3J2-1

Basic Study on Self-focusing Effect of Polarization Inverted Transmitter with Up-chirp Signal Driving for Sub-aperture Array

分極反転型配列送波器用いた周波数変調及び開口分割による集束効果の基礎的検討

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1. Introduction

In our previous study, we developed an acoustic camera (4-DWISS) with viewing range of longer than 5m.[1] Present study is for a range shorter than the before. New target system will look around working robot arms on a ROV whose hands are researching and sampling high stiffness subsea materials, in this case Cobalt-rich crust. [2] Therefore high resolution in near field on our new system is required.

In this report, authors proposed an advanced Frequency-controlled beam steering method with beam scanning by polarization inverted array for beam focusing by up-chirp signal driving, and improved resolution by sub-aperture array configuration.

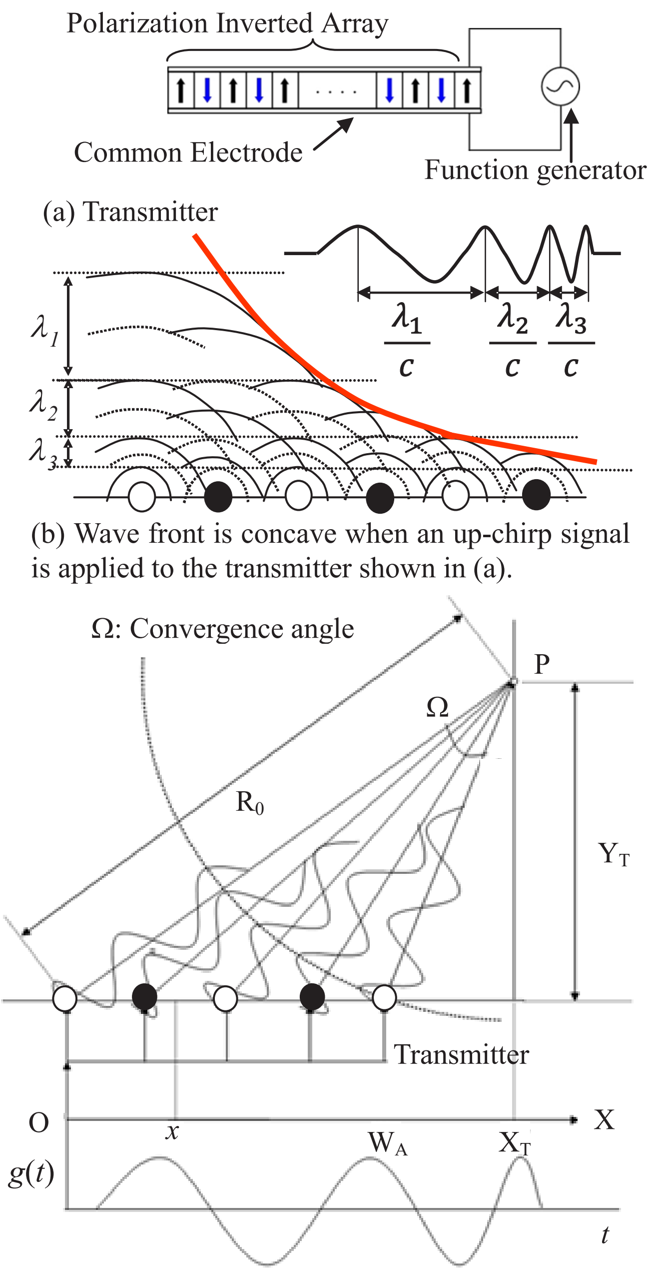
2. Theory

The theory is based on Frequency- controlled beam steering method [3] whose transmitter, shown in Fig. 1 (a), has a bank of elements configured to inverse the polarization axis of the adjacent of element, the electrodes are common. When an AC signal frequency '*f*' drives for the array, the sound will be driven in the θ direction. Since θ is determined by Eq. (1), where λ and d are wave length and element pitch, respectively, it depends on the frequency. In other words, using an LMF pulse you can achieve beam steering with single driving signal.

$$\theta = \sin^{-1}\left(\frac{\lambda}{2d}\right) \qquad (1)$$

Here, when an up-chirp signal is applied to the transmitter, the wave front is concave (Fig. 1 (b)). If an up-chirp signal g(t) is selected Eq. (2), where k_0 and c are wavenumber along the array (=π/ε) and sound speed, respectively, the wave front is exactly focused on the point P (Fig. 1 (c)).

$$g(t) = \sin(k_0 x) = \sin\left[k_0\left[X_T - \sqrt{(R_0 - ct)^2 - {Y_T}^2}\right]\right] \qquad (2)$$



(a) Transmitter

(b) Wave front is concave when an up-chirp signal is applied to the transmitter shown in (a).

