HIGH-POWER 2D THERAPEUTIC ARRAYS WITH SPIRAL DISTRIBUTION OF QUADRATIC OR TRAPEZOIDAL ELEMENTS

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OBJECTIVE
Nonlinear regimes of thermal tissue ablation and histotripsy methods of generating purely mechanical lesions in tissue are attracting a growing interest in HIFU therapies. These methods utilize periodic sequences of ultrasound bursts with very high peak pressures and often require the presence of shock fronts in the focal region of the beam. Significant increase in transducer peak power compared to the conventional HIFU systems is necessary to generate such fields. This increase is technical challenging, especially for two-dimensional multi-element phased arrays with quasi-random element distribution. In this paper, we consider new array configurations using tightly packed elements and still maintaining an aperiodic nature of their distribution at the array surface.

METHODS
The most advantageous configuration of such arrays should combine a random element distribution and also the maximum possible density of their packaging. This combination was achieved using square or trapezoidal-shaped elements whose centers are located on an Archimedean spiral or other similar spiral trajectories, including multi-armed spirals, originated from the edge of the central hole used for a diagnostic imaging transducer. Acoustic fields generated by two 1 MHz arrays consisting of 512 elements were simulated and compared. The first array was comprised of quasi-randomly distributed circle elements of 6 mm diameter; the second array - of square 6 x 6 mm elements, the centers of which were located on the Archimedean spiral.

RESULTS
The results of modeling showed that for a spiral compact array the total power and thus the focal intensity was 60% higher than for the conventional random array with circle elements. However, the volume of the focus steering, within which the focal intensity was not reduced by more than 50% of the maximum intensity, was approximately 60% smaller for the tightly packed array. The reason for this effect is the larger effective size of a square element compared to the circle one which resulted in the narrower directivity pattern.

![Fig. 1: Examples of possible shapes and spiral distributions of the array elements: a) Archimedean spiral; b) multi-armed spirals; c) quadratic shaped elements; d) trapezoidal shaped elements.](image)

CONCLUSIONS
For a given aperture of the array, the use of the spiral-type distribution of elements and quadratic or trapezoidal elements is an advantageous configuration comparing to other array configurations (random and periodic) since it enables denser packing of elements and therefore higher intensity at the focus without deterioration of the array field. The work was supported by the RSF grant 14-12-00974.