Study about Combination Types of M-sequences in Alternate Transmission of Different Codes for Pulse Compression

Khanistha Leetang[1†], Shinnosuke Hirata[2] and Hiroyuki Hachiya[3] (Tokyo Tech.)

1. Introduction

The ultrasonic pulse echo method is a famous technique to measure the distance of objects by time of flight of the reflected echo signal. The distance resolution is obtained from the pulse width, that is the M-sequence, due to improvement of the echo's SNR[1]. Ordinarily, the n-th order of M-sequence can be used to generate the 2^n-1 binary words[2]. Therefore, the alternate transmission of two different codes can improve the resolution of distance measurement. There is a trade-off between the time resolution and the measurable deapth. In the M-sequence pulse compression, the length of an M-sequence code corresponds to the pulse-repetition time. Moreover, the noise characteristics of combination types are different depending on the pattern pairs. In the high order of M-sequence have a lot of noise characteristics to analyze.

In this research, a relationship among combination types of M-sequence in alternate transmission of different codes for pulse compression is described.

2. Combination types in alternate transmission of different M-sequence code

The M-sequence is a pseudo-random binary code which can be generated from a linear feedback shift register (LFSR). The modulated signal is continuously cyclical transmission in pulse compression. Then, the received signal is correlated with the reference signal corresponding to the transmitted signal. When the code of the received signal and the reference signal match, a high correlation value is obtained in the cross-correlation function.

In case of pulse compression, the measurable depth can be extended by the increase of the M-sequence code. Provided that the initial position numbers and positions of pattern tap in the LFSR change, a different M-sequence can be generated. Correlation values between different codes are lower than the correlation peak. Therefore, the different codes of A and B are alternately to transmit signal as illustrated in **Fig. 1**. In addition, the length of correlation peaks in the cross-correlation function of A and B can improve the distance resolution which means indicated measurable depth in double time of resolution.

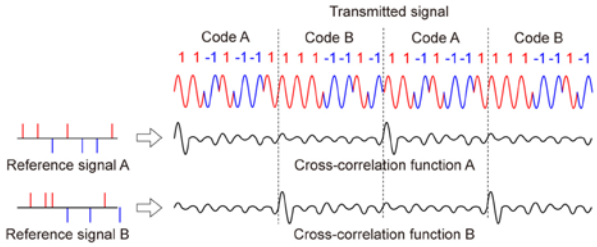


Fig. 1 Cross-correlation function in case of alternate transmission of two different codes.

The combination types consist of symmetry pairs, preferred pairs and other pairs except multiples of 4th order which has been 4 combination types that consist symmetry pairs high-interference pairs quasi-preferred pairs and other pairs. In this research, the symmetry pairs are inverse pattern combinations. The preferred pairs and high-interference pairs are cross correlation results that have a 3 values and 4 values of peak amplitude respectively.

3. Evaluation of characteristics of each combination

In the extended M-sequence codes by alternate transmission of different codes, the cross-correlation results are obtained from the truncation noise and interference noise around the correlation peaks. The SNR of correlation peaks is degraded by selecting M-sequence pattern of different codes appropriately. The truncation noise and interference noise are divergent depending on the initial values and the combination types. Therefore, the maximum peak amplitude of absolute noise (MP) and the standard deviation of noise (STD) are evaluated in all patterns of n-th order M-sequence. At the high order has a lot of noise characteristics to analysis. Therefore, a relationship among combination types of M-sequence in alternate transmission of different codes can be applied to reduce the amount of pattern to analyze the best pattern in each order.

In this report, the result of 8th order M-sequence is indicated as an example. In the 8th order M-sequence, the amount of tap patterns are 16 patterns and the combinations of tap pattern

leetang@us.sc.e.titech.ac.jp, shin@sc.e.titech.ac.jp, hachiya@sc.e.titech.ac.jp

Table 1 The amount of combination tap pattern of 8th order M-sequence to analyze

Combination types	Numbers of combination patterns
Symmetry pairs	8
Preferred pairs	8
Quasi-preferred pairs	16
Other pairs	88

