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Study on Directionality Control by M-sequence Encoding Ultrasonic Transducer.
M 系列符号化探触子による指向性制御に関する研究

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1. Introduction

Nondestructive testing is carried out to keep the safety and reliability of structures and products, and ultrasonic testing is especially used widely. In ultrasonic testing, in order to raise the ability in flaw detection, it is necessary to use an ultrasonic probe with a broadband and high sensitivity. The pulse compression techniques using M-sequence and LFM (linear frequency modulation) wave have been reported as a method improving the SN ratio and resolution in ultrasonic testing [1]. However, in order to generate M-sequence or LFM wave, a special hardware like an arbitrary waveform generator is needed, and a power amplifier have to be also prepared.

In this study, an ultrasonic transducer that was able to generate M-sequence without such special equipments and to perform a pulse compression by a general pulsar and PC was developed. It aimed to obtain wave motion information in cross section selectively without scanning and to control the directivity by the pulse compression performance of M-sequence encoding ultrasonic transducer.

2. Fabrication of M-sequence pulse compression transducer

We have been studying about an encoding aperture technique which was possible to distinguish ultrasonic echoes spatially by applying a broad-band piezoelectric polymer film. And it has been demonstrated that a developed encoding array transducer was able to image a cross-section by one-time transmission [2]. In this study, we proposed an ultrasonic transducer which was possible to transmit M-sequence pulse train by stacking a broad-band piezoelectric polymer film in which the polarization direction was controlled according to an M-sequence. It was expected that ultrasonic testing can be carried out with the same effect as a general pulse compression method by using such ultrasonic transducer. Moreover, this proposed method did not need a special hardware like an arbitrary waveform generator. We call such transducer a pulse compression ultrasonic transducer.

Pulse compression ultrasonic transducers using an M-sequence with several bits length have been fabricated. The structure of the transducer with 3 bits length M-sequence is shown in Fig. 1. The polar characteristic of transmitted wave depends on the direction of dipole in a piezoelectric polymer film. Therefore, a pulse train can be transmitted when a piezoelectric film is stacked inserting the delay layer with a suitable thickness. In the fabricated transducer, PVDF film of 52 μm in thickness was used in order to transmit an ultrasonic wave of 10 MHz, and polyimide film of 175 μm in thickness was used as a delay layer. A transmitted wave in water by this transducer is shown in Fig. 2. It was confirmed that a pulse train

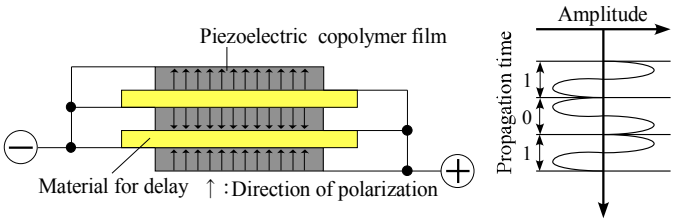


Fig.1 Generation principle of pulse train encoded by M-sequence.

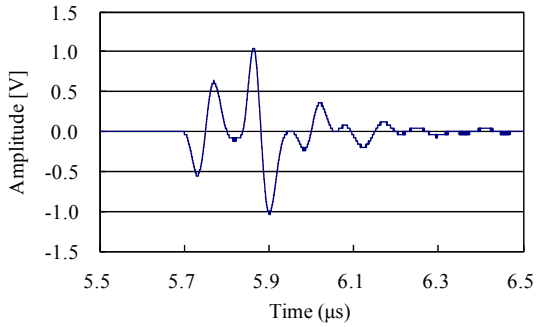


Fig.2 M-sequence pulse train generated by the developed ultrasonic transducer.

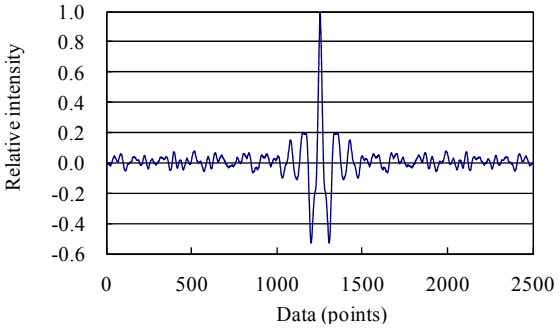
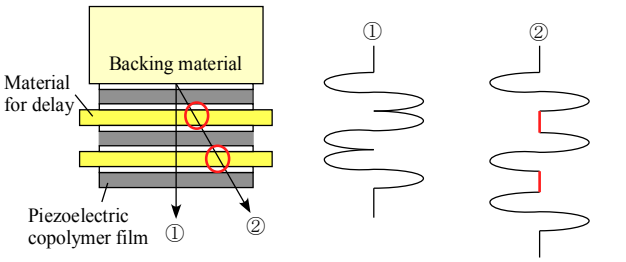


Fig.3 Pulse compression waveform by the developed ultrasonic transducer.

according to the M-sequence of 3 bits length was transmitted. And the performance of the transducers was evaluated by autocorrelation of received wave by the transducers. An example of pulse compression waves in water is shown in Fig. 3.

