Ultrasonic dispersion and attenuation in bubbly liquids

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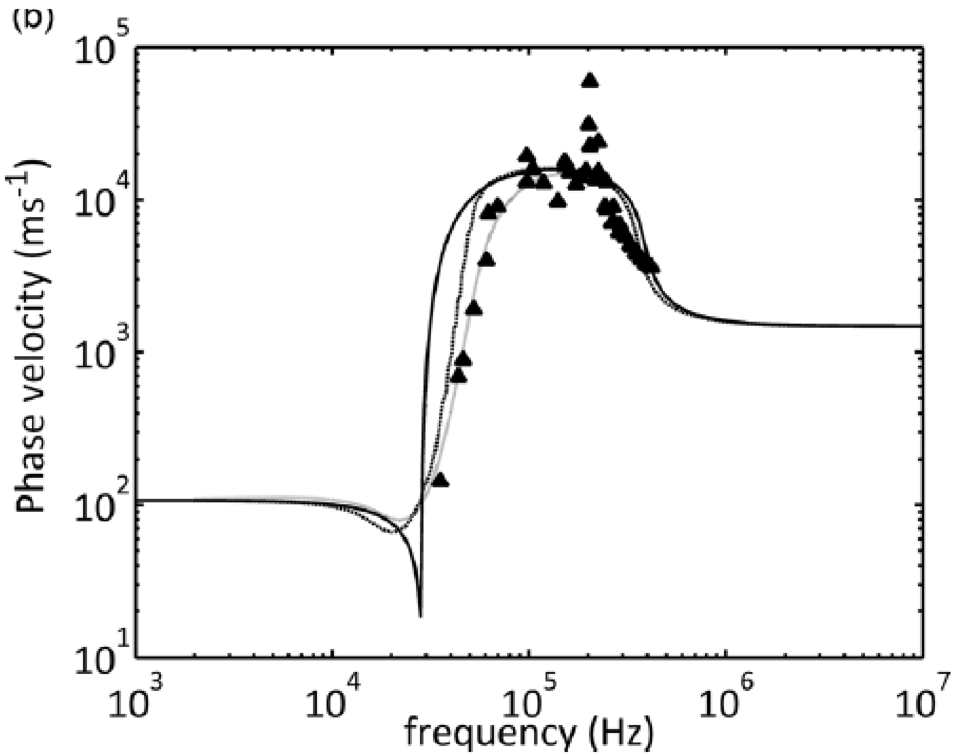
Introduction

Air bubbles strongly influence the ultrasonic behavior of liquids even in very small percentages

They create strong dispersion and attenuation.



Propagation velocities of more than 10 km/s are predicted and measured!!

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Shiva Kant Shukla[a)] and Luis Elvira, J. Acoust. Soc. Am. 137 (5), May 2015

Introduction

Measurement of phase velocity vs. frequency curves is delicate.

In the present work we use shampoo as a model medium to check:

The effect of bubbles on the propagation

The reliability of the methodology for production of the dispersion curve

The change of dispersive behavior as the bubbles are released and the heterogeneity decreases

Shampoo offers visual transparency which makes easier the assessment compared to other media (like concrete, which is the initial motivation of the study)

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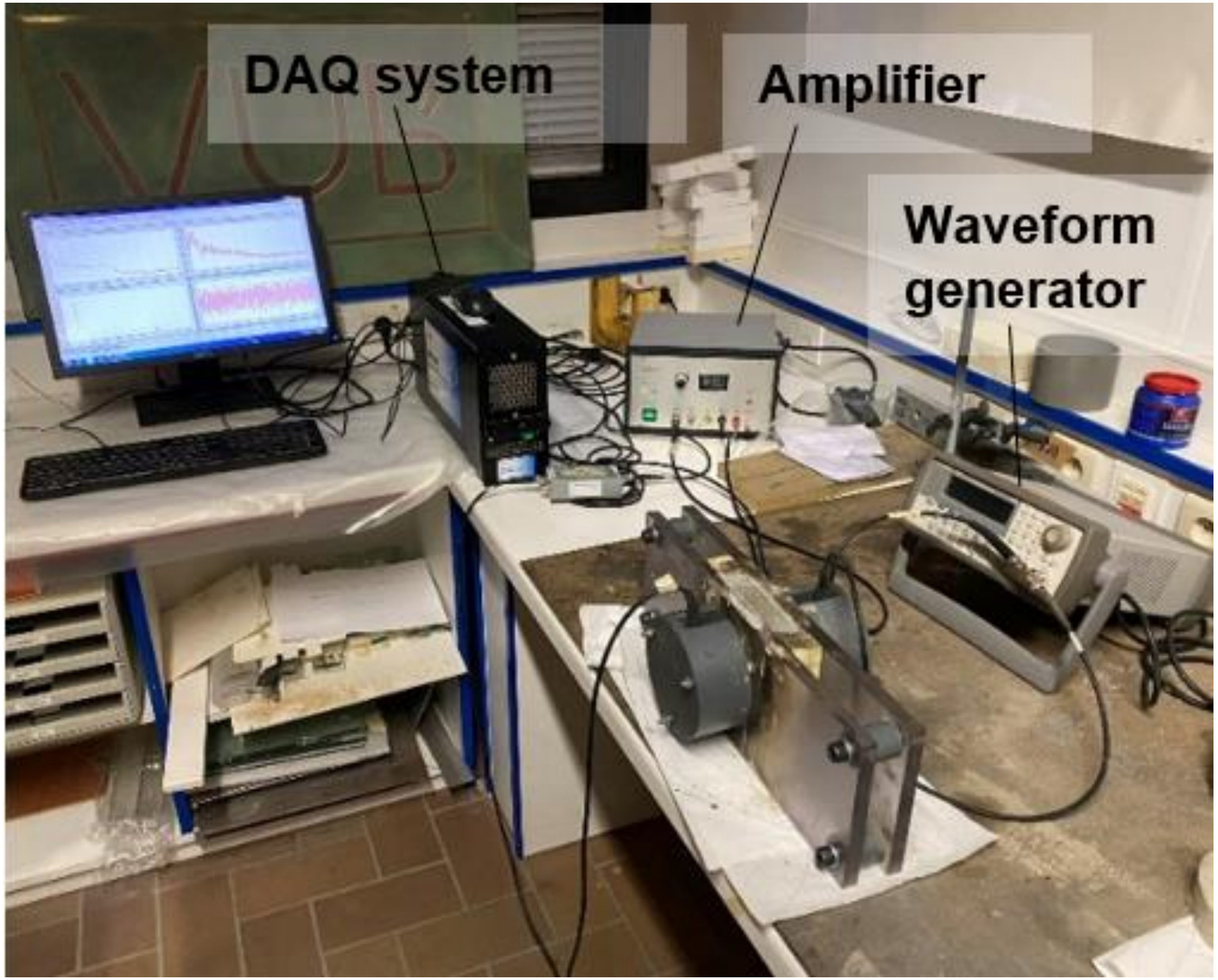
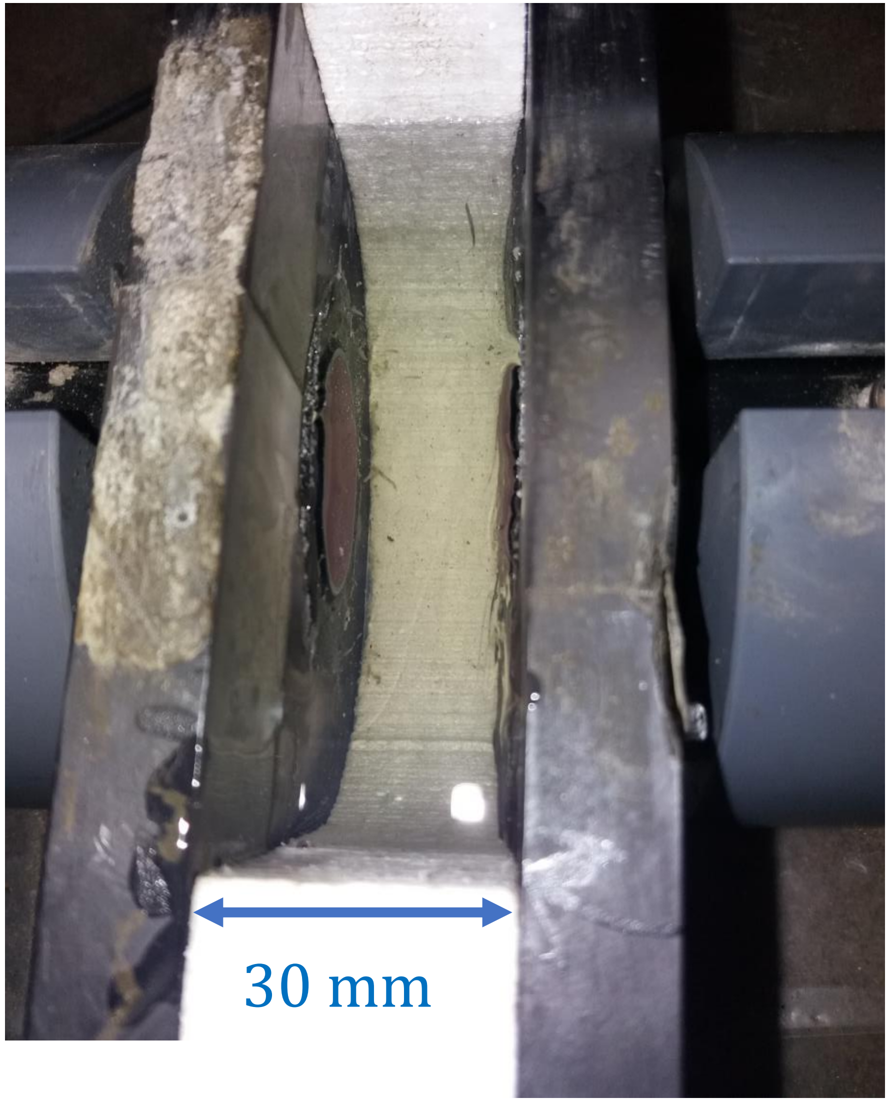
Experimental details



