# RFID systems in medical environment: EMC issues

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***Abstract*— RFID is a promising technology in the healthcare area in order to improve patient safety and increase efficiency and reduce costs in the daily healthcare work. This paper analyzes the available literature regarding both interference of RFID systems in medical equipment and the interferences of medical equipment on RFID systems. The conclusion of this analysis is that is necessary to develop standards in order to protect medical equipment from RFID interferences, and standards to plan the deployment of RFID installations taking into account electromagnetic compatibility issues.**

***Keywords-component; RFID; medical environment;, electromagnetic interferences;***

## I. INTRODUCTION

The Radio frequency identification (RFID) has been identified as one of the ten greatest contributory technologies of the 21st century [1]. This technology has found a rapidly growing market with multitude applications in many industrial sectors including medical and pharmaceutical areas. Market analysts expect the world market for RFID tags and systems in healthcare will rise rapidly (from €110 million in 2006 to €2.6 billion in 2016) [2].

RFID belongs to the Automatic Identification and Data Capture (AIDC) technology. The identification processes based on this technology are more reliable and less expensive than those that are not automated. RFID represent an important improvement inside this technology because the use of radiofrequencies, that means that the communication is fast (many tags can be read at the same time), and is established over greater distances than optical communications without necessity of optical line of sight [3]. This fact reduces the need of human intervention in the identification process and the possible errors related with it.

RFID systems could be very complexes and built in different implementations depending on the necessities of the application, nevertheless there are always present three components: the RF subsystem responsible of the identification and the information transmission using wireless technologies; the enterprise subsystem in charge of storing, processing and analyzing data coming from the RF subsystem; and the inter-enterprise subsystem who share information across organizations.

Regarding EMC issues the focus of attention is the RF subsystem. The RF subsystem has two components: the RFID tags (small electronic systems that are affixed to objects or embedded in them). Each tag has a unique identifier and may also have other features such as memory to store additional data, environmental sensors, and security mechanisms. The second components are RFID readers, which are devices that wirelessly communicate with tags to identify the associated item [3].

Both the tag and the reader are two-way radios. Each has an antenna and is capable of modulating and demodulating radio signals. The RIFD tags are time limited at the reading position. This time limitation makes this wireless technology a real time communication (RTC) system where retransmissions are not allowed.

The highpoints of being a wireless system is also an inconvenience if we think in terms of interference. The antenna would receive the useful signal and also the interferences present in a noisy environment. So if retransmission is not allowed, the EMC issues in the RFID environment are very important in order to avoid errors and possible associated security problems. A careful analysis of the scenario where a particular RFID system works is necessary to solve the possible EMC problems.

The analysis of medical environments are particularly difficult because in them we can find several kinds of interference sources: the electronic medical equipment (ESU, MRI, pulsed Laser, etc.) the information technology equipment used in the hospital (telemetry systems, computers, mobile phones, etc.), RF fields from external sources (FM radio, TV, base stations for mobile phones, etc), motors, fluorescent lights, switch gear and equipment powered by switched mode power supplies [4],[5],[6].

The use of RFID systems in healthcare institutions is just starting. The possible benefits of the use of this technology range from cost reductions, to improvements on organization and patient safety. Many hospitals have begun to adopt active RFID systems with the goal of locating pieces of equipment when medical staff needs them. This traceability serves two purposes. First, medical staff, especially nurses, can spend less time looking for the equipment that they need and spend more time providing direct patient care. Second, hospitals can more efficiently utilize the equipment they have and lower expenses on equipment rental and purchasing. Other hospitals have begun to adopt active RFIDs for patient and personnel identification and location purposes [7].

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RFID technology is also suggested as a solution to prevent the problem of retained sponges in surgery, instead the current procedure of counting objects after the operation [8]. This is not the only application of RFID in operating rooms. RFID can make a profound impact are patient safety, inventory management, and asset tracking in operating rooms. Tracking intravenous poles, infusion pumps, operating table accessories, or specialty patient monitoring cables, and other instruments can at least increase the efficiency during surgery. Inventory management is differentiated from asset tracking in that it focuses on consumable supplies and ensures these are reordered automatically. Regarding patient, safety, RFID can solve problems related with wrong treatments, or confusions among patients. RFID in these areas can, among other beneficial outcomes, lead to fewer medical errors, reduction of cost, and increased efficiency [9].

