Investigation of Specific Absorption Rate of Electromagnetic fields at 100MHz in The Head of a Person Wearing Hoodless Protection Garment.

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Abstract — **This paper presents a study of Specific Absorption Rate (SAR) induced in the head of a person wearing protection garment without hood. Electromagnetic fields in the head are determined using a combination of the Finite Difference in Time Domain (FDTD) method and the Method of Moments (MoM). The maximum level of ambient electric field, to which a person can be exposed in the case in which he uses a protection garment without hood, is given.**

I. INTRODUCTION

The wireless communications and broadcast operators have to address workers exposure to the electromagnetic fields. For that purpose, the workers can be equipped with radio-frequency protection combination to reduce their exposure. These protection combinations attenuate the electromagnetic fields in the same manner as a Faraday cage can do. The various combinations can show ergonomic disparities. In particular, the most constraining part for the users is the hood. This is the reason for which it is noticed that most of technicians do not put the hood. It is thus necessary to analyse the Specific Absorption Rate, (SAR) for such situation. As is known, the SAR is used to evaluate power absorbed in the tissues per unit mass expressed in Watt/kg and can be calculated using the known formula:

$$SAR = \frac{\sigma . |E|^2}{2\rho} \quad (1)$$

where σ is the tissue conductivity, ρ is the tissue density and E is the magnitude of the electrical field. The basic restrictions given by ICNIRP (International Commission on Non-Ionising Radiation Protection) [1] have been established to specify the safe limit of the power absorbed by the tissues. These limits are 0.4 Watt/kg for the whole body and 10 Watt/kg average over a mass of 10 grams on a local level. To estimate this SAR, measurements and/or simulations have to be performed, to evaluate electromagnetic fields in tissues.

We seek to determine to which ambient level of electromagnetic field, a person, wearing a protection garment without hood can be exposed. Of course, this level must respect the basic restrictions levels imposed by these recommendations [1]. We are concerned by operating frequencies for FM broadcasting (88-108 MHz). For this purpose, the SAR induced in the head of a person protected by a combination without hood, for various types of exposure is simulated.

II. PRINCIPLE OF STUDY

Several electromagnetic simulations are carried out for the study of several different configurations of exposures for a person close to a source.

The model of the individual is broken into two different objects: Firstly the naked head without hood and secondly the protective clothing. According to geometrical data (dimensions) and electromagnetic ones (permittivity and permeability), the two objects are modelled using two rigorous numerical methods for calculation electromagnetic fields. The integral equations technique solved by the Method of Moment (MoM) is adapted to characterise wire structure of protective clothing as well as the source. While the Finite Difference in Time Domain (FDTD) method is adapted to model the human head and the strongly heterogeneous morphology. In the whole study, the influence of the head on protective clothing and on the source is not taken into account. Thus only a one-way exchange of data between results calculated by the two methods is performed, namely from these calculated by the method of integral equations towards these calculated by the FDTD. For this propose the transfer of the fields from one object to the other is carried out using the equivalence principle, which makes it possible to replace radiated electromagnetic fields by equivalent electric and magnetic sources that are calculated by the MoM. These sources are applied in a closed surface,

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called thereafter Huygens box, including the object that is modelled by the FDTD [2].

The person who wears protective clothing is supposed to be standing tight with legs and arms along the body. He measures in height, without the head, 1.55 m and has a width on the thorax level of 60 cm and thickness of 40 cm. The neck has a diameter of 16 cm. Clothing is considered to have a wire form. It is considered composed of 468 wires of length 10 cm each, which corresponds to λ/30 at the working frequency of 100 MHz (Fig. 1). In order to break the symmetry of clothing and to givė it a ruffled aspect, numerical noise is inserted at the level of the assemblage wire points.

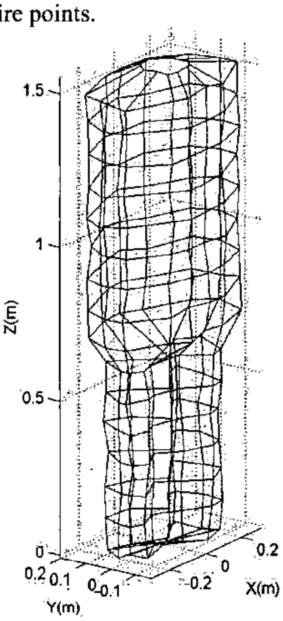


Fig. 1. Clothing modelled by the MoM.

The source is composed of a vertical network of two dipoles at a distance of 0.7λ between their feeding gaps. Two dipoles are tuned to the 100 MHz frequency (Fig. 2). They are fed in phase using a voltage of 1V. The dipoles have a radius of 1 mm. A segmentation of 21 segments per dipole is adopted, which represents a grid of λ/42.

