Environmental safety aspects of using UHF RFID systems in hospitals

Aspekty środowiskowego bezpieczeństwa wykorzystania systemów UHF RFID w szpitalach

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Abstract

Various applications of Radio Frequency IDentification (RFID) technology in the medical environment are characterised. The electromagnetic field (EMF) emitted by RFID handheld readers (RFID guns) is characterised and evaluated with respect to humans exposure metrics – the strength of the electric field affecting anyone present near various UHF (ultra-high frequency) RFID guns and the specific absorption rate (SAR) values in their body. UHF RFID systems are the most popular of such systems used in hospitals. The performed studies indicate that the EMF exposure level near the RFID gun antenna and SAR values (a measure of the thermal effects of EMF exposure) caused by exposure from the RFID reader may exceed the limits of the electric field and SAR issued by international guidelines or legislation. Potentially excessive exposure to EMF emitted by UHF RFID readers is not limited to the user of the device, but may also apply to patients or bystanders. Only UHF RFID guns with an EMF emission lower than 1 W may be considered as an insignificant source of human exposure. The use of readers with a radiated power exceeding 1 W requires the evaluation of the EMF level using measurements, and also the evaluation of SAR by numerical modelling in the case of their use in close proximity to humans. In all cases, insufficient electromagnetic immunity of electronic devices (including medical implants) should be considered near RFID guns at least up to half of the reading range away from the RFID reader. The electromagnetic hazards related to the use of RFID guns may be limited by relevant preventive measures, as shown in this paper, together with the principles of an *in-situ* evaluation of electromagnetic hazards near the UHF RFID guns.

Key words: biomedical engineering, environmental engineering, occupational exposure, public health, AIMD, Internet of Things

Streszczenie

Scharakteryzowano różne zastosowania technologii identyfikacji radiowej (RFID) w środowisku medycznym. Pole elektromagnetyczne emitowane przez ręczne czytniki RFID (RFID guns) zostało scharakteryzowane i ocenione w odniesieniu do miar narażenia ludzi – natężenia pola elektrycznego oddziałującego na osoby znajdujące się w pobliżu różnych czytników RFID UHF (ultrawysokiej częstotliwości) i współczynnika SAR w ich ciele. System UHF RFID jest najpopularniejszym z systemów RFID użytkowanych m.in. w szpitalach. Przeprowadzone badania wskazują, że poziom ekspozycji na pole elektromagnetyczne w pobliżu anteny ręcznego czytnika RFID i wartości SAR (miara skutków termicznych oddziaływania pola elektromagnetycznego) spowodowane tą ekspozycją mogą przekraczać limity, opublikowane w zleceniach międzynarodowych lub przepisach. Nadmierna ekspozycja na pole elektromagnetyczne emitowane przez czytniki RFID UHF może dotyczyć nie tylko użytkownika urządzenia, ale również pacjenta lub osoby postronnej. Tylko ręczne czytniki RFID UHF o emisji pola elektromagnetycznego poniżej 1 W można uznać za nieistotne źródło narażenia ludzi. Korzystanie z czytników o mocy przekraczającej 1 W wymaga oceny poziomu pola elektromagnetycznego za pomocą pomiarów, a również oceny SAR za pomocą modelowania numerycznego w przypadku ich użycia w bezpośredniej bliskości ludzi. We wszystkich przypadkach niewystarczającą odporność elektromagnetyczną urządzeń elektronicznych (w tym implantów medycznych) należy rozważyć w pobliżu czytników RFID co najmniej do odległości od czytnika RFID równej połowie jego zasięgu odczytu. Zagrożenia elektromagnetyczne związane z używaniem ręcznych czytników RFID mogą być ograniczone przez odpowiednie środki ochronne, jak pokazano w tym artykule, wraz z zasadami oceny zagrożeń elektromagnetycznych *in-situ* w pobliżu ręcznych czytników UHF RFID.