Generator Agilent 33220A
Excitation: 1 cycle of 250 kHz
Transducers (pulser and receiver): Olympus V1012 Standard Contact Videoscan (peak at 250 kHz)
Plexiglass container, with U-shaped EPDM
Distance between transducers 30 mm
DAQ: Micro II Mistras, SR 10 MHz

Experimental details

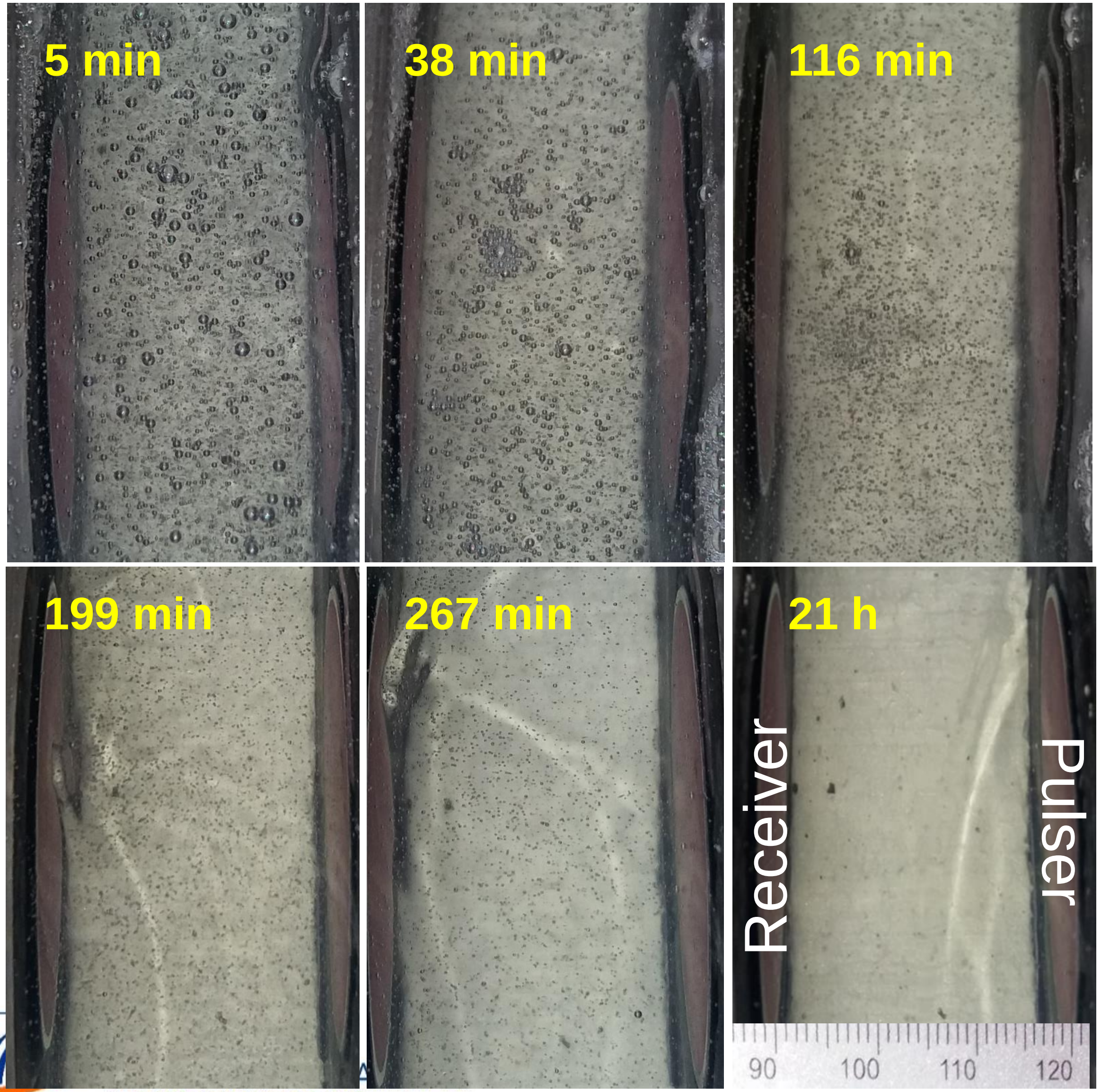
Receiver



Pulser

Close-up on the mold filled with liquid.

