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Influence of Doppler shift in ultrasonic distance and velocity measurement using M-sequence modulated signals

M 系列変調信号を用いた距離速度計測における
ドップラーシフトの影響

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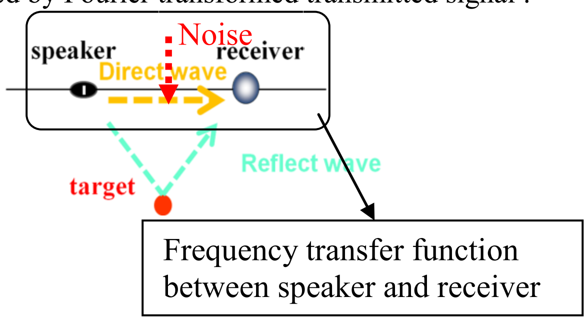
1. Introduction

Acoustic sensing in air is now mainly used for 1 dimensional short range distance measurement, It is difficult to measure long range too much environmental noises and attenuation in air. Using correlation processing and M-sequence modulated signals , SNR of echo can be improved. However, if carrier frequency changed by Doppler shift, correlation value of M-sequence modulated signal is decreased. Therefore, SNR can not be improved. In this research, we considered the influence to the M-sequence signal of Doppler shift.

2. Sound speed detection using frequency transfer function

Doppler shift frequency has a close relation to sound speed and the speed of target, so it is necessary to know precision sound speed. Sound speed also can be detected by temperature, However in order to know sound speed in actual experimental system, we measured sound speed using frequency transfer function. Fig.1 is the simulative composition of experimental system. We calculated frequency transfer function of this system from transmitted signal and received signal fig.2. Frequency transfer function can be calculated from Fourier transformed received signal by divided by Fourier transformed transmitted signal .



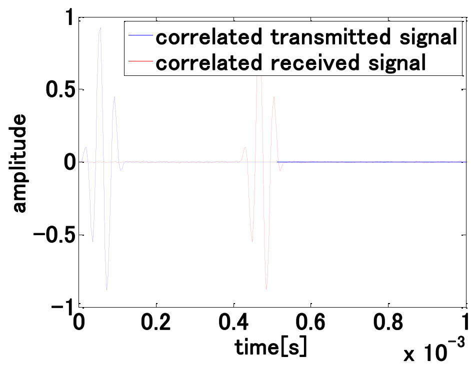


Fig.2 Correlated transmitted signal and correlated received signal

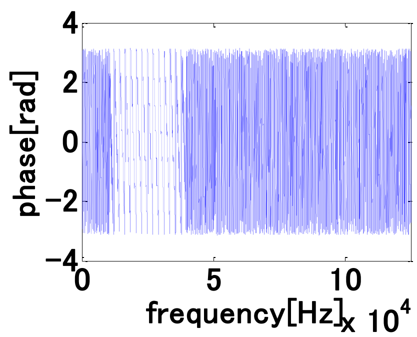


Fig.3 Phase of frequency transfer function

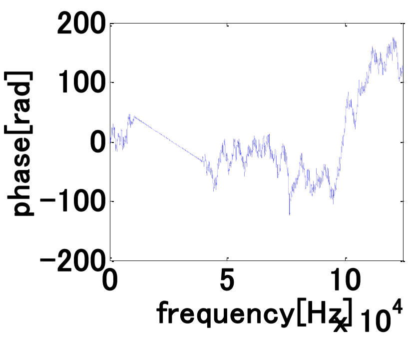
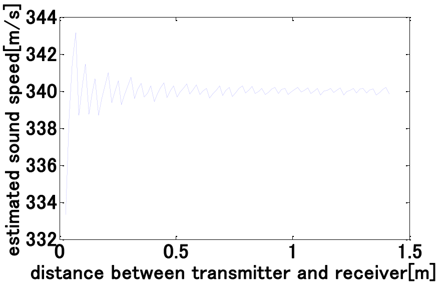


