

Multiphysics Simulation of Electrothermally Generated Pressure in the Human Brain

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Extensive safety guidelines have been developed around radiofrequency (RF) exposure safety for human health, but less investigation has been done on health effects due to exposure to short RF pulses. We developed a Multiphysics simulation of the interaction of pulsed electromagnetic waves with the human head using short duration microwave pulses in order to observe pressure waves generated from the electrothermal acoustic effect in the human head. The value and location of the maximum effect on pressures generated within the brain varied due to the pulse magnitude, length, and direction of incidence. Using publicly available MRI data, we incorporated layers of skin, skull, cerebral spinal fluid, grey matter, and white matter into a finite element geometry. Simulations were based on a 1 GHz frequency pulse with pulse lengths varying from 1 to 100 microseconds. Electrical and mechanical material properties were taken from publicly available databases, and a linear mechanics material model was used to model stress, strain, and pressure within the head, with the skull being modeled as a rigid boundary.

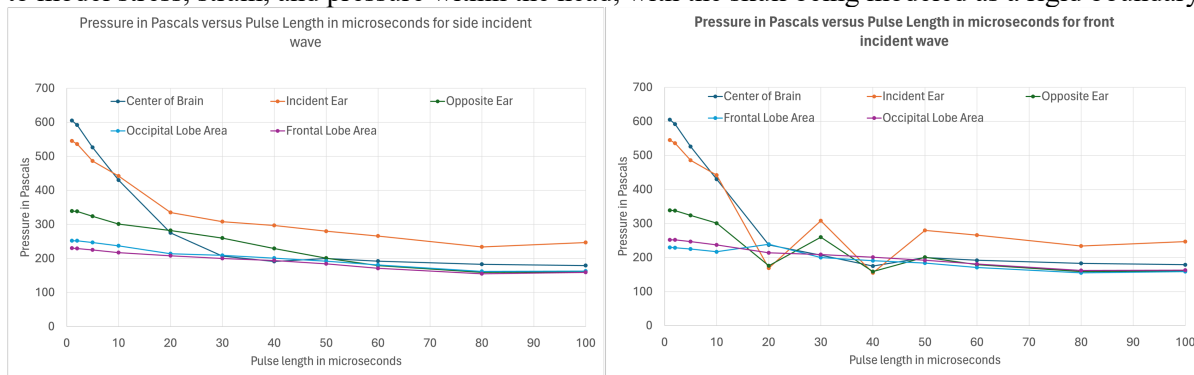


Figure 1. Pressure waves for side incident electromagnetic pulse, toward ear (left) and face (right).

The direction of the externally applied microwave pulse was varied, with the incidence being modeled both for a plane wave directed to the ear and to the face. The pitch angle was varied from $+90^\circ$ (top of the head down) to -90° (bottom of the head up) in increments of 15° . Figure 1 shows the pressure as a function of pulse length for 5 specific selected points for waves directed toward the ear and toward the face: near the incident ear, near the opposite ear, near the center of the head, near the right frontal lobe, and near the right occipital lobe. Pressure due to the electrothermal acoustic (ETA) effect was determined for the first 100 microseconds following the application of the incident pulse. Results indicate that the regions within the head that see the highest pressures vary, based on the direction of the applied field. The values of the maximum pressures at the 5 selected points are strongly dependent on the pulse length for energy matched pulses as well as being dependent on the direction of the applied pulse. It can be concluded from our simulations that certain pulse lengths and incident wave directions can have either stronger or weaker effects on pressure distributions within the human head.

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