Cumulative Phase Delay Imaging - a new contrast enhanced imaging modality

Cumulative phase delay imaging – a new contrast enhanced imaging modality

Libertario Demi[1], Ruud J.G. Van Sloun[1], Xinran Zhao[1], Hessel Wijkstra[2,1], Massimo Mischi[1]

[1]Department of Electrical Engineering, Laboratory of Biomedical Diagnostics, Eindhoven University of Technology, the Netherlands
[2]AMC University Hospital, Amsterdam, the Netherlands

Introduction

Recently, a new marker for ultrasound contrast agents (UCAs) has been introduced [1-2]. A cumulative phase delay (*D*) between the second harmonic and fundamental pressure component is in fact observable for ultrasound propagating through UCAs. This phenomenon is absent in the case of tissue nonlinearity and is dependent on insonating pressure and frequency, UCA concentration, and propagation path length through UCAs. In this paper, the first ultrasound image based on this marker is presented.

Methods

The ULA-OP research platform [3], in combination with a LA332 linear array probe (Esaote, Firenze Italy), has been used to image a gelatin phantom containing a PVC plate (used as a reflector) and a cylindrical cavity with a diameter of 7 mm (placed in between the observation point and the PVC plate), see Figure 1.

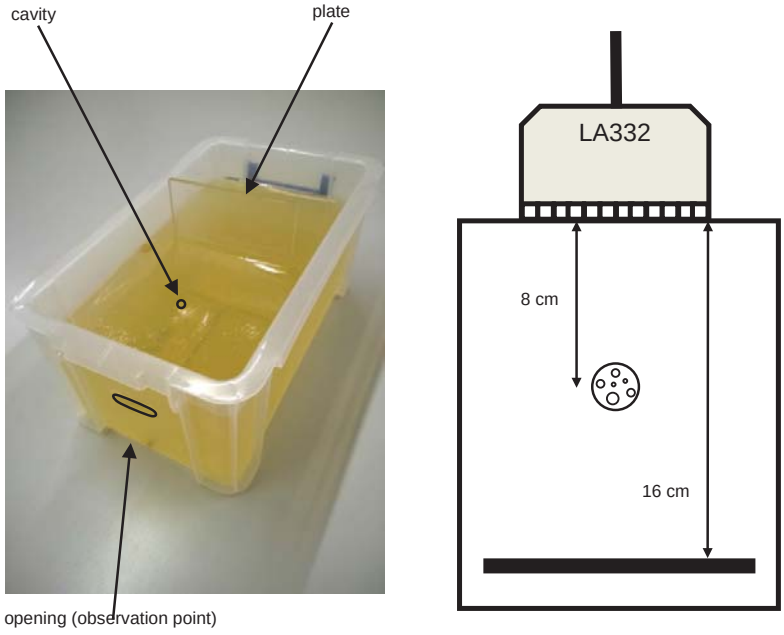

Figure 1: Picture (left) and schematic top view (right) of the phantom.

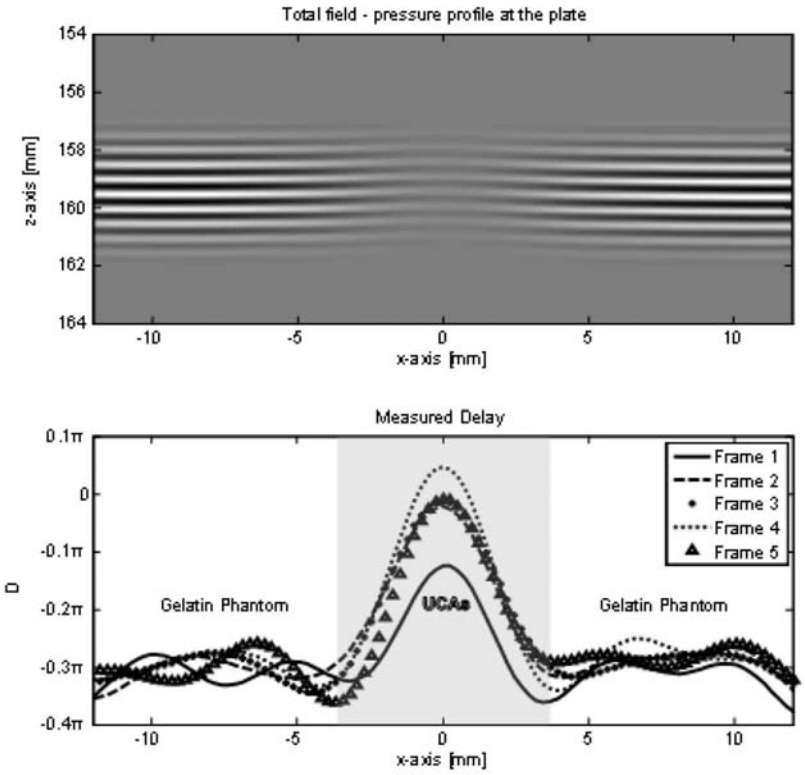

Figure 2: Total field backscattered at the plate (top) and estimated second harmonic to fundamental component cumulative phase delay profile from five consecutive frames (bottom).