Fig.4 Phase of frequency transfer function

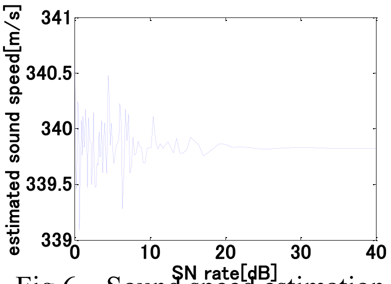
The relation between sound speed and frequency transfer function fig.3 is expressed by following equation.

$$\phi = 2\pi f \frac{d}{c}$$

Φ is the phase of frequency transfer function, f is carrier frequency, d is the distance between speaker and receiver and c is the sound speed. sound speed can be detected from angle of phase of unwrapped frequency transfer function fig.4.We changed the distance between transmitter and receiver fig.5(a) and also changed SN rate fig.5(b), then measured sound speed.



(a)



(b)

Fig.6 Sound speed estimation.
(a) : Changing distance between speaker and receiver.
(b) : Changing SN rate

In this simulation, we set sound speed 340 m/s. Estimated sound speed has about 0.2 m/s error at the best condition.

3. Influence of Doppler effect to M-sequence modulated signals

M-sequence modulated signal's correlativity is easily lost when Doppler shift is caused and carrier frequency is changed. We investigate M-sequence modulated signal's correlation value when carrier frequency is changed in the following settings fig.7.

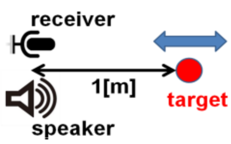


Fig.7 simulation settings

Target is moving right or left at same speed. Target cause Doppler effect and change carrier frequency $\pm 0.1\%$. In normal condition (Doppler shift is not caused).Carrier frequency is 25 kHz , sampling frequency is 250kHz , and using 8~10th order M-sequence signals. Correlation processing using M-sequence signal raise SN rate to $\sqrt{2^n - 1}$. In which n is the order of M-sequence modulated signal. It is advantageous to use high order M-sequence to raise SN rate. But according to the simulation results fig.8(a), high order M-sequence correlation value falls more easily than low order M-sequence.Fig.8(b) is the maximum value plot of the M-sequence correlation at difference frequency. M-sequence correlation value takes half of the maximum when frequency changed about 0.62 time the frequency of signal length shifting by 1 wave in every order.

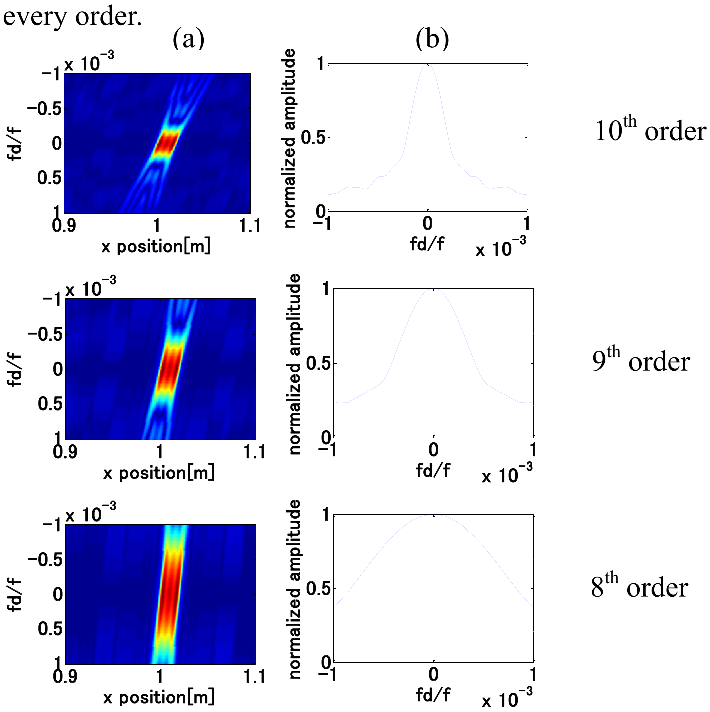


Fig.8 M-sequence correlation value

5. Conclusions and future

In this research, we suppose the way of sound speed detection from frequency transfer function and investigate the influence of Doppler shift to M-sequence signal.Future, we aim to detect target's speed and position using multiple frequency correlation machine.

References

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