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論 文 要 旨

THESIS SUMMARY

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学生氏名： Student's Name	Khanistha Leetang	指導教員（主）： Academic Supervisor(main)	蜂屋弘之
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The pulse-echo method is a typical method of ultrasonic distance measurement based on pulse transmission and time-of-flight (TOF) determination. The pulse width corresponds to the distance resolution. Therefore, a short pulse is applied to obtain the high distance resolution. Moreover, to improve the signal-to-noise ratio (SNR), pulse compression is often employed for the pulse-echo method. In pulse compression, a frequency-swept signal or a pseudo-random modulated signal is transmitted, then the received signal is correlated with the reference (transmitted) signal. When the received signal and the reference signal match, the high correlation value (compressed pulse) appears in the cross-correlation function. The temporal resolution of the distance measurement is the time required for a single measurement. The short pulse-repetition time in the pulse-echo method represents the high temporal resolution. In that case, however, the long-distance cannot be measured because the pulse-repetition time corresponds to the maximum limit of the measurable TOF (distance). Therefore, there is a trade-off relationship between the temporal resolution and the measurable distance in the pulse-echo method.

In this thesis, the alternate transmission of different coded signals in pulse compression is proposed to extend the measurable distance of the pulse-echo method without the degradation of the temporal resolution. In the proposed method, two different coded signals are alternatively and continually transmitted, then the received signal is correlated with each reference signal to obtain each cross-correlation function. In each cross-correlation function, the compressed pulses alternatively appear, and the interval that corresponds to the pulse-repetition time is extended by double of that in the one-code transmission. Therefore, the measurable distance can be extended with the same temporal resolution as the one-code transmission by the alternate distance measurement from each cross-correlation function. However, the noise by interference between different coded signals occurs between the compressed pulses. If the noise, which is defined as the noise between peaks (NBP), is larger than the compressed pulses, actual distance cannot be measured, and the SNR can be degraded. Therefore, the combination of different coded signals with low NBP is searched, and the suitable combinations are determined. The linear-frequency-modulated (LFM) signal combination and M-sequence signal combination were studied in this thesis. In the case of the LFM signal, the combination of the up-chirp and the down-chirp can be employed to the alternate transmission. NBPs were estimated on the parameters, the center frequency of 35 kHz, the sweep bands from 10 kHz to 30 kHz, the signal lengths from 3.6 to 43.8 ms. In the case of M-sequence, a continuous signal is alternatively modulated by one cycle of each M-sequence to be transmitted signal. Then, the received signal is correlated with each reference signal, which corresponds to each M-sequence. There are several code combinations in the M-sequence. Therefore, the peak interval in each cross-correlation function can be extended many times. Since NBP differs greatly depending on the combination of M-sequence codes, a combination of codes that reduces NBP was examined.

In the typical modulation, a few sine waves or their inverse waves are assigned to 1 or -1 (integer modulation). The modulation in which the initial phase of sine waves is conjugately shifted by 1 or -1 is also investigated (complex modulation). In the proposed modulation, initial phases of different coded signals are shifted in the complex modulation. In the cross-correlation function, the alternate transmission of phase-shifted complex M-sequences can be applied to suppress NBP. Therefore, the initial phase of different coded signals is shifted in the complex modulation. The variations of maximum and average amplitudes of truncation and truncated interference noises, acquired from the phase differences, are

evaluated.

The maximum noise amplitude of NBP in the LFM signal is decreased at the long length of the signal. On the other hand, the maximum amplitude of NBP in the M-sequence signal is decreased in the high order M-sequences. NBP was compared for the combination of LFM and M sequence under the same signal length condition. By examining many combinations of M-sequence signals, we were able to understand the characteristics of the combinations in which the NBP increases and the combinations in which the NBP decreases. In addition to a combination with a small interference noise called a preferred pair, there is a combination that can realize the smallest NBP among symmetry pairs in which the order of the code sequences is reversed. The combination of LFM is advantageous when the system bandwidth is wide, but the expansion of the measurement distance is doubled. When the system bandwidth is not so wide, the combination of complex modulated M-sequence signals will enable lower NBP and more than double the measurement distance.

Experiments were conducted to confirm the results of the simulation. The experimental results agree well with the simulation results, and it was clarified that the measurement distance of the pulse-echo method can be expanded by the alternate transmission of different codes.