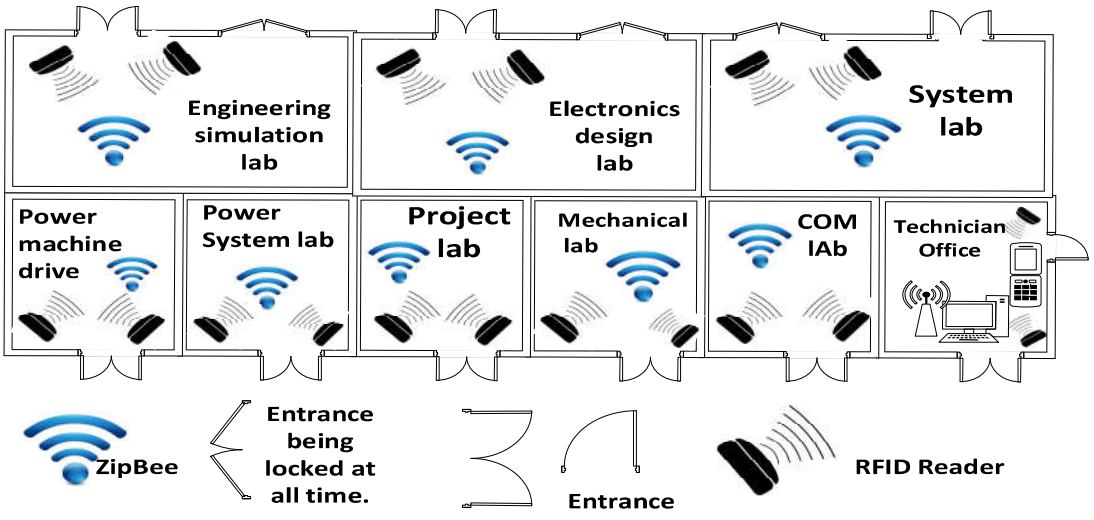

Figure 5: Floor plan of proposed engineering laboratory system

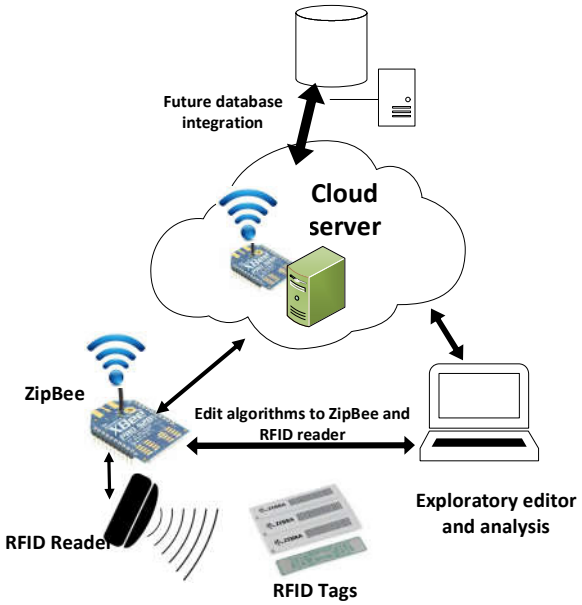

Figure 6: Wireless access workflow

- A Personal computer (PC) or laptop able to access to ZigBee and cloud server to update the changes or extract the data from the cloud server.
- An auto trigger message on the overdue calibration date of equipment is deployed in the cloud server. Where it operates every day to check all the last calibration date.
- Cloud server collects and stores the incoming data. It may combine all the other access points' information from other RFID reader and the future database integration.
- All the RFID produces Tag data once the tag is detected and ultimately sends data to the ZigBee transmitter. Then, the receiver ZigBee will received the data and sends to the cloud server.
- Technicians or high level authority access the historical data from the cloud server and develop algorithms to process and analyse it. Machine learning techniques can be applied for predicting future information.
- Development of a control algorithms is based on the current labs in KDU UC as per section 2: current laboratory issues.

COST ESTIMATION

Table 2 below shows component listing and its cost for this project. It is based on one (1) control centre office and eight (8) labs. The prices are based on QQ online Trading (http://qqtrading.com.my). The estimated cost for RFID system is RM 51,549. The payback period is estimated within 24 months based on the one (1) manpower can be reduced with basic salary RM2200 per month.

ENVIRONMENTAL EFFECT OF RFID

A technical knowledge is required when implementation of RFID technology, such as frequency, packaging, memory, sensor, IT system and etc. In fact, a study [12] proved that RFID usage can improve environmental sustainability. However, RFID is not suitable be used on metal materials, high electromagnetic radiation and in the presence of water. RFID applications must comply with safety hazard requirement in terms magnitude of electromagnetic radiation. Thus, necessary upstream risk assessment is to be carried out in order to reduce this risk.