The cavity contained a 240 μL/L SonoVue® UCA concentration. The gelatin phantom was scanned with an insonating frequency f_0 = 3 MHz and a mechanical index MI = 0.05, measured in water at the cavity location with a HGL-0400 hydrophone (Onda, Sunnyvale, CA). The echoes obtained from the PVC plate were processed as described in [1-2] in order to obtain, for each line imaged, a measure of the cumulative phase delay $D=2\pi\Delta t f_0$, with Δt being the time delay between the second harmonic and the fundamental component. Exploiting the employed linear array, as shown in Figure 2, D can be estimated as a function of space in the lateral direction. The axis of the cylindrical cavity was positioned at (z,x)=(80 mm, 0 mm), with z and x being the axial and lateral direction, respectively, and with the center of the linear array aperture coinciding with the center of the coordinate system.

For this particular in-vitro configuration, we can exploit the symmetry of the target and assume consecutive frames as if acquired from different observation angles. Consequently, a sinogram can be constructed, and an ultrasound image generated in a tomographic fashion using the filtered back-projection method [4].

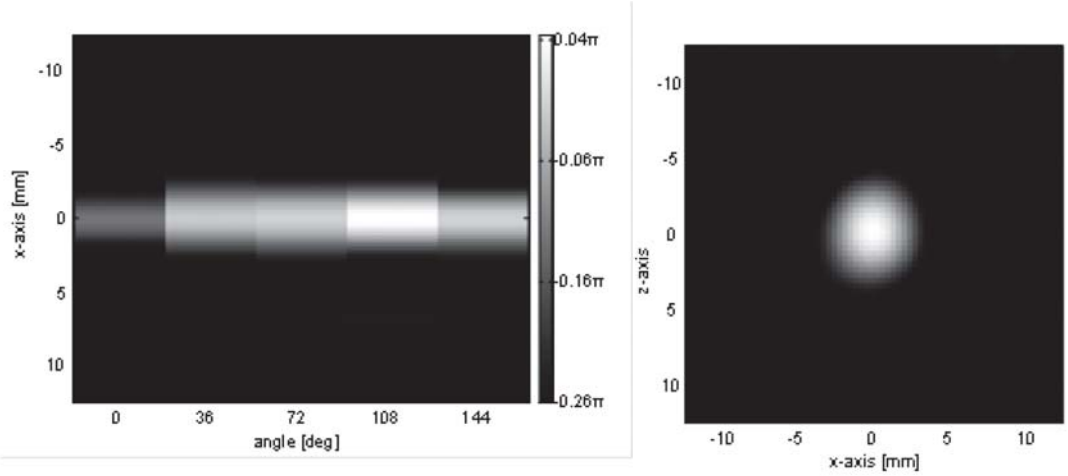

Figure 3: Sinogram (left) and corresponding ultrasound *D*-image (right) obtained by imaging a 7-mm diameter cavity filled with a 240 μL/L concentration of SonoVue® contrast agent.

Results

Figure 2 (top) shows the total field backscattered at the plate. Attenuation of the total field due to the presence of UCAs in the propagation path can be observed. The bottom plot shows the estimated second harmonic to fundamental cumulative phase delay *D* from five consecutive frames, as a function of *x*. This plot shows variations of *D* in the presence of UCAs along the propagation path, with *D* increasing for longer propagation path length through UCAs. In particular, a measure of *D* of approximately -0.3π has been always observed in the absence of UCAs.

Figure 3 shows the sinogram (left) and obtained ultrasound *D*-image (right) using the filtered back-projection method. Five consecutive frames have been used, and assumed to be acquired at an angle of 0, 36, 72, 108, and 144 degree, respectively.

Conclusion and Discussion

We presented the first ultrasound image based on the cumulative phase delay between second harmonic and fundamental component observed for ultrasound propagating through UCAs. Although a simple set-up was adopted, where the symmetry of the imaged target facilitated the image formation, this result confirms the applicability of the presented cumulative delay as an UCA marker for imaging.

Comparison with standard contrast-enhanced ultrasound imaging modalities, together with the optimization of the acquisition parameters will be the focus of future work. Imaging in the presence of flowing rather than static UCAs will also be investigated.

References

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