3Pa6-4

The source identification using multiple linear chirp signals for a multisource continuous active sonar

複数の線形チャープ信号を用いた多音源連続波アクティブソーナー用音源識別

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1. Introduction

Pulsed continuous waves (PCW) is used as transmitted signals of traditional active sonars. Using PCW, the detection of underwater targets is discrete because PCW is not transmitted until the echo of previous sweep from the target is received. For that reason, sonar operators possibly lost the targets for each sweeps.

To solve this probrem, continuous active sonars (CAS) have been researched and developped.[1)] The method of CAS uses frequency moduration-continuous wave (FM-CW) which is also used for radar. Among FM-CWs, a linear frequency modulated wave (LFM) is mainly used as transmitted signals.

On the other hand, multi static sonar (MSS), using PCW, has been developped to increase detection volume.[2)] So if CAS is adapted to MSS, the probability of detection of underwater targets can be increaced. However, if LFM is used as transmitted signal for MSS, it is difficult to identify the echoes of transmitted signals because of crosstalk between them.

One of scheme to identify sources is to use coded signals as transmitted signals.[3)] In this paper, we propose using multiple linear chirp signals (MLC) for a multi source FM-CW CAS to identify sourses. This scheme can be applied easly to traditional FM-CW CAS using LFM.

2. Signal processing

In this section, the difference between FM-CW signal processing using LFM and MLC is explained.

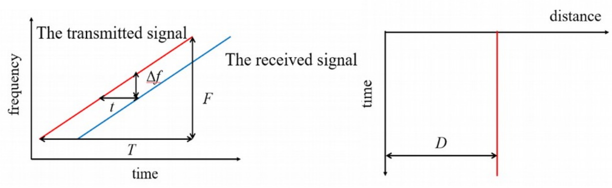
Fig.1 shows images of (a) a transmitted signal (the red line) and the received signal (the blue line) and (b) the time-to-distance display as output by FM-CW using LFM with one source and a receiver. First, the received signal is converted into a time-to-frequency domain by fast Fourier transform (FFT). After that, the distance to the target D (= $cT\Delta f / 2F$) is determined by solving the simultaneous equations of t and Δf where t is the time from the begining of transmission signals to the first echo arrival and Δf is the difference of frequencies of transmitted signal and received signal at the same time: the expression ($t = 2D / c$) among t, D and the underwater sound speed c and the similar relational expression ($\Delta f / t = F / T$) among Δf, t, the bandwidth of LFM F and the period of one sweep T.

Next, we assume an example of crosstalk echoes with multiple sources. In **Fig. 2**, the difference in line type represents the difference in sources. D_{ij} indicates the calculated distance to the target using the transmitted signal from s_i and received signal from s_j. When $i = j$, D_{ij} (D_{ii}) is the correct distance to the target. On the other hand, when $i \neq j$, D_{ij} is the incorrect distance to the target, but there is no way to determine the source from received signals.

Fig. 3 shows (a) proposed transmitted signal and received signal and (b) the time-to-distance display as output by FM-CW processing using MLC. First, transmitted signal is reputation of MLC block as continuous wave. Next, the correlation $R(t)$ of the received signal and the MLC block is calculated to obtain t. Taking this step, echoes from other sources can be removed. Therefore, the correct D is calculated by time-distance relational expression ($t = 2D / c$).

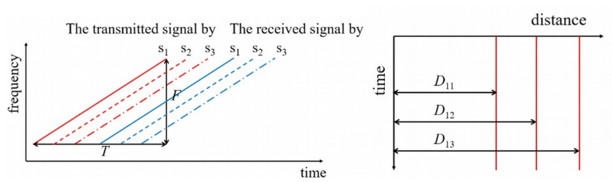
3. Simulation

We confirmed the isolation of multiple sources from a received signal. Table. 1 shows the simulation condition. The flow of the simulation is below. **Fig. 4** shows transmitted MLC signals by each source. The received signal is a summation of these transmitted signals with noise. Here, in order to evaluate the ability of identification under the most difficult circumstance, the echoes by each transmitted signals are received at the same time in this simulation. **Fig. 5** shows the generated received signal. Then, the correlation between the received signal and each transmitted signal is calculated. **Fig. 6** shows correlation results between the received signal and transmitted signals of each source. In each case, correlation have one peak. This means that sources of transmitted signals can be identified.



