17th SYMPOSIUM ON HYDROACOUSTICS

Jurata May 23-26, 2000

BIHARMONIC TRANSMITTING ARRAY

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The paper presents an underwater source radiating biharmonic wave of finite amplitude. The source is designed as an array of many elements. Results of experimental investigations allow to assess the pressure field distribution of examining source. Special attention was paid to the observation of phenomena in the area of forming nonlinear waves. Two transmitting arrays were used, both consisting of 16 circular transducers. The resonant frequency of radiating elements equals to 600 kHz or 1.5 MHz, respectively. The frequency range of the first of the sources is 540 kHz - 660 kHz, and of the second 1.2 MHz - 1.8 MHz. Investigation was carried out for various pressure values at the radiating surface.

INTRODUCTION

Sources radiating biharmonic wave of finite amplitude known as parametric sources are used in underwater investigations [4] especially in bottom and sub-bottom profiling [1, 8]. They can also be used as sources of wave of relatively low frequency designed for measurement purpose. In many cases the transmitting array of the parametric source consists of many elements, each of them is characterized by the same geometric and piezoceramic parameters [6, 7, 9]. In some cases other radiating apertures are applied [2, 5]. Array of multi elements could be used as a plane source or - together with an additional lens could be applied in a focusing source construction.

We have examined in our investigations two models of biharmonic underwater sources of finite amplitude wave. Special attention was paid to observing the nonlinear phenomena manifesting themselves in the appearance of waves of "new" frequencies in the vicinity of the source of wave.

1. TRANSMITTING ARRAY

Two transmitting arrays were examined, each of them consisting of 16 circular piezoceramic elements arranged as shown in Fig. 1. The first array was composed of elements 25-mm-diam of 600 kHz resonant frequency. The applied matching layer allowed to obtain the frequency range of radiation from 540 kHz to 660 kHz. The second array was designed using 10-mm-diam elements of 1.5 MHz resonant frequency. Its frequency band was 1.2 MHz - 1.8 MHz.

The construction of both of the sources was similar. The elements of the array were grouped in four sections, each composed of four piezoelements. Each section could be supplied independently. It allowed by means of parallel connection of two various sections to obtain two arrangements of elements shown in Fig. 2. Each group of transducers distinguished in the pictures could be supplied with signal of different frequency.

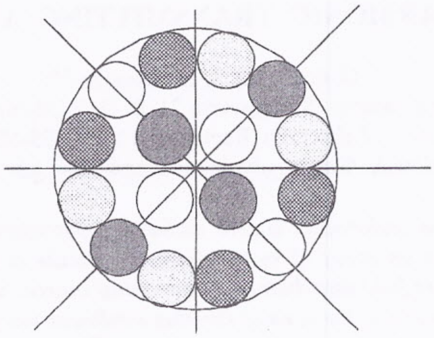

Fig. 1. The arrangement of the array - four sections of four transducers

a) b)

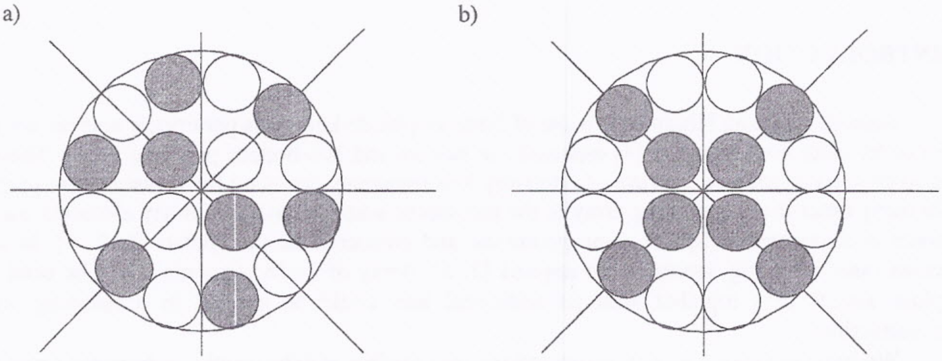

Fig. 2. Possible arrangements of array radiating biharmonic wave

The pressure field distribution of the source of a complex aperture differs significantly from the distribution of field produced by a singular circular piston. The pressure field distribution depends on the arrangement of radiating elements.

The matter of a great importance in investigation of the interaction of two waves of different frequencies radiating by the same array is the information on similarity of spatial distribution of the field of each primary wave. Before starting measurements we assessed the area in which the radiated waves could interact by means of numerical calculation of the Helmholtz equation [10]. An example of prediction of the pressure distribution of waves emitted by array is illustrated in the next figures. Curves shown in Fig. 3 and Fig 4 are calculated assuming that the arrangement of the array is the same as in Fig. 2a and transducers marked as black radiate the wave of 600 kHz frequency whereas the white marked transducers radiate the wave of 660 kHz frequency. Fig. 3 presents pressure distribution along the array axis while Fig. 4 the transverse pressure distribution at the fixed distance greater than the Rayleigh distance.