Słowa kluczowe: inżynieria biomedyczna, inżynieria środowiska, narażenie zawodowe, zdrowie publiczne, AIMD, Internet Rzeczy

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The structure of RFID systems

The electronic labelling of various objects is frequently based on Radio Frequency IDentification (RFID) technology, which uses a wireless exchange of information and energy between readers and electronic chips attached to objects (recognised as tags), Figure 1. RFID systems include tags and readers (fixed gates or handheld guns). The tags are small electronic devices designed to store information (individual code, fixed or modified over the tagged object life) [1]. Tags may include an autonomous source of electricity (a battery powering active tags) or need an external source of energy (in the case of passive tags). The tag may be covered inside the object, because it does not need to be within the line of sight of the reader. The readers are two-way radio transmitter-receivers that can process the electromagnetic field (EMF) to read the code of each tag, modify the data stored inside or power up passive tags [1]. RFID technology has various and rapidly developing applications, such as monitoring, controlling or managing objects in shops, warehouses, libraries, enterprises, etc. in order to increase visibility, efficiency, and to gather data around relevant interactions [2,3].

A physical RFID tag may be incorporated with browser-based software to increase its efficiency. For this purpose, a hybrid system working in the Internet of Things (IoT) system is often used, including an RFID reader combined with a device for wireless data transmission such as a Wi-Fi (Wireless Fidelity) modem [4]. This software makes it possible to see real-time data relevant to each piece of tracked equipment or person. This combination of RFID real-time locating system hardware and software provides a powerful data collection tool to improve efficiency and reduce the costs of various processes. An RFID system may replace or supplement barcodes and more traditional electromagnetic security devices [5].

a) *b)*

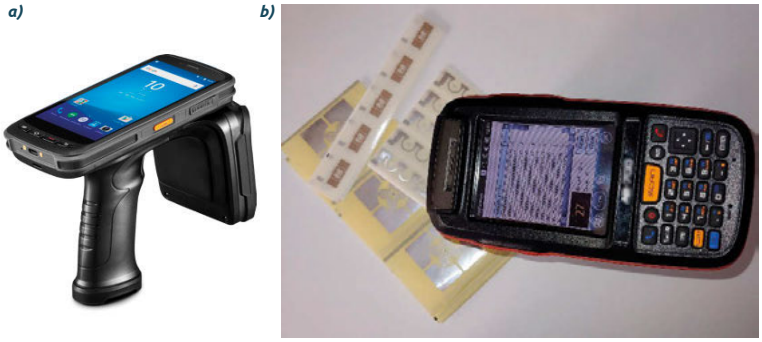

Figure 1 *An example of an RFID gun composed from an external antenna attached to a palmtop (a) [https://www.jtspeedwork.com/long-distance-uhf-rfid-gun-reader-for-asset-management_p126.html], and RFID tags and integrated reader (b)*
Source: Authors' collection.

RFID applications in the medical environment

Quite a new but rapidly growing area is the use of RFID technology in healthcare. This takes many forms – from tracking surgical tools to tracking patients and personnel. The adoption of RFID in the medical industry has been widespread and very efficient. RFID tracking solutions are able to help healthcare facilities manage mobile medical equipment, improve patient workflow, monitor environmental conditions and protect patients, personnel and visitors from various hazards. Hospitals are among the first users, combining active and passive RFID tags, where active RFID technology tracks high-value, or frequently moved items, while passive RFID technology tracks smaller, lower cost items that only need room-level identification [6]. For example, medical facility rooms can collect data from transmissions of RFID tags worn by patients and personnel, e.g. inside identification badges, as well as from tags attached to mobile medical devices [7]. Examples of applications using RFID technology in medical environment include the following:

1. medicine and pharmaceuticals (liquid-filled assets) tracking. Using RFID can reduce the amount of time spent counting, allowing pharmaceuticals to be counted more often, ensuring accurate data and that the correct types and amounts of drugs are on hand. RFID tags inside or on each bottle or box can be read with handheld readers during the inventory process, or constantly inventoried through fixed readers and shelf antennas. Some hospitals and pharmaceutical manufacturers also use RFID tags for authentication purposes.
2. tracking patients and personnel. Patients and personnel are identified ("labelled") with RFID tags in hospitals primarily for three reasons: to verify patient information, to reduce waiting times and bottlenecks, and to locate patients. A tag is an ideal way of identifying patients, because it can help in emergency situations by ensuring patients are not given the wrong medication or sent to the wrong area in the hospital. Tags are also used to truck new-born babies in order to avoid swapping and to lower the risk of infant abduction; hospitals place RFID tags on all infants' legs in order to monitor and track each child.
3. tool tracking with sterilisation and autoclave/returnable asset tracking. RFID tags ensure that each tool is sterilised prior to use – a properly implemented system could shed light on sterilisation methods for individual tools.
4. single-use items inventory tracking/out of stocks. RFID can provide a cost-effective inventory solution for single-use items, which can be stored in inventory rooms, shelving units, or in vending machines outfitted with RFID.
5. large equipment, assets tracking. RFID can counteract the phenomenon of misplaced or missing high-value items in hospitals, such as portable testing machines or hospital beds. Some hospitals implement the RFID system to read only certain areas or rooms, while others setup their systems to cover entire hallways or floors.
6. security, access control, people tracking. RFID use not only prevents unauthorised access to restricted areas, but provides patients, medicine, and medical equipment with a level of security that deters theft or damage.

