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Experimental and numerical investigation of ultrasonic transmission through the skull bone and associated temperature rise

Mathieu Pernot[a], Emmanuel Bossy[b], Marie Muller[a], Christine Boué[b], Jean-François Aubry[a], Mickael Tanter[a], Mathias Fink[a] and Albert-Claude Boccara[b]
[a]Laboratoire Ondes et Acoustique, ESPCI, Université Paris 7, CNRS, 10 rue Vauquelin, 75005 Paris, France
[b]Laboratoire Photons et Matière, ESPCI/CNRS, 10 rue Vauquelin, 75231 Paris Cedex 05, France

The feasibility of transcranial high-intensity focused-ultrasound (HIFU) therapy within the brain relies on the ability to transmit ultrasound through the skull bone at relatively high ultrasound power. Absorption of ultrasound through the skull bone may cause important temperature rises, and is therefore an important parameter to control. Ultrasonic measurements have shown that the ultrasound beam undergoes a significant attenuation when propagating through the skull, with values on the order of 10 to 20 dB/cm/MHz. To predict temperature rise from such values, it is fundamental to weigh the relative role of absorption to the total ultrasonic attenuation (scattering + absorption + specular reflection). In this work, two types of numerical simulations and experiments are performed to investigate this relative role. Through-transmission of 1 MHz ultrasound was performed numerically using a 3D Finite-Difference Time-Domain (FDTD) algorithm coupled to a 3D bone model obtained from high-resolution synchrotron microtomography, and compared to experimental measurements obtained with the same bone sample. Temperature rises were numerically simulated using the 3D bone model coupled to the heat equation, and compared to infrared thermography obtained experimentally while high-intensity ultrasound was propagating through the sample.