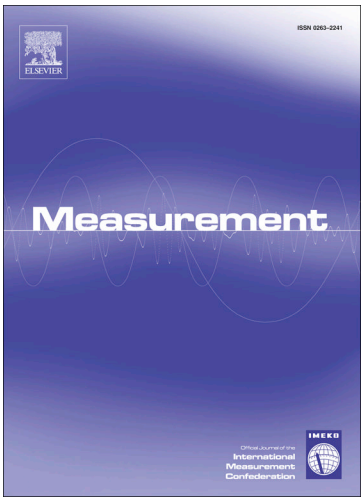

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Measuring uncertainty of ultrasonic longitudinal phase velocity estimation using different time-delay estimation methods based on cross-correlation: Computational simulation and experiments

José F. S. Costa-Júnior[a], Guillermo A. Cortela[b], Luis E. Maggi[c], Tiago F. D. Rocha[a], Wagner C. A. Pereira[a], Rodrigo P. B. Costa-Felix[d] and André V. Alvarenga[d]

[a] Biomedical Engineering Program/COPPE, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

[b] Laboratorio de Acustica Ultrasonora, Instituto de Física, Universidad de la República, Montevideo, Uruguay

[c] Center of Biological and Nature Sciences, Universidade Federal do Acre, Rio Branco, Brazil

[d] Laboratory of Ultrasound, National Institute of Metrology, Quality and Technology, Rio de Janeiro, Brazil

Abstract

Although few studies on ultrasonic materials characterization present the expanded uncertainty, it is very important to quantify the final quality of the result. In addition, many of these studies do not mention the method used to estimate time delay, which is employed to calculate the longitudinal phase velocity (v_{TS}). Therefore, the purpose of this study is to estimate the uncertainties of v_{TS} values obtained by different time-delay estimation methods based on cross-correlation. In addition, computational simulation was used to validate the experimental results. The results of the computational simulation showed that when the sampling frequency is 50 MHz, the bias phase velocity was greater than 1.2 $m \cdot s^{-1}$ for almost all time-delay estimation methods. Therefore, it is not advisable to use a sampling frequency less than or equal to 50 MHz. In all cases, the expanded uncertainty was below 3.5 $m \cdot s^{-1}$. The statistical test results indicated a significant difference between the values of the longitudinal phase velocity estimated with a given method, as a function of the sampling frequency and the estimated velocity with each method as a function of the received bandwidth of transducer. The expanded uncertainty for phase velocity is intrinsically dependent on accurate speed of ultrasound estimation in the reference medium. The speed of ultrasound and temperature are correlated, therefore, precise estimation of the reference medium temperature is important to maintain the overall precision of the method employed in this study. The novelty of this work resides in the comparison of different time-delay estimation using measurement uncertainty as parameter. Furthermore, after the detailed step by step assessment of uncertainties for the dissimilar computational methods, one can easily estimate the uncertainty by his own using this paper as guidance.

Keywords: Signal processing; Time-delay methods; Measurement uncertainty; Phase velocity