Computational Estimation of Personal Exposure Against Electromagnetic Fields Emitted by Typical RFID Applications at 125 kHz and 13.56 MHz

Stefan Cecil
Austrian Research Centers GmbH-ARC
Seibersdorf, Austria
stefan.cecil@arcs.ac.at

Gernot Schmid
Austrian Research Centers GmbH-ARC
Seibersdorf, Austria
gernot.schmid@arcs.ac.at

Abstract **– Based on numerical (FDTD) computations the maximum induced body currents and specific absorption rates during exposure to generic sources representing 125 kHz and 13.56 MHz RFID devices were estimated. Two different realistic worst case exposure conditions were assumed with an anatomical body model having it's back (spine) or it's elbow as close as 5 cm from the generic transmitting loop antenna models. Moreover, the situations for the cases with and without metallic implants in the body parts close to the transmit antennas were compared for the considered exposure scenarios. The obtained results demonstrated, that even in the case when spatially (over body dimensions) averaged field strengths are compliant with the reference levels of current safety standards, the basic restrictions in terms of SAR and current density might be locally exceeded due to the highly heterogeneous field distributions and high local field strength close to the antennas. Therefore, a serious consideration of personal safety aspects must be strongly recommended to RFID manufacturers.**

I. Introduction

RFID devices operating in the low frequency (LF) and radio frequency (RF) range are frequently deployed for access control in public areas. In a typical scenario these RFID systems operate with passive RFID tags, which require a minimum magnetic field strength for power up the tag (e.g. a contactless smart card). This means, that persons (tag holders) passing the system are exposed to the magnetic field emitted by the RFID device. On the other hand personal exposure to electric, magnetic and electromagnetic fields must be limited in order to avoid adverse health effects and corresponding exposure limits for the general public are given in [1]. In the frequency range up to 10 MHz the induced current density (J) inside the body, and in the frequency range between 10 MHz and 10 GHz the specific absorption rate (SAR) are the relevant physical quantities which must be limited. Beside these so called **basic restrictions** in terms of the not easily accessible quantities J and SAR, [1] specifies also **reference levels** in terms of magnetic (H) and electric (E) field strengths which can be assessed more easily. These reference levels are derived form the basic restrictions under the assumption of homogeneous whole body exposure and maximum coupling of the field into the body. Therefore they provide conservative exposure limits. When comparing incident magnetic as well as electric field strengths against the reference levels, the field quantities have to be understood as spatially averaged over the body area. However, in order to prevent harmful localized overexposure of parts of the body, it must be ensured at the same time, that the basic restrictions are also locally met. This is especially of interest for exposure to sources, which cause highly heterogeneous field distributions, as typical for RFID transmitters. Table 1 summarizes the basic restrictions as well as the reference values for typical RFID frequencies of 125 kHz and 13.56 MHz according to [1]. In the present paper selected exposure situations were analyzed with respect to localized exposure in body parts close to the transmitting RFID antennas based on numerical computations using the FDTD method and a realistic anatomical body model.

Table 1 – Basic restrictions and Reference levels for 125 kHz and 13.56 MHz according to [1]

	125 kHz	**13.56 MHz**
Basic restriction **J***	250 mA/m^2	-
Basic restriction for localized **SAR**** in head and trunk	-	2 W/kg
Basic restriction for localized **SAR**** in limbs	-	4 W/kg
Reference level H	5 A/m	0.073 A/m
Reference level E	87 V/m	28 V/m

* average over 1 cm^2 perpendicular to direction of current flow
** average over 10g of tissue and over 6 minutes

II. Materials and Methods

Two different types of exposure scenarios were considered for two different generic sources of 125 kHz and 13.56 MHz each, representing typical RFID transmitter antennas employed in access control systems. In the first scenario ("elbow scenario" in the following) it was assumed that the elbow of the exposed person is located close to the maximum of the magnetic field emitted by the antenna (approx. 5 cm distance), and in the second scenario ("spine scenario" in the following) the person was assumed to stand with it's back close to the antenna (approx. 5 cm distance). Furthermore, each of the exposure scenarios was considered once with a normal, i.e., implant free body and once with a metallic implant in the body part close to the transmit antenna in order to investigate possible influences of the induced current distributions by the implants. In the elbow scenario 2 plates and 10 screws were modeled as commonly applied in medicine for fixing distal fractures of the humerus. In the spine scenario an inter-spinous process spacer was modeled (Figure 1).