Experimental details

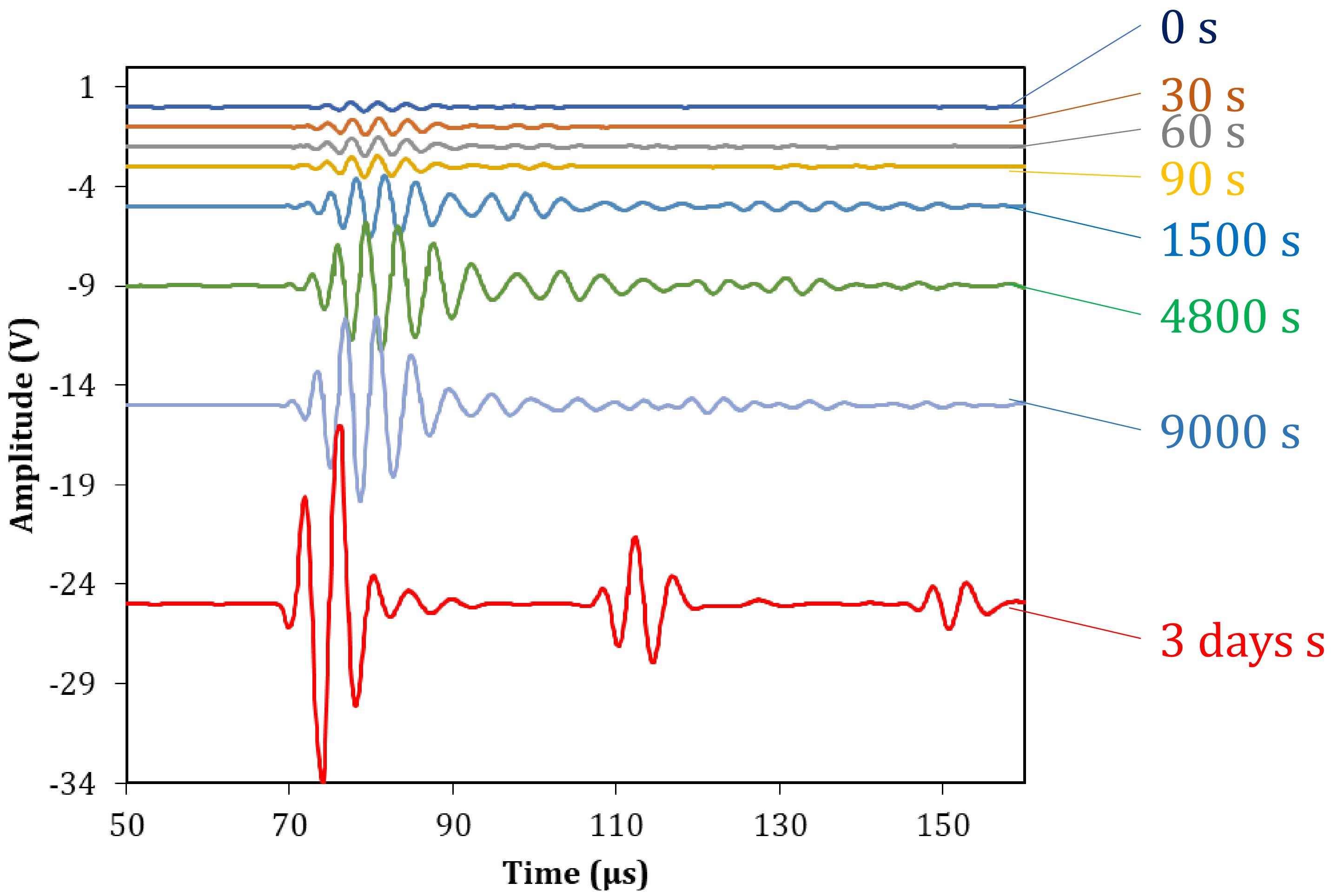


Air is introduced by a thin straw and bubbles are created.

Gradually they are released.

Results

Waveforms



Initially the amplitude is quite small. It increases rapidly as the big air bubbles are quickly emerging.

The increase continues for several hours but with decreasing rate.

It seems that the amplitude (measured peak to peak) reaches a plateau around 7 hours

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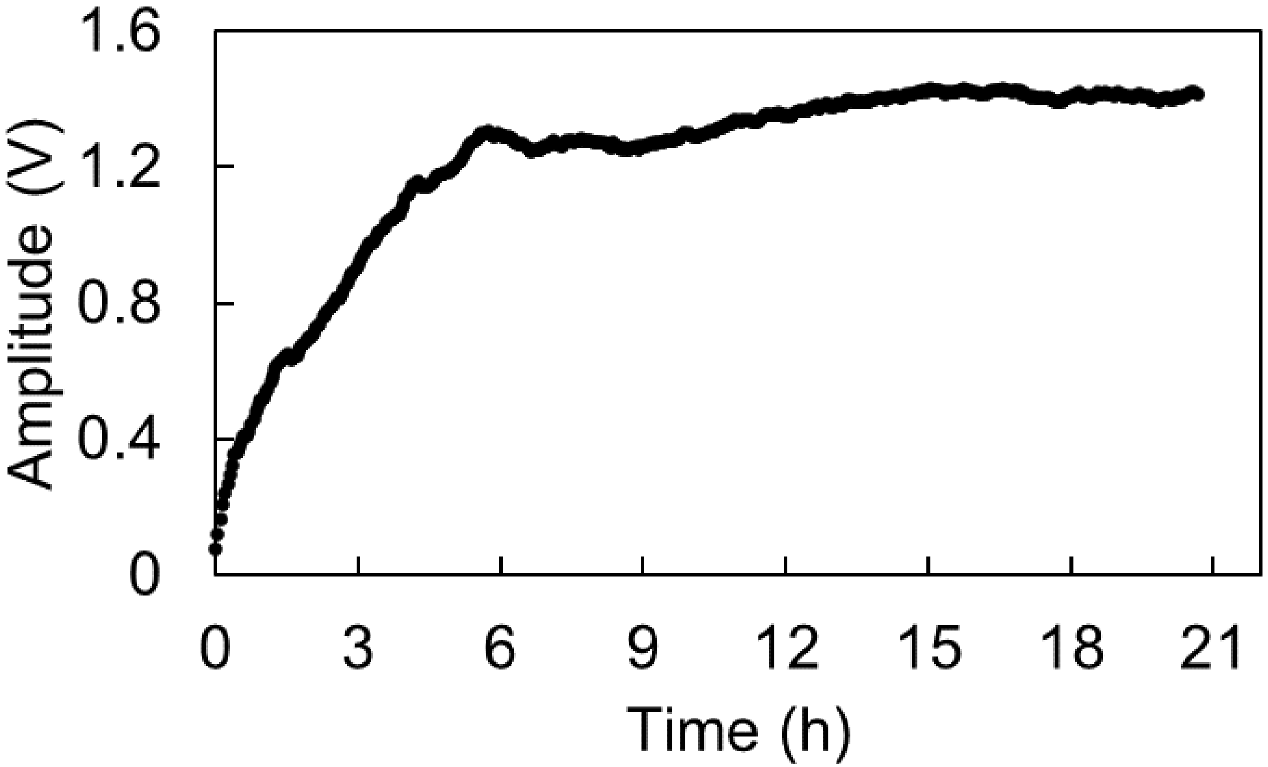
Results

