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Ultrasonic Sensing Using the Split-and-merge Up-and-down Chirp Signal
分離統合アップ/ダウンチャープ信号を用いた空中超音波センシング

Katsuhiko Sakata[1†], Kan Okubo[1], Satoshi Akamine[1], Norio Tagawa[1], Masayuki Tanabe[2] ([1]Tokyo Met.Univ.：[2]Kumamoto Univ.)
坂田克彦 [1†]，大久保寛 [1]，赤嶺智史 [1]，田川憲男 [1]，田邉将之 [2]（[1]首都大学東京，[2]熊本大学）

1. Introduction

In recent years, with the development of computer technologies, a single processing method becomes important for the real-time ultrasonic sensing in air.

In the ultrasonic sensing, a higher signal-to -noise ratio (SNR) is also required for precise detection using ultrasound images. However, use of short pulse transmission cannot obtain high SNR images due to the atmospheric attenuation. To solve this problem, a pulse compression technique (PCT) is used. The PCT, while it is firstly used in radars, has been researched in the field of ultrasound imaging over the last decade for the requirement of a higher image quality.

Many types of codes have been investigated; we use a linear chirp in this study because of its robustness in terms of SNR and sensitivity to Doppler effect. Generally, the SNR of the PCT using a linear chirp is proportional to the product of the time duration T and the bandwidth B. Therefore, the time duration T should be increased for a higher SNR.

However, if an object is close to the transmitter and the echo signal is overlapped with the long coded transmitted signal, it is difficult to separate the echo signal from the superimposed signal due to limitation of adjusting the dynamic range of the analog-to-digital converter (1).

To overcome the problem, the authors had proposed and evaluated a new method based on a split-and-merge strategy (1). This method realized near- and far-field imaging processes simultaneously with higher SNRs.

In ultrasonic sensing in air, multi-transmitting and receiving also should be considered to obtain higher resolution and higher SNR images. In this study, we propose the signal processing technique based on a split-and-merge and up-and-down (SM-UD) chirp signal. Moreover, this method applies to the multi- transmitting and receiving system.

2. Aspect of split-and-merge(SM) chirp signal

Figure 1 shows the procedure of this method: The long coded signal is split into *N* signals; divided signals are transmitted and echo signals are received; the received signals are shifted and merged, and the merged signal is decoded with a matched filter that coincides with the before-split signal.

These processes make it possible to provide near- and far-field imaging with higher SNRs at the cost of frame rate, for the increase in the number of division decreases the frame rate.

Therefore, we improve this method by transmitting plural signals simultaneously whose frequency power spectra are separated from each other.

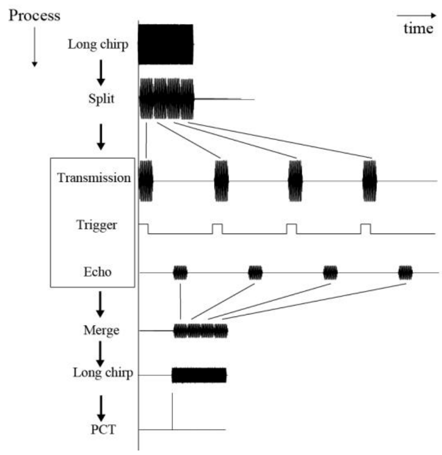

Fig.1 PCT based on a split-and-merge (SM) strategy using chirp signal.

3. Multi- transmitting up-and-down (UD) chirp signal

Figure 2 shows the procedure of Multi-transmitting UD chirp signal: We combine the up and down chirp signals to reduce the mutual coupling. For simplicity, we assume that the bandwidth of chirp signal is 20kHz (30kHz to 50kHz) and the original signal is split into two signals (i.e., S_{11}:30-40kHz; S_{12}:40-50kHz; S_{21}:50-40kHz; S_{22}:40-30kHz). Two transmitters are also assumed to be used.

Next, we receive SM-UD echo signals with superimposition as shown in Fig. 3. Received signals can be compressed by PCT as Fig. 4. Moreover, Fig.5 shows the strategy of merge and compression using the received multi- signals.

In Fig. 5, the signal compressed with the merged signal is similar to the signal compressed with the original signal (See Fig. 6). According to Fig.4, we can carry out PCT to chirp signal with bandwidth of 10 kHz. Consequently, the compressed signal has lower SNR than that of the merged signal.

Additionally, as Fig. 7, we can realize the quasi-high frame rate imaging by means of the continuously merge technique.

4. Conclusions

In our experiments, we suggest and evaluate the method based on a SM-UD chirp signal and multi- transmitting and receiving for the ultrasonic sensing in air. We confirm the feasibility of near- and far-field imaging by the proposed method. Additionally, we apply SM-UD signals to multi-receiving.

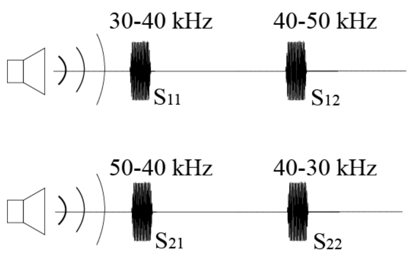

Fig. 2 Multi- transmitting split UD chirp signal.

Fig. 3 Receiving SM-UD echo signals.

References

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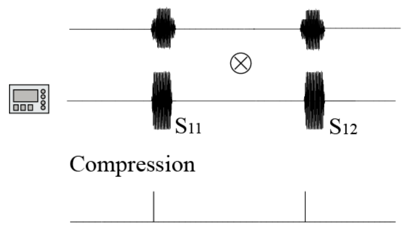

Fig. 4 Compression of non-merged chirp signal.

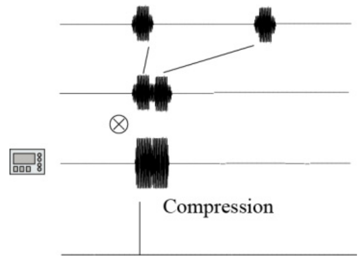

Fig. 5 Compression of merged chirp signal.

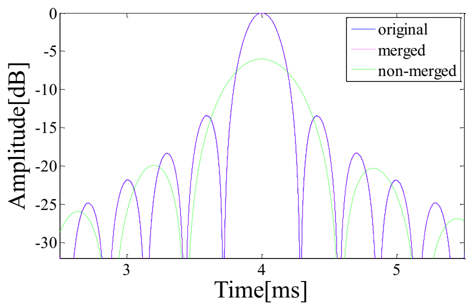

Fig.4 Comparison of compression waveform

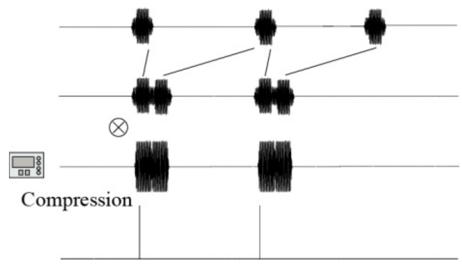

Fig. 5 Strategy for quasi-high frame rate imaging.