7. laundry tracking. RFID laundry tags use is an efficient way to keep track of towels, blankets and sheets, etc., as well as ensuring that they are sterile.

Exposure to EMF near UHF RFID readers

The worst-case EMF exposure of personnel from UHF RFID readers used in hospitals is associated with the use of handheld readers (recognised as RFID guns) [8,9,10]. The work activities related to the typical operation of a UHF RFID gun reader (working in an IoT system) include: triggering the reading process (i.e. EMF emissions) and moving the reader closer to the marked (tagged) object while observing the image on the display. During such activities, the RFID gun is the maximum distance from the torso, at the length of the outstretched arm (approx. 50-60 cm), which may be maintained for a while only. However, during prolonged activity the device is usually kept at a distance of approx. (20-30) cm away from the torso.

The RFID gun is normally kept in hand or is suspended on the shoulder using a special holster/lanyard. While it is being used, it is held in the hands at the height of the hips up to the chest (Figure 2). The result is that EMF emitted by the active gun antenna affects the operator's palm, chest, head and hip/legs, as well as other people or electronic devices (including active implantable medical devices (AIMD), e.g. pacemakers and insulin pumps, and other medical devices) present nearby.

Figure 2 *Handheld UHF RFID gun reader: a) an example of the body position of the operator scanning wares marked by RFID tags, b) an example of the manual reading of tagged object*
Source: Authors' collection.

The most commonly used UHF (ultra-high frequency) RFID systems in the world operate in the frequency range 860-965 MHz (in Europe: 865-868 MHz) [1]. They may use fixed readers (antennas with dimensions from several centimetres up to approximately one metre). Alternatively, handheld RFID guns (usually with antennas smaller than 20 centimetres), which are built into small portable electronic devices or used as a kind of periphery accessory with tablets, palmtops or smartphones [10]. An activated RFID reader searching for passive RFID tags attached to objects under interest produce continuous EMF emissions. The output power of an RFID reader antenna is usually lower than 1 W, though stronger devices may also be used, especially when a long reading range is required. The output power of Wi-Fi modems are usually lower – at the level of 0.2 W.

When the reading range (required in a particular application) is shorter, the level of radiated power may also be lowered while manufacturing, or by the user [8].

Electromagnetic hazards that require consideration while using RFID guns, while the activation of the RFID reader, include:

- the thermal effects of EMF interaction on workers present near to active devices, due to the body being heated by EMF energy absorbed in the tissue (analysed with respect to exposure of the head and torso and in the hands) – recognised as a direct electromagnetic hazard
- malfunctions in electronic devices (e.g. control and measurement devices, including medical devices used in hospitals and operated nearby), including AIMD or body worn electronic devices, caused by the insufficient electromagnetic immunity[1] of particular devices – recognised as the indirect electromagnetic hazard [9,11].

The assessment of EMF exposure related to the use of UHF RFID guns

The evaluation of EMF exposure may be discussed with respect to the internationally accepted measures characterising thermal effects of exposure to EMF (specific energy absorption rate (SAR), expressed in watts per kilogram, W/kg, and relevant limits for the protection from the electromagnetic hazards of the general public or workers, at a level five times higher). Such limits provided by the International Commission on Non-ionizing Radiation Protection (ICNIRP) exposure guidelines were also used as the rationale for various legal provisions, such as the non-binding European Council Recommendation 1999/519/EC regarding public EMF exposure, European Directive 2013/35/EU regarding the EMF exposure of workers, as well as relevant legislation in various countries.[2] The SAR values for realistic exposure scenarios are assessable only from numerical modelling using sophisticated, high resolution models of the human body. All the intended operating

[1] Electromagnetic immunity tests constitute an important part of the electromagnetic compatibility (EMC) technical requirements regarding the design of electronic devices.

