Acoustic Field Comparison of High Intensity Focused Ultrasound Using Experimental Characterization and Finite Element Simulation

J. L. Teja[1], A. Vera[1], L. Leija[1]

[1]Department of Electrical Engineering, Cinvestav-IPN, Mexico D.F., Mexico

Abstract

Introduction: High Intensity Focused Ultrasound (HIFU) is a technique currently used for different medical treatments such as thermal ablation, hyperthermia, and bleeding control [1]. This kind of technique is based on the use of an acoustic transducer with a concave face used to focus the ultrasound energy in a specific zone (Figure 1). The acoustic field characterization in transducers is important for the prediction of the ultrasound bioeffects [2]. A simulation model that mimics a characterized acoustic field could be a primary model to start different designs to improve medical HIFU devices. This work presents a quantitative comparison between experimental and simulated acoustic fields of HIFU. Two HIFU transducers were used: Onda Corporation® 2-30-100/4 and 2-20-20/2 with a nominal frequency of 4MHz and 2 MHz, respectively.

Use of COMSOL Multiphysics®: The acoustic fields through water of the two HIFU transducers were measured and simulation models were carried out in similar conditions. The models were defined by using time-harmonic analysis in pressure in the Acoustics Module and the geometry used was 2D axisymmetric. A concave geometry was set up as a pressure source in order to mimic a HIFU transducer face. The propagation medium considers water as well as the experimental test and the boundaries were considered to have the water acoustic impedance in order to avoid reflections of the propagation wave (Figure 2). The ultrasound wave velocity and density of the water was set up as 1500 m/s^2 and 1000 kg/m^3, which are considered properties in a temperature around 25 °C. The models were solved with a mesh size of 1/5 times the wavelength of the pressure waves along the water medium.

Results: Acoustic fields that show the acoustic pressure distribution along water in planes xz (Figure 3) and xy (Figure 4) were obtained by characterization and simulation. Pressure changes at -3 dB and -6 dB of power decay were enclosed by a contour into the acoustic propagation plane of the experimental and the simulated data. Both experimental and simulated contours were compared within the mentioned contours by using factor fc (ratio of the areas enclosed for the contours), ellipsoidal shape ratio Er (shape of the contours), and the Euclidian distance d between the contours. For HIFU 2-30-100/4 the comparison values in the -6 dB contour through xz plane were: fc = 92.4%, Er = 82.9% and d = 0.83 ± 0.28 mm. For HIFU transducer 2-20-20/2, the comparison values in the same contour and plane as the previously showed were: fc = 66.0%, Er

= 86.4% and d = 0.30 ± 0.16 mm.

Conclusion: A high level of similarity was obtained between the acoustic field characterized and simulated. Percentages of similarity are above 80% in transducer HIFU 2-30100/4 and percentages of similarity are above 60% in transducer HIFU 2-20-20/2. This is a great approach to start new simulation models that involve the same HIFU transducer in different conditions such as a model of tissue ablation with HIFU for oncology.

Reference

[1] Haar, G.T. and C. Coussios, High intensity focused ultrasound: physical principles and devices.Int J Hyperthermia, 2007. 23(2): p. 89-104.
[2] Canney, M.S., et al., Acoustic characterization of high intensity focused ultrasound fields: A combined measurement and modeling approach. The Journal of the Acoustical Society of America, 2008. 124(4): p. 2406-2420.

Figures used in the abstract

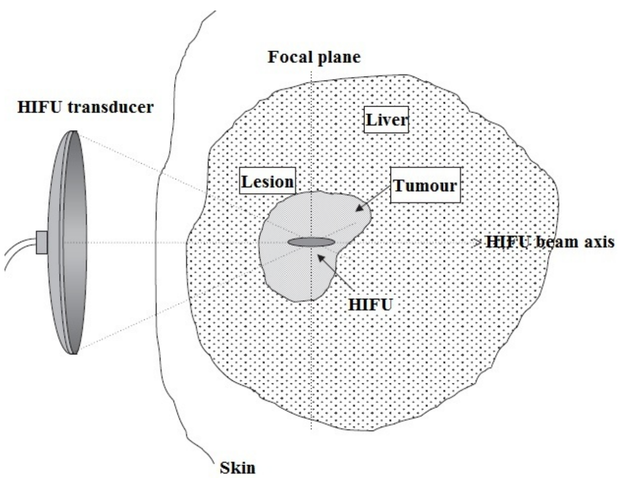

Figure 1: Schematic drawing of HIFU treatment in oncology [1]. Carcinogenic tumor is burned by focalized ultrasonic radiation.