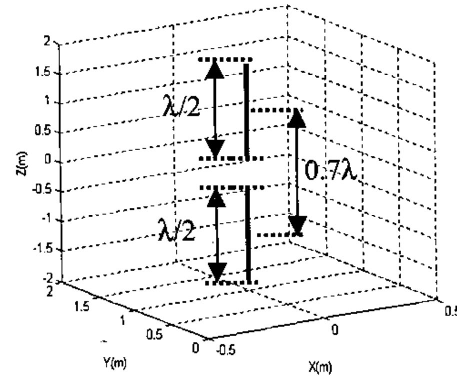


Fig. 2. The source modelled by the MoM

The modelled head follows the human morphology and it is heterogeneous. The used model is obtained from magnetic resonance image (MRI). This image is segmented to identify the various biological tissues, which form the human head. Once these tissues are identified, they are labeled in order to associate each tissue to its corresponding dielectric characteristics (Tab. I). Using these treatments, the head has a resolution of 5x5x5 mm and is contained in a parallelepiped of 18x24x25.5 cm (Fig. 3).

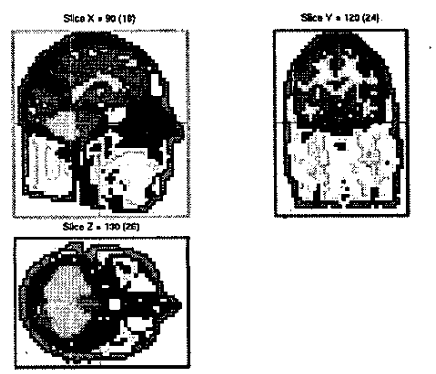
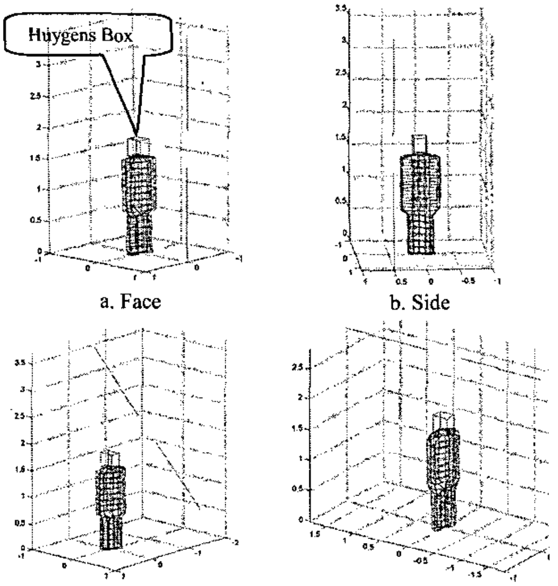


Fig. 3. Morphological description of the head for various cuts modeled by the FDTD.

TABLE I
CHARACTERISTICS PHYSICS OF HUMAN LIVING TISSUE AT 100 MHZ

Tissues	ε_r	σ (S/m)	ρ (Kg/m^3)	Tissues	ε_r	σ (S/m)	ρ (Kg/m^3)
Air	1.0	0.0	0.001	Skin (wet)	66.0	0.52	1125
Fat	12.7	0.068	916	Grey Matter	80.1	0.56	1038
Nerve spine	47.3	0.34	107	Blood	76.8	1.23	1058
Muscle	66.2	0.73	1046	CSF (Cerebral Spinal Fluid)	88.9	2.11	1007
White matter	56.8	0.32	1038	Eye aqua humor	69.1	1.5	1009
Cerebellum cervelet	89.8	0.79	1038	Bone average	21.5	0.12	1850

To study the influence of the type of exposure, various possibilities of illuminations are considered, namely: exposure of face, side, diagonal and top. Figure 4 represents the orientation in the space for the three objects, namely: Huygens box including the head, clothing protective and the source. In each studied configuration, the source is set distant of 0.3m, 0.65m, 1m and 3m from the bust of the person who wears protective clothing. An exposure in the zone of far field from the source is also studied using an illumination by a plane wave.



a. Face b. Side

c. Diagonal c. Top

Fig. 4. Various exposure configurations

IV. Result at 100MHz

More than one hundred cases of exposure are studied. For each case, the power absorption by the head, due to the conductivity of human tissues, as well as the maximum local SAR averaged over a mass of 10 grams are calculated. An evaluation of the total SAR on the whole body with or without protective clothing is determined. The whole body SAR is estimated by dividing the power absorbed by the head (the power absorbed by the other parts of the body is negligible because of the protection garment) by the weight of an individual of 40 kg which represents a worst case situation. This whole body SAR is referred as the whole body SAR with protective clothing but without hood. For comparison purpose, we define also an estimated whole body SAR without protective clothing by assuming that the absorbed power per mass unit, i.e. the total power absorbed in the head divided by the weight of the head, 6.5 kg, is the same in the rest of the body.

The SAR level depends on the incident field level. As the incident field is not constant over the Huygens box, an ambient field is defined as the average of the incident field over the Huygens box. The SAR can be normalized for an ambient field level of 1 V/m and the SAR is proportional the square the ambient field. The ambient field level for a given SAR is expressed by.

$$E = \sqrt{\frac{SAR}{SAR_{1V/m}}}.1(V/m) \qquad (2)$$

In this way it is possible to answer the following question: knowing the limits of SAR (0.4 W/kg for the whole body and 10 W/kg on a local level), up to what level of ambient electric field one can be exposed while remaining below the basic restrictions levels?