[2] W Polsce limity narażenia pracowników na pole elektromagnetyczne i wymagania dotyczące ich ochrony przed nadmiernym narażeniem zostały określone w rozporządzeniach Ministra Rodziny, Pracy i Polityki Społecznej [DzU 2018, poz. 331 i 1286].

conditions, as well as the reasonably foreseeable conditions of human exposure from the UHF RFID readers, should be taken into account in the exposure evaluation required by provisions of international law, e.g. by European Directive 2014/53/EU (RED) [12].

Given that SAR values are assessable in realistic exposure scenarios by complex numerical calculations only, in addition to SAR limits (recognised as Basic Restrictions or Exposure Limit Values), the operational limits of the electric and magnetic field strength (recognised as Reference Levels or Action Levels, expressed in volts per metre, V/m, and amperes per metre, A/m, respectively) were issued for the *in-situ* control of the EMF exposure parameters (both averaged over 6-minutes).[3]

The requirements regarding electromagnetic immunity are split between various electronic devices. The devices for which malfunctions are potentially more hazardous to humans are usually expected to have a higher immunity (which means that their functioning is not disturbed by stronger EMF exposure). However, the improvements in immunity usually significantly increase the costs of manufacturing a particular device – leading to compromises between the safety and economic issues. The test levels of EMF exposure used in EMC immunity tests differ from 10-20 times lower than the general public Reference Levels mentioned above (applicable to the most common electronic devices) up to levels comparable to workers' Action Levels, or even higher when electronic devices are expected to be used in the vicinity of the sources of very strong EMF. The EMF test levels used in EMF immunity tests of AIMD and medical devices are usually 2-20 times lower than the general public Reference Levels.[4]

EMF exposure levels near the UHF RFID gun antenna

A study related to EMF exposure from UHF RFID readers involving measurements of EMF distribution near the RFID gun antenna indicates that the electric field strength from a UHF RFID reader with a radiated power of 1 W exceeds the level of general public Reference Levels set by Recommendation 1999/519/EC at distances of up to 20 cm. The EMF exceeding exposure limits for workers exposure issued by European Directive 2013/35/EU does not exceed 10 cm [8,13].

The electric field strength values measured near the antenna of UHF RFID gun reader (e.g. at distances required in EMC emission tests: 20 cm; 50 cm; 100 cm; 300 cm and 1000 cm) are equal to approximately: 64%; 30%; 16%; 5.6% and 1.0% of the value measured at a distance of 10 cm from the antenna, respectively, as shown in Figure 3.

The range of EMF exceeding EMC immunity testing levels (where indirect electromagnetic hazards may appear), applicable for electronic devices (including AIMD and other medical devices) was found to be comparable to half of the main working parameter of the RFID system, which is recognized as its "reading range". The reading range increases as the EMF emissions from the reader increase, as well as with the use of more sensitive tags (Figure 3).[5]

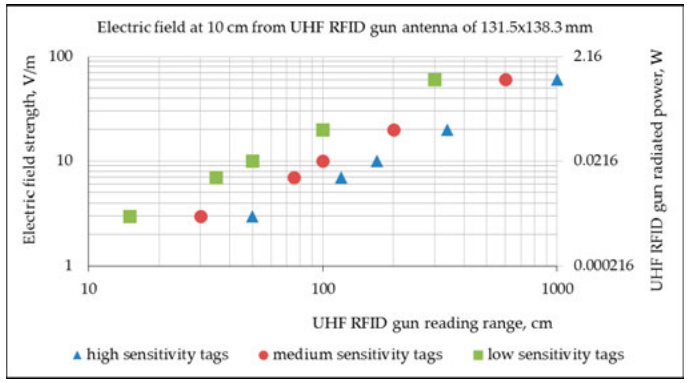

Figure 3 *The relation between the EMF level emitted by UHF RFID guns (the value of electric field strength evaluated at a distance of 10 cm from the antenna of the RFID gun) and their reading ranges when guns are used with tags of various sensitivity*
Source: Based on [8].

Given the results of the evaluation of EMF exposure near the RFID readers, any users of AIMD who are in close proximity to a UHF RFID gun reader should be treated as individuals at particular risk from EMF exposure (even significantly shorter than 6 minutes).

