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Evaluation about propagation characteristics of pass-through airborne ultrasound for ultrasonic bone assessment
超音波骨評価を目的とした透過した空中超音波の伝搬特性評価

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1. Introduction

Quantitative diagnoses using the propagation characteristics of ultrasound are widely used because it is minimally invasive and free from X-ray exposure. In particular, quantitative ultrasound (QUS), which is the quantitative diagnosis of osteoporosis using the propagation characteristics in cancellous bones, is studied and applied in clinical practice. To effectively propagate ultrasound in the human body, ultrasonic transducers are typically brought into contact with the body surface. In this study, the non-contact measurement of the propagation characteristics using pass-through airborne ultrasound has been proposed[1, 2].

Airborne ultrasound which passed through the human body is extremely attenuated due to a large reflection from the body surface. Therefore, detection of pass-through ultrasound is difficult for typical signal processing. In this report, ultrasound which passed through the heel and the phantom are evaluated in the commercially device and the proposed system.

2. Evaluation on commercially device

Attenuation of pass-through ultrasound in the commercially device is evaluated. The used ultrasonic bone-density measurement device was the Minelyzer, as illustrated in **Fig. 1**. The used phantom, which is for calibration of the Minelyzer, is illustrated in **Fig. 2**. The indicated speed of sound (SOS) in the phantom is 1637±4 m/s. The phantom has faced parallel planes and inclined planes, whose angle is 30°. In the measurement, impulse waves of 170 $V_{0\text{-}p}$ were applied to the transducer, whose central frequency is approximately 500 kHz. Both sides of the heel and inclined planes of the phantom were brought into contact with transducers through an ultrasonic gel. The received signals of another transducer were recorded by an oscilloscope.

The wave forms and spectrums of ultrasound, which passed through the heel and the phantom, are illustrated in **Fig. 3**. These results are mean values of 18 measurements. In lower frequency than 400 kHz, attenuation in the heel was smaller than that in the phantom. Then, attenuation in the heel was larger than that in the phantom around 500 kHz, which is the central frequency of transducers. Therefore, the amplitude of ultrasound which passed through the heel was smaller than that of the phantom in this devise. The measured SOSs in the heel and the phantom by this device were 1540 m/s and 1640 m/s, respectively.

Fig. 1 Minelyzer, which is used commercially device of ultrasonic bone-density measurement.

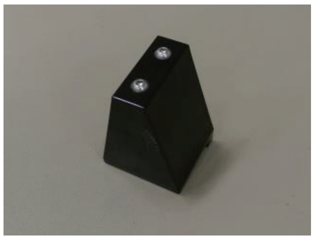

Fig. 2 Used phantom, which is for calibration of Minelyzer.

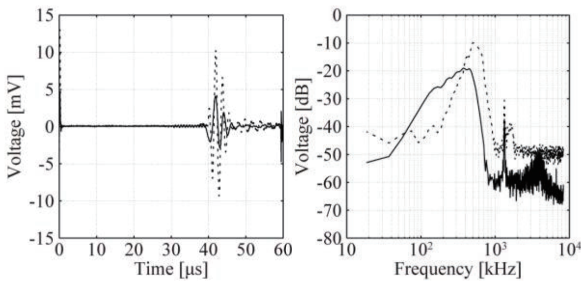

Fig. 3 Wave forms and spectrums of ultrasound which passed through heel (solid line) and inclined planes of phantom (dot line) in Minelyzer.

3. Contact measurement by proposed system

Attenuation of pass-through ultrasound in the proposed system is evaluated. Therefore, transducers were brought into contact with the heel and the phantom. The proposed system is illustrated in **Fig. 4**. In the measurement, pulse waves of 3 μs and 150

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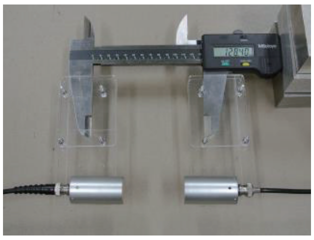

Fig. 4 Transducers of proposed system for non-contact measurement of propagation characteristics in heel.