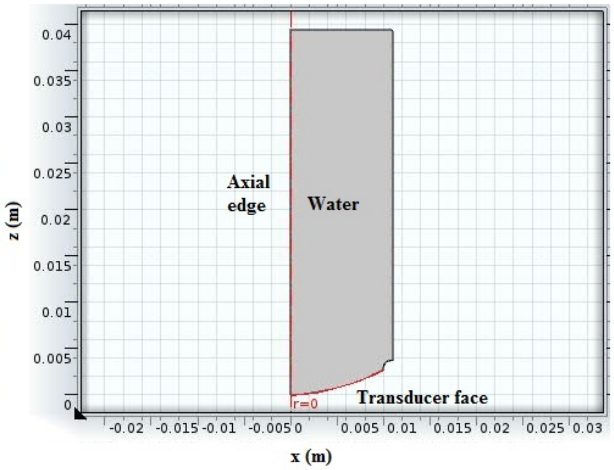

Figure 2: Geometry of the finite element model used to simulate acoustic propagation through water (HIFU 2-20-20/2). The model boundaries are defined as water impedance in order to allow wave propagation and a half of concave geometry is defined as pressure source that mimics the concave transducer face.

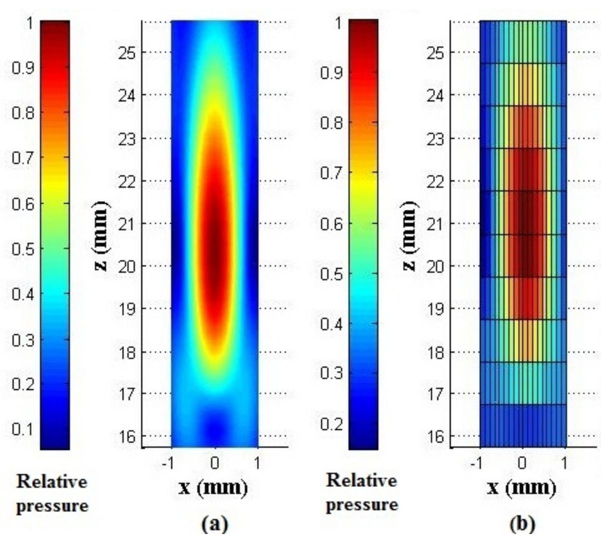

Figure 3: Acoustic field of FEM simulation model (a) and measured data (b) along xz plane. Transducer focal area for both cases is located about 20 mm from the transducer concave face along axis z.

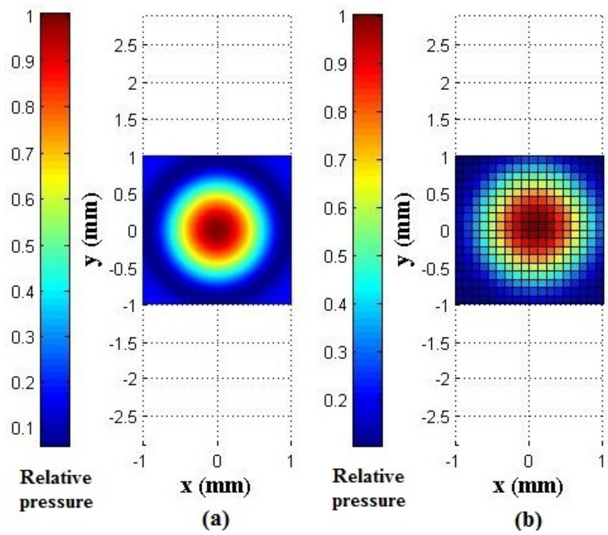

Figure 4: Acoustic field of FEM simulation model (a) and measured data (b) along xy plane (cross-sectional plane). Both planes are xy slices at 20 mm along the z axis.