Amplitude



Initially the amplitude is quite small. It increases rapidly as the big air bubbles are quickly emerging.
The increase continues for several hours but with decreasing rate.
It seems that the amplitude (measured peak to peak) reaches a plateau around 6 hours

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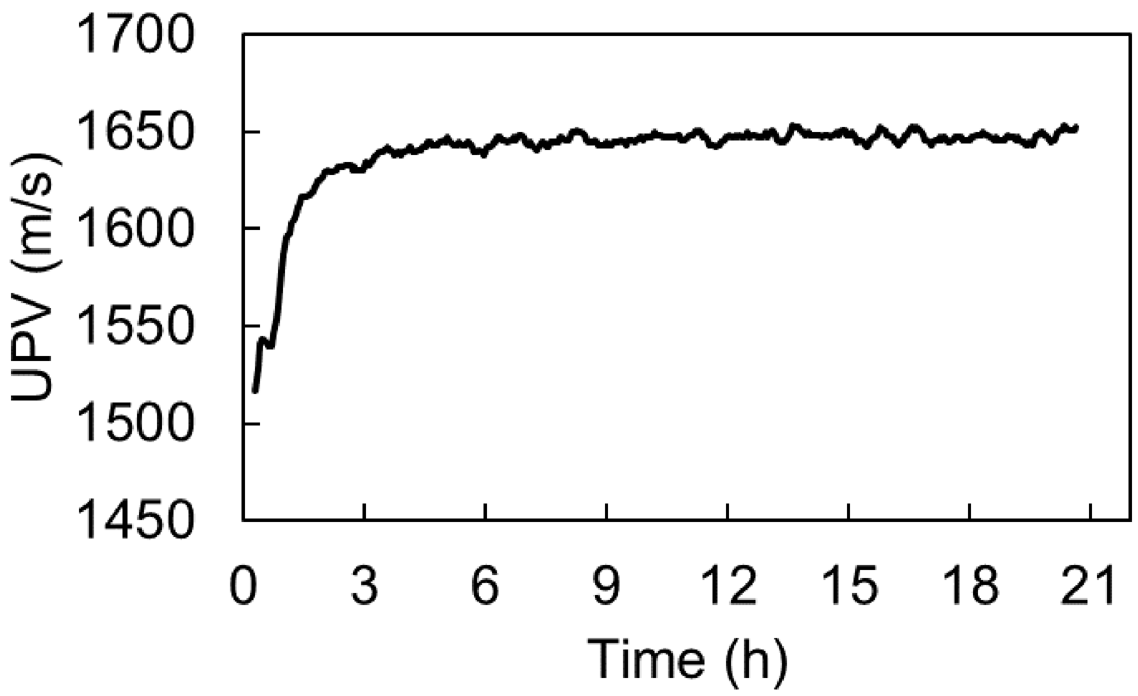
Results

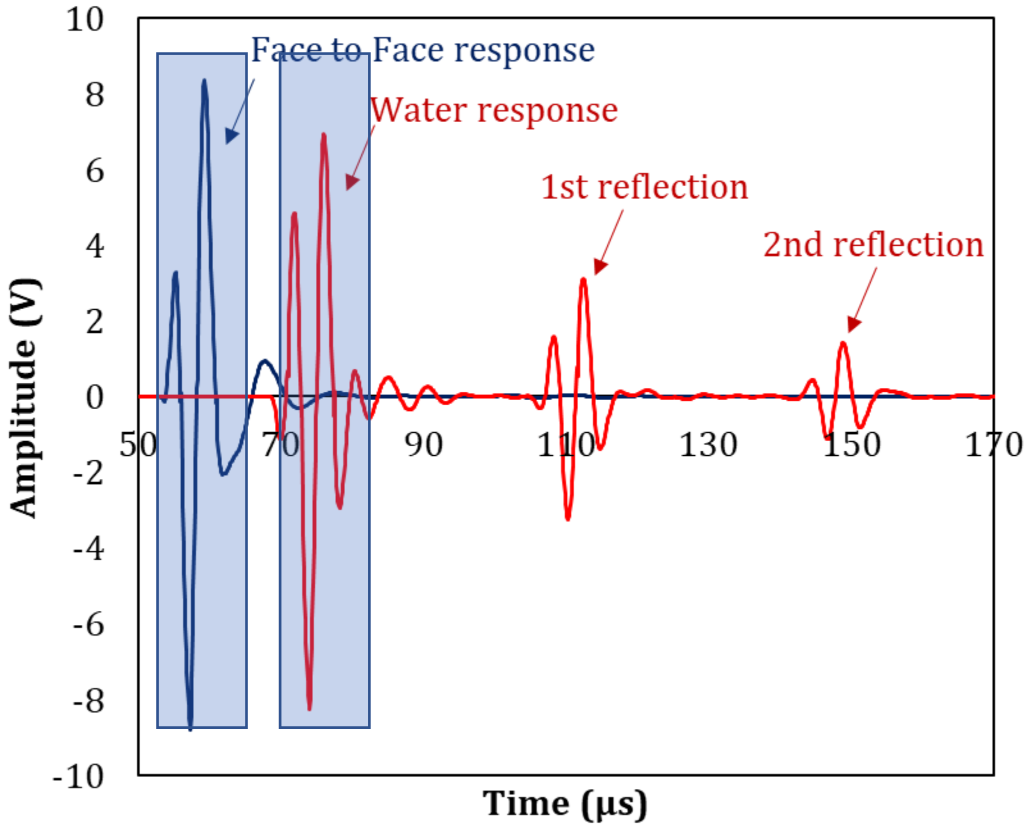
Pulse velocity



Pulse velocity measured by threshold crossing increases rapidly as the big air bubbles are quickly emerging.
The increase continues for several hours but seems to reach the plateau earlier than amplitude (around 3-4 hours)

