3Pa5-4

Transmission condition for stable depiction of thoracic spine based on differences in reflection and scattering characteristics of medical ultrasound

医用超音波の反射・散乱特性の差異を利用した胸椎描出における送信好条件の検討

Taiga Bando[1†], Shohei Mori[2], Hiroshi Kanai[2,1], Eiko Onishi[3], Masanori Yamauchi[3], and Mototaka Arakawa[1,2] ([1]Grad. School of Biomed. Eng., Tohoku Univ.; [2]Grad. School of Eng., Tohoku Univ.; [3]Anesthesiology, Tohoku Univ. Hospital)

阪東泰河 [1†]，森 翔平 [2]，金井 浩 [2,1]，大西詠子 [3]，山内正憲 [3]，荒川元孝 [1,2]
([1] 東北大院 医工, [2] 東北大院 工, [3] 東北大学病院 麻酔科)

1. Introduction

In epidural anesthesia, a needle is inserted into the spinal gap. Medical ultrasound is used to assist in locating the puncture position. However, due to the reflection property of bone and the attenuation in muscle tissue, it is difficult to identify the puncture position by the general B-mode image. We have proposed an imaging method of thoracic vertebrae using the difference between the reflection of bone and the scattering of muscle tissue, but this method has a problem that muscle tissue might be depicted as bone.[1)]

This method uses the difference in the angular amplitude characteristics between the reflection and scattering, each of which is calculated from the enveloped amplitude of the received signal obtained by each element of the ultrasound probe from an object. If the difference in the angular amplitude characteristics between reflection and scattering is large, the target could be estimated more accurately. In the present study, we investigated the relationship between the angular amplitude characteristics and the number of the transmitted elements through simulation experiments.

2. Method

In the present study, we use the element data, which is the raw received signal at each element of the probe. **Figure 1** shows the schematic diagram where a focused wave is transmitted to a point scatterer just below the center of the probe. x_{r} and $\mathrm{P}_0(x_0, d_0)$ are the receiving position of the probe and the position of the point scatterer, respectively, and θ is the prospective angle from the point scatterer to the receiving position of the probe. The reception time of the signal at each element from a point target follows the ideal delay line from the scatterer. The angular amplitude characteristics are the plots of the enveloped amplitude on the ideal delay line. Since an ultrasonic wave is specularly reflected on the surface of the reflector although it is scattered in all directions at the scatterer, the angular amplitude characteristics show different for the reflectors and scatterers.

Figure 2 shows a schematic diagram of the RF signal $y_{ks_im}(t)$, which is transmitted from the kth element of the linear probe, scattered by the scatterer s_i, and received by the mth element. The received signal $y_m(t)$ at the mth element is obtained by the sum of $\{y_{ks_im}(t)\}$ for all transmitted elements $\{k\}$ and all scatterers $\{s_i\}$. The received signal $y_{ks_im}(t)$ from the surface of a reflector is simulated by arranging the scatterers $\{s_i\}$ densely in line.

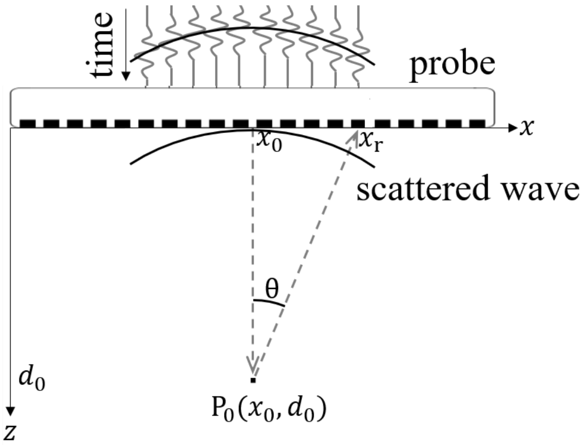

Fig. 1. Schematic diagram of transmission of a focused wave to a point scatterer.

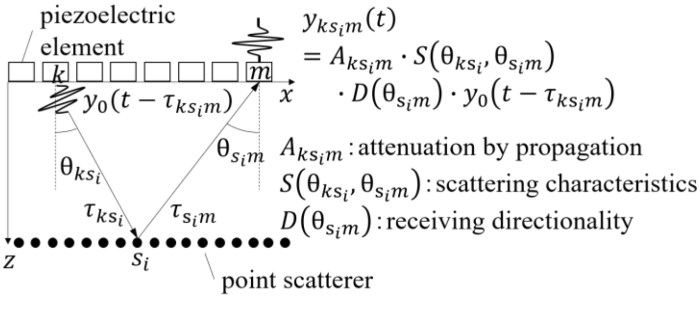

Fig. 2. Schematic diagram of the RF signal $y_{ks_im}(t)$.

3. Simulation experiments

A single-element data $y_{ks_im}(t)$ obtained from a molybdenum thin wire in a water tank was used to simulate the received signals. The reflector was simulated by point scatterers aligned with a 20-μm interval in line. The focal depth and the number of received elements were set to 30 mm and 96, respectively. The angular amplitude characteristics of reflection and scattering and the acoustic field distribution near the focal point were simulated and compared for the number of the transmitted elements of 96, 72, 48, 24, and 1.

