Numerical Evaluation of local SAR in Anatomical Phantom Implanted with Metallic Osteosynthesis Plates Exposed to 2GHz RF Fields

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Abstract

RF exposure guidelines recognize that an increase in local SAR due to metallic implants is possible, depending upon the size and shape of the implant and the position. This study describes the local SAR calculations for an anatomical human with metallic osteosynthesis plates embedded in the mandibular zone exposed to 2GHz RF fields; FDTD analysis is applied. The main objective is to assess whether combination of two metallic plates aligned in parallel in the head region could be expected to cause SAR enhancements under near-field exposure condition at 2 GHz.

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 established [1-3]. These guidelines provide no quantitative discussions about their relevance to humans with metallic objects embedded in their bodies. However, given the progress in biomedical technologies, the number of such users continues to increase, such as active implantable pacemakers and medical metallic plates, upper limb prostheses, and prosthetic legs. It is important to estimate the amount of exposure that users with metallic implants will experience.

Some papers regarding interaction of radio frequency (RF) EMF and metallic implants have been published, and studies on the EMF exposure of users with passive metallic implants have reported measurements and numerical estimations by using numerical humans [4-7]. A basic metric used as the reference value is the specific absorption rate (SAR), which is defined as averaged energy absorbed by the human body in any 6 minute period divided by the weight of tissues. SAR averaging mass is harmonized as 10 g in the international guidelines/standard based on the relationship with the temperature elevation for frequencies up to 6 GHz [8, 9].

The main objective of this paper is to assess whether combination of two metallic plates aligned in parallel in the head region could be expected to cause SAR enhancements. An anatomical phantom model [10] is used in which osteosynthesis plates of mandibular fractures are implanted. The peak 10-g averaged SAR dependencies in the mandibular zone are quantitatively investigated with metal plates of various sizes and shapes. Finite-difference time-domain (FDTD) analysis is applied [11].

2. Anatomical human model implanted with metallic osteosynthesis plates for the treatment of mandibular fractures

A numerical model of human implanted with metallic osteosynthesis plates for the treatment of mandibular fractures is constructed. Implant size, shape, and region are decided based on reports [12, 13]. It has been reported that a metallic implant (e.g. skull plates, fixtures, bone plates and ear rings) might change the distribution of the EM energy in the human body. Various types of osteosynthesis material are used in healing process of mandibular fractures. In some case, combination of two plates is applied instead of single plate because of surgical reason such as space limit, stability, strength and so on. The combination of two parallel aligned metallic plates, under very rare exposure conditions, might cause a more notable enhancement in peak mass averaged SAR. The constructed numerical human model implanted with two metallic plates is shown in Figure 1. This model is developed from an anatomical high-resolution human model made by the National Institute of Information and Communications Technology (NICT) in Japan [10]. It consists of 51 heterogeneous tissues and has $2\times2\times2$ mm^3 resolution. Two metallic mini-plates are

implanted in parallel at the median mandibular [13]. These plates are modeled as PEC (perfect electric conductor) and treated using topological morphing operation to perform 3D bending [11]. The plates are assumed to replace the equivalent volume of bone tissue based on voxel-based modeling.

3. SAR calculation for human implanted with metallic plates

Local SAR values in the human head were evaluated. The details of the FDTD analysis configurations are summarized in Table I. The dielectric constants of biological tissues were derived from the Gabriel Report [14]. The 10-g averaged SAR estimation for the human model implanted with metallic plates was performed under near-field exposure using a half-wavelength dipole antenna at 2 GHz. The spatial relation between the human model and the dipole antenna is shown in Figure 2. The dipole antenna was set 30 mm from the median mandibular of the human model and fed by a 1 V voltage source. The 4×4 mm^2 lattice points of antenna feeding were reproduced on the xz plane, where the center of the mandibular plates is taken as the reference point. Figure 3 shows the peak values of 10-g averaged SAR in the median mandibular region with the dipole antenna placed at each lattice point. The vertical axis and horizontal axis indicate the antenna location, and contour lines indicate peak value of the 10-g averaged SAR shown in Figure 3(a). In Figure 3(b), the increase (in percent) due to the plates is relative to the 10-g averaged SAR of the human without plates. The 10-g averaged SAR is 0.018 W/kg and the increase rate is 26.4% at the reference point (x = 0, z = 0). The increase rate of the 10-g averaged SAR depends on antenna position. The maximum increase rate is 34% near the reference position (x = -4, z = -4). In addition, the minimum value of the increase rate is -4 % at the nasal region. It was possible that a difference arises for the increasing rate of the 10-g averaged SAR according to the spatial relationship of the dipole antenna and the plates.

4. Conclusion

Local SARs for a human model with osteosynthesis plates in the head region were evaluated. By using an anatomical phantom implanted with metallic plates at the median mandibular, the effect of combination of two metallic implants, were simulated under near-field exposure condition at 2 GHz. The results indicated that the increase rate was 34% under the condition.