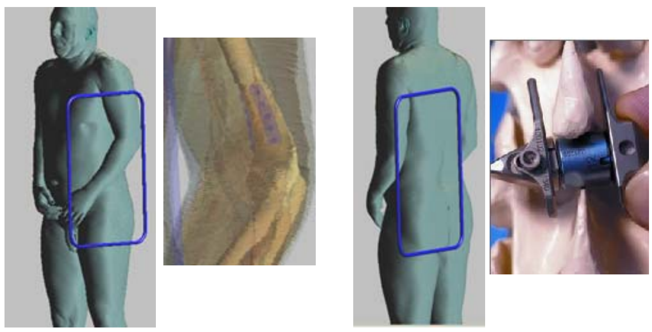

Figure 1 – Considered Exposure Scenarios (see text for detailed explanation)

The antenna was modeled as a simple loop of dimensions 40 cm x 60 cm causing a magnetic field distribution as it can be typically expected from the considered RFID transmitters (Figure 2). In the area where the body was closest to the antenna (at 5 cm distance) the maximum local rms magnetic field strengths were 100 A/m for the 125 kHz and 15 A/m for the 13.56 MHz source.

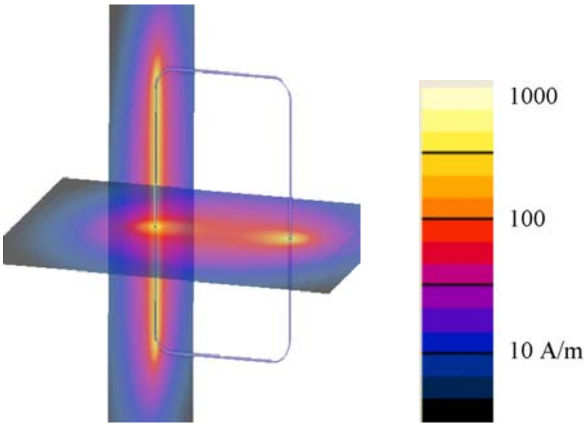

FIGURE 2 – MAGNETIC FIELD DISTRIBUTION AROUND THE 125 KHZ GENERIC TRANSMIT LOOP ANETNNA

The anatomical body model, based on the visible human data set and representing more than 100 different body tissues, provides an anatomical resolution of 0.5 x 0.5 mm^2 in horizontal and 2 mm in vertical direction.

For the numerical computations the commercially available simulation platform SEMCAD X (SPEAG, Zurich, Switzerland), based on the Finite Difference Time Domain Method (FDTD) was used. The whole computational domain was discretized using a non-uniform FDTD grid with grid steps between 1 and 5 mm. In the area of interest, i.e., in a volume of approximately 15000 cm^3 surrounding the implants the grid step was kept constant at 1 mm. The dielectric properties of the body tissues were set according to [2]. In order to overcome lengthy computation times in case of the 125 kHz exposure, the method of frequency scaling was applied. This method allows to scale FDTD results obtained at higher frequencies to the lower frequency range. The scaling is applicable, if the higher calculation frequency and the target frequency have a wavelength at least ten times larger than the dimensions of the computational domain and if displacement currents are small compared to conduction currents. These conditions are met in the calculated scenarios and for the properties of the body tissues ($\sigma >> \omega\varepsilon_0\varepsilon_r$). Therefore the induced current density in the body model can be scaled proportional to the frequency from the higher calculation frequency to the lower target frequency. The method of frequency scaling has been described and verified by several authors in the past. (e.g. [3]). For the computations at 13.56 MHz regular FDTD computations were carried out. The computational results were evaluated in terms of the 1 cm^2-averaged maximum current densities (for 125 kHz exposure) and the maximum 10g averaged SAR (for 13.56 MHz exposure) **inside** the tissue, i.e., current densities inside the implant and also in the voxel layer immediately surrounding the implants were excluded from the evaluation.

