Experimental Estimation of SAR Enhancement Due to Two Parallel Implanted Metal Plates Using a Head Phantom and Thermograph

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ABSTRACT

The main objective of this study is to assess whether two parallel metal plates implanted in the head region could be expected to cause SAR enhancements under UHF near-field exposure. In this paper, we achieve precise temperature distribution measurements for a physical head phantom implanted with two metallic plates using thermograph. The phantom was newly manufactured using silicone rubber and carbon material. In the measured distributions, temperature increase due to the metallic plates was clearly observed in the gap of two metal plates region. Obtained measurement data can be used for validation study for further SAR estimations using numerical analysis.

Categories and Subject Descriptors

Microwave interaction with biological tissues

General Terms

Measurement, Verification.

Keywords

Specific absorption rate, Medical implants, RF exposure, Thermographic method.

1. INTRODUCTION

With regard to the electromagnetic field (EMF) emitted from wireless communication devices, radio radiation protection guidelines for human exposure to EMF have been formulated. These guidelines have been established internationally by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [1] and the Institute of Electrical and Electronic Engineers (IEEE) [2]. In Japan, a telecommunications technology council report has been published [3]. These guidelines provide no quantitative discussions about their relevance to humans with metallic objects implanted in their bodies because it is difficult to precisely evaluate local SAR around the implants inside the human body. However, given the progress in biomedical technologies, the number of such users continues to increase, such as active implantable pacemakers and medical metal plates, upper limb prostheses, and prosthetic legs. It is important to estimate the amount of exposure that users with metallic implants will experience. Due to recent technological advancement in numerical simulation region, these difficult issues can be treated using precise computer simulation. Some papers regarding interaction of radio frequency (RF) EMF and passive metallic implants have been published [4]-[7].

This paper describes experimental estimation of local SAR enhancement for human with osteosynthesis metal plates embedded in the mandibular exposed to RF EMF. Recently, various types of osteosynthesis plate are used in healing process of mandibular fractures. In some case, combination of two metal plates is applied instead of single plate because of surgical reason such as space limit, stability, strength and so on. The main objective of this paper is to assess whether combination of two metal plate implants aligned in parallel could cause SAR enhancements under RF exposure at mobile radio frequency-band.

2. HUMAN WITH IMPLANTED TWO METAL PLATES ALIGNED IN PARALLEL

This paper assumes that a human implanted with metal plates for the treatment of mandibular fractures is exposed to EMF at mobile radio frequency band. The metal implant size, shape, and region are decided based upon reports [8,9]. First, in order to obtain basic characteristics of SAR enhancement due to two parallel plates implanted in human head, numerical estimation of SAR using a simple layered model are achieved. Figure 1 shows a layered head phantom model. This model consists of skin, fat, muscle, bone and brain [10]. The thickness of each tissues are summarized Table 1. The dielectric constants of biological tissues were derived from the Gabriel Report [11]. Metal plate(s) is/are implanted on surface of bone-layer, the thickness of plate is 2 mm. In this paper, numerical simulations are performed using the SEMCAD X [12].

Table 1. Thickness of tissues

Tissue	Thickness
Skin	2.4 mm
Fat	2.4 mm
Muscle	2.4 mm
Bone	6.0 mm
Brain	50 mm

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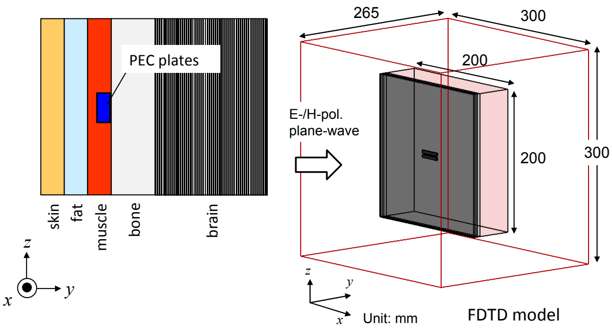


Figure 1. Layered head phantom model.

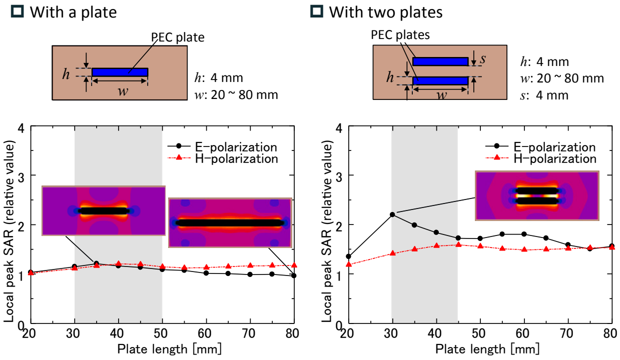


Figure 2. Local peak SAR dependence on the length of metal plate(s).

