Delft University of Technology

# Erratum: Lamb Waves and Adaptive Beamforming for Aberration Correction in Medical Ultrasound Imaging

## Lamb Waves and Adaptive Beamforming for Aberration Correction in Medical Ultrasound Imaging (IEEE Trans.Ultrason., Ferroelectr., Freq. Control, early access (2020) DOI: 10.1109/TUFFC.2020.3007345)

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# Erratum to "Lamb Waves and Adaptive Beamforming for Aberration Correction in Medical Ultrasound Imaging"

Moein Mozaffarzadeh, Claudio Minonzio, Nico de Jong, Martin D. Verweij, Simone Hemm, Guillaume Renaud, and Verya Daeichin

In the above article [1], we mentioned that the superposition of the different symmetric (S) modes in the frequency-wavenumber (f-k) domain results in a high-intensity region where its slope corresponds to the longitudinal wave speed in the slab. However, we have recently understood that this high-intensity region belongs to the propagation of a wave called lateral wave or head wave [2]–[5]. It is generated if the longitudinal sound speed of the aberrator (i.e., the PVC slab) is larger than that of water and if the incident wavefront is curved. When the incidence angle at the interface between water and PVC is near the critical angle, the refracted wave in PVC reradiates a small part of its energy into the fluid (i.e., the head wave). As discussed in [4], if the thickness of the waveguide is larger than the wavelength, the first arriving signal is the head wave. This is also the case in our study [1] where the ultrasound wavelength of a compressional wave in PVC was close to 1 mm, and a PVC slab with a thickness of 8 mm was used.

In this Erratum, numerical simulations (with SimSonic solver [5]) and experimental measurements (with the same PVC slab used in [1]) are conducted to investigate the propagation of the Lamb waves and head wave in detail, for the specific configuration studied in [1]. The pitch and element width of the P4-1 probe were used to assemble the numerical signals [see Fig. 1(a)]. If all the data simulated for the P4-1 probe is used, there indeed is a region with a slope [see Fig. 1(b)], but this has a low intensity, meaning that the head wave has a relatively low amplitude compared to the specular reflections. Once the head wave is isolated, the sound speed can be estimated with a 0.3% error from the f-k domain plot [see Fig. 1(c)]. No significant difference is observed between Fig. 1(b) and (d), in which the head wave is muted.

Our experimental results show that if only the head wave (the first arriving signal) is used [see Fig. 2(b)], the slope of the linear fitting in the f-k domain also yields the longitudinal sound speed of the PVC with a 0.3% error.

Of note, the signal processing (i.e., linear fitting in the f-k domain) used in our study [1] still works for the head wave and is correct provided that the aberrator is parallel to the probe [6].

Also, in [1, p. 6], it is mentioned that "the curved structure of the skull might lead to other types of modes, such as the torsional modes." Here, we acknowledge that this sentence is not correct, as torsional modes only exist in cylindrical waveguides or rectangular bars.

We would like to mention that Guillaume Renaud is added as a coauthor to acknowledge his contribution to the findings reported in this Erratum.

