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Exposure of workers to the electromagnetic field of a RF welding machine

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Abstract. Radio-frequency welding machines generate a high electromagnetic field. Workers using such appliances are daily exposed to this field, thus it is important to quantify their exposure. We performed measurements on a real device, and found that the radiated field is composed of several frequencies spanning from 27 MHz to 108 MHz. The effect of human tissues dielectric parameters on the external electromagnetic field is quantified numerically. We found that the field is strongly modified by the presence of the body, but the values of dielectric parameters of tissues have a little influence on the external electric field, as long as they have the same order of magnitude.

1 Introduction

INRS estimates around 100 000 radio-frequency (RF) industrial machines in France, which generate a high electromagnetic field [1]. For this reason, the main objective of EXTI¹ (PNREST Anses, 2015/2 RF/02) is to develop an effective tool for easily obtaining relevant information on workers exposure to RF electromagnetic fields and, if necessary, to propose appropriate measures to reduce exposure. In the present work, the effect of human body immersed in an RF electromagnetic field was studied by simulating a preliminary virtual phantom built with concentric spherical layers of different materials.

2 Materials and methods

A shielded plastic welding machine (3 kW RF output power) was used as test device. The distance between the machine and the nearest wall was greater than 1m. The magnetic field was measured in different points in front of the electrode at a sampling frequency of 250 MHz. With these preliminary measurements we have characterized the frequency spectrum of the RF field, which has been used for numerical simulations.

A RF model implemented for finite element simulations in HFSS was developed. The model was built starting from the CAD of the plastic welding machine electrodes. For simplicity, in these preliminary simulations a multilayer sphere (Table I) has been used instead of a realistic anthropomorphic computational phantom. For living tissues the dielectric properties in [2] were used. The source is simulated as a lumped port between the electrodes with a power of 3 kW and at 2 different frequencies (27.12 MHz and 108.48 MHz). For each phantom and frequency the electric field peak value (in V/m) is shown in Table I, while for the most interesting simulations the electric field vectors are shown in Figure 1.

¹ EXTI : EXposition des Travailleurs aux champs électromagnétiques Industriels.

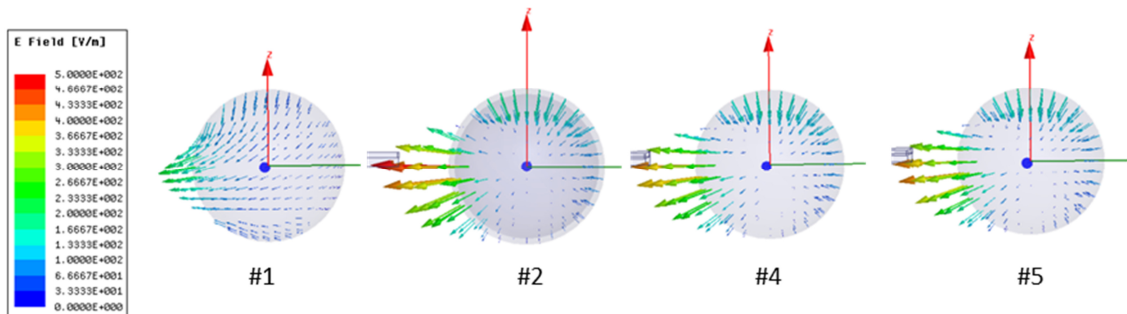


Fig. 1 Electric field orientation for different models (defined in Table I) at 27.12 MHz

3 Results and conclusion

Some of the simulated configurations are depicted in Fig. 1. It is found that the presence of the phantom (#2,4,5) modifies to a large extent the electric field, with respect of the case where the phantom is absent (#1). Moreover, in presence of any phantom it is observed that the electric field is nearly perpendicular to the external surface of the phantom, which can be easily explained by the high permittivity and conductivity of the phantom with respect of air (Table I). In the simulated frequency range (27.12 – 108.48 MHz) the peak value of the electric field exhibits a low dependence (about 10%) on the dielectric parameters of the material which compose the phantom, as long as they have the same order of magnitude of biological tissues. In particular, the internal structure of the phantom seems to play a quite minor role. The main factor which explain the observed differences between the phantoms #2,3 and #4,5,6 is the high relative permittivity of the skin, compared to the one of PVC.

On the base of these preliminary simulations, we aim for building an instrumented phantom composed of PVC filled (at least partially) with a tissue-mimic liquid. In fact, it is well known that the human body modifies significantly the electric field distribution. As our purpose is to check the compliance with basic restrictions, the electric field must be measured in presence of a phantom which mimics the human body, in order to obtain realistic data to be used for numerical dosimetry. Probes for measuring the normal component $\mathbf{n} \cdot \mathbf{E}$ of the electric field should be placed on the surface of the phantom. The knowledge of $\mathbf{n} \cdot \mathbf{E}$, measured in realistic situations, should allow to numerically compute the electric field inside the body, so as to characterize the human exposure of workers to the RF field (more detailed simulations will be shown in the full paper).

Table I – Electric field peak value for different modelling configurations. For each material the radius (r) in mm, the relative permittivity (ϵ) and the conductivity (σ) in S/m at 27 MHz are shown in brackets

#	Model	E (V/m) at 27.12 MHz	E (V/m) at 108.48 MHz
1	No phantom	235.97	109.75
2	Skin (r = 130, $\epsilon = 166$, $\sigma = 0.33$), blood (r = 120, $\epsilon = 127$, $\sigma = 1.16$)	492.92	257.20
3	Skin (r = 130, $\epsilon = 166$, $\sigma = 0.33$), blood (r = 120, $\epsilon = 127$, $\sigma = 1.16$), brain (r = 60, $\epsilon = 221$, $\sigma = 0.57$)	493.48	257.38
4	PVC (r = 130, $\epsilon = 2.7$, $\sigma = 0$), blood (r = 120, $\epsilon = 127$, $\sigma = 1.16$)	437.68	232.54
5	PVC (r = 130, $\epsilon = 2.7$, $\sigma = 0$), blood (r = 120, $\epsilon = 127$, $\sigma = 1.16$), PVC (r = 90), vacuum (r = 80, $\epsilon = 1$, $\sigma = 0$)	449.21	234.11
6	PVC (r = 130, $\epsilon = 2.7$, $\sigma = 0$), blood (r = 120, $\epsilon = 127$, $\sigma = 1.16$), PVC (r = 60), vacuum (r = 50, $\epsilon = 1$, $\sigma = 0$)	436.97	232.18

References

- [1] Demaret, P., & Donati, P. (2011). *Intégrer le risque «rayonnements électromagnétiques» dans le document unique d'évaluation des risques professionnels*. Hygiène et Sécurité du Travail – Cahiers de notes documentaires, HST ND 2350 – 225 – 11, pp. 45-53.
- [2] <https://www.itis.ethz.ch/virtual-population/tissue-properties/database/dielectric-properties/>