All the values of the ambient field at which the basic restrictions are reached for each case of exposure are synthesized graphically as given in figure 5.

Using the above mentioned proposed calculation technique to evaluate the whole body SAR with or without clothing, it can be seen that it is always interesting to wear protective clothing even without hood. Indeed, with protective clothing but without hood (star: *), the person can expose himself to a field level higher than that in the case of absence of clothing (cross: +). When wearing protective clothing without hood, the most restrictive compliance criteria is the local SAR. The ambient field level up to which compliance is fulfilled is given by the lowest ambient field level at the points indicated by the circle for local SAR (Fig.5). The lowest level is reached for the configuration known as « Diagonal » for a distance of the clothing of 1m from the source. We can note that the level of the ambient electric field, when the basic restrictions are reached, is higher than the reference level of 61V/m at 100MHz.

IV. Result in FM band

Among the various exposures configurations already simulated at 100MHz, some of them are studied again at 88MHz and 108MHz, in order to determine the ambient field when the basic restrictions are reached, in the FM frequency band.

For each frequency, the dielectric characteristics of the human head tissues which are updated. The living tissue human conductivity varies slightly in this frequency band. Only, the white matter and the grey matter have variations levels which are detached from other tissues. Their variation is of the order of 3%. The variation of relative permittivity is a little more important but remains lower than 7%. The strongest variations are held by the cerebellum, namely: the grey matter and the white matter. On the other hand the tissues dielectric characteristics, as the eye aqua humor, remain practically constant in this frequency band.

As in the preceding paragraph, when the basic restrictions are reached in each case of exposure, all the values of the ambient field are synthesized graphically (Fig. 5) for the frequencies of 88 MHz and 108 MHz. The conclusions remain the same for those frequencies as for the frequency 100 MHz. The ambient field level decreases with the increase of the frequency. So the ambient field, which is the one that gives the smallest local SAR corresponds to the frequency of 108MHz.

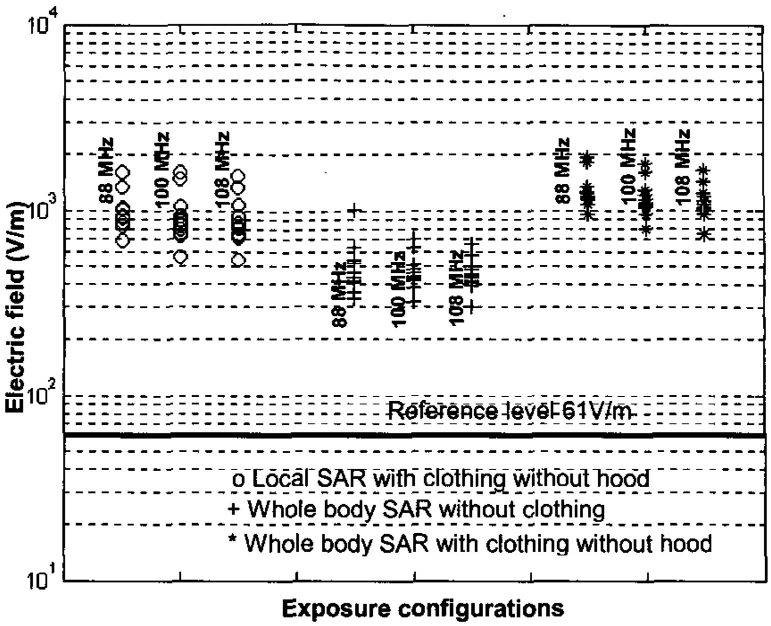


Fig. 5. Value of the ambient field at which the basic restrictions are reached: for three frequencies 88 MHz, 100 MHz and 108 MHz.

CONCLUSION

It is shown that the determination of the SAR in the head of a person wearing hoodless protective garment was possible and efficient. For this purpose, the electromagnetic fields in the human head are precisely determined using a combination of the MoM and the FDTD rigorous numerical methods to which accurate electromagnetic data for the head are feeded using Magnetic resonance imaging (MRI) techniques. The FDTD is used to model a human head having strongly heterogeneous morphology. Software, based on the integral equations resolution, is used to model protective clothing and the source. The equivalence principle is employed to carry out the information transfer of software to the other. A hundred configurations of different exposures are studied. This reveals that when the basic restrictions are reached, the ambient electric field limit can be higher than the reference level (61V/m at the FM band). For the studied exposures cases, the ambient electric field can reach three times the reference level. Our study shows that it is possible that the reference levels can be exceeded in the near zone to the antenna even if the basic restrictions are respected within the configuration, exposed to an FM source.

REFERENCES

[1] ICNIRP guidelines, "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic field (up to 300 GHz) ", Health Physics, vol. 74, 1998.

[2] E. Nicolas, D. Lautru, F. Jacquin, M. F. Wong, and J. Wiart, "Specific Absorption Rate Assessments Based on a Selective Isotropic Measuring System for Electromagnetic Fields", IEEE Trans. on Instrumentation and Measurements, Vol. 50, No. 2, April 2001, pp. 397-401.