048 **SIMULTANEOUS ECHO IMAGING AND ELASTICITY/DISPLACEMENT MEASUREMENT WITH HIGH INTENSITY FOCUS ULTRASOUND TREATMENT AND/OR ACOUSTICAL RADIATION FORCE IMAGING.**

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Summary: For echo imaging and displacement/elasticity measurement/imaging using a concave aperture type transducer, the reshaping of PSFs or speckle patterns to be axially and laterally symmetric through filtering spectra is confirmed to be effective, i.e., increasing a measurement accuracy and an image quality.

1. Introduction

The developments of useful ultrasound (US)–echo–based tissue displacement measurement methods and beamforming methods increase the applications of displacement/strain measurements (e.g. various blood flows, motions of the heart, liver, etc.). For instance, our previously developed combination of the multidimensional autocorrelation method (MAM) and lateral modulation (LM) methods (e.g. [1]) or a single beam method (e.g. [2]) resulted in accurate two– or three–dimensional displacement vector/strain tensor measurements. We have also been developing combined digital US diagnosis/treatment systems (e.g. [3]), in which (i) a diagnostic US echography can be performed, (ii) a high intensity focus US (HIFU) treatment can also be performed for an echo–based and/or radiation–force–based diagnostic measurement/imaging, as well as the combination used with diagnostic ultrasounds, (iii) a radiation force can also be used for an echo–based measurement/imaging.

Last year, various useful applications of coherences of ultrasounds and low frequency waves were reported [4]. Specifically, spectral frequency divisions and/or coherent superpositions of spectra or echo signals are performed with weighting for yielding (1) a high spatial resolution imaging/treatment, (2) accurate displacement vector/strain tensor measurements, (3) desired mechanical and/or thermal sources, (4) desired low frequency deformations or low frequency wave propagations and (5) accurate temperature measurements, etc. Interferences of US or low frequency beams/waves are properly used for synthesizing new beamforming/wave parameters such as a wavefront, a propagation direction, a steering angle, frequencies, bandwidths, focuses etc. Quasi–beams/quasi-waves can also be generated by signal processing (i.e., not physically generated ones). A temporal and/or spatial filtering can also be performed in the frequency domain to change beam/wave properties or separate signals or waves (e.g. plural crossed beams/waves, and mechanical and thermal strains, etc.).

In this report, simultaneous a high spatial resolution echo imaging and accurate elasticity/displacement measurements are performed through the spatial filtering of spectra [4] with respect to HIFU transmissions for a thermal treatment and/or an acoustical radiation force imaging (simulations) [5].

2. Simulations

The spectra filtering was performed with respect to a large spatial bandwidth echo data obtained using two concave transducers (both aperture dia., 12 mm; focus depths, 35 mm; 5 MHz) [4]. The transducers are simulated using Field II [6]. Echo data were also simulated for a same scattering tissue with same uniform axial and lateral strains (0 to 3 %). A strong scatter was set in a region of interest. Two cases are simulated for the same deformed tissue: (i) one transducer is used to obtain non-steered echo data and (ii) two transducers are laterally, symmetrically steered and received echo data are superposed to achieve an LM. For Case (ii), the spatial filtering can be performed with respect to superposed, separated, or respectively received echo data [4]. The point spread functions (PSFs) were made to be circular, or axially and laterally symmetric (Fig. 1: envelope-detection). Fig. 2 shows parabolic-detections of the PSFs. These images respectively have dynamic ranges of $20\log_{10}(\text{maximum/RMS})^2$. The reshaping PSF effected measurement accuracies of strains as well as qualities of echo images. Displacement vector measurements were performed using MAM.

For respective (a) non-steering (0°) and (b) LM with steering (5°), B-mode images were obtained from non-filtered and filtered spectra (Fig. 3: envelope-detection). After the filtering spectra, the strong scatter and speckle patterns are visualized to be axially and laterally symmetric, particularly for LM. Measurement accuracies (statistics) of axial and lateral displacements were evaluated (Figs. 4 and 5; caution: the different biases included in the axial and lateral displacements).