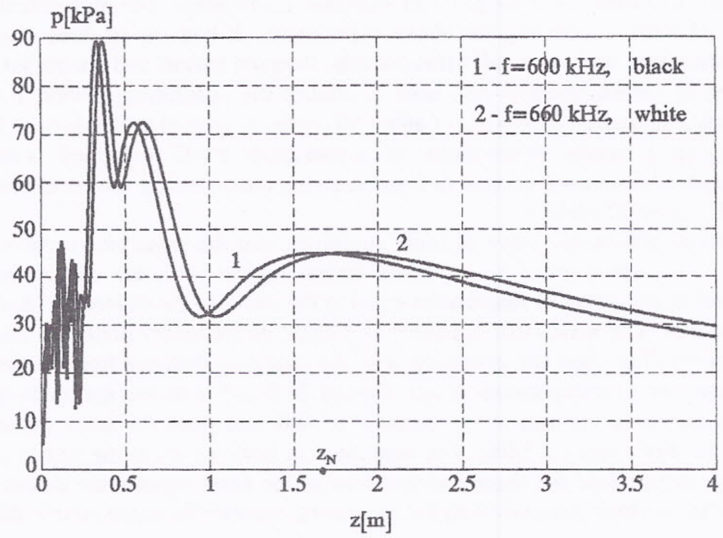

Fig. 3. Pressure distribution along the axis of array of transducers arrangement shown in Fig. 2a

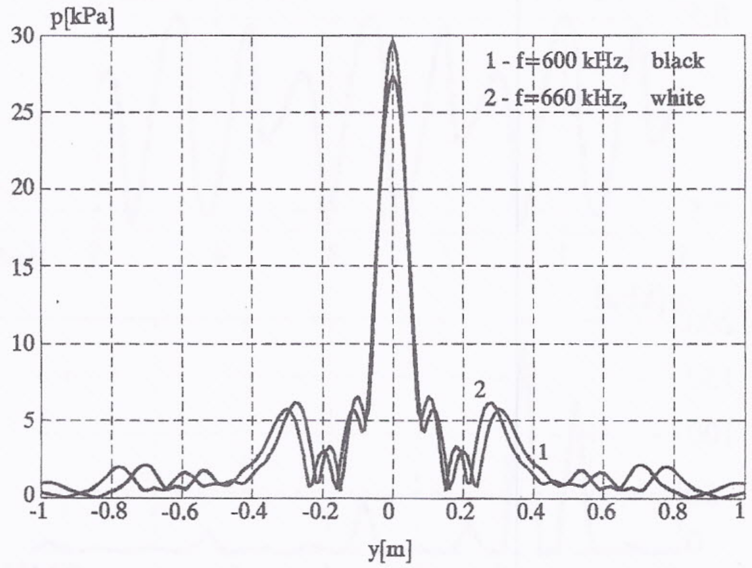

Fig. 4. Transverse pressure distribution at the distance of 4 m from array of transducers arrangement shown in Fig. 2a

2. RESULTS OF MEASUREMENTS

Measurements of field distribution of finite amplitude sources were carried out using the experimental arrangement described in [3]. The examined array were positioned along a larger horizontal axis in a tank 1.4 m long, 1.2 m wide and 1.2 m deep. The high precision equipment has to be used when conducting the above experiments. It consists of three translation guides each perpendicular to each other, all fitted out with stepping motors and controlled automatically. The PC used in measurement is also used to control the positioning device. For pseudo CW measurements a sinusoidal tone burst of about 50 cycles is applied to the device. The pressure is measured using a needle hydrophone of 1-mm-diam PVdF equipped with preamplifier manufactured by Acoustics Precision Ltd. Its receiving characteristic covers the frequency range from 0.5 MHz up to 20 MHz.

Radiation of biharmonic wave of finite amplitude into the same area involves considerable broadening of the spectrum of wave. There appear higher harmonic components of primary waves, as well as the waves of frequencies equal to the sum and the difference of the frequencies of primary waves. The waves that appeared as a result of secondary nonlinear interaction could also be observed. The spectrum evolution with the changing distance from the source could be illustrated using the example shown in next figures. In Fig. 5 is shown the shape of wave and its spectrum measured in the axis at the distance of 400 mm from the array radiating waves of frequencies 1.2 MHz and 1.8 MHz. The amplitude of both waves at the source was about 244 kPa. In Fig. 6 is presented the shape and spectrum of the same wave at the distance of 800 mm. In this case the spectrum enriches with the increasing distance from the source due to nonlinear interaction.

