Body effect on SAR in the human eye close to metallic spectacles for plane-microwave exposure

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Abstract: We recently clarified that an isolated head as model does not approximate a whole body for numerically estimating the specific absorption rate (SAR) in the human eye exposed to E-polarized plane wave, even at high frequencies above 0.6 GHz. This letter describes the case of the human eye close to metallic spectacles. As a result, we find that the average SAR is more affected by the body than that of the model without the spectacles.

Keywords: biological effects, SAR, eye, spectacles, body effect, plane-microwave

Classification: Electromagnetic Compatibility (EMC)

References

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1 Introduction

Mobile communication equipment use in the front of the face is becoming increasingly common. On the other hand, the human eye seems to be one of the most hazardously exposed body organs. There are consequently many studies on the specific absorption rate (SAR) as the hazard index of the human eye for far field (plane wave) and near field exposures [1, 2]. The significant finding is the occurrence of hot spots inside the eye at several GHz.

If metal objects exist inside or outside of a human head, the SAR is expected to rise in a certain situation, which is not preferable from the viewpoint of electromagnetic wave protection. Therefore, for instance, the SAR in the human eye close to metallic spectacles exposed to far field and near field has been analyzed by various human models [3, 4]. The isolated head models are used in these studies because the eye size is sufficiently shorter than the wavelength at subject frequencies. However, we recently clarified that the head model does not approximate the whole body for E-polarized plane wave exposure, even at high frequencies above 0.6 GHz [5].

In this letter, we numerically analyze the body effect on the SAR in the human eye close to metallic spectacles exposed to E-polarized plane wave in the frequency range from 0.6 to 6 GHz.

2 Model analysis and discussion

Fig. 1 illustrates the Brooks anatomically realistic human model [6] close to metallic spectacles exposed to E-polarized plane wave represented by the frequency $f$ and power $P_i$, and the central vertical cross section ($yz$ plane) of the spectacles and eye. The height from the top of the head is set as $h$. The eye opening is a nearly ellipse which has a major axis of 23 mm and a minor axis of 9 mm, and the eye consists of 4 tissues of aqueous humor, cornea, lens, and sclera and is about 7.3 g in

![Fig. 1. Human model close to metallic spectacles exposed to E-polarized plane wave, and cross section of the spectacles and eye.](image-url)
mass. The spectacle lens is 4 mm and 2 mm thick glass (relative dielectric constant: 3.8) of a nearly ellipse which has a major axis of 54 mm and 28 mm and a minor axis of 30 mm and 12 mm, respectively. The center of the lens and eye almost coincide. The finite difference time domain (FDTD) method with 1 mm resolution implementing the 8 layers uniaxial PML as the absorbing boundary is used in numerical analysis. We compare the SAR of a spherical model whose exact solution is known with that of this method and confirmed that the accuracy of this method is sufficient. Since the SAR difference between the left and right eyes is relatively small, we treat only the right eye. In addition, we use the model of $h = 100$ cm as a whole body [5].

Figs. 2(a) and (b) show the frequency characteristics of the average SAR in the eye of the whole body model and comparative isolated head model ($h = 25$ cm) respectively, where the solid and dotted lines represent the cases with and without the spectacles, and $P_i = 5$ mW/cm$^2$ which is the maximum permissible exposure limit in the guideline of controlled environments over 1.5 GHz [7]. The average SAR of the whole body model with the spectacles increases as frequency rises up to 2.3 GHz, above which it decreases gradually. It is larger than the average SAR of the whole body model without the spectacles in the frequency range from 1 to 3.8 GHz and is about 1.8 times at the maximum value of 2.3 GHz. Also, it is smaller than the average SAR of the whole body model without spectacles at frequencies

![Fig. 2. Frequency characteristics of average SAR in the eye of human model; (a) Whole body, (b) Isolated head, $P_i = 5$ mW/cm$^2$.](image)
over 3.9 GHz. The reason for this will be discussed below. The average SAR of the isolated head model with the spectacles decreases abruptly until 2.1 GHz after reaching the maximum at 1.9 GHz that has the same tendency as in Ref. [3]. It is obvious from the above results that actual SAR characteristics of Fig. 2(a) cannot be estimated using the isolated head model without the body effect [5].

In order to discuss more detailed, Figs. 3(a), (b), and (c) show the SAR distributions in the central $yz$ plane of the eye of the whole body model at $f = 1$ GHz, $f = 2.3$ GHz, $f = 4.5$ GHz; Left- with spectacles, Right- without spectacles, $P_i = 5$ mW/cm$^2$.

Fig. 3. SAR distributions in the central $yz$ plane of the eye of human whole body model at (a) $f = 1$ GHz, (b) $f = 2.3$ GHz, (c) $f = 4.5$ GHz; Left- with spectacles, Right- without spectacles, $P_i = 5$ mW/cm$^2$.,
Finally, note that the largest average SAR at 2.3 GHz is 2.81 W/kg, which does not exceed the limit of 10 W/kg averaged over 10 g of tissue in the guidelines of controlled environment [7].

3 Conclusion

We analyzed the body effect on the SAR in the human eye close to spectacles for E-polarized plane wave exposure in the frequency range from 0.6 to 6 GHz using a whole-body approximation model. We find an interesting feature that the average SAR of the model with the spectacles is about 1.8 times at the maximum larger than that of the model without spectacles in the wider frequency range from 1 to 3.8 GHz. This is a different finding from the isolated head model that the average SAR decreases abruptly after the maximum resonance. Therefore, the use of the head model is inappropriate to estimate the effects of the spectacles on the eye’s SAR.

The future subject is to discuss the uncertainty of SAR due to various parameters such as size of eye opening, shapes of spectacle frame, and others.