Portable medical devices represent an important resource for assisting healthcare delivery. The movement of portable devices often results in them being unavailable when needed. Tracking portable medical devices using RFID may provide a promising solution to the problems encountered in locating this kind of equipment [10].

HF RFID systems have been considered to power and communicate with implantable medical devices, applying appropriate safeguards and engineering practices to preserve patient safety and privacy [11].

The trend today is to involve RFID systems in the daily running of Hospitals. In [12] a case study that demonstrated RFID integration into the medical world at one Taiwan hospital is presented. This work analyzes the advantages and inconveniences of the use of RFID systems in medical environments and point several important issues that may be studied before the implantation of these technologies in hospitals, among others spectrum management to avoid EMI problems.

RFID systems operate in several frequency bands that could be coincident with those used in hospital environment by medical devices. The exact RFID frequency is controlled by the Radio Regulatory body in each country. The most common frequencies are: 125 - 134 kHz (LF), 13.56 MHz (HF), 433 MHz, 855 – 966 MHz (UHF), 2.45 GHz. Table I shows the potential sources of interference for RFID systems in the European Union allocation Spectrum [13]. (The allocation and management of radio spectrum in Europe is administered by national regulatory authorities, nevertheless these authorities work within the harmonized framework that is established through international and European policy initiatives).

The presence of RFID technology in hospitals can lead to EMC problems. On one hand RFID systems can interfere with sensitive medical devices working in its influence area, causing malfunction that can affect to patient safety, on the other hand, medical devices can generate electromagnetic radiated fields that can affect the performance of RFID systems, and this could constitute a threat to the patient safety if the device is devoted to the patient identification or medicine dosage.

In recent years, some EMC problems involving RFID systems and medical devices have been reported in the literature. Next section is devoted to the analysis of these incidents.

TABLE I. COMMON SOURCES OF RF INTERFERENCE

| **Potential sources of interference for RFID systems** | |
|---|---|
| ***Frequency band and use*** | ***applications*** |
| **125 - 134 kHz**<br>Maritime mobile<br>Fixed<br>Radio navigation | Inductive SRD<br>Maritime applications<br>Military applications<br>Ultra Low Power Active Medical Implants |
| **13.56 MHz**<br>Fixed<br>Mobile (except aeronautical mobile) | Inductive SRD<br>ISM applications<br>Military applications<br>Non Specific SRD applications |
| **433 MHz**<br>Amateur Radio<br>Radiolocation<br>Land mobile<br>Earth exploration-satellite | Active sensors (satellite)<br>Amateur<br>ISM<br>Non-Specific SRDs<br>PPDR |
| **855– 966 MHz**<br><br>Broadcasting<br>Mobile<br>Radiolocation,<br>Aeronautical Radionavigation<br>Aeronautical Mobile | GSM-900, GSMOBV, GSM-R<br>IMT-2000/UMTS (3G Mobile)<br>Radio microphones<br>Assistive Listening Devices<br>Non-Specific SRDs<br>Wireless audio applications<br>Defense systems<br>Alarms<br>PMR/PAMR |
| **2.45 GHz**<br><br>Fixed<br>Mobile<br>Amateur-satellite<br>Radiolocation | Amateur Satellite<br>ISM<br>Non-Specific SRDs<br>Radiodetermination applications<br>Railway applications<br>Wideband Data Transmission Systems |

## II. ELECTROMAGNETIC INTERFERENCES FROM RFID IN MEDICAL ENVIRONMENTS. REVIEW OF CASE REPORTS

RFID technology, like any other radio technology, relies on the use of electromagnetic radiation to communicate information. The potential risk of electromagnetic radiation in medical environment includes malfunction of medical equipment, influences of electromagnetic radiation to other materials, including medical supplies such as blood products, vaccines, and pharmaceuticals [3], and hazards of electromagnetic radiation to people.

