RF Induced Thermoelastic Pressures in A Human Head Model in MRI Birdcage Coils

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Introduction

With the development of high-field strength and ultra-fast MRI instruments, there have been increasing concerns about its safety and potential health hazards. Microwave auditory effect has been widely reported as a biological response evoked by irradiating the human head with pulsed microwave energy. The mechanism of interaction for the auditory effect is understood to be a microwave pulse induced thermoelastic expansion, due to the small but rapid temperature rise in soft tissues, which generates an acoustic wave of pressure. This paper investigates the pressure and power spectra of thermoelastic pressure waves generated by RF pulses absorbed by subjects inside a MRI coil.

Method

The RF induced thermoelastic waves in a sphere with human-brain material loading high-pass birdcages coil operating at 64 MHz (1.5T) and 300 MHz (7.0T) are studied. The computations were conducted using the FDTD method both for the electromagnetic and elastic waves. We first computed the SAR and temperature distributions. We then calculated the thermoelastic waves generated by the thermal stress, based on the elastic-wave equation in lossless media.

For the numerical evaluations, we used a high-pass birdcage coil (radius=14cm and length=22cm) with 16 rungs and a rung width=1cm. The radius and length of the shield were 18cm and 28cm, respectively. Current sources are placed at the midpoint of each end-ring element. Each current source was set to be a sinusoidal waveform with a 22.5-degree phase-shift between elements. The FDTD cell dimensions were set to at 5 mm to shorten the time required to complete the simulation. The brain equivalent material in the sphere has the following properties: dielectric constant of 82.8 and 52, and conductivity of 0.4 and 0.55 S/m at 64 MHz (1.5T) and 300 MHz (7.0T), respectively. We used single, rectangular excitation pulses with a pulse width of 200 μs duration, modulated by error function in order to reduce higher frequency components that cannot be efficiently computed by the FDTD method. A stress-free boundary condition was applied at the surface of the spherical head model.

Result and Discussion

Results of computed pressure waves in the center of the brain sphere are given in Fig 1, and the power spectra are shown in Fig 2. Because we normalized the absorbed power to 10W, the peaks of pressure amplitude at 1.5T and 7.0T appear almost the same. Note that the sound pressure begins at zero, then grows to a peak value, and is followed by a sudden rise to another peak. The amplitudes of pressure waves are reduced immediately after cessation of the pulse, and begin to oscillate with a similar pattern. The power spectra of the pressure waves show that the dominant frequency components are about 10 kHz. While the power at 7.0T is much higher than that at 1.5T, their similarity indicates that the power peak corresponds to the resonant frequency of pressure waves in the sphere. The RF induced thermoelastic pressure wave appears to depend both on the pulse width and absorbed power. The analysis of thermoelastic waves in a heterogeneous structure (human head) is currently under investigation.

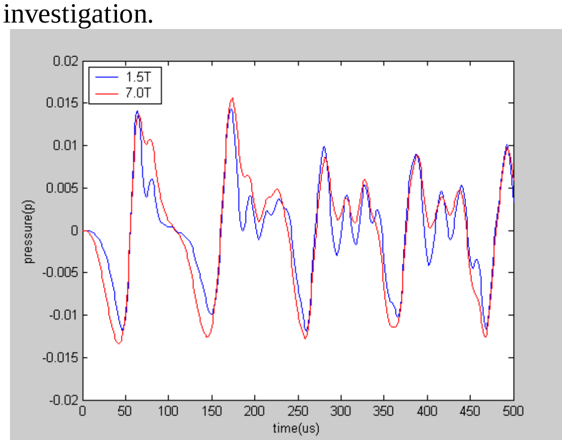

Fig 1

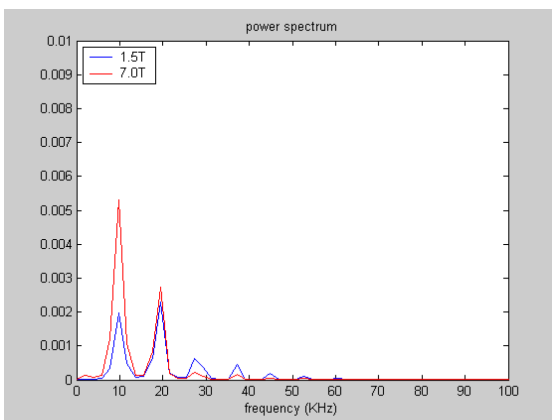

Fig 2

Reference

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