SAR values caused by EMF exposure near the antenna of an active UHF RFID gun

The worst-case exposure scenario may be counted as caused by a six-minute continuous emission of EMF at maximum output

[3] Wielkością odpowiadającą limitom narażenia pracowników określonym w Dyrektywie 2013/35/UE (Action Levels dotyczące natężenia pola elektrycznego i natężenia pola magnetycznego) są bazowe limity Interwencyjnych Poziomów Narażenia (IPNob), określone w rozporządzeniu Ministra RPiPS [DzU 2018, poz. 1286] – IPN bazowy dotyczący natężenia pola elektrycznego o częstotliwości wykorzystywanej przez systemy UHF RFID wynosi 60 V/m.

[4] Wymagania dotyczące poziomów testowych badań EMC odporności urządzeń elektronicznych na zakłócenia powodowane oddziaływaniem pola elektromagnetycznego określono przykładowo dla urządzeń medycznych w normach IEC 60601-1-2:2014 i IEC 61000-4-3: testy w polu o poziomie 3 V/m dotyczą sprzętu profesjonalnego, przeznaczonego do użytkowania w środowisku profesjonalnej opieki medycznej, a testy w polu o poziomie 10 V/m dotyczą sprzętu przeznaczonego do użytkowania w środowisku „domowym". Również sprzęt powszechnego użytku przeznaczony do użytkowania w środowisku ogólnym przechodzi badania EMC odporności w polu elektromagnetycznym o poziomie 3 V/m [IEC 61000-6-1:2016 i IEC 61000-6-2:2016].

[5] Wielkością odpowiadającą limitom określającym zasięg pola elektromagnetycznego, w którym konieczna jest ochrona przed pośrednimi zagrożeniami elektromagnetycznymi (m.in. zakłóceniami działania elektronicznych implantów medycznych – ang. active implantable medical devices – AIMD) są w prawie pracy pomocnicze limity Interwencyjnych Poziomów Narażenia (IPNp), określone w rozporządzeniu Ministra RPiPS jako limit dolnej granicy strefy pośredniej [DzU 2018, poz. 1286] – IPNp dotyczący natężenia pola elektrycznego o częstotliwości wykorzystywanej przez systemy UHF RFID wynosi 7 V/m, a więc zasięg pola elektromagnetycznego strefy pośredniej jest nieco mniejszy od wspomnianego zasięgu pola elektrycznego o natężeniu 3 V/m (stosowanego w podstawowych testach odporności EMC).

power, though a more typical exposure situation is with a shorter duration of exposure from the RFID gun. Under realistic exposure scenarios with respect to the RFID gun position, the reading gun is located next to the body of the operator, the scanned person or a bystander (Figure 4).

The results of a study considering the computer modelling of realistic exposure scenarios showed that UHF RFID guns with an output power not exceeding 1 W may be considered as a source of low EMF exposure to the user, and one that is compliant with the mentioned general public SAR limits. However, it must be noted that RFID guns with emissions exceeding 1 W may be used in various locations without special permission for use (e.g. up to 2 W in Europe, following the ETSI/EN 302-208 V3.1.1:2016, being a standard harmonised with Directive 2014/53/EU (RED)). RFID readers emitting several watts may also be used, but only with administrative permission from the relevant authority. EMF exposure from a UHF RFID reader with a radiated power exceeding 1 W in close proximity to the user's body requires an assessment of the SAR values caused by it.

When the output power of the user's UHF RFID gun is not known, or it is expected to emit over 1 W, the preliminary evaluation of the direct electromagnetic hazards during its use may be performed on the basis of EMF measurements nearby. Numerical simulations of the SAR values in the hand, head and torso and whole body in the numerical model of the UHF RFID user, analysed with respect to the electric field strength, (E, evaluated at 10 cm away from the antenna) show that SAR may be counted as compliant with the SAR general public limits when:

- E < 70 V/m (localised SAR in the user's hand compliant with limits and the level of EMF emissions providing a reading range of 350-1100 cm with used tags of various sensitivity, Figure 3),
- E < 100 V/m (localised SAR in the head and torso of the scanned person and reading range of 550-1750 cm, respectively),
- E < 90 V/m (whole body averaged SAR of the scanned person and reading range of 450-1500 cm, respectively).

The use of UHF RFID guns producing exposure to EMF exceeding these levels requires the application of adequate protection measures to limit direct electromagnetic hazards. Any case of using UHF RFID guns requires the application of protection measures to limit indirect electromagnetic hazards.

The presented characteristics of electromagnetic hazards may apply to the currently used devices compatible with the requirements of standards ETSI EN 302-208 V3.1.1:2016-12.

