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Numerical simulation studies regarding the workers' radiofrequency exposure monitoring using wearable multi-location measurement system

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Abstract

The simulation study was to examine the effectiveness of reducing a discrepancy between parameters of unperturbed radiofrequency electromagnetic field (EMF) exposure in the work environment and results of workers exposure measurements using body-worn measurement systems, through performing simultaneous multi sensor (multi-location) measurements by sensors worn at various body locations and subsequent averaging of the results of such measurements. The obtained results revealed that the discrepancy in the outcome of EMF exposure assessments (the value of E-field strength normalized to the parameters of unperturbed E-field) coming from body-worn measurement system (delivering the parameters of EMF disturbed by the body of user wearing this system) may be significantly reduced by using a distributed (multi-location) measurement system. When using the three-point system with one of sensors on the helmet, the lowest discrepancy in the results of exposure evaluation using body-worn system is in case of location of other sensors on the chest and waist.

1. Introduction

The body-worn measurement systems (BW-MS), i.e. data loggers worn on the body and equipped in sensor(s) of any environmental factor, are widely applicable in the monitoring of environmental safety or health hazards in the work environment, such as chemical agents, noise, ultraviolet radiation. Such measurement systems are used also in the monitoring of workers' exposure to electromagnetic fields (EMF) of any frequency - from static magnetic field, over the low frequency magnetic and electric fields, up to radiofrequency/microwave radiation (parameterized in the most cases by electric field affecting worker). Such system allows for monitoring of the exposure frequency composition and its variability in time caused by the real regular activity in the work place of the individual worker who is wearing this BW-MS.

The conditions during recording EMF exposure profile using BW-MS differ from the conditions when a classic (standardized) methods of evaluating EMF exposure are applied. When the workers' exposure profile is compared with limit values provided by international safety guidelines for parameters of unperturbed EMF, the relevant standardized exposure evaluation methods require that measurements be performed without the presence of anyone near the insulated from the ground EMF-sensors in use (i.e. assessing the unperturbed EMF is required).

The aim of this simulation study was to examine the effectiveness of reducing a discrepancy between parameters of unperturbed radiofrequency (RF) EMF exposure in the work environment and results of measurements of workers exposure to such EMF while using BW-MS system, through performing simultaneous multi sensor (multi-location) measurements by sensors worn at various body locations and subsequent averaging of the results of such measurements.

2. Methods

The numerical simulations applied finite-difference time-domain (FDTD) solver of Sim4Life software (Zurich Med Tech, Zurich, Switzerland) and an anatomical male model (Duke v3.1: height 1.77 m, weight 70.2 kg) placed in a free space (analyzed space of 4x4x4 m volume) with boundaries at a horizontal distance of 1.5-1.8 m from the body model, and a vertical distance of 1.3 m from the top and the bottom in the case of the model insulated from the ground, or from the top of grounded model located directly on the bottom plane of the analyzed space.

Considered exposure scenarios are mimicking typical exposure to homogeneous RF EMF (more precisely "far-field" electric field (E-field) strength, usually expressed in volt per meter, V/m) which is affecting worker and is varying in polarization and direction of propagation with regard to the Duke model axis: (i) transverse – from right to left side and E-field vertical; (ii) sagittal – from front to back and E-field vertical; (iii) vertical – from top to bottom and E-field horizontal perpendicular to the frontal cross-section; (iv) vertical – from top to bottom and E-field horizontal perpendicular to the sagittal cross-section.

On the basis of the calculation results, the E-field strength was determined at seven locations near the body model: at a distance of 55 mm from the front, back, sides and top of the body surface, for horizontal cross-sections at relevant heights: (i) 1.08 m for the waist from the front and back; (ii) 1.34 m for the chest from the front and back; (iii) 1.39 m for the right and left arms; and (iv) 1.82 cm for the head. These locations modelled point-assessments of the E-field to mimic the results of measurements using BW-MS equipped with E-field sensors, with a geometrical center in a considered locations near the human body. The calculated E-field strength was averaged over the sphere with 50 mm diameter, compliant to typical size of the E-field sensors in the equipment used in the work place exposure monitoring.

3. Results

Computer modelling were taken for the 27-3600 MHz frequency range, widely used in industrial and radio communication applications. The BW-MS sensitive in this frequency range to RF EMF allows to monitor hazards caused by electromagnetic emissions from various sources used in the work place, such as radio communication broadcasting antennas, mobile phone base stations, radiofrequency dielectric welders and sealers, microwave dryers and ovens, and many more [1-3].

The human body significantly affects RF EMF spatial distribution, which means that measurements taken using BW-MS have significantly higher sensitivity to the exposure scenario than in the case of measurements of unperturbed EMF [4]. For the set of modelled exposure scenarios, the discrepancy in the results of the BW-MS based exposure assessment, comparing to the values of unperturbed E-field in the relevant sensor location, was assessed using the ratio of the E-field calculated near the body model in relation to the unperturbed E-field value. The use of a distributed multi-location BW-MS was modelled by averaging the E-field values obtained for relevant locations of more than one sensor.

The obtained discrepancy in the results of measurements using BW-MS in the set of modelled exposure scenarios reached the level of 7-fold in case of single-sensor exposure evaluation. The analysis of discrepancy of the use of multi-location systems confirmed that by using at least three sensors around the body it may be significantly reduced (Fig. 1).

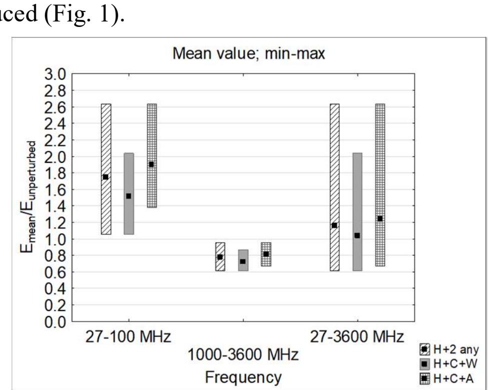

Figure 1. The discrepancy between the results of RF-EM exposure evaluation using three-point BW-MS (with one sensor on helmet), normalized to the unperturbed E-field: minimum-maximum ranges and average values in considered exposure scenarios; E-field sensors locations: H+2any – helmet, chest and waist or arm; H+C+W – helmet, chest and waist; H+C+A – helmet, chest and arm.

Taking into account that in the work environment the use of helmets is frequently required, the use of three-point BW-MS with one sensor located on the helmet was assumed, and two sensors on the chest, waist or arm (in previously mentioned all directions of RF EMF propagation and E-field vector polarizations). In such case the lowest discrepancy in the results of BW-MS exposure evaluation is in case of location of three sensors on the helmet, chest and waist.

4. Conclusions

The obtained results revealed that the discrepancy in the outcome of RF EMF exposure assessments (the value of E-field strength normalized to the parameters of unperturbed E-field) coming from BW-MS (delivering the parameters of EMF disturbed by the body of user wearing this system) may be significantly reduced by using a distributed (multi-location) measurement system.

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