Regarding people exposure, RFID frequencies are classified as Non-Ionizing. The known effects of this radiation are principally short-term effects caused by heating processes. The minimum safety and health regulation in the European Union regarding the exposure of workers to risks derived from electromagnetic fields are Directives 2004/40/EC and 2008/46/CE. For the general public there is the Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz). RFID systems electromagnetic field levels are below these limits even when subjects are situated just a few centimeters from the RFID antenna [14].

The influence of RFID in medical supplies is being investigated. Bassen et al. in [15] presents an exposure system to evaluate possible RFID effects on solid and liquid pharmaceutical and biologic products. They have used this system in a pilot exposure study in collaboration with the FDA Center for Drug Evaluation and Research and the FDA Center for Biologics Evaluation and Research. They test over 20 different types of drugs and biologic products, and conclude that more work needs to be performed to determine the effect RFID fields in pharmaceutical and biological products.

There are several publications related with the study of malfunction of medical equipment due to RFID systems. Christe et al. in [16] present the study of the potential interactions between RFID equipment and medical devices. They test non-invasive blood pressure monitors, pulse oximetry monitors, infusion pumps, ECG monitors and sequential compression devices. RFID equipment were near field and far field antennas transceivers and passive tags. They conclude that RFID systems can be used without concern in general patient care rooms to manage inventory track items, and ease patient billing data collection, when antennas are placed in appropriate locations for these use scenarios.

Yue Ying et al. analyze the interferences between two different UHF RFID systems (868 MHz) and fifteen medical devices (infusion pumps, patient monitors, heart-lung machines, anaesthesia workstations and intensive care ventilators. All 15 medical devices have been tested with both readers. They found that eight medical devices exhibited no interference and seven showed interference. Interference differs between both readers and occurs at different distances. Authors compare the measured field strength at the distance where interference occurs with the values of IEC61000-4-3. They found that all medical devices except one have met the 10 V/m requirement of the standard. Authors conclude that RFID technology can be used in medical environments if several precautionary measures are taken [17].

Houliston et al. in [18] analyze the interference of RFID systems in an infusion pump of the same type as one that have failed due to the RFID electromagnetic interference. They have found that the infusion pump was not affected by low-power RFID readers, even when in direct contact. The pump was disrupted by a high-power reader at 10 cm distance when an RFID tag was attached, and by a combination of high-power and low-power readers at 10 cm distance.

Seidman et al examine the electromagnetic compatibility between RFID readers and implantable pacemakers or ICDs. During in vitro testing, 15 implantable pacemakers and 15 ICDs were exposed to 13 passive RFID readers of LF (134 kHz), HF (13.56) MHz and UHF (915 MHz). Authors found that pacemakers experimented some reaction in 67% of test (at a maximum distance of 60 cm) and ICD's experimented also some reaction in 47% of test at a maximum distance of 40 cm, when exposed to LF RFID. Reactions from implantable pacemakers and ICDs included pacing inhibition, inappropriate pacing, noise reversion mode, changed pacing rates, inappropriate delivery of antitachycardia pacing, inappropriate delivery of high voltage shocks, and a device programming change. When HF RFID was applied, a reaction was observed for 6% of all pacemaker tests (maximum distance 22.5 cm) and 1% of all ICD tests (maximum distance 7.5 cm). For UHF RFID exposure, both pacemakers and ICD's do not experiment any reaction. Authors conclude that although there is evidence of EMI problems in LF and HF RFID bands, they do not constitute an urgent public health risk [19].

An extensive study of the EMI from RFID systems in critical care equipment was carried out by van der Togt et al. They test 41 different medical devices against the EMI of two RFID systems (active 125 kHz and passive 868 MHz). The tests were performed without a patient being connected, under controlled conditions. Incidents of EMI were classified according to a critical care adverse events scale as hazardous, significant, or light. Authors found that in 123 EMI tests (3 per medical device), RFID induced 34 EMI incidents: 22 were classified as hazardous, 2 as significant, and 10 as light. The passive 868-MHz RFID signal induced a higher number of incidents (26 incidents in 41 EMI tests; 63%) compared with the active 125-kHz RFID signal (8 incidents in 41 EMI tests; 20%); There was 8 devices affected by both passive and active RFID systems. The median distance between the RFID reader and the medical device in all EMI incidents was 30 cm (range, 0.1-600 cm). From these results, authors conclude that the implementation of RFID in the critical care environment should require on-site EMI tests and updates of international standards [20].

