Acoustic characteristics of bi-frequency drive annular transducers

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1. Introduction

To improve the image quality by reducing the speckle noise on the echographic image, the authors have been studying a broadband ultrasonic imaging system. An annular broadband transducer, which is capable of transmitting multifrequency ultrasonic pulsed waves by driving bi-frequency due to the nonlinear propagation, has been designed. However, we observed the secondary wave larger than the primary wave which was measured by a hydrophone nearby the prototype transducer. It is difficult to explain this phenomenon by the nonlinear propagation. In this paper, thus we measure acoustic characteristics of this transducer and discuss the reason of the larger secondary wave than the primary wave.

2. Bi-frequency Drive Annular Transducer

The circular lead zirconate titanate (PZT) of 7 mm in diameter is coaxially arranged in the ring PZT of 9 mm in inner diameter and 17 mm in outer diameter. The ring and circular ones transmit ultrasonic pulsed wave of 2 and 8 MHz center frequency, respectively. So, ultrasonic beams of the both frequency components are formed at the same time. Thus, the secondary waves of 4, 6 and 10 MHz are generated as the second harmonic, difference and sum of the transmitted fundamental waves based on the nonlinear propagation. Fig. 1 shows an example of ultrasonic pulsed waveform and its spectra measured by a needle-type polyvinylidene fluoride (PVDF) hydrophone. Compared with the frequency components of the spectra observes 10 MHz component larger than 8 MHz component. It is difficult to appear such a phenomenon because of the nonlinear propagation.

3. Vibration Velocity Measurements

We measured vibration velocities of a bare transducer and a mechanical sector type probe. The probe was used for actually imaging and the same transducer as above-mentioned one was built into. Vegetable oil was filled in the probe as matching medium. The velocities at the center of the radiation surface were measured by the laser doppler vibrometer (LDV). Both PZT were connected in parallel and driven at same time. Fig. 2 and Fig. 3 show the waveform of the measured vibration velocity and its spectra. The transducer was driven by the frequency of 2 MHz and applied voltage of 15.2 and 14.4 Vp, respectively. Measured amplitudes were 38.0 and 150 mm/s. Difference between input signal and other signals was larger than 20 dB in both measurements. Similarly, Fig. 4 and Fig. 5 show the results when driving frequency was 8 MHz and applied voltages were 2.6 and 4.4 Vp, respectively. Measured amplitudes were 47.5 and 20.0 mm/s. The differences were larger than 30 dB and 20 dB. Compared with the measurements of the bare transducer and the probe, the probe vibrates fast by lower applied voltage at 2 MHz. By contraries, the transducer vibrates fast at 8 MHz.

4. Results and Discussion

From the results, the both transducers vibrated only by the driving frequency at the radiation surface. Therefore, multifrequency was
generated by sound propagation. Doppler modulation due to sound source moving and nonlinear vibration of micro-bubles suspended in the oil are suspected as the additional cause of generation of larger secondary wave components.

5. Conclusion

According to the spectra of vibration velocity measured by LDV, the peak frequency of the spectra agreed with the driving frequency. We suggested the possibility of multifrequency due to Doppler effect and nonlinear vibration of micro-bubbles suspended in the oil in the probe.

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References