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Evaluation of SAR in Human Body Models Exposed to EMF at 865 MHz emitted from UHF RFID Fixed Readers working in the Internet of Things (IoT) System †

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Abstract: The aim of this ongoing study was to evaluate the specific energy absorption rate (SAR) values in the body of a person present near fixed readers of ultra-high frequency (UHF) RFID passive tags incorporated in Real-Time Locating Systems (RTLS), operating at a frequency range of 865 868 MHz, considering various exposure scenarios. The modelled electromagnetic field (EMF) source was a rectangular microstrip antenna designed at resonance frequency in free space at 865 MHz. The SAR values in the body exposed to EMF 5 cm away from the UHF RFID readers need consideration with respect to general public exposure limits, when the radiated power exceeds 8 W.

Keywords: biomedical engineering; environmental engineering; numerical simulations; occupational exposure; public health; specific energy absorption rate (SAR); RadioFrequency IDentification (RFID); Real-Time Locating Systems (RTLS)

1. Introduction

The advantages of Internet of Things (IoT) technology have led to the development of Real-Time Locating Systems (RTLS) used for identifying, monitoring and tracking objects within indoor or confined environments (e.g., tracking devices, things or people in factories, warehouses or offices, and even tracking patients, biological materials and pharmaceuticals in medical centres) [1]. One of the technologies that may be incorporated in RTLS is a RadioFrequency IDentification (RFID) system [2]. The displacement of workers or other people, for example healthcare workers and patients, often requires approaching RFID readers, and thus exposure to the electromagnetic field (EMF) emitted there.

The aim of this ongoing study was to evaluate the specific energy absorption rate (SAR) values in the body of a person present near to fixed readers of ultra-high frequency (UHF) RFID passive tags operating in the frequency range 865 - 868 MHz, considering various exposure scenarios.

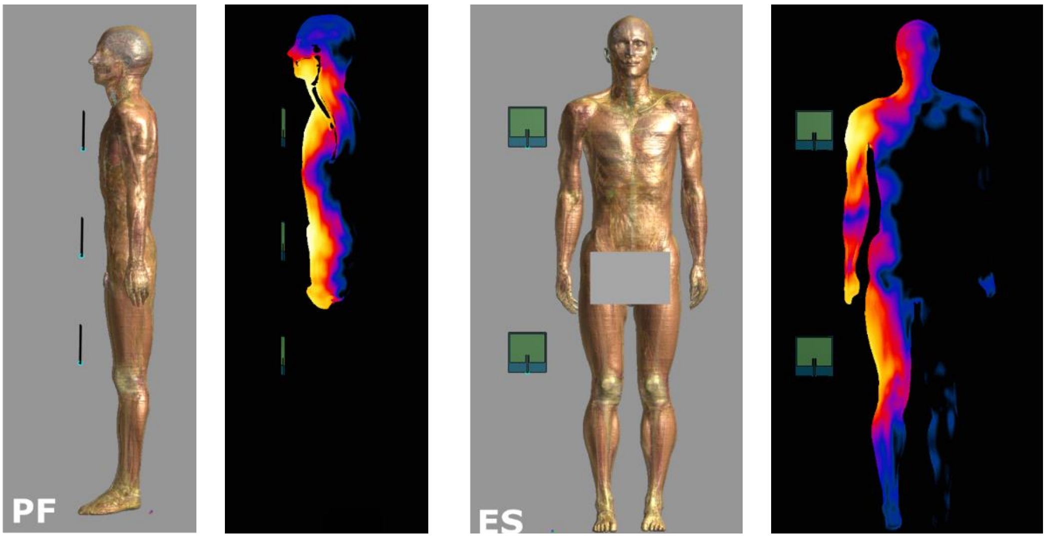
2. Materials and Methods

2.1. Numerical Model of the EMF Source

The modelled EMF source was a rectangular microstrip patch antenna designed to operate at 865 MHz to support the frequency range of UHF RFID applications in Europe. An antenna of dimensions 99.6 × 122.5 mm was placed on substrate and ground layers with dimensions 131.5 × 138.3 mm, for more details see [3]. Copper with a thickness of 0.035 mm, an electric conductivity of 5.813 × 107 S/m and a relative permittivity of 1 was used for the antenna; Rogers RO3003 with a thickness of 1.52 mm, an electric conductivity of 2.2 × 10^{-4} S/m and a relative permittivity of 2.92 was used as substrate; ground with a thickness of 0.035 mm was modelled as PEC (perfect electric conductor).

2.2. Exposure Scenarios

The investigations covered exposure scenarios with various number of UHF RFID single antennas fixed to the walls (two or three antennas, located at a distance of 5 cm to the closest surface of the human body and in various locations against the human body: antennas plane (P) or side-on (E) located in front (F) of or to the side (S) of the human body) (Figure 1).