III. RESULTS

The obtained results clearly indicated that for 125 kHz the limit values of the basic restrictions were locally considerably exceeded in body parts close to the transmitting antennas under the assumed exposure conditions (Table 2). For the 125 kHz exposure no time averaging of the induced current density can be applied. In case of the 13.56 MHz system the time span during which people are exposed in the high field region is usually much less than 6 minutes. Consequently, when e.g., assuming an exposure duration of 10 s the maximum time- and 10g averaged local SAR in the spine scenario yields 7.31 W/kg, which is in spite of time-averaging clearly over the corresponding basic restriction of 2 W/kg according to [1].

TABLE 2 – COMPUTATIONAL RESULTS IN TERMS OF MAXIMUM INDUCED CURRENT DENSITIES (125 KHZ) AND SAR (13.56 MHZ)

		125 kHz $J_{rms,max,\ 1cm^2\ avg}$ [mA/m2]	**13.56 MHz** $SAR_{,max,\ 10g\ avg}$ [W/kg]
"spine" scenario	w/o implant	2630	5.75
	with implant	3300	7.31
"elbow" scenario	w/o implant	1640	3.33
	with implant	1680	3.67

Furthermore, it can be seen, that the presence of the metallic implants enhances the induced current densities and SAR inside the tissue. Beside the expected high induced currents at the surface of the metallic implants, concentrations of electric currents in the tissue appear close to edges of the implants (Figure 3)

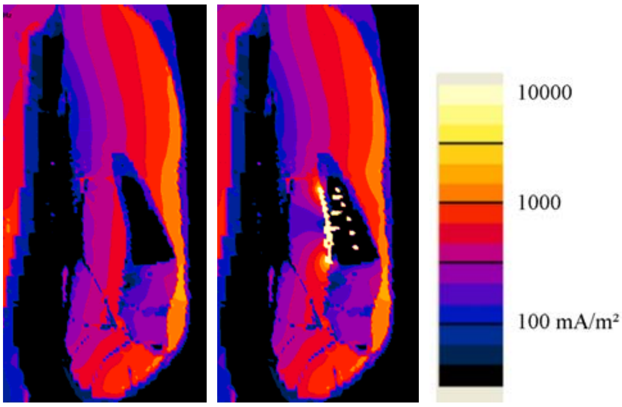

FIGURE 3 – CURRENT DISTRIBUTION (NOT AVERAGED) IN A CROSS SECTION THROUGH THE ELBOW IN THE 125 KHZ EXPOSURE CONDITION WITHOUT (LEFT) AND WITH (RIGHT) THE METALLIC IMPLANTS COMMONLY USED FOR FRACTURE FIXATION

IV. CONCLUSION

The presented results indicated that local exposure in the magnetic fields of typical RFID systems operating in the 125 kHz and 13.56 MHz range can become an issue, which needs to be addressed by the manufacturers of such systems. Also in cases when spatially averaged field strengths are compliant to the reference levels the locally induced current densities can exceed the basic restrictions under worst case exposure conditions. Even though the presented results are related only to very specific RFID applications it is generally strongly suggested to the manufacturers to seriously consider the issue of personal safety. Furthermore, not considered in this paper but probably also important, the aspects of possible electromagnetic interference with electronic implants as e.g, pacemakers and implantable cardioverter defibrillators should be taken into account.

REFERENCES

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