3. Control of directivity in M-sequence encoding ultrasonic transducer

The directivity control with M-sequence encoding ultrasonic transducer is explained as follows. In M-sequence encoding ultrasonic transducer, the delay material with a suitable thickness was set between each piezoelectric polymer film. The propagation time in the delay layer varies according to the propagation route in the transducer as shown in Fig. 4. Therefore, M-sequence encoding transducer could distinguish received waveform according to the detecting direction. In other words, it was thought that the directivity control would become possible if the angle dependence of M-sequence pulse train was confirmed.



(a) Direction of propagation (b) Waveform of ① (c) Waveform of ②

Fig.4 Directivity of M-sequence pulse train.

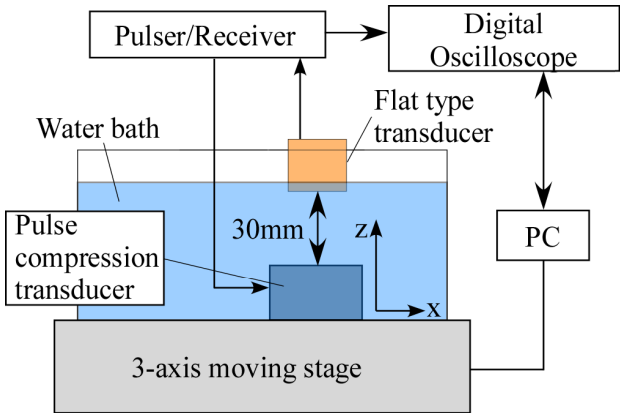


Fig.5 Experimental system.

In order to evaluate the dependence of bit length in M-sequence, a pulse compression ultrasonic transducer using 7 bits length M-sequence has been also fabricated. The performance in the directivity control of the transducers was evaluated by 1-D PSF in detecting direction. A pulse compression transducer and a broad-band transducer were respectively set as a transmitter and a receiver in a water bath as shown in Fig. 5. A pulse compression processing was carried out by calculating cross-correlation in received waves. Figure 6 shows a comparison of 1D PSF in two transducers (M-sequence pulse compression transducers with 3 bits and 7 bits length). This figure expresses the directivity of each transducer. It was confirmed that the directivity of 7 bits length was more sharp than it of 3 bits length from the full width at half maximum (FWHM) in each PSF. Furthermore, it was demonstrated that the developed transducer was able to obtain wave motion information in cross section selectively without scanning.

5. Conclusions

In this study, a pulse compression ultrasonic transducer was developed to transmit a pulse train encoded by M-sequence. The characteristic in directivity control of this transducer was investigated by the experiment. It was confirmed that the received waveform by the developed pulse compression ultrasonic transducer had an angle dependency. It was shown that the directivity was able to control by the angle dependence. And, it was found that the dependency improved according to the bit length in M-sequence. It will be expected that the pulse compression ultrasonic transducer is useful for the ultrasonic testing because of its simple system.

6. References

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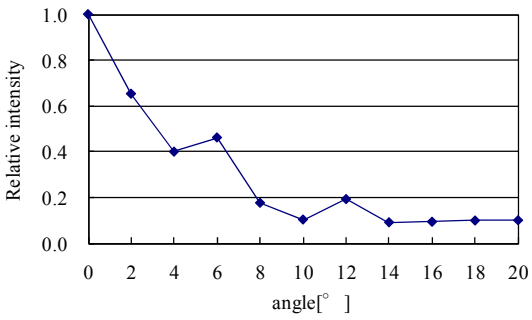
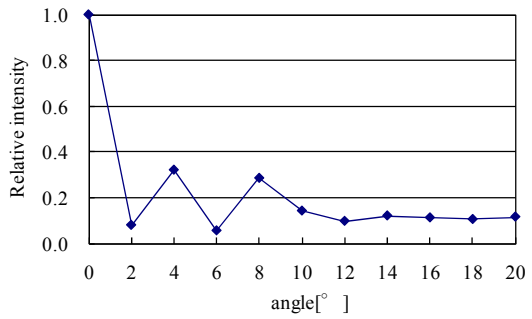


(a) 3 bits length



(b) 7 bits length

Fig.6 1-D PSF by each M-sequence transducer.