4. Result and Discussion

Figure 3 shows the results of the angular amplitude characteristics of reflection and scattering. As the number of the transmitted elements decreased, the angular amplitude characteristics of the reflector significantly decreased at both ends, while those of the scatterer were almost unchanged.

Figure 4 shows the results of the acoustic field distribution in the lateral direction near the focal point. The lateral resolution decreased as the number of transmitting elements decreased because the width of the transmitted beam increased.

The root-mean-square differences (RMSDs) of the angular amplitude characteristics between reflection and scattering for the number of the transmitted elements of 96, 72, 48, 24, and 1 were 0.18, 0.29, 0.48, 0.70, and 0.52, respectively.

Since the RMSDs increased as the number of the transmitted elements decreased, we expect that the difference in the angular amplitude characteristics between reflection and scattering becomes more emphasized by decreasing the number of the transmitted elements. In the present study, the number of the transmitted elements of 24 was suitable for emphasizing the difference in angular amplitude characteristics between reflection and scattering because the maximum RMSD was obtained. However, the lateral resolution decreased as the number of the transmitted elements increased. There is a trade-off relationship between the difference in the angular amplitude characteristics of reflection and scattering and the lateral resolution.

For *in vivo* measurements, it is necessary to determine the suitable number of the transmitted elements, considering the signal-to-noise ratio and the effect on angular amplitude characteristics that the bone is not perfectly flat.

5. Conclusion

In this paper, we discussed the effects of the number of the transmitted elements on the angular amplitude characteristics. The trade-off relationship between the differences in the amplitude-angle characteristics of reflection and scattering and the lateral resolution was confirmed relating to the number of the transmitted elements. In future work, we will investigate the suitable number of the transmitted elements in *in vivo* experiments.

taiga.bando.t2@dc.tohoku.ac.jp

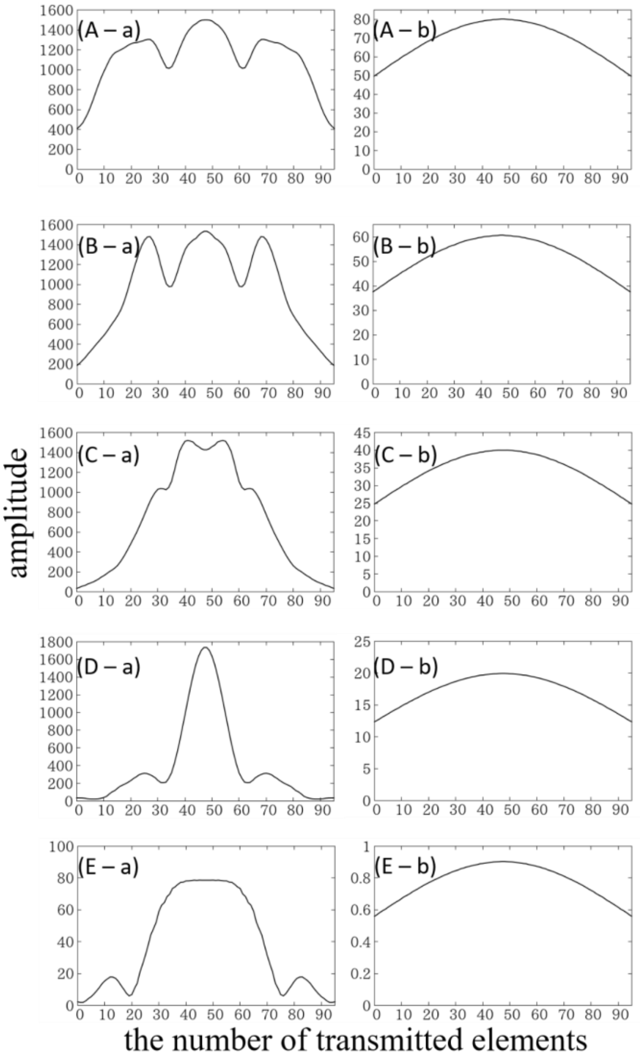

Fig. 3. Angular amplitude characteristics. (A), (B), (C), (D), (E): the numbers of the received element numbers are 96, 72, 48, 24, 1, respectively. (a) Reflector, (b) scatterer.

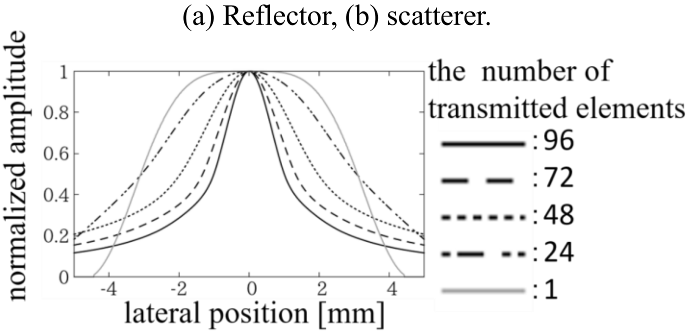

Fig. 4. Acoustic field distribution in the lateral direction near the focal point.

Acknowledgment

This work was partially supported by JSPS KAKENHI 20H02156.

References

1) T. Hashimoto, S. Mori, M. Arakawa, E. Onishi, M. Yamauchi, and H. Kanai: Jpn. J. Appl. Phys. **60** (2021) SDDE15.