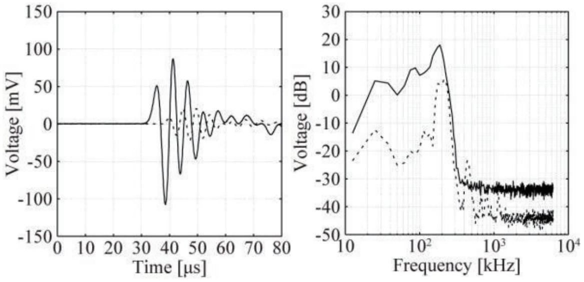

Fig. 5 Wave forms and spectrums of ultrasound which passed through heel (solid line) and parallel planes of phantom (dot line) in proposed system.

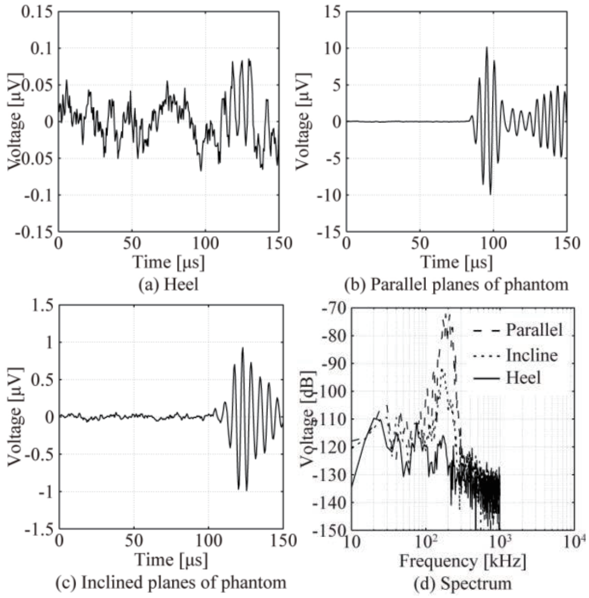

Fig. 6 Correlated signals and spectrums of airborne ultrasound which passed through heel, parallel planes of phantom, and inclined planes of phantom.

$V_{0\text{-}p}$ were applied to the transducer, whose central frequency is approximately 200 kHz. Both sides of the heel and parallel planes of the phantom were brought into contact with transducers through an ultrasonic gel. The received signals of another transducer were recorded by an oscilloscope.

The wave forms and spectrums of ultrasound, which passed through the heel and the phantom, are illustrated in **Fig. 5**. These results are mean values of 20 measurements. Attenuation in the heel was smaller than that in the phantom around 200 kHz, which is the central frequency of transducers. Therefore, the amplitude of ultrasound which passed through the heel was larger than that of the phantom in the proposed system. The estimated SOSs in the heel and the phantom by this system were 1570 m/s and 1610 m/s, respectively.

4. Non-contact measurement by proposed system

Attenuation of pass-through airborne ultrasound in the proposed system is evaluated. Pass-through airborne ultrasound is extremely attenuated. Therefore, the SNRs of received signals were improved by pulse compression using M-sequence. In the measurement, 19th-order M-sequence modulated signals were transmitted. A pulse wave of 3 μs and 150 $V_{0\text{-}p}$ was assigned to 1 digit of M-sequence. The distance between transducers was 75 mm. The received signals were recorded by a data logger, and correlated with the used M-sequence in a computer.

The correlated signals of ultrasound which passed through the heel and the phantom, are illustrated in **Fig. 6**. In the case of the heel, pass-through ultrasound is found around 120 μs. However, the TOF cannot be determined due to the large attenuation. In the case of parallel planes of the phantom, pass-through ultrasound is found around 80 μs. The amplitude of ultrasound which passed through the heel was smaller than that of the phantom by 40 dB. On the other hand, in the case of inclined planes of the phantom, pass-through ultrasound is found around 110 μs. The amplitude of ultrasound which passed through inclined planes was smaller than that of parallel planes by 20 dB. Therefore, airborne ultrasound which passed through the heel also seems to be attenuated by reflection and scattering from the heel surface.

5. Conclusions

A non-contact measurement of the propagation characteristics in the heel using pass-through airborne ultrasound has been studied. Ultrasound which passed through the heel and the phantom were evaluated in this report. Pass-through airborne ultrasound was attenuated by the configuration of the heel surface or phantom planes.

Acknowledgment

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References

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