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Robust experimental evaluation method for the safety assessment of implants with respect to RF-induced heating during MRI

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1 Introduction

Traditional *in vitro* experiments generally entail a measurement of induced temperature rise or SAR at sampled locations in the vicinity of the implant by ways of temperature or dosimetric sensors [2, 1]; the sampled locations are typically within the regions of high heating, such as locations close to the interface between tissue and electrode contact. Due to the high spatial gradient of the induced temperature and SAR distributions (e.g., 2 dB/mm for temperature and 5 dB/mm for SAR is not uncommon), highly accurate positioning of the sensors (sub-mm accuracy) is required to obtain measurement values with reasonable experimental uncertainty. Based on the traditional method, we propose a complementary evaluation method that overcome the stringent requirement on the sensor positioning by using simple numerical modeling and image processing algorithms.

2 Proposed Method

The implementation of proposed method is divided into three parts: 1) use an RF birdcage coil and an elliptical phantom to provide a constant magnitude and phase electric field tangential along the implant as incident condition. 2) high-precision robotic measurement system and data acquisition system with dosimetric probes are used to perform the RF-induced SAR measurement. 3) a high-resolution induced SAR distribution of the electrode by numerically modeled (SAR_{HR}) is used as a feature-based registration of the induced SAR measured by the dosimetric probe (SAR_{meas}). The co-registration is implemented as a simple translation of SAR_{HR} along the three cardinal axes by $\mathbf{\Delta} = (\Delta x, \Delta y, \Delta z)$, and down-sampling to the measurement locations, $\boldsymbol{r}_i$. In short, a linear least-square is applied to solve for the real-valued scalar, α, and the translation vector, $\mathbf{\Delta}$:

$$\min_{\alpha,\mathbf{\Delta}} \sum_{i=1}^{N} \|\alpha SAR_{\text{HR}}(\boldsymbol{r}_i + \mathbf{\Delta}) - SAR_{\text{meas}}(\boldsymbol{r}_i)\|^2 \tag{1}$$

where N is the number of sampled measurement points. An optimal solution set, α_{opt} and $\mathbf{\Delta}_{\text{opt}}$, is determined by the set of α and $\mathbf{\Delta}$ that produces the minimum squared error. And $P_{\text{TIP}} = \alpha_{\text{opt}} P_0$ is the estimated power deposition of the implant, where P_0 is the power deposition calculated from a volume integral containing the -50 dB contour relative to the maximum deposition in SAR_{HR}.

3 Summary

The proposed method was applied to three implant samples and robustness of the method was examined with a variety of data acquisition procedures. The implant power estimation uncertainty obtained with our method is 0.7 dB. This is much less than that of the traditional method, estimated to be about 3 dB. The proposed method was successfully validated against full-wave computational electromagnetics simulations of the completely modeled implants and RF exposure conditions, the deviation between the powe deposition estimated by the proposed method and with full-wave simulations are less than 0.6 dB.

References

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