Matrix approach of aberration correction in ultrasound imaging

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Background, Motivation and Objective

Conventional ultrasound imaging generally relies on two major assumptions. The reflected wave-field only contains singly-scattered echoes and the insonified medium is homogeneous, with a constant speed-of-sound. Nonetheless, when aberrations and/or multiple scattering events take place, those hypotheses are no longer valid. Liver imaging is an appropriate example in which ultrasonic waves propagate through multiple layers of fat and muscle tissues before reaching the organ. The image quality is then degraded and reverberation artefacts may appear. Moreover the speed of sound may vary with position, resulting in multiple isoplanatic patches (different aberration laws in several areas of the image). To maintain an optimal resolution, adaptive correction techniques have been developed [1]. They consist in convolving the transmitted and received wave fronts by an adaptive filter that compensate for the wave-front distortions induced by the medium heterogeneities. Nevertheless, those methods require iterative focusing, are time-consuming and their range of action is limited to one single isoplanatic patch.

Statement of Contribution/Methods

In this work, a matrix approach of ultrasound imaging is developed and dedicated to the correction of aberrations. This method is based on the study of the reflection matrix **R** that contains all the back-scattered wave-fronts for a set of incident waves [2]. By back-propagating **R** to any focal plane in transmit and receive, a focused reflection matrix **Rf** is built between virtual transducers at each depth in a breast phantom (Fig. 1 a).

Results/Discussion

While the main diagonal of **Rf** directly yields a conventional ultrasound image (Fig. 1 c), its off-diagonal elements measure the cross-talk between virtual transducers. This information proves to be valuable for aberration correction. Moreover, it enables a local and quantitative assessment of the focusing quality, even in speckle (Fig. 1 e). Fig.1 b) shows the result of the aberration correction on the matrix **Rf**. The contrast of the corrected image is clearly improved and its resolution is pushed back toward the diffraction limit (Fig.1 d,e).

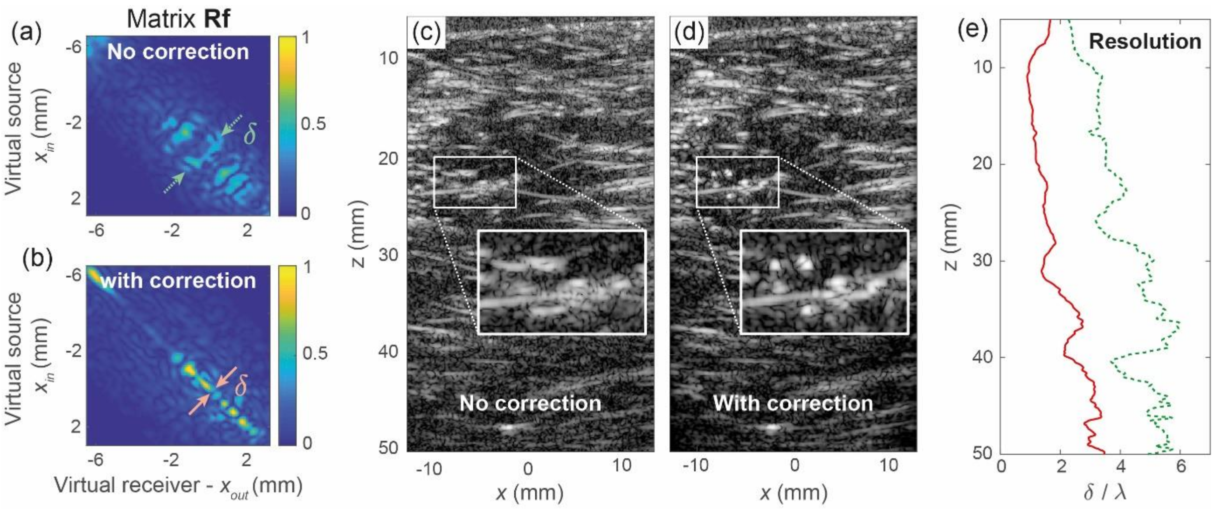

Fig. 1: Application of the matrix approach on a breast phantom. (a, b) Matrix Rf at z = 30 mm before and after correction. (c, d) Ultrasound images. (e) Width of the focal spot versus depth (red curve: no correction, green dashed curve: with correction).

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[2] A. Badon, D. Li, G. Lerosey, A. C. Boccara, M. Fink, A. Aubry, *Sci. Adv.* **2**, **2016**, e1600370