Results

Dispersion curve

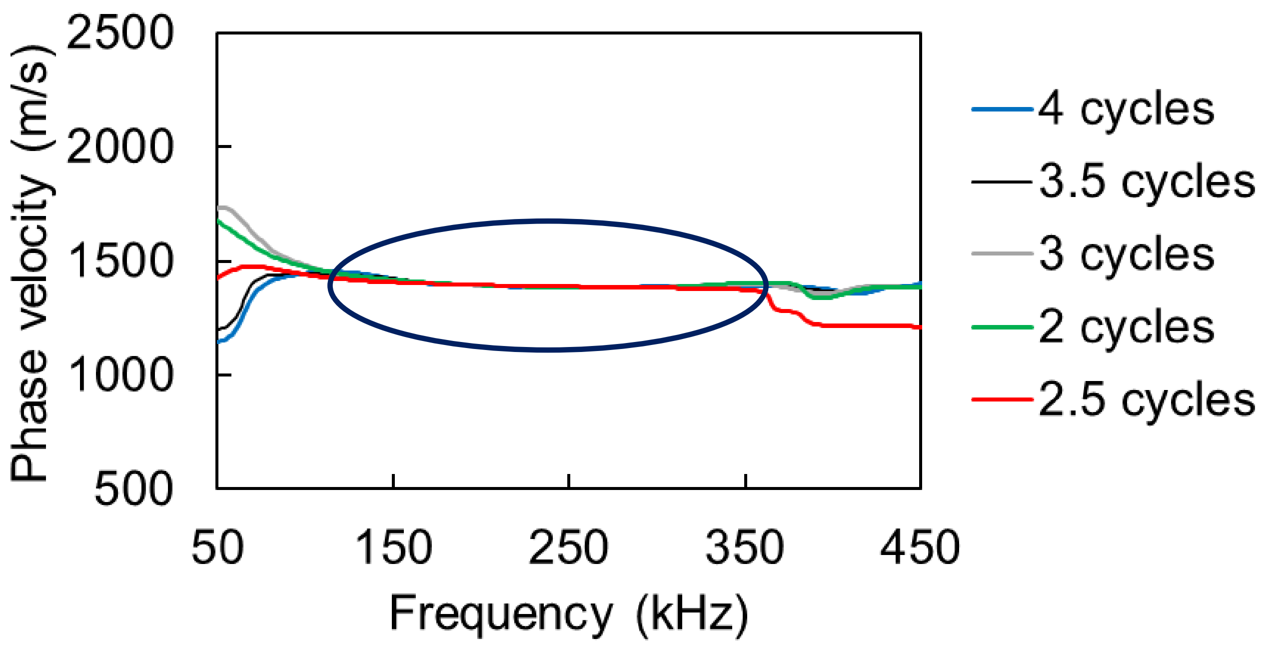


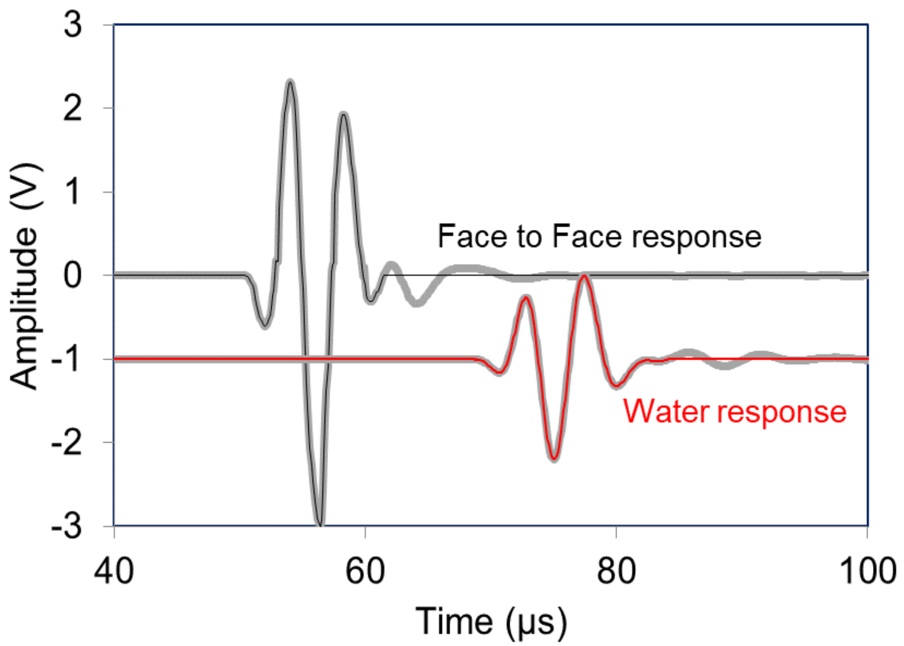
The phase velocity vs. frequency curve is calculated by the difference of phase in frequency domain (Sachse and Pao, 1978) We use the “Face to Face response” and the “water response” isolating the meaningful cycles and zero-padding the rest.

Results

Dispersion

The signal consists of several cycles. Changing the part that is considered in the analysis (full, some cycles etc. influences only at low and high frequencies.

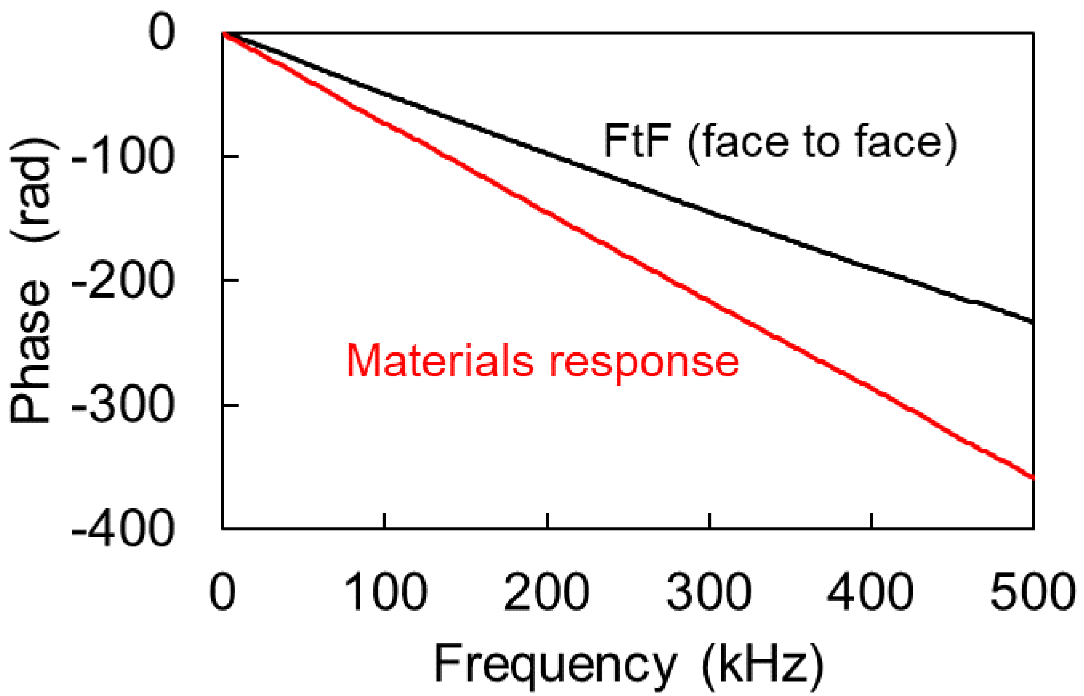




The band between 120 and 350 kHz is considered more reliable. 2.5 cycles were taken into account. The rest of the waveforms is zero-padded.

