

Measurement of a fix point displacement on seafloor by using phase conjugation of underwater acoustic wave

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A simulation was carried out on the measurement of a fixed point displacement on seafloor by using phase conjugation of underwater acoustic wave. Phase conjugation is a process known well in the field of optics and is utilized for variety of applications, such as Laser resonators, holography and so on. The primary feature of the phase conjugation is cancellation of propagation distortion. When we consider a phase conjugate mirror which generates phase conjugate wave and assume that the spatial property of the propagating medium is stationary over the time needed for a round trip, a phase conjugate wave reflected at that mirror propagates opposite direction of the original incident wave showing time-reversed signature. Furthermore, a reflected phase conjugate wave of a spherical wave transmitted from a point source is a spherical wave converging to the original source point. Because of this feature, the phase conjugate mirror is also called as a time-reversal mirror. Recently these phenomena of phase conjugation are also demonstrated experimentally for underwater acoustic waves, such as in Kuperman et al. (1998). In underwater acoustics, a source-receiver transponder on seafloor is replaced for an original source and a vertical source-receiver transducer array is replaced for a phase conjugate mirror. The waveform of an acoustic pulse transmitted from the source transponder is distorted when it received at the vertical transducer array, because the pulse is reflected by sea surface and seafloor and also refracted by the thermal structure of ocean. The pulse is received at each element of the vertical array, time reversed and retransmitted. The retransmitted pulses converge to the original source transponder in an original shape interfering one another. This process has some interesting feature; it is not affected by frequency of an acoustic wave and property of the medium, such as water depth, topography of seafloor and thermal structure of seawater, and so on, as far as the property is stable enough for a round trip time. However, the phenomena of convergence of retransmitted wave do not produce some useful value by itself.

We proposed a method of transferring phase information from the array to the source. At the array, phase-shift modification is performed to the received pulses in the way relation of phase conjugation is not broken after they are time reversed. And then these phase-shifted signals are transmitted from each element of the array. The shapes of pulses converged at the source are the same as the original. However, phases of their carrier signal are shifted according to the amount performed at the array. Phase modification of this method is continuous and linear ranging from -2π to $+2\pi$. By this method, phase information of the source can be controlled by the array.

Usually, at the source the phase of a phase conjugate wave is same to the originally transmitted wave. But in long term, phase conjugation can be broken because of the change of propagating condition which includes water depth, topography, temperature profile of seawater and displacement of the source. The collapse of phase conjugation can be detected by observing the acoustic field at the source. Acoustic amplitude structure at the source is known to be less affected by propagating condition. On the other hand, acoustic phase structure is known to change linearly. In our simulation we considered the displacement of the source as the changing element of propagating condition. As for other conditions, water depth is 100 m and distance between the array and the source is 5 km. Transmitting wave from the source is ten-cycle tone burst wave with carrier frequency of 500 Hz. Although acoustic phase change of received wave at the source generated by the source displacement is very slight, it can be detected by phase interference method for successive wave whose phase are shifted at the array, and the amount of the displacement can be measured.