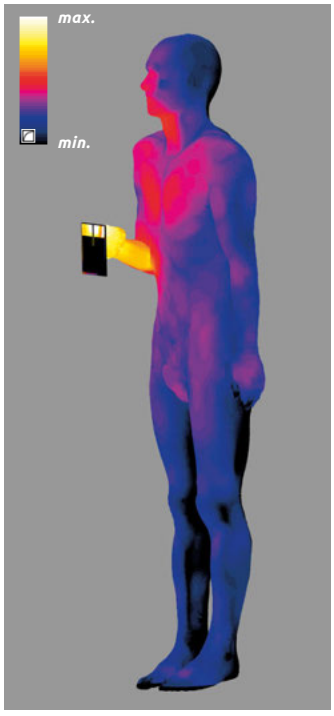

Figure 4 *An example of the distribution of SAR in a numerical model of a UHF RFID gun reader operator (the white colour indicates the highest SAR values)*
Source: Authors' collection.

Limiting electromagnetic hazards caused by the UHF RFID readers

The complete elimination of EMF exposure from UHF RFID guns is impossible due to the need to locate such a device close to the body of users, patients or bystanders, but it can be limited, along with the electromagnetic hazards. Protective measures against electromagnetic hazards, as required by the provisions of the labour law (based on the provisions set by the Directive 2013/35/EU), and the programme of their implementation, include:

- the recognition of EMF sources
- the recognition of an occupational environment under the possible EMF influence and workers potentially exposed
- the labelling of EMF sources, electromagnetic hazards and exposed workspaces, and informing workers about them, including symbols indicating hazards from a malfunction of AIMD (e.g. according to ISO 7010:2011)
- health surveillance when a high level of EMF exposure was found, or for workers at particular risks (including AIMD users and pregnant workers – when Directive 2013/35/EU is applicable)
- the periodic training of workers on electromagnetic hazards and protective measures applied
- the periodic evaluation of electromagnetic hazards.

Planning protective measures and assessing the effectiveness of their application should relate to reducing the EMF level in the workspace, as well as its impact on workers.

Individual recognition is also required for the conditions of exposure to EMF during activities other than the discussed typical use of devices (e.g. during service works), as well as the exposure of everybody exposed to EMF (regardless of the reason).

Examples of good practices in applying protective measures limiting electromagnetic hazards:

- increasing the distance between the body and the RFID reader (the use of devices at least 100 cm away from the torso ensures limited EMF exposure)

– limiting the radiated power of the RFID reader (reading range) to a minimum acceptable for the functionality of the device, i.e. at the shortest range when the reader is capable of reading a tagged object
– using the most sensitive tags (e.g. the latest generation of tags), as these increase the reading range of the RFID system at a particular level of EMF emission from the reader
– shortening the reader operating time (to significantly less than six minutes), which reduces the thermal effects of humans EMF exposure in its surroundings.

This way of using a RFID gun will also limit the EMF influence on humans nearby, and is justified by the 2B categorisation of radiofrequency electromagnetic radiation (potentially carcinogenic for humans) issued in 2013 by the International Agency for Research on Cancer (IARC) [14].

Additional protective measures are not necessary unless specified in the device's user manual.

The principles of an *in-situ* evaluation of electromagnetic hazards near UHF RFID guns[6]

I. EMF source under consideration:

1) UHF RFID handheld readers (guns) operating in the frequency range 860-965 MHz (in Europe: 865-868 MHz);
2) EMF is continuously emitting from the manually activated device;
3) When the type of RFID system is not confirmed, the experimental verification may be performed by analysing the frequency of the emitted EMF through the use of a relevant spectrum analyser.

II. Evaluation of the indirect electromagnetic hazards (covering AIMD malfunctions, evaluated by electric field strength values, E, in V/m):

1) Indirect electromagnetic hazards may occur near all UHF RFID guns, up to a distance away from the device that may be estimated as half the reading range of a particular RFID application.
2) The reading range is the maximum distance between the RFID reader and the RFID tag, at which the tag (tagged object) is "found" (recognised) by the reader (the reading range depends on the level of EMF emitted by the reader, as well as the sensitivity of the RFID tags used in a particular application).
3) When a precise recognition of the range of EMF that may cause indirect electromagnetic hazards is required, it may be set at the distance from the RFID gun where the measured distribution of E values in the vicinity of the UHF RFID reader drops below 3 V/m.