Results

Dispersion calculation

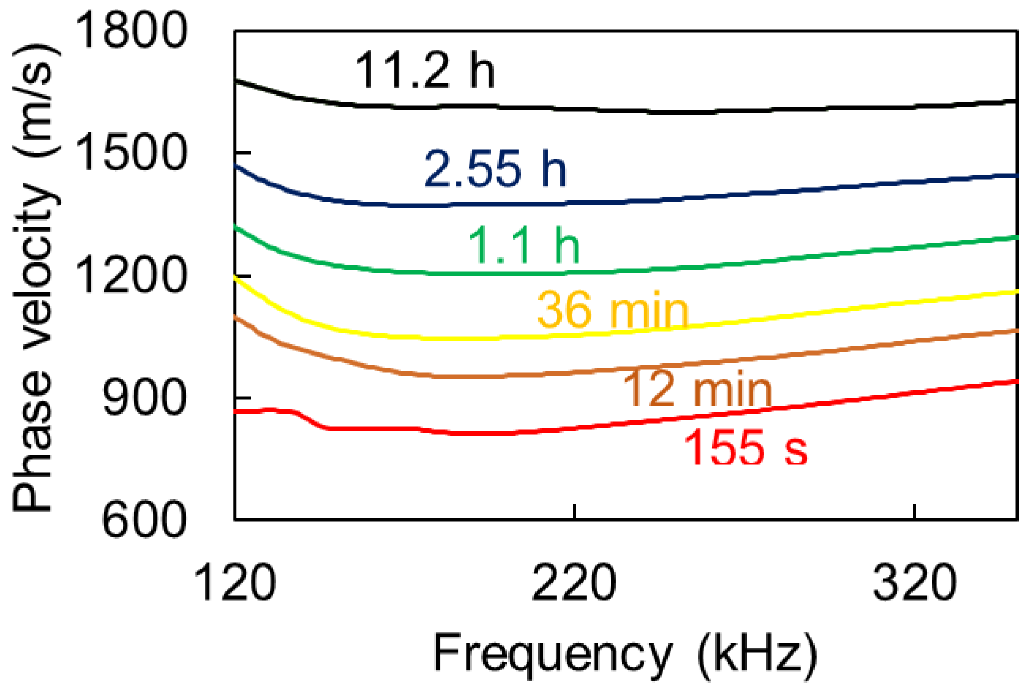


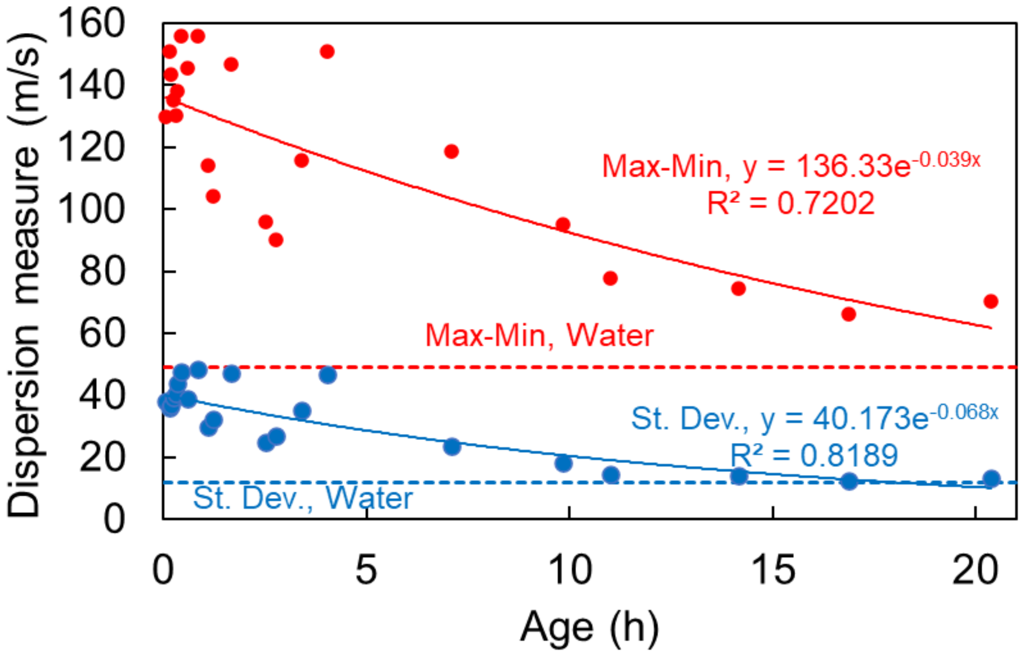
The phase velocity for each frequency component is calculated by the difference in phase (FFT)

$$C(f) = \frac{2\pi \cdot x \cdot f}{\delta\theta(f)}$$

Results

Dispersion





Initially, the curves are lower and show stronger frequency dependence. At 11 h they have obtained the final form, which is between 1600-1700 m/s and smoother. The st. dev. of the curve decreases with time.

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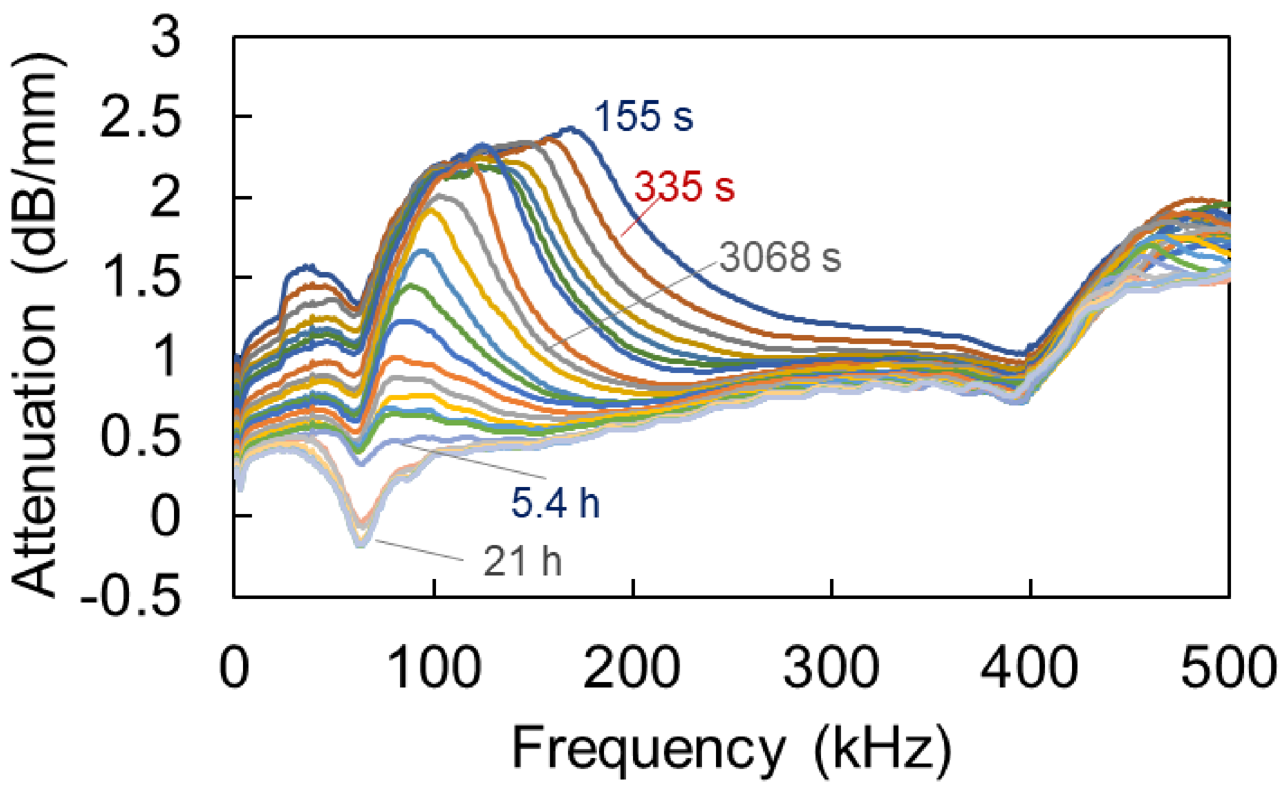
Results