Fig. 4 shows displacement measurement accuracies evaluated for non-steering and LM with 5°

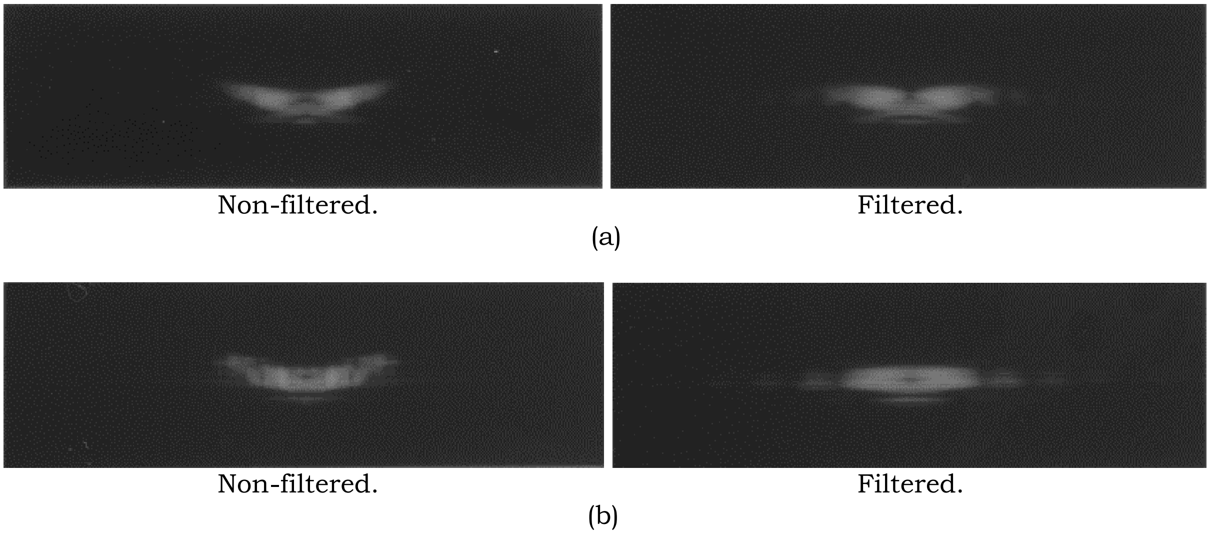


Fig. 1. Envelop-detected PSFs obtained using concave transducers. (a) No steering; (b) LM with 5°.

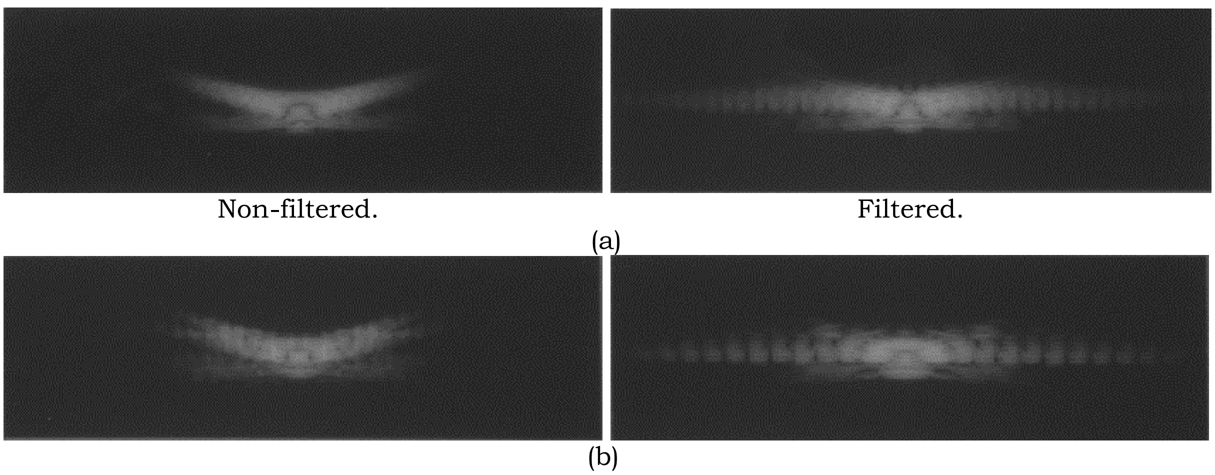


Fig. 2. Parabolic detection of PSFs obtained using concave transducers. (a) No steering; (b) LM with 5°.