TABLE 2. Hardware and components costing

No	Item	Cost per set
	Hardware in one (1) room	
1	Raspberry Pi set	RM 265
2	Power Adapter for Raspberry pi 3	RM 25
3	2 channels UHF reader S006	RM 3200
4	RFID Antenna	RM 1500
5	LCD 10x10	RM 800
	Total for one(1) room	RM 5790
	Total for eight (8) room	**RM 46329**
	Hardware in control center room	
1	RFID Tags	RM 880
2	RFID Tag printer	RM 490
3	GSM module	RM 85
4	Industrial buzzer	RM 165
5	ZigBee Wireless Receiver	RM 200
6	Alibaba Cloud Server (3years)	RM 1800
7	Personal computer (PC)	RM 1600
	Total for control center room	**RM 5220**

CONCLUSIONS

The conceptual framework of this project intends to demonstrate the integration of Internet of Things, the next technological revolution with RFID technology in creating an efficient and effective tracking system in view of sustaining compliance of quality policy and standards. This project incorporates an innovative approach in terms of early alerting mechanism and critically this overall concept is much superior in contrast to the manual version which are questionable due to a high probability of human error and time consumption.

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REFERENCES

[1] Pravesh Kumar Tejan, Shilpi Kain (2017) "Smart Inventory Management System For Warehouse Industry Using IoT Sensors & Machine Learned Data Analytics" International Journal of Innovations & Advancement in Computer Science IJIACS. ISSN 2347 – 8616 Volume 6, Issue 9 September.

[2] N. R. Mohamad, A. B. Jiim, A. Salleh, N. M. Z Hashim, M. Z. A Abd. Aziz, Z. Zakaria , N.A Ab. Hadi (2015) "Implementation and Effect of Long Range RFID Technology at Ultra High Frequency Band in Bus Detection System for Blind People" International Journal Of Advanced Research in Engineering & Management (IJAREM) International, Vol. 01, Issue 09, December.

[3] Babar, A.A.; Elsherbeni, A.Z.; Sydänheimo, L.; Ukkonen, L. (2013) RFID tags for challenging environments. IEEE Microw. Mag, 26–35.

[4] Björninen, T.; Delzo, K.E.; Ukkonen, L.; Elsherbeni, A.Z.; Sydänheimo, L. Long Range Metal Mountable Tag Antenna for Passive UHF RFID Systems. (2011) In Proceedings of the IEEE International Conference on RFID-Technologies and Applications, Sitges, Spain, 15–16 September.

[5] ElMahgoub, K.; Elsherbeni, T.; Yang, F.; Elsherbeni, A.Z.; Sydänheimo, L.; Ukkonen, L. (2010) Logo-antenna based RFID tags for advertising application. ACES J., 25, 174–181.
[6] Virtanen, J.; Ukkonen, L.; Elsherbeni, A.Z.; Demir, V.; Sydänheimo, L. (2010) Comparison of Different Electromagnetic Solvers for Modeling of Inkjet Printed RFID Humidity Sensor. In Proceedings of the 26th Annual Review of Progress in Applied Computational Electromagnetics, Tampere, Finland, 26–29 April 2010; pp. 270–275.
[7] Gareth R.T. White, Georgina Gardiner, Guru Prabhakar, and Azley Abd Razak. (2007) "A Comparison of Barcoding and RFID Technologies in Practice". Journal of Information, Information Technology, and Organizations. Volume 2.
[8] Chong Ryol Park, Ki Hwan Eom (2011) "RFID Label Tag Design for Metallic Surface Environments" Sensors 2011, 11, 938-948; ISSN 1424-8220 doi:10.3390/s110100938.
[9] Flores, J.L.M., Srikant, S.S., Sareen, B., Vagga (2005) A. Performance of RFID Tags in Near and Far Field. In Proceedings of IEEE International Conference on Personal Wireless Communications, New Delhi, India, 23–25 January 2005; pp. 353-357.
[10] Jiang. B., Fishkin, K.P., Roy, S., Philipose, M (2006). Unobtrusive Long-Range Detection of Passive RFID Tag Motion. IEEE Trans. Instrum. Meas. 55, 187- 196
[11] Ross Bunker, Atef Elsherbeni. (2017) "A Modular Integrated RFID System for Inventory Control Applications" MDPI Electronics, 6, 9; doi:10.3390.
[12] Neethu Anna Mathew, K M Abubeker.(2017) "IoT based Real Time Patient Monitoring and Analysis using Raspberry Pi 3". International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS-2017).
[13] Chih-Yung Chang, Chin-Hwa Kuo, Jian-Cheng Chen and Tzu-Chia Wang. (2015)" Design and Implementation of an IoT Access Point for Smart Home" Appl. Sci. 2015, 5, 1882-1903; doi:10.3390/app5041882.
[14] C. H. S. Mason, Y. William, F. Y. C. Albert and S. Darmandran, "Design and implementation of sub-GHz wireless light switch with integrated Wi-Fi," 2014 IEEE International Conference on Communication, Networks and Satellite (COMNETSAT), Jakarta, 2014, pp. 34-38."