Attenuation vs. frequency



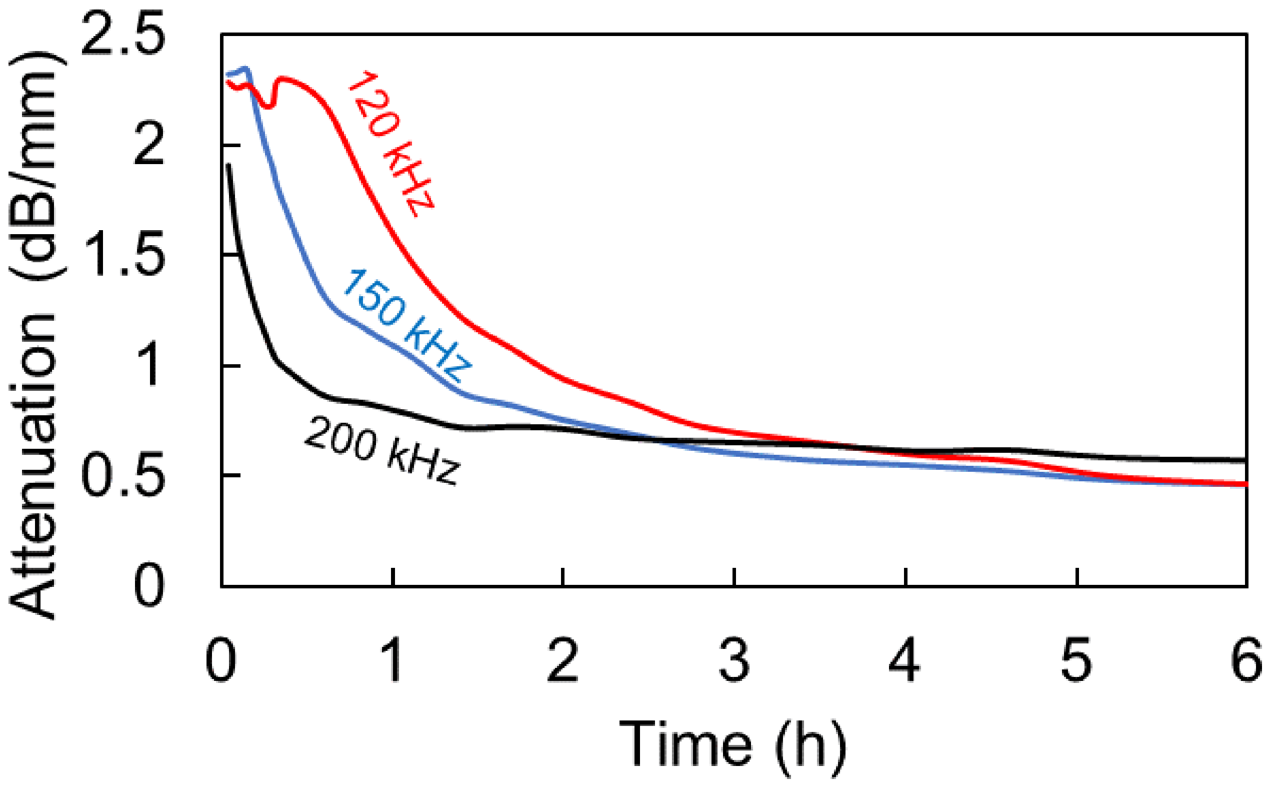
Attenuation is calculated by the FFT magnitude functions of the FtF (A_1), the response (A_2) and the distance, *x*:

$$att = \frac{1}{x} 20 \cdot log\left(\frac{A_2}{A_1}\frac{(f)}{(f)}\right)$$

Attenuation curves quickly drop with the release of the air bubbles.

Results

Attenuation vs. frequency



Focusing on specific frequencies, it seems that the higher ones reach saturation earlier than lower. The attenuation for 120 kHz, stays almost constant for more than 30 min, while for 200 kHz, it starts to decrease from the first measurement (3 min)

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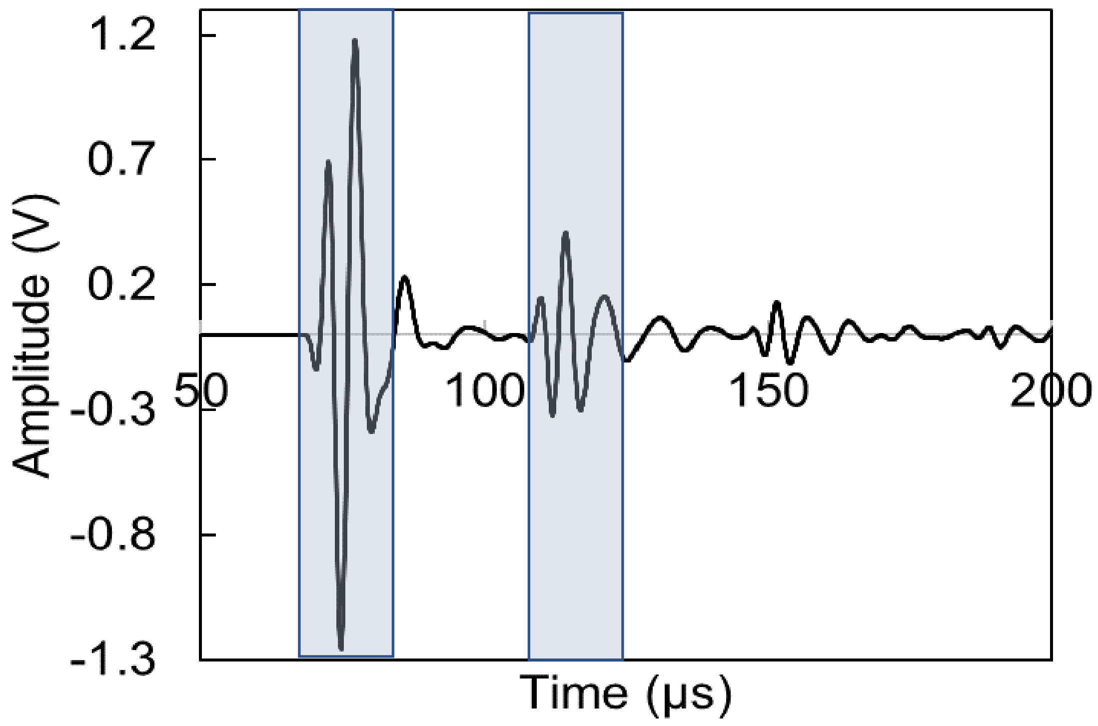
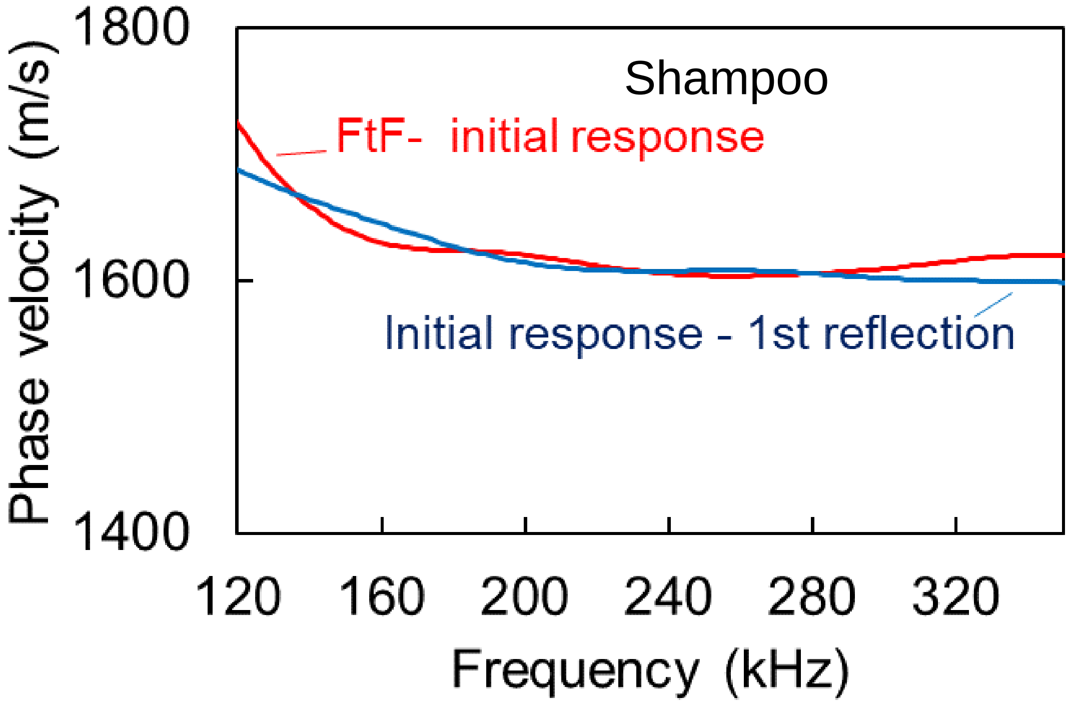
Investigation