5. Acknowledgments

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6. References

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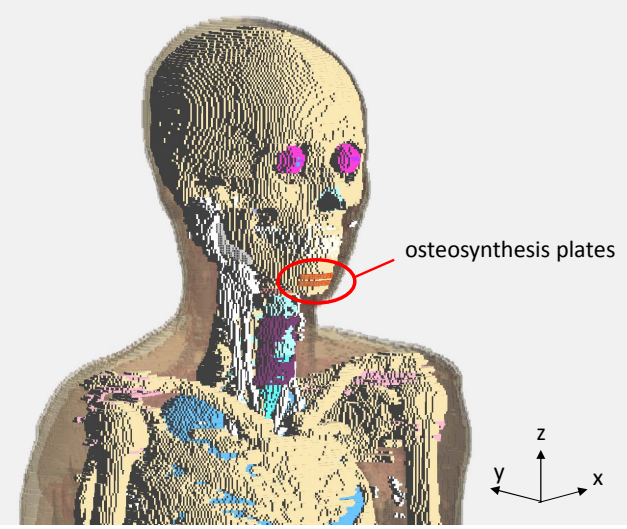
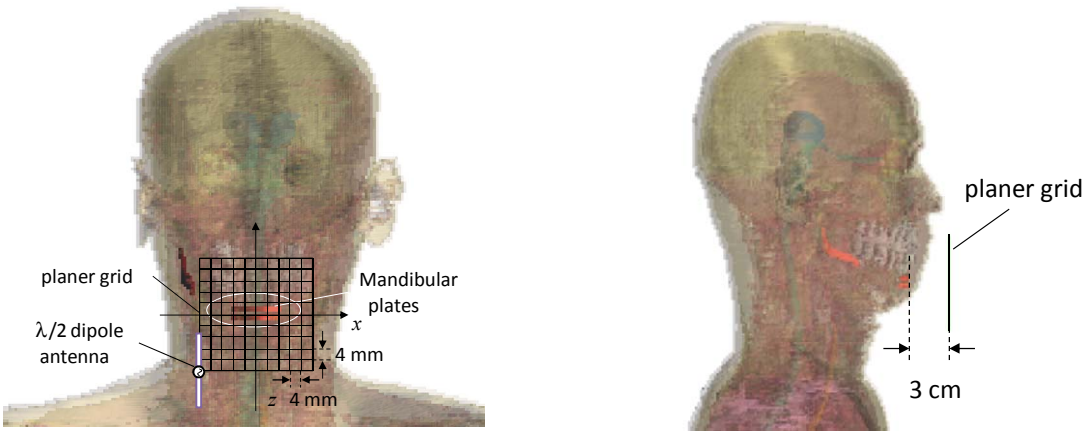


Figure 1. Developed numerical phantom based on treatment of mandibular fracture.

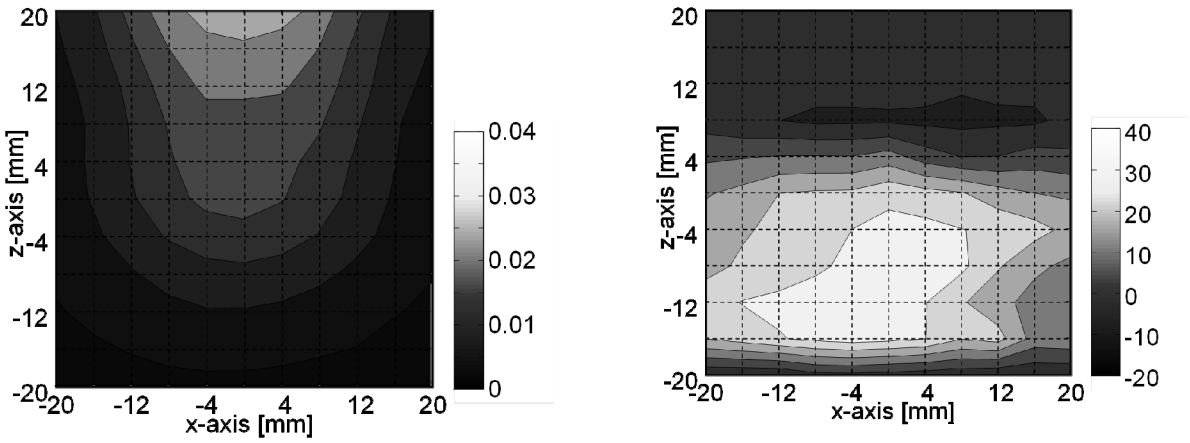
Table I. FDTD parameters

Problem space	307 x 184 x 915 (cells)
Resolution	2 mm
Frequency	2000 MHz
Number of periods	30 periods
Absorbing B. C.	Uniaxial-PML (9 layers)
Material	Human tissues: Gabriel parameter [14] Metallic plates: PEC



(a) front plane (b) right-side plane

Figure 2. Representation of the positional relation between human and dipole antenna.



(a) Maximum value of 10-g averaged SAR (b) Increase rate due to plates

Figure 3. Peak value of 10-g averaged SAR when the antenna is placed at each lattice point.