Table 2 summarizes the results of all these works

TABLE II. MALFUNCTION OF MEDICAL EQUIPMENT DUE TO RFID SYSTEMS

| **Author (year)** | **# devices (# tests)** | **RFID band** | **Power** | **Distance where interference occurs** | **# devices affected (# positive tests)** |
|---|---|---|---|---|---|
| van der Togt (2008) | 41 (123) | LF<br>LF active<br>UHF | 4W, 2µW | 6 m – 0.1 cm (median 30 cm) | 8 (41)<br>26(41)<br>26 (41) |
| Christe (2008) | 25 (1600) | UHF | 4W | - | 0 |
| Ying (2009) | 15 (30) | UHF | 4W | 60 cm - 10 cm | 7 (10) |
| Houliston (2009) | 1 (15) | UHF | > 2W | 10 cm | 1 (2) |
| Seidman 2010 | 30 (1091) | LF<br>HF<br>UHF | 0.5W-10W | 60 cm – 2.5 cm | (243)<br>(22)<br>(-) |

From the published works we can conclude that there is a concern from the effect that RFID systems can have in hospitals from the EMI point of view. But the lack of a systematic methodology in the performed test makes impossible to extract clear conclusion of how to proceed.

It attracts the attention that Christe et al do not found interferences in any of the1600 test while the other authors present a remarkable incidence: Van der Tog 24%, Ying 33% and Seidman 48.8% .

Given the expectancy that RFID systems have generated in medical organizations and the relative high number of positive EMI test of the published works is necessary to establish standards to regulate the installation of RFID devices in

medical environments, and also to have a set of guidelines to analyze the effect of RFID systems in a determinate installation.

## III. ELECTROMAGNETIC INTERFERENCES ON RFID SYSTEMS

RFID is increasingly considered as one of the most promising technologies in the healthcare area in order to save lives, prevent errors, save costs, and increase security.

Currently, the three main areas benefiting from RFID technology in the health care industry are: asset management (being able to locate a mobile equipment at all times results in better utilization and reduces the amount of time that staff spends searching for equipment); patient care (being able to correctly identify a patient for treatment, allowing error prevention of products, e.g. drug dose, correct blood detection and treatment, mother/baby mismatch, auto-rejection of wrong parts etc); inventory management (being able to identify what you actually have in your current inventory and where that inventory is being consumed reduces out-of-stock situations) [2].

But RFID technology itself is not exempt from Electromagnetic Interference. Cheng et al. in [21] show that the presence of electromagnetic interference can affect tags' detectability and range in manufacturing facilities that have heavy electrical equipment. Pous et al. in [22] have demonstrated that an RFID system according to ISO/IEC 14443-B standard could be interfered by radiated transient signals generated in a close mains wire, producing errors in the detection of the tag and when reading addresses. Also, authors have demonstrated that it is essential to take into account the transient interferences to ensure the correct behavior of the digital communication systems.

Electromagnetic interferences in medical environments are usual, mainly in areas where high power equipment work. For example, in operating rooms, when an electrosurgical unit is used, large amounts of energy at hundreds of kilohertz are applied to the patient through cables which generate electric and magnetic radiated fields [23].

So when planning the installation of an RFID system in a healthcare environment is necessary to take into account these issues to avoid errors that could affect to the patient safety.

## IV. CONCLUSSIONS

RFID is a promising technology in the healthcare area in order to improve patient safety and increase efficiency and reduce costs in the daily healthcare work. Nevertheless to implant successfully this technology in healthcare environments is necessary to develop standards to protect medical equipment from RFID interferences (mainly near field interferences), and standards to plan the deployment of RFID installations taking into account electromagnetic compatibility issues. Finally, a particular analysis of each particular facility will be necessary to ensure the good performance of the RFID systems.

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