Dispersion curve using the reflection





When a clear reflection is recorded, for the reliable frequency range, calculating the phase delay between the initial response and the reflection leads to nearly identical dispersion curve as the one calculated by the FtF and the initial response. The difference is maximum 30 m/s.

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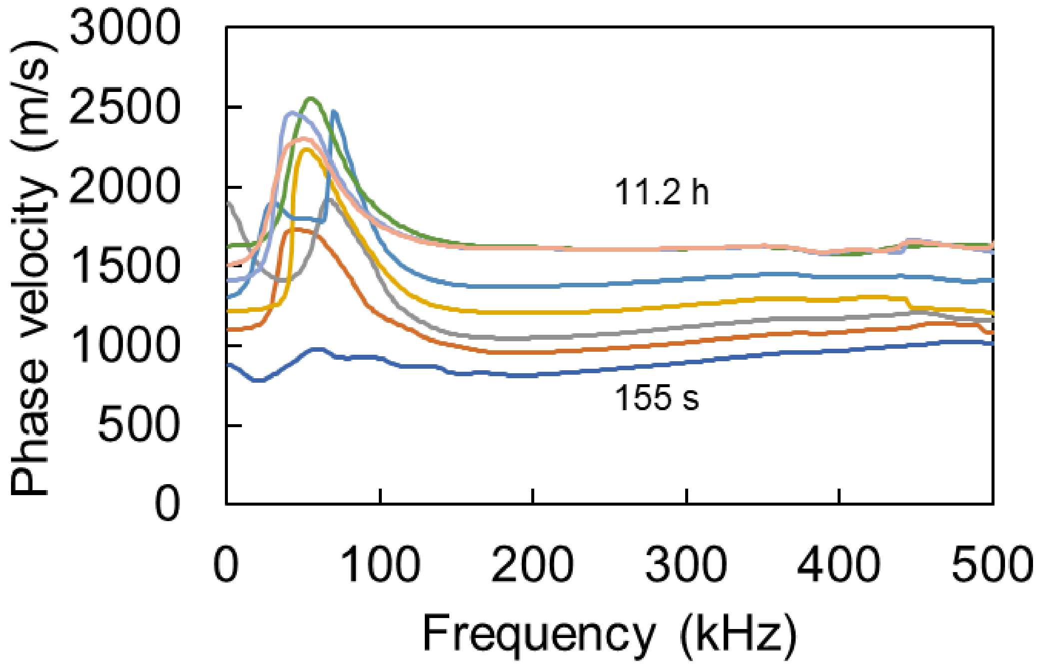
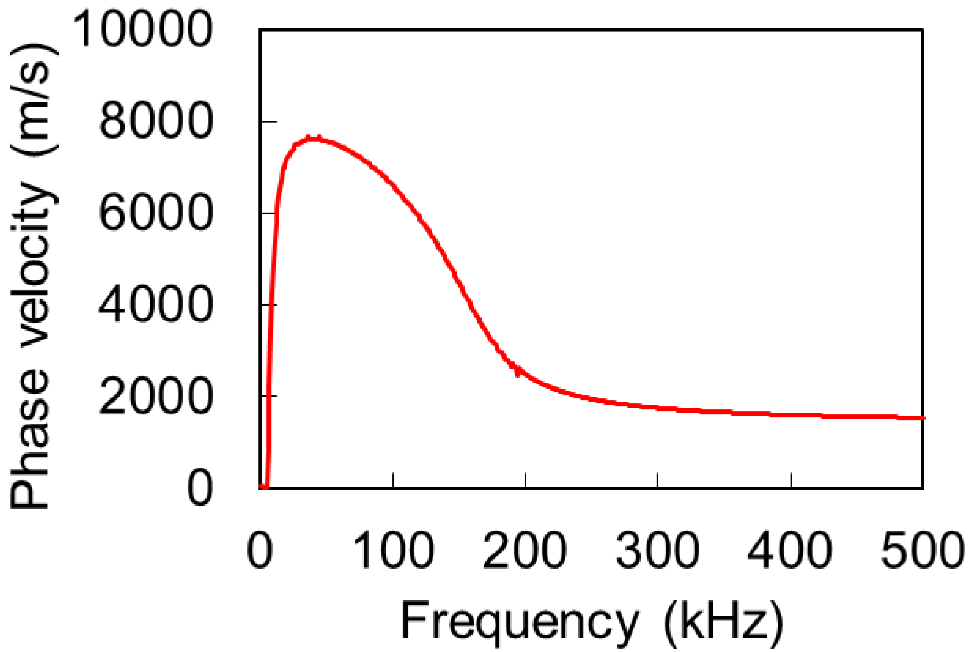
Investigation

Dispersion curves – comparison with scattering model





It is interesting to expand outside the “reliability” zone, because the experimental evidence implies resonance peaks below 100 kHz.
The same is predicted by scattering models (Waterman-Truel, cavities of 1 mm with 5% vol.)

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Conclusions

Air bubbles strongly influence wave propagation in liquids. They:

- lower pulse velocity and amplitude
- increase the dependence to frequency (dispersion)
- Increase the attenuation curve

It is interesting to:

- Systematically study theoretical curves based on scattering models
- Expand to wider bands where even stronger phenomena are expected
- Transparent viscous liquids are a good model to study the effect of bubble aiming at the characterization of other medial like fresh concrete

Thank you for your attention

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