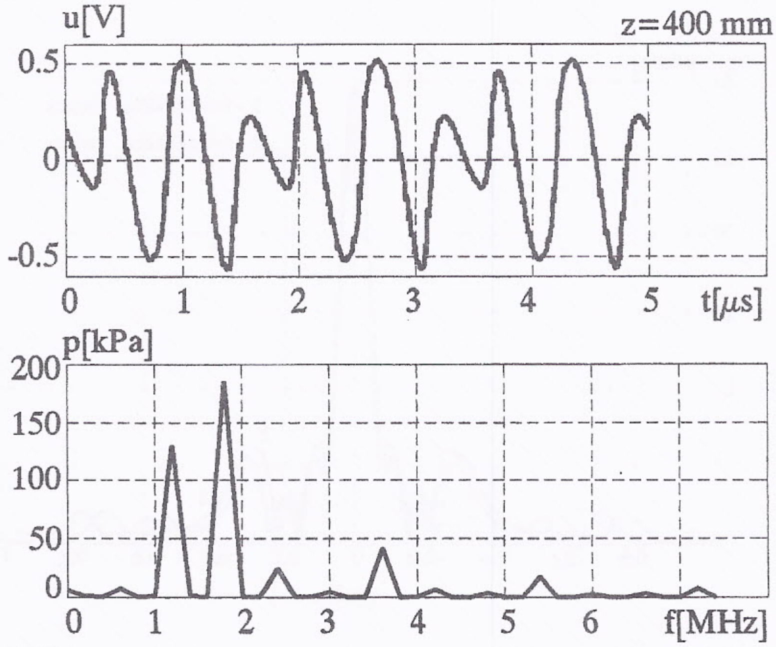

Fig. 5. The shape of wave and its spectrum in the axis at the distance of 400 mm from the array radiating waves of 1.2 MHz and 1.8 MHz frequencies

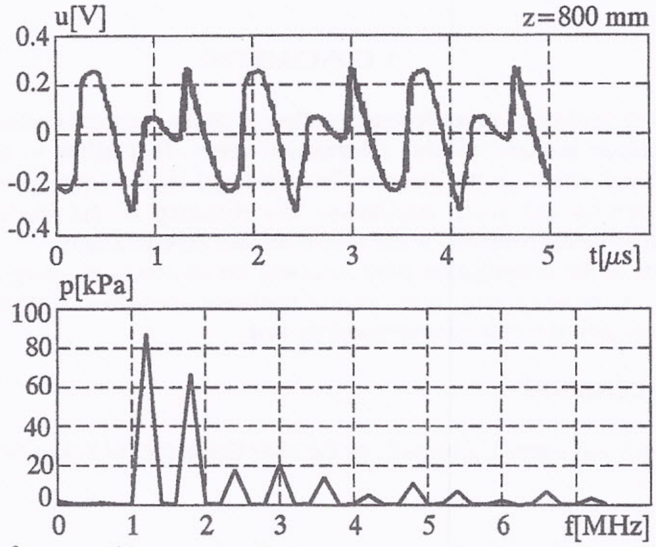

Fig. 6. The shape of wave and its spectrum in the axis at the distance of 800 mm from the array radiating waves of 1.2 MHz and 1.8 MHz frequencies

The evolution of the spectrum may be assessed by determining the changes in the amplitudes of particular components of spectrum as a function of the distance from the source. The next picture depicts the changes in the amplitude of the following waves:

1 - wave of 2.4 MHz frequency - the second harmonics of 1.2 MHz primary wave

2 - wave of 3.6 MHz frequency - the second harmonic of 1.8 MHz primary wave and at the same time the third harmonic of 1.2 MHz primary wave

3 - wave of 5.4 MHz frequency - the third harmonic of 1.8 MHz primary wave.

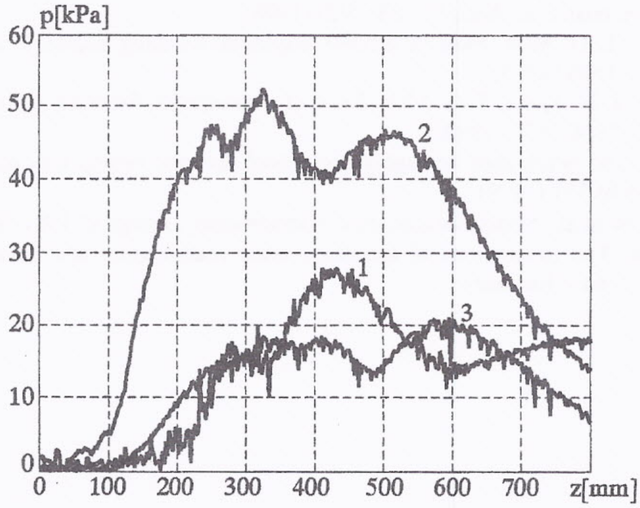

Fig. 7. The changes of the amplitudes of the harmonic components along the beam axis increasing inside the biharmonic array field: 2.4 MHz (1), 3.6 MHz (2), 5.4 MHz (3)

3. CONCLUSIONS

Experiments performed in our laboratory allow to obtain some interesting data on properties of finite amplitude sources radiating biharmonic waves. They allow to observe arising and growing nonlinear effects in the pressure field produced by the array radiating two waves of different frequencies and finite amplitudes. The enriching of the spectrum during waves propagation in nonlinear medium - water were evaluated experimentally.

The results of the investigation allow to assess the efficiency of energy transmission from primary waves to waves arising in the area of nonlinear interaction. Unfortunately the area of observation was limited by the dimensions of the tank.

ACKNOWLEDGMENTS

The research was supported partially by the State Committee of Scientific Research grant No 7 T07B 072 14.

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