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Study on Pulse Compression Ultrasonic Transducer Made with Piezoelectric Copolymer Films
広帯域高分子圧電膜を用いたパルス圧縮超音波探触子に関する研究

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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 must be also prepared.

In this study, it aimed to develop a novel ultrasonic transducer which can generate M-sequence wave by only a general pulser without such a special device. The ultrasonic transducer has been fabricated using piezoelectric polymer PVDF. The performance of this transducer has been evaluated by one-dimensional point spread function (1-D PSF) compared with a general ultrasonic transducer.

2. Fabrication of an 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 of 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.

A pulse compression ultrasonic transducer using an M-sequence has been fabricated. The structure of the transducer with 3 bits length M-sequence is shown in Fig. 1. The polarization 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 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 according to the M-sequence of 3 bits length was transmitted.

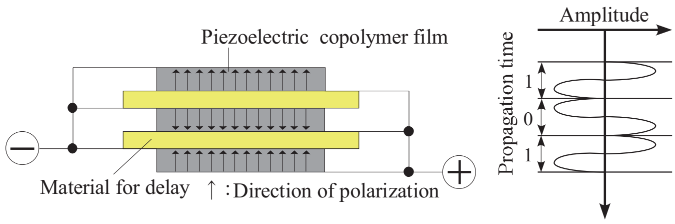

Fig.1 Generation principle of pulse train encoded by M-sequence

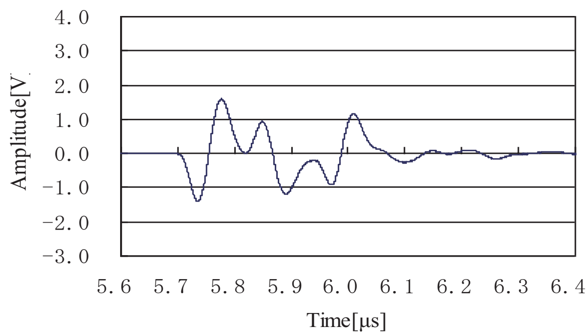

Fig.2 M-sequence pulse train generated by the developed ultrasonic probe

3. Performance of a pulse compression ultrasonic transducer with M-sequence

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 of the transducers

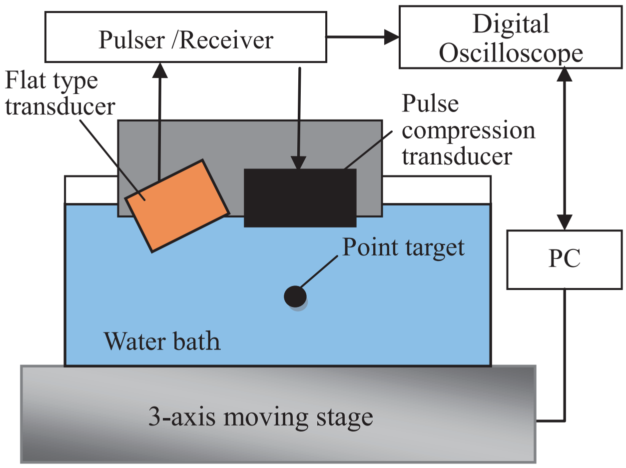

Fig. 3 Experimental system

was evaluated by 1-D PSF on the acoustic axis of the transducers. 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. 3. A pulse compression processing was carried out by calculating cross-correlation in received waves. The 1-D PSFs were obtained using echoes from a point target (piano string of ϕ0.5 mm). Figure 4 shows a comparison of 1D PSF in three transducers (M-sequence pulse compression transducers with 3 bits and 7 bits length, and a commercial flat-type ultrasonic transducer). The horizontal axis in Fig. 4 shows the range from 30.0 mm to 33.0 mm because the origin is 30.0mm away from the transmitter. From this figure, the full width at half maximum (FWHM) in each transducer was about 0.30 mm in 3 bits length, about 0.15 mm in 7 bits length and about 0.80 mm in commercial transducer. It was confirmed that the resolution along the acoustic axis could be improved depending on the bit length in a pulse compression transducer with M-sequence. Furthermore, it was demonstrated that the SN ratio in M-sequence pulse compression transducer could be higher than the commercial transducer.

5. Conclusions

In this study, a pulse compression ultrasonic transducer was developed to transmit a pulse train encoded by M-sequence. The transmission of M-sequence pulse train was observed in the experiment in water bath using only a conventional pulser apparatus. It was confirmed that the developed pulse compression ultrasonic transducer with M-sequence has the performance which corresponds to a general pulse compression method and was improved depending on 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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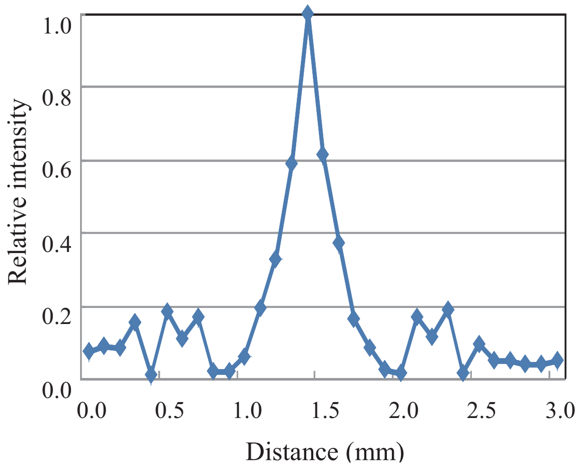
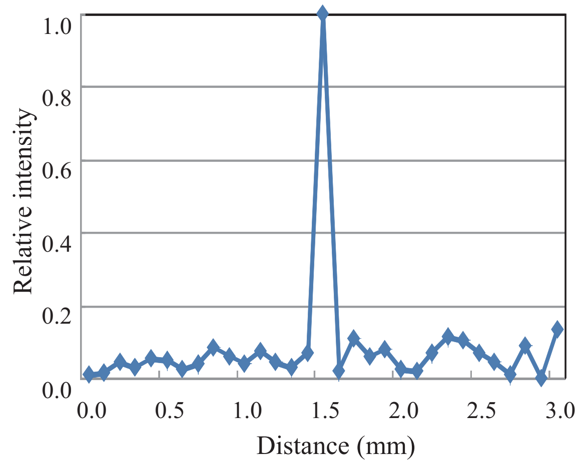
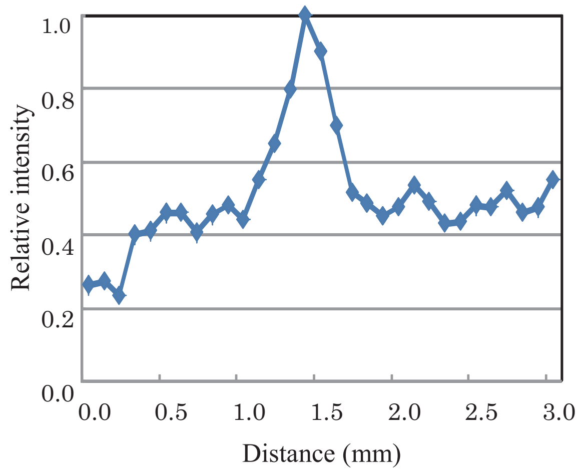


(a) M-sequence transducer of 3 bits length



(b) M-sequence transducer of 7 bits length



(c) Commercial transducer

Fig. 4 1-D PSF by each transducer