III. Evaluation of the direct electromagnetic hazards (covering thermal effects, evaluated by SAR values, in W/kg):

1) UHF RFID guns with an EMF emission lower than 1 W may be considered as an insignificant source of human exposure that does not cause direct exposure effects in the body of

[6] **Zasady oceny *in-situ* zagrożeń elektromagnetycznych w pobliżu ręcznych czytników UHF RFID**

I. Rozpatrywane źródło pola elektromagnetycznego:

1) Ręczne czytniki (ang.: guns) UHF RFID pracujące w zakresie częstotliwości 860–965 MHz (w Europie: 865–868 MHz).

2) Ręcznie aktywowane urządzenia emituje pole elektromagnetyczne w sposób ciągły.

3) Jeżeli rodzaj systemu RFID nie zostanie potwierdzony, weryfikacja eksperymentalna może zostać przeprowadzona poprzez analizę częstotliwości emitowanego pola elektromagnetycznego za pomocą odpowiedniego analizatora widma.

II. Ocena pośrednich zagrożeń elektromagnetycznych (obejmujących zakłócenia pracy urządzeń AIMD, oceniana za pomocą wartości natężenia pola elektrycznego, E, w V/m):

1) Pośrednie zagrożenia elektromagnetyczne mogą wystąpić w pobliżu wszystkich czytników RFID UHF, w odległości od urządzenia, którą można oszacować jako połowę Zasięgu Odczytu (ZO) określonego systemu RFID.

2) ZO to maksymalna odległość między czytnikiem RFID a znacznikiem RFID, przy której znacznik (oznaczony obiekt) jest „znajdowany" (rozpoznawany) przez czytnik (ZO zależy od poziomu pola elektromagnetycznego emitowanego przez czytnik, a także od czułość tagów RFID używanych w poszczególnych systemach).

3) Gdy wymagane jest dokładne rozpoznanie zasięgu pola elektromagnetycznego, które może powodować pośrednie zagrożenia elektromagnetyczne, można przyjąć, że jest to odległości od czytnika RFID, gdzie zmierzona wartość E w pobliżu czytnika RFID UHF spada poniżej 3 V/m.

III. Ocena bezpośrednich zagrożeń elektromagnetycznych (obejmujących skutki termiczne, oszacowane na podstawie wartości SAR, w W/kg):

1) Czytniki RFID UHF o emisji słabszej od 1 W można uznać za nieistotne źródło narażenia ludzi, które nie powoduje narażenia pracowników, pacjentów lub osób postronnych przekraczającego odpowiednie limity SAR określone dla ochrony ogółu ludności przed zagrożeniami bezpośrednimi.

2) Korzystanie z czytników o emisji przekraczającej 1 W, znajdujących się w bezpośredniej bliskości ludzi, wymaga oceny poziomu pola elektromagnetycznego za pomocą pomiarów oraz oceny SAR za pomocą modelowania numerycznego, gdy nie można zastosować środków ochrony zwiększających odległość między ludźmi a urządzeniem RFID.

3) Rozkład wartości E w pobliżu czytników RFID UHF jest zwykle mierzony co najmniej od 10 cm do 100 cm od anteny (w odległości od urządzenia pokrywającej potencjalną lokalizację w pobliżu ludzi lub urządzeń elektronicznych), co 10 cm (rozdzielczość przestrzenna), w trzech kierunkach ortogonalnych (bez obecności ludzi).

4) Zmierzone E < 70 V/m w oczekiwanym położeniu powierzchni ciała człowieka podczas używania czytnika RFID UHF wskazuje na zgodność poziomu ekspozycji na pole elektromagnetyczne z limitami SAR dotyczącymi ochrony ludności. Gdy oddziaływanie pola elektromagnetycznego na ludzi przy czytniku RFID jest silniejsze, stosuje się odpowiednie środki ochronne w celu zmniejszenia poziomu narażenia; alternatywnie przeprowadza się dokładniejszą ocenę wartości SAR za pomocą symulacji numerycznych.