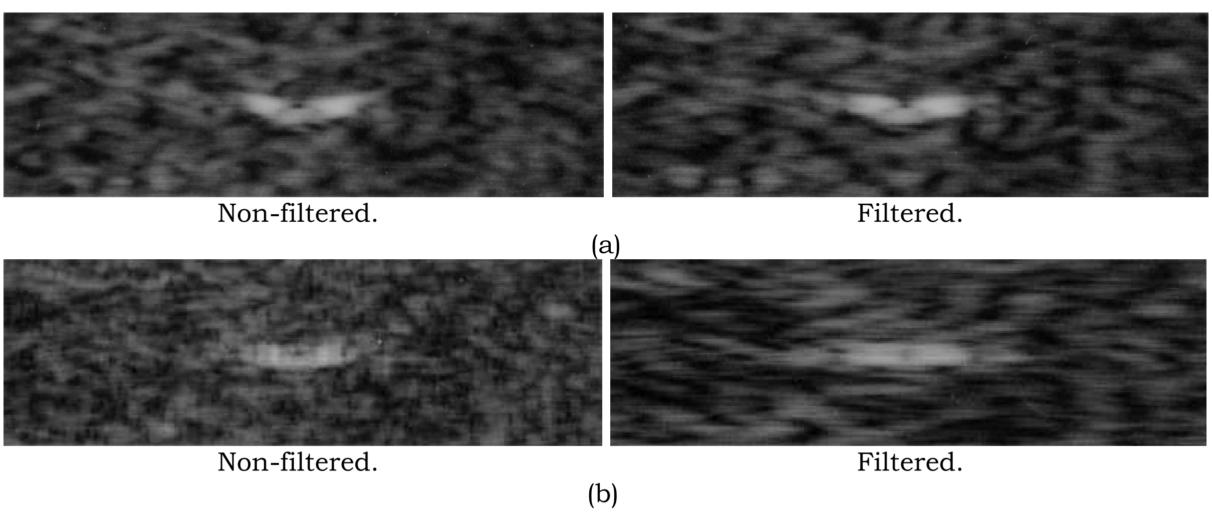
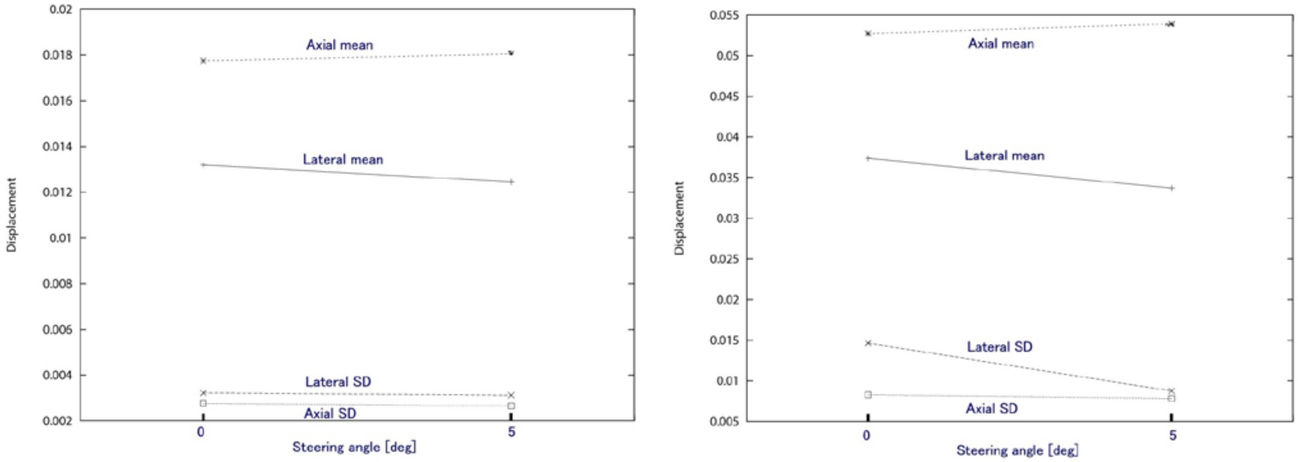