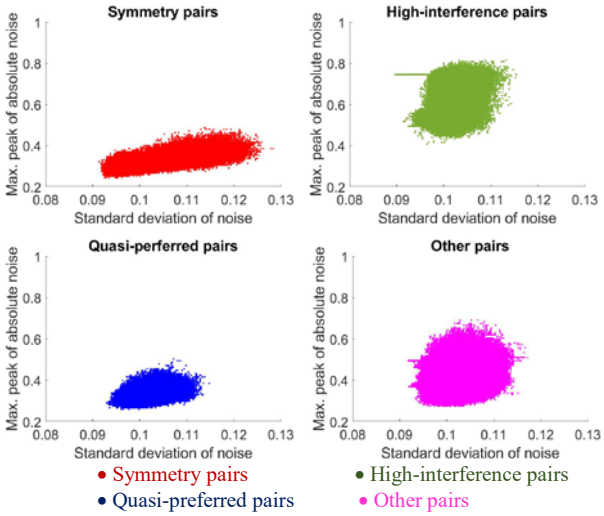


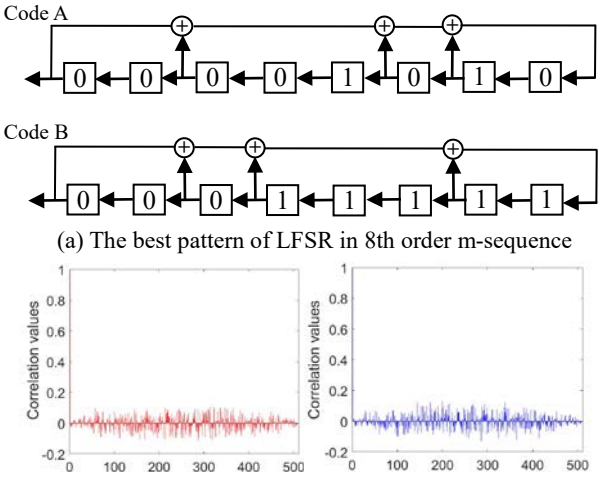
Fig. 2 The combination type characteristics of MPs and STDs of N_a+N_b in case of 8th order M-sequence.

M-sequence are 120 patterns which consist of 4 combination types as illustrated in **Table 1**. Moreover, the amount of initial values is 2^8-1. Hence, all the patterns to be analyzed by MATLAB program are 7803000 patterns. The combination type characteristics of MPs and STDs in N_a+N_b in case of the 8th order M-sequence is illustrated in **Fig. 2**. Moreover, the minimum values of MPs and STDs with lowest MPs in 8th order M-sequence is symmetry pairs values as illustrated in **Table 2**. The results of N_a+N_b can be calculated from the MPs and STDs of N_a and N_b. In this results, degradation of SNR can be improved by selecting initial values and combination patterns appropriately.

In case of 8th order can be classified the results of each combination type distinctly. The high-interference pairs are terribly due to be the higher peak amplitude values. On the other hand, the symmetry combination type is better. For the best pattern of M-sequence can be selected by minimum values of MPs and STDs in N_a+N_b. In addition, the best patterns in each order can be selected from symmetry pairs of combination types. The optimal M-sequence codes and cross-correlation function of 8th order M-sequence is illustrated in Fig. 3. The left hand and right hand of figure 3(b) are illustrated the cross-correlation

Table 2 Minimum values of MPs and STDs with lowest MPs in case of 8th order M-sequence

	MP	STD	Combination type
N_a+N_b	0.2431	0.0925	Symmetry pairs
N_a+N_b	0.4078	0.0965	High-interference pairs
N_a+N_b	0.2588	0.0961	Quasi-preferred pairs
N_a+N_b	0.2745	0.0960	Other pairs



(a) The best pattern of LFSR in 8th order m-sequence

(b) The cross-correlation function A and B

Fig. 3 The optimal M-sequence codes and cross-correlation functions of 8th order M-sequence.

results with reference code A and code B respectively.

4. Conclusion

A relationship among combination types of M-sequence in alternate transmission of different codes for pulse compression is proposed. The SNR of correlation peaks is degraded by selecting initial values and combination patterns appropriately. In case the MPs of N_a+N_b is minimum and the STDs of N_a+N_b is lower as possible, the alternate transmission of M-sequence code can be improved the measurable depth in double time of distance resolution. A relationship of combination types can be indicated the noise characteristics of M-sequence signal. Moreover, the noise characteristics of combination types have been different character significantly. However, the best values in finite length of M-sequence is a part of symmetry pairs habitually. Therefore, the patterns of symmetry pairs can be analyzed to find the best m-sequence.

References

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