5) Pomiary rozkładu wartości E w pobliżu urządzenia RFID UHF należy wykonywać za pomocą profesjonalnego urządzenia pomiarowego z sondą pola elektrycznego odpowiedniej o czułości i zakresie pomiarowym (co najmniej 3-150 V/m), przy częstotliwościach odpowiadających zakresowi pracy urządzeń RFID UHF (860–970 MHz) i potwierdzonej odporności na oddziaływanie pola elektromagnetycznego z innych pasm częstotliwości; alternatywnym sposobem jest wykonanie szerokopasmowych pomiarów wartości E w miejscu, w którym jedynym źródłem pola elektromagnetycznego jest oceniane urządzenie RFID (np. w pomieszczeniu ekranowanym elektromagnetycznie, w którym odbicia pola elektromagnetycznego są wystarczająco ograniczone).

6) Odległości punktów pomiarowych pola elektromagnetycznego istotne dla oceny bezpośrednich zagrożeń elektromagnetycznych różnią się znacznie od stosowanych w testach emisji w zakresie badań kompatybilności elektromagnetycznej (EMC).

7) Należy również zwrócić uwagę, że wartości SAR w tkankach sąsiadujących z jakimkolwiek elektrycznie przewodzącym implantem medycznym mogą być wyższe niż w ciele osoby bez implantu, a użytkowników implantów zalicza się do osób szczególnie chronionych ze względu na działanie pola elektromagnetycznego [8].

personnel, patients or bystanders exceeding relevant SAR general public limits.

2) The use of readers with a radiated power exceeding 1 W in close proximity to humans requires an evaluation of the EMF level using measurements, and an evaluation of SAR by numerical modelling when protection measures increasing the distance between humans and RFID device may not be applied.
3) The EMF distribution of E values in the vicinity of UHF RFID readers is usually measured at least from 10 cm up to 100 cm from the antenna (at distances from devices covering the potential location of humans or electronic devices nearby), with a 10 cm step in distance (spatial resolution), in three orthogonal directions (without the presence of humans there).
4) The measured E < 70 V/m at the expected location of the surface of the human body during the use of a UHF RFID gun indicates compliance of the EMF exposure level with the SAR general public limits. When EMF affecting humans from the RFID gun is stronger, the application of sufficient protection measures is needed in order to reduce the exposure level; alternatively, a more in-depth evaluation of SAR values, using numerical simulations, would be applied.
5) Measurements of the distribution of E values in the vicinity of UHF RFID devices needs to be performed using a professional measurement device with an electric field probe with a sensitivity and measurement range (at least 3-150 V/m) in the UHF RFID frequencies (860-970 MHz) suitable for evaluating RFID emissions and confirmed immunity for electromagnetic influence from other frequency bands. An alternative way is to perform wide band E values measurements in locations where the only source of EMF is the RFID device under consideration (such as an electromagnetically shielded room where EMF reflections inside are sufficiently limited).
6) The distances of EMF measurement points relevant for the evaluation of direct electromagnetic hazards varied significantly from those used in electromagnetic compatibility (EMC) emission tests.
7) It needs also to be noted that SAR values in tissues adjacent to any electrically conductive medical implant may be higher than in the body of regular person, and that implant users need to be considered among persons at particular risk from EMF exposure [8].

Conclusions

– Various medical RFID applications and electromagnetic hazards caused by exposure to EMF emitted by UHF RFID guns were characterised. Direct and indirect electromagnetic hazards were evaluated with respect to EMF distribution near UHF RFID devices and its absorption inside human body, characterised by SAR values (a measure of the thermal direct biophysical effects of EMF exposure at frequencies emitted by UHF RFID readers).
– The results indicate that, under certain operating conditions, the EMF exposure level near the RFID gun antenna and the SAR values in personnel caused by exposure from the RFID reader may exceed the limits of electric field strength and SAR issued by international guidelines or legislation.
– Potentially excessive exposure to EMF emitted by UHF RFID readers is not limited to the user of the device, but may also apply to a patient or a bystander.
– Only UHF RFID guns with EMF emissions lower than 1 W may be considered as an insignificant source of human exposure. The use of readers with a power exceeding 1 W in close proximity to humans requires an evaluation of the EMF level using measurements, and an evaluation of SAR by numerical modelling when protection measures increasing the distance between humans and an RFID device may not be applied.
– In all cases, insufficient electromagnetic immunity of electronic devices (including AIMD and other medical devices) should be considered at least up to half of the reading range away from the RFID reader.

– The electromagnetic hazards related to the use of RFID guns may be limited by relevant preventive measures, as also shown in this paper, together with the principles of an *in-situ* evaluation of electromagnetic hazards near UHF RFID guns.

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