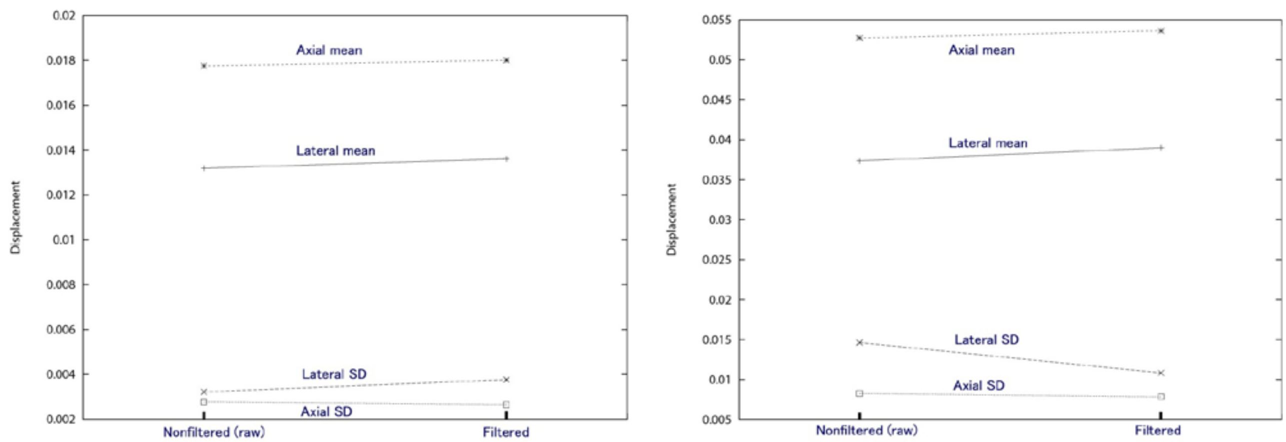
Fig. 3. Echo images obtained through envelop-detection using concave transducers. (a) No steering; (b) LM with 5°.

steering when axial and lateral strains are respectively (a) 1% and (b) 3%. As shown, for the large axial and lateral strains (3%), LM yielded a more accurate lateral displacement measurement than the non-steering. For the non-steering case with axial and lateral strains larger than 2%, the reshaping PSF increased the measurement accuracy of a lateral displacement (see Fig. 5b for 3% strains, for instance).



(a) (b)

Fig. 4. Displacement measurement accuracies evaluated using simulated concave transducers for non-steering and LM with 5° steering. Axial and lateral strains: (a) 1%; (b) 3%.



(a) (b)

Fig. 5. Effects of filtering spectra on displacement measurement accuracies evaluated using simulated concave transducers for non-steering. Strains: (a) 1%; (b) 3%.

3. Conclusions

For echo imaging and displacement/elasticity measurement/imaging, the reshaping of PSFs or speckle patterns to be axially and laterally symmetric through the filtering spectra was confirmed to be effective with respect to the use of concave transducers, i.e., increasing a measurement accuracy and image quality. With respect to the envelope and parabolic detections, the differences in a spatial resolution and a contrast-to-noise ratio (CNR) will be reported in detail elsewhere. The same approach will also be used for a microscopic imaging using the concave aperture type transducer.

References

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