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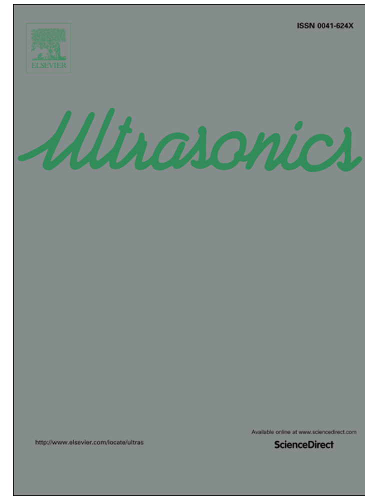

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A robust approach to apodization design in phased arrays for ultrasound imaging

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Abstract

Apodization is a common way to control the sidelobe level of the beampattern. To design the apodization, it is usually assumed that the medium is homogenous with a fixed value of sound speed, despite the fact that the speed may vary by a great value in practical situations. On the other hand, the beamforming performance is highly affected by the speed value. In this paper, the beampattern sensitivity to the speed variations is firstly investigated through both mathematical representations and simulation results showing that the speed errors lead to a sever degradation of the beampattern in terms of both mainlobe width and sidelobe level. Then, we consider an optimization problem robust to the speed variations which minimizes the sidelobe level while maintaining a predefined mainlobe width. Furthermore, the optimization problem is reformulated as a convex problem using semidefinite relaxation (SDR) method to be solved more efficiently. The solutions are evaluated for some exemplary phased arrays at different values of focusing depths and mainlobe widths. The results show that the robust apodization is capable of maintaining the mainlobe properties for all possible values of the speed, while minimizing the sidelobe level. Moreover, the superiority of the robust method against non-robust method is highlighted at lower focusing depths and smaller mainlobe widths.

Keywords—ultrasound; beampattern; apodization; convex optimization; robustness; speed variations

1. Introduction

Resolution and contrast are two crucial factors in diagnostic ultrasound imaging. Contrast can be determined by difference between sidelobe level and mainlobe peak, and resolution can be defined by the mainlobe width of the beampattern. On the other hand, most conventional imaging systems consider a fixed value for the sound speed of the imaging medium to calculate the beamforming delays, whereas the speed usually varies in the medium resulting in a degraded beampattern.

The purpose of this work is to establish a mathematical structure for designing robust apodization such that the beampattern properties are maintained for all possible variations of the speed. Toward this end, the beampattern sensitivity to the sound speed variations is firstly evaluated both through mathematical and numerical illustration. After that, the robust designing

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