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An Evolutionary Algorithm Approach for Optimized Design of Spherically Shaped Therapeutic Phased Array Transducers

Jingfei Liu[1], Kevin Wang[1], Stanislav Y. Emelianov[1,2]
[1]*Georgia Institute of Technology, Atlanta, USA,* [2]*Emory University, Atlanta, USA*

Background, Motivation and Objective

Spherical phased array transducers are an effective tool in ultrasound therapies including non-invasive thermal ablation and brain stimulation. The critical challenge in designing such arrays is sound field optimization, which requires suppressing grating and sidelobes (undesired sound field features) while maintaining adequate energy level of main lobe. Commercial arrays typically contain elements that are arranged regularly with readily-identified patterns. Although this design maximized the energy output of main lobe, it generates high-intensity grating lobes in the sound field, especially in the axial direction of the beam. An effective method to suppress these grating lobes while maintain adequate main beam energy level is to randomly distribute elements. However, for critical applications such as neural modulation, further optimization of the sound field is strongly desired. In this work, we investigated an evolutionary algorithm approach for optimizing random array design.

Statement of Contribution/Methods

The optimization tests were performed on a series of spherical arrays with their elements randomly distributed. These arrays have the same parameters: 73 circular elements of 2.5 in diameter working at 2.5 MHz, a radius of curvature of 40 mm and an aperture of 52 mm. The intensity sound fields were calculated using an open source software 'FOCUS'. The standard genetic algorithm was implemented with a novel mutation and crossover function. A population of 80 randomized arrays were initialized, each generation individuals are selected for mutation or crossover, and the process continues with the best-fit arrays until termination.

Results/Discussion

For comparison, a regular spherical array design and its sound intensity field in an axial plane are shown in Fig. 1 A and B; those of a typical random spherical array in Fig. 1C and D. The axial intensity profiles of these array are compared with that of an optimized random spherical array in Fig. 1E. Compared with the regular array, Fig. 1E shows that the grating lobes of the random array, especially in the nearfield (z = 30-35 mm), decrease dramatically; but their first sidelobes still maintain a similar intensity level. However, after the evolutionary optimization, the intensity levels of the first side lobes dropped by 3-4 dB, making all undesired lobes under -15 dB with respect the main lobe. Although better optimization is yet to achieve, this result shows the effectiveness of such an evolutionary algorithm.

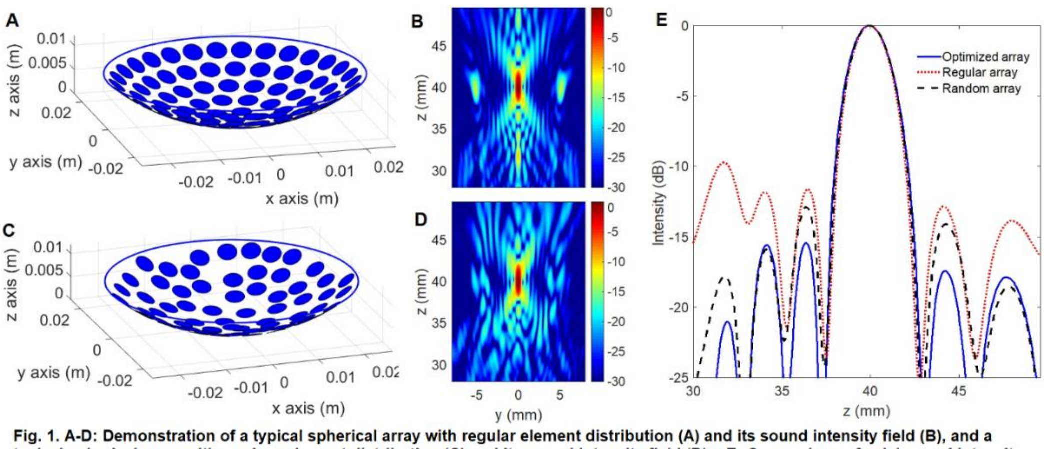

Fig. 1. A-D: Demonstration of a typical spherical array with regular element distribution (A) and its sound intensity field (B), and a typical spherical array with random element distribution (C) and its sound intensity field (D). E: Comparison of axial sound intensity profiles of the arrays with regular element distribution, random element distribution, and optimized random element distribution.