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Extension of the crosstalk cancellation method in ultrasonic transducer arrays from the harmonic regime to the transient one

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ABSTRACT

This paper describes a procedure to extend the crosstalk correction method presented in a previous paper [A. Bybi, S. Grondel, J. Assaad, A.–C. Hladky-Hennion, M. Rguiti, Reducing crosstalk in array structures by controlling the excitation voltage of individual elements: a feasibility study, Ultrasonics, 53 (6) (2013) 1135–1140] from the harmonic regime to the transient one. For this purpose a part of an ultrasonic transducer array radiating in water is modeled around the frequency 0.5 MHz using the finite element method. The study is carried out at low frequency in order to respect the same operating conditions than the previous paper. This choice facilitated the fabrication of the transducer arrays and the comparison of the numerical results with the experimental ones. The modeled array is composed of seventeen elements with the central element excited, while the others are grounded. The matching layers and the backing are not taken into account which limits the crosstalk only to the piezoelectric elements and fluid. This consideration reduces the structure density mesh and results in faster computation time (about 25 min for each configuration using a computer with a processor Intel Core i5-3210M, frequency 2.5 GHz and having 4 Go memory (RAM)).

The novelty of this research work is to prove the efficiency of the crosstalk correction method in large frequency band as it is the case in medical imaging. The numerical results show the validity of the approach and demonstrate that crosstalk can be reduced by at least 13 dB in terms of displacement. Consequently, the directivity pattern of the individual element can be improved.

1. Introduction

Crosstalk associated with acoustic wave propagation between successive array elements is a major problem in transducer arrays, as it is responsible for anomalous behavior in the directivity of the array.

Different solutions have been proposed to reduce it. In a first approach [1–4] a numerical model of the acoustic array is used in order to study the effects of design modifications on crosstalk. These studies investigate more particularly the geometry and dimensions of the kerf filling material because kerf fill is known to be the main component of the transducer which affects crosstalk most significantly. Another approach consists in developing a systematic method for active cancellation of crosstalk. The efficiency of the later method has been demonstrated numerically and experimentally in harmonic regime [5,6]. In the case of transient excitations, Zhou et al. [7,8] have developed another solution using the transfer function matrix relating input voltages to the output pressures. In this case, the measurement precision of the elements transfer function with an hydrophone or using other methods like the direct receive transfer measurement or pulse echo technique [9] appears limited.

In medical imaging and non-destructive testing systems, the ultrasonic transducer arrays are utilized in transient regime instead of the harmonic regime. Thus, the aim of this paper is to extend the correction method previously proposed and tested experimentally and numerically in harmonic regime [6,10] to transient one. It must be stated that its efficiency has been demonstrated in the case of harmonic regime at the mechanical resonance frequency [10]. In the first section of this paper, a procedure to adapt the cancellation solution in harmonic domain to transient domain is proposed. Then, a transducer array composed of seventeen-element is modeled using FE in both cases without crosstalk correction and with crosstalk correction. Finally, feasibility and performance of the method in transient regime are analyzed and discussed.

2. Presentation of the correction method in transient regime

In transient regime, the calculation of the correction electrical signals to apply to each element of the transducer array is done

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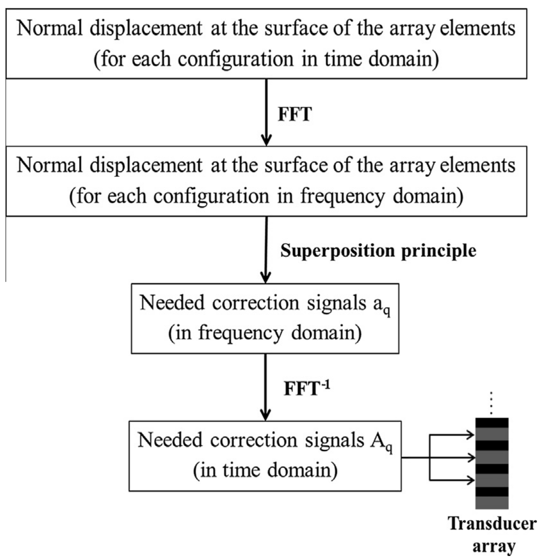

Fig. 1. Procedure utilized to calculate the correction signals in transient regime.