(**a**) (**b**) (**c**) (**d**)

Figure 1. Exposure scenario with two UHF RFID antennas to the side of the human model (**a**) and SAR distribution in the frontal cross-section (**b**); white colour—higher SAR values.

2.3. Numerical Model of Human Body

An anatomical numerical male model Duke, composed of over 300 tissues/organs, a height of 177 cm and a weight of 70.2 kg, developed by the IT'IS (Information Technologies in Society) Foundation, were used in the investigations [4].

2.4. Numerical Simulations

Numerical simulations were carried out using Sim4Life software (Zurich Med Tech, Switzerland) using finite difference time-domain solvers (FDTD). The finest resolution used in the investigations was 0.03 mm, set for the antenna, and 2 mm set for the model of the human body. The uncertainty of numerical simulations was estimated as not exceeding ±25% (K = 1), within the range compliant with state-of-art in the field [5].

3. Results and Discussion

The numerical model of the UHF RFID antenna was validated by comparing the electric field distribution near the reader, obtained by measurements and numerical simulations. Differences below 10% were demonstrated, for more details see [3].

Table 1 shows the results of the numerical simulations of SAR values related to exposure to EMF at 865 MHz near to UHF RFID antennas at an input power to each single antenna of 1 W, analysed with respect to continuous exposure – the worst-case exposure scenario with respect to the exposure duration and the rules of evaluating the thermal load from human exposure to EMF (set to be time-averaged over six minutes for local SAR averaged over a 10 g mass of any continuous tissue, SAR10g, and over 30 min for SAR averaged over the entire exposed body, WBSAR).

Table 1. SAR values in the human body model Duke for various exposure scenarios, at 5 cm to UHF RFID antennas for an input power to the antenna of 1 W @ 865 MHz.

Exposure Scenario [1]	WBSAR [2], W/kg	SAR10g [3], W/kg	e.r.p. [4], W
2 antennas, PF	0.007	0.225	2.0
3 antennas, PF	0.012	0.231	1.8
2 antennas, PS	0.006	0.027	1.2
3 antennas, PS	0.010	0.039	1.3
2 antennas, EF	0.006	0.092	1.5
3 antennas, EF	0.010	0.112	1.7
2 antennas, ES	0.005	0.017	1.3
3 antennas, ES	0.008	0.022	1.5

[1] antennas plane (P) or side-on (E), located in front (F) of or to the side (S) of the human body; [2] WBSAR—SAR evaluated as averaged over the entire exposed body; [3] SAR10g—maximum local SAR averaged over a 10 g mass of any continuous tissue; [4] ERP—effective radiated power.

The highest SAR values (0.231 W/kg for SAR10g and 0.012 W/kg for WBSAR) were found in the exposure scenario PF (antennas plane located in front of the human body model) which involved three antennas. The SAR10g values obtained for exposure scenarios with two antennas were up to 40% lower than values obtained for exposure scenarios with three antennas. Additionally, up to 8-times (two antennas) and 6-times (three antennas) higher SAR10g values were found for antennas located in front of the human body in comparison to cases with antennas located to the side of it, and up to 2-times higher values for exposure cases with the human body located near antennas plane in comparison to antennas side-on.

According to ETSI EN 302 208 V3.3.0 (2020-05), being a harmonised standard with Directive 2014/53/EU (recognised as the RED directive) for RFID equipment operating in the 865–868 MHz and 915–921 MHz bands, their use does not require special permission when the effective radiated power (ERP) from the antenna does not exceed 2 W or 4 W, respectively [6,7]. RFID devices equipped with more powerful antennas may be used only when adequate administrative permission has been obtained. The results of this study showed that SAR values in the body exposed to EMF, 5 cm away from UHF RFID antennas may exceed the limits established for the general public (2 W/kg for SAR10g in torso and head; and 0.08 W/kg for WBSAR). Taking into account numerical simulations results, the limit of WBSAR may be exceeded when ERP from the antenna exceeds 12 W, and the limit of SAR10g may be exceeded when ERP from the antenna exceeds 15 W. However, taking into account also the expanded uncertainty of the discussed numerical simulations, WBSAR and SAR10g limits may be exceeded at the EMF emission levels of 8 W and 10 W, respectively.

4. Conclusions

The results of this work show that the absorption in the human body of an EMF emitted by UHF RFID antennas incorporated in an RTLS, IoT system may have a significant influence on humans when ERP from an antenna exceeds 8 W (devices emitting such a level of power need appropriate administrative permission for use). This requires further research, taking into account other exposure scenarios such as the various distances between the UHF RFID antennas and the human body, as well as anatomical variabilities between various humans.

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