RF Heating Assessment through Electric Field measurements and Computational Modeling in Phantoms

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INTRODUCTION

The specific absorption rate (SAR) represents the amount of RF absorbed in a subject. SAR is caused by the finite conductivity of the biological tissues which causes absorption of the electric field (E-field) of the RF pulses in MRI. While the associated B-field of the RF is used for imaging in MRI and these images represent the B-field of the RF they can not be used to quantify the SAR. As such, we used a probe [1] designed for E-field measurement at 340 MHz to map the E-field through a phantom within a TEM coil. We matched these measurements to results obtained using full wave analysis of a TEM model mathematically loaded with similar phantoms and a good agreement was obtained.

METHODS

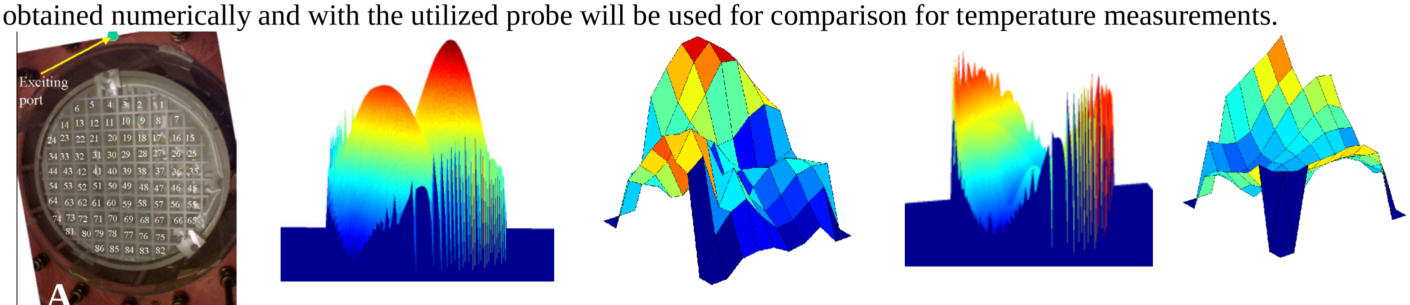
The measurements were carried out within a 16-strut TEM RF coil in single port drive mode. A dipole antenna based E-field probe was built and optimized for 340 MHz operations. Using this E-probe the electric field inside the phantom of air, distilled water, and saline of 125 mM NaCl concentration were mapped. A function generator operating at 340 MHz was used as the source exciting the E-field of the TEM coil through a single port. Finite difference time domain codes (FDTD) codes were developed and utilized the same load within the mathematical models of TEM coil. Electric fields were computed after tuning the coil with load present in it to 340 MHz.

RESULTS AND DISCUSSIONS

Measurements of the E-field within distilled water show that the inhomogeneities were aggravated as expected due to the high dielectric constant and low conductivity. Not significant interactions are observed between the excitation port and the load. Within a saline phantom with conductivity comparable with biological tissues a strong attenuation of the E-field is observed. The regions of high RF concentration, however, are diminished. The main features of the measurements are as following. (1) the computed E-field within distilled water (Fig. 1 B) correlates well experimentally measured E-field within this medium (Fig. 1C), (2) in both results E-field within distilled water has center focusing effect (Fig. 1C), (3) E-field within saline demonstrates strong coupling with the exciting rod in both computation (Fig. 1D) and experimental measurement (Fig. 1E). These results agree with that presented in [2]. As such there is a remarkable agreement between measurement and FDTD computations. Considering that it is impossible to measure E-field in vivo for deep tissues of brain, for example, these measurements are valuable in guiding our path for alleviating and eliminating the high RF concentration in humans high field MRI applications. Also, it can be used as verification tool for computational modeling.

CONCLUSION

Away from the excitation port (s), the inhomogeneity of E-field distribution seemed to improve as conductivity was added to the phantom. The E-field map correlated well with the FDTD computed values. The E^2-images representing SAR maps obtained numerically and with the utilized probe will be used for comparison for temperature measurements.



B C D E

Figure 1. (A) The experimental set-up for the measurement of the E-field at the designated point on a mid axial plane of a cylindrical phantom filled with distilled water (B), and saline (E), and their corresponding FDTD computational maps (B) and (D). The computations and the measurements were obtained using a TEM resonator operating under linear excitation at 340 MHz.

REFERENCES

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