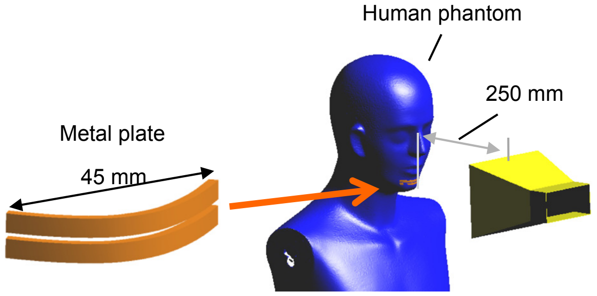
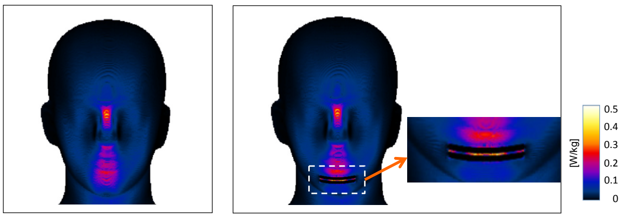


Figure 3. Exposure set-up for SAR measurement.



(a) w/o plate (b) with two parallel implanted metal plates

Figure 4. Numerical results of local SAR distributions with / without parallel metal plates (2.4 GHz, E-pol., 0.2 W of antenna Input power).

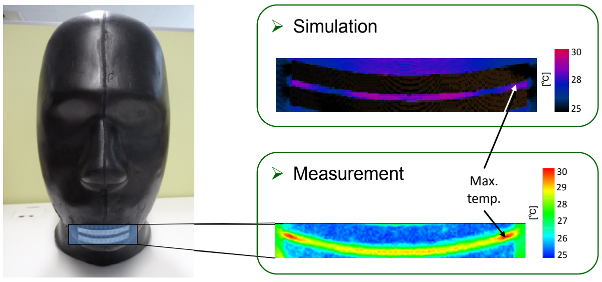


Figure 5. Temperature elevation distributions on phantom surface around metal implants. (after 10 sec exposure)

The dependencies of the local peak SAR on the length of the metal plate(s) are shown in figure 2. Here we assumed 2 GHz-band plane-wave exposure with vertical / horizontal polarization. From the figures, in the case of two metal plates with particular length implanted, SAR enhancement is clearly observed in the gap of two metal plates region exposed with vertical (E-) polarization. Next, we conduct experimental investigation to confirm and evaluate this peak SAR enhancement due to two parallel implanted metal plates using a physical head phantom and thermograph.

3. EXPERIMENTAL ESTIMATION FOR SAR ENHANCEMENT USING A HEAD PHANTOM AND THERMOGRAPH

A physical phantom implanted with two metal plates is developed and thermographic method are used to obtain temperature distribution. Figure 3 shows exposure set-up for measurements. Two metal mini-plates are embedded at the median mandibular. The plates are made of cupper and are treated as simplified planes without fixing screws in this experiment. The solid phantom was manufactured using silicone rubber and carbon material. The dielectric constants of the material was assumed 2/3 muscle equivalent tissue at 2.4 GHz. Numerical results of local SAR distributions on the head region of with and without metal plates ,when 2.4 GHz vertical polarization wave is radiated from the horn antenna, are shown in Figure 3. Also in this case, SAR enhancement in the gap region of two metal plates can be observed. Using thermograph, temperature elevation distribution was measured in front of the metal plates of the phantom. After 10 seconds RF exposure, when the antenna input power was set to be 500 W, the temperature distribution was measured. Figure 5 shows example of surface temperature distributions of gap region of the two parallel metal implants. In the temperature distributions, temperature increase due to the metal plates was clearly observed the gap, especially near the plate edges. In addition, based upon the measured temperature elevation, calculated value of SAR agreed well with numerical simulation result. The obtained measurement data can be used for validation study for further SAR estimations using numerical analysis.

4. CONCLUSION

This paper introduced experimental evaluations for local SAR enhancement for a human with two metal implants aligned in parallel. To investigate the impact of the two metal implants, temperature distribution measurements using solid phantoms and thermograph were conducted. In the measured distributions, temperature increase due to the metallic plates was clearly observed in the gap of two metal plates region.

Future works include evaluating the local SARs while changing the size or shape of the metallic plates and other types of metallic objects.

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