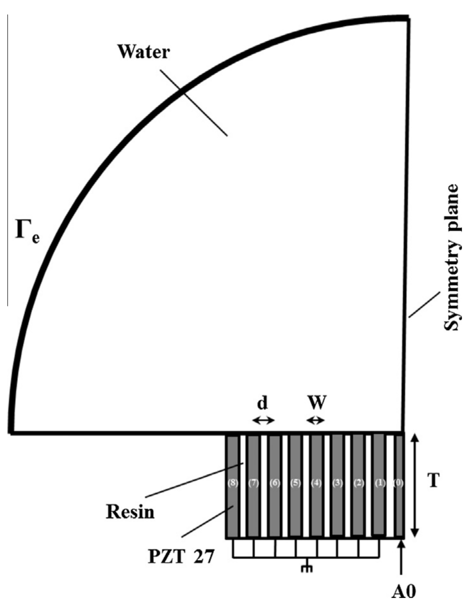

Fig. 2. Schematic description of a seventeen-element transducer array radiating in water.

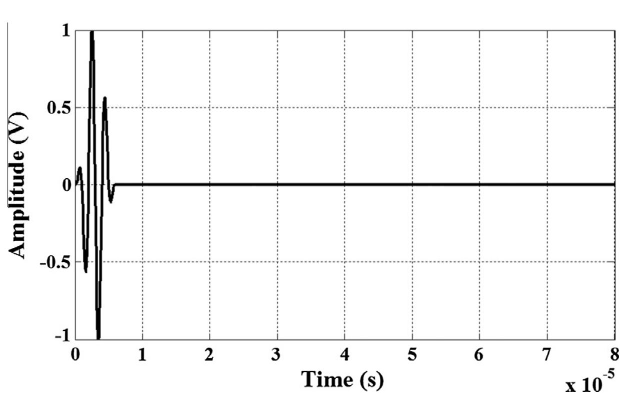

Fig. 3. Electrical excitation applied to the central element.

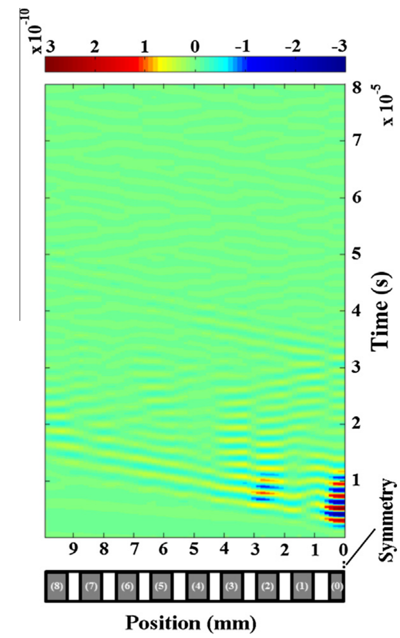

Fig. 4. Time–space representation of the normal displacement at the surface of the transducer array.

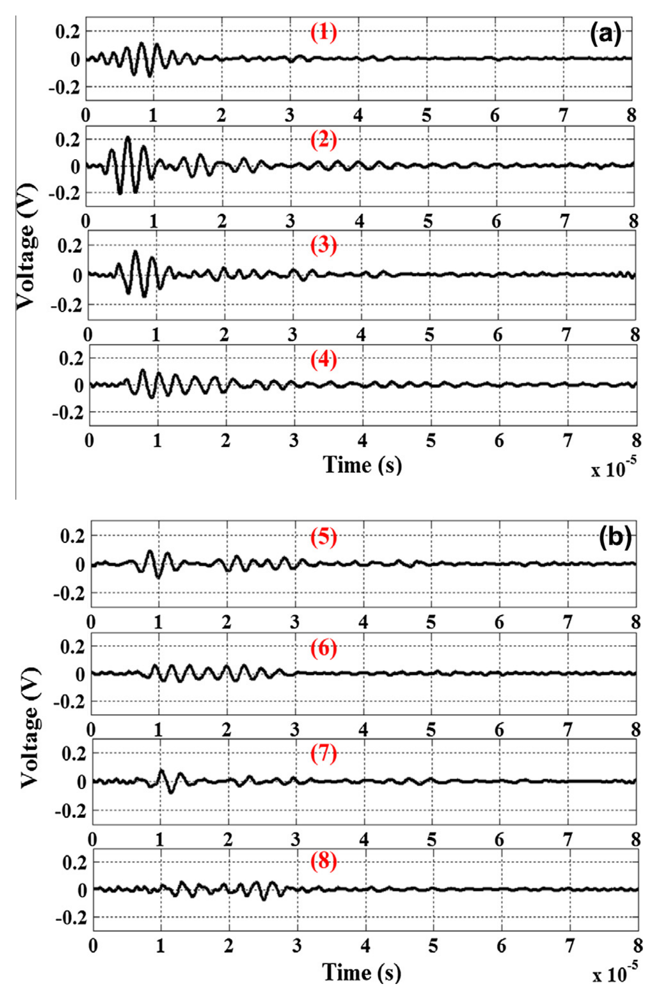

Fig. 5. Correction electrical signals applied to: (a) the first, second, third and fourth neighboring elements and (b) the fifth, sixth, seventh and eighth neighboring elements.