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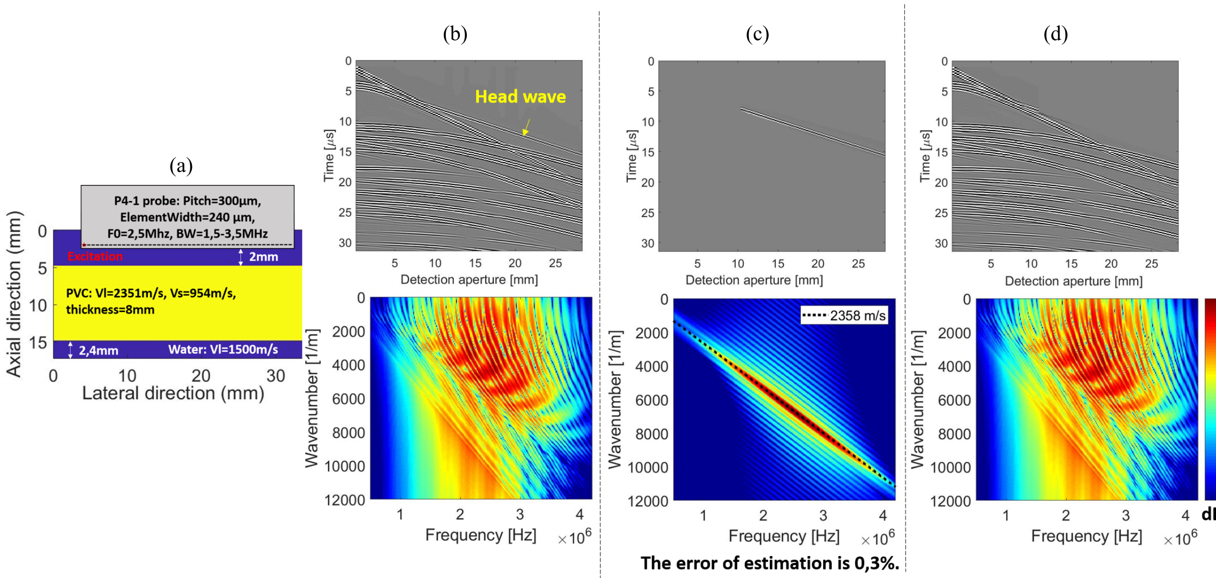


Fig. 1. (a) Numerical model used in SimSonic. F0, BW, Vl, and Vs are the central frequency, bandwidth, longitudinal wave velocity, and transverse wave velocity, respectively. (b)–(d) Numerical space–time domain data and the corresponding f-k representation. (b) All the data. (c) Only the head wave. (d) Head wave is removed.

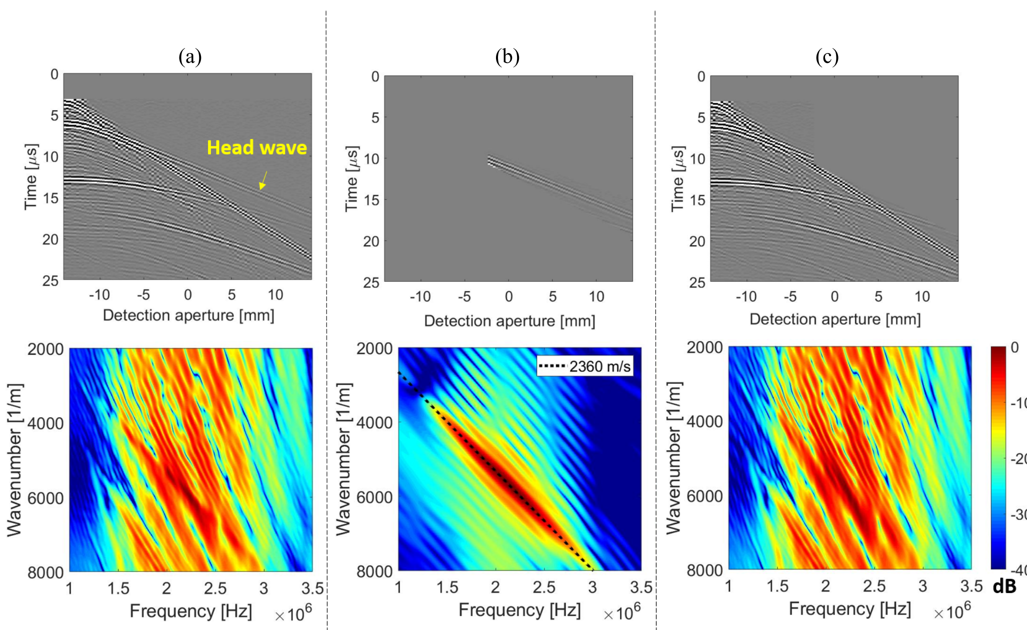


Fig. 2. Experimental space–time domain data and the corresponding f-k representation. A P4-1 ultrasound probe and a PVC slab with a thickness of 8 mm were used in the experiment. (a) All the data. (b) Only the head wave. (c) Head wave is removed.

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