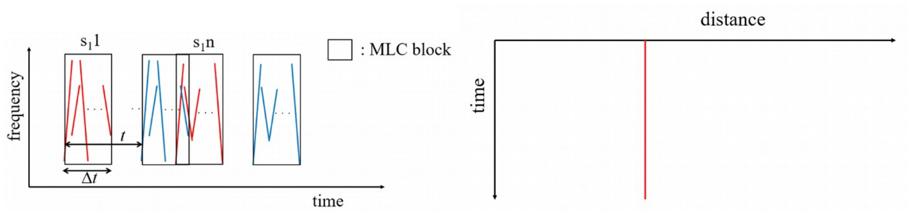
(a) (b)

Fig. 1 Images of (a) a transmitted signal (the red line) and the received signal (the blue line) and (b) the time-to-distance display as output by FM-CW using LFM with one source and a receiver



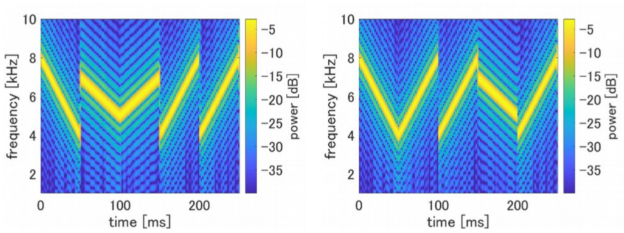
(a) (b)

Fig. 2 The image of (a) transmitted signal and received signals and (b) the time-to-distance display as output by FM-CW processing using LFM with three sources and one receiver



(a) (b)

Fig. 3 (a) proposed transmitted signal and received signal and (b) the time-to-distance display as output by FM-CW processing using MLC



(a) s1 (b) s2 (c) s3

Fig. 4 Transmitted signals by each source

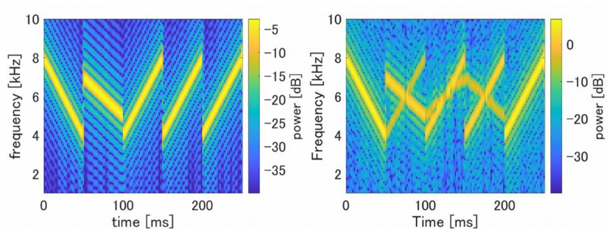
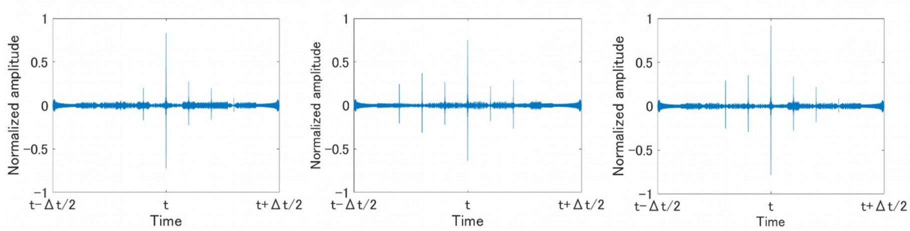


Fig. 5 Received signal



(a) s_1 (b) s_2 (c) s_3

Fig. 6 Correlations between the received signal and transmitted signals of each source

Table. 1 The simulation condition

The number of sources	3
Received signal to noise ratio	10 dB
The number of slopes of linear chirps for MLC	4

4. Conclusion

In this study, we proposed using MLC for a multi sources FM-CW and simulated the signal processing from generating a block of MLC to correlating. And then, we confirmed the identification sources.

Next, we will evaluate the number of sources and slope variation in MLC within the limited bandwidth in real ocean environment. We also plan experiment in a water tank.

References

1. P.C. Hines, "Experimental comparison of continuous active and pulsed active sonars in littoral waters," In Proceedings of Underwater Acoustics 2013, Corfu, Greece, June 2013.
2. Daun, M. & Ehlers, F. Tracking Algorithms for Multistatic Sonar Systems. EURASIP Adv. Signal Process. **2010**, (2010) 461538.
3. K. Yamanaka, S. Hirata and H. Hachiya: Jpn. J. Appl. Phys. **55** (2016) 07KC09.