(c) Wave front focused on point P when up-chirp signal $g(t)$ is applied to the transmitter shown in (a).

Fig. 1 Wave front is focused on point P by using Frequency- controlled beam steering method.

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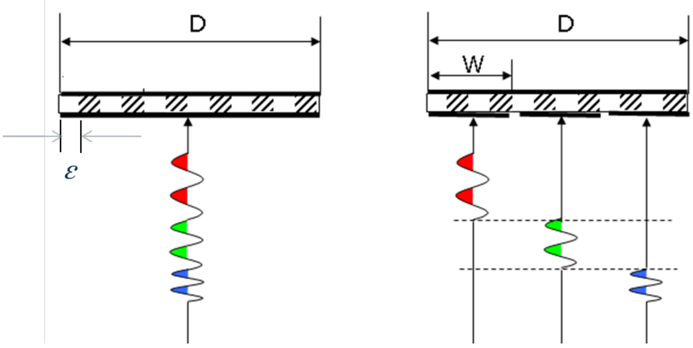
Advanced method is in order to improve the performance of this basic one. Total aperture array is divided into several sub-aperture arrays (Fig. 2). And the up-chirp signal is also divided into the same number as the sub-aperture and driven for corresponding individual sub-aperture.



(a) Total aperture array (b) Sub-aperture array

Fig. 2 Sub-aperture array of inverted polarization transmitter and up-chirp signals.

3. Numerical Calculations

Numerical results of the new method with total, two sub-apertures, and three sub-apertures array with the same total aperture width condition, which were shown in upper pictures of Fig. 3. All figures were assigned intensity to represent normalized sound pressure of each maximum value. For comparison, measured results in lower pictures of the same figure. In this test experiment, to get sub- aperture array experimentally, the total aperture receiver array was masked by some piece of rubbers in checkered pattern. Numerical results show good agreement with measured results. Further increasing the number of sub aperture division narrows the area of convergence.

Additionally, calculation of spatial resolving power of this method and examination of diffraction limit from Fig.3 were already done. Author will show you them in my presentation.

4. Conclusion

A focusing method, based on Frequency-controlled beam steering method, by up-chirp signal for polarization inverting array is proposed. Spatial resolving power of the method is analytically and experimentally evaluated. By this experiment, it is confirmed that the proposed method provides almost comparable spatial resolving power to the diffraction limit in all spatial directions.

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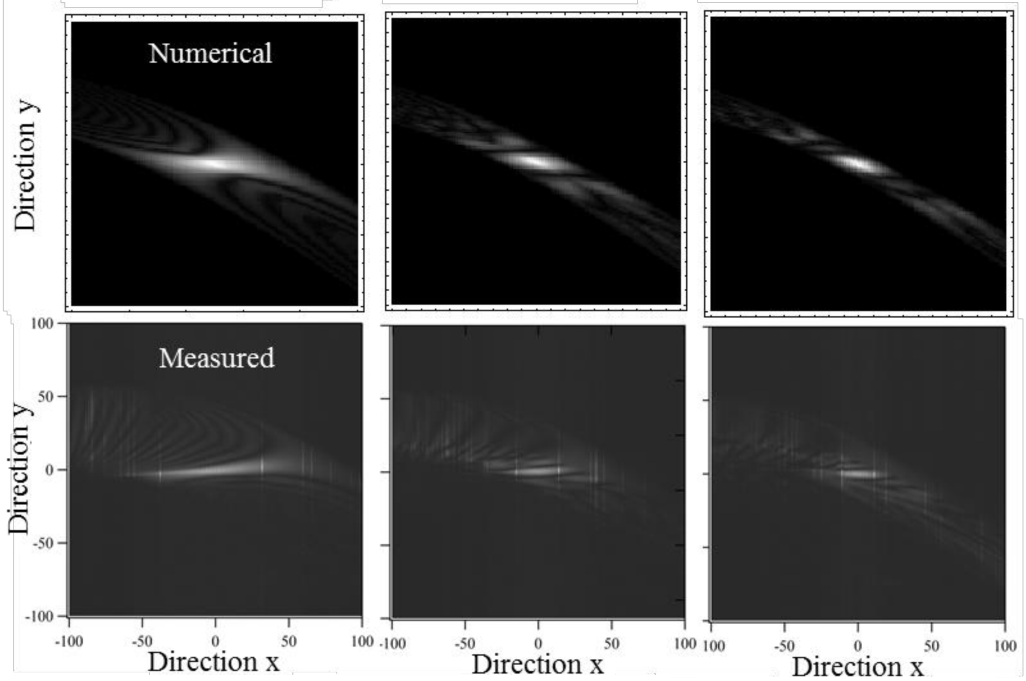

(a) Total array (b) 2 Sub-array (c) 3 Sub-array

Fig. 3 Spatial resolving power of the method.