DIRECTIVITY PATTERNS FOR A SHORT LINE ARRAY OF BARREL-STAVE FLEXTENSIONAL TRANSDUCERS

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1. INTRODUCTION

Barrel-stave flextensional transducers are compact underwater sound sources that were developed over the past two decades at DRDC Atlantic [1, 2]. Several designs were built for a variety of applications including horizontal line arrays, active sonobuoys, acoustic communications systems, and broadband transmitters.

For security applications such as underwater alarm systems and diver warning systems, short arrays with directional radiation patterns in the audible frequency band may be attractive. The barrel-stave flextensional transducer shown in Fig. 1 is ideal for these applications owing to its small size. In this work, the directivity patterns of a short barrel-stave transducer line array are presented.

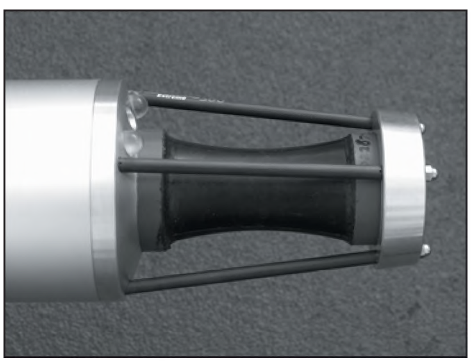

Fig. 1. A barrel-stave flextensional transducer integrated into an expendable submarine communications buoy.

2. TRANSDUCER PERFORMANCE

Four barrel-stave flextensional transducers driven by piezoceramic stacks were built at DRDC Atlantic for a short line array. Each transducer had an outside diameter of 5.7 cm, length of 12.7 cm, and mass of 1.1 kg.

The performance parameters, measured at the DRDC Atlantic Acoustic Calibration Barge on Bedford Basin near Halifax, are listed in Table 1. The fundamental flexural resonance frequency, transmitting voltage response (TVR) at resonance, and mechanical quality factor (Q) at resonance were well matched. At the flexural resonance, the transducer is omnidirectional since it is small compared to a wavelength. The pattern at 2.0 kHz is shown in Fig. 2.

Table 1. Transducer performance parameters.

Transducer	Frequency (Hz)	TVR[a] (dB//1μPa-m/V)	Q[a]
Element 1	1550	126.7	3.5
Element 2	1540	126.6	3.5
Element 3	1540	126.8	3.6
Element 4	1540	126.9	3.5

[a]Values determined at the resonance frequency.

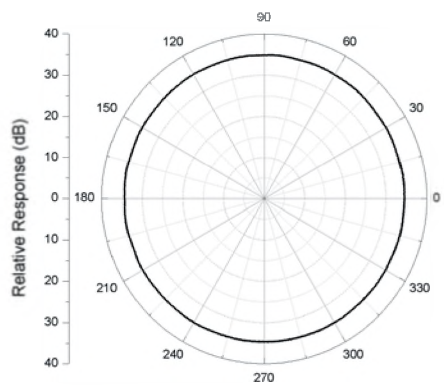

Fig. 2. At 2.0 kHz the barrel-stave transducer is omnidirectional. The transducer's longitudinal axis lies along the 90°-270° axis.

3. ARRAY DIRECTIVITY PATTERNS

The four-element line array shown in Fig. 3 was constructed and tested at the NAVSEA Seneca Lake Sonar Test Facility near Dresden in upstate New York. The length of the array was 1.3 m with a 40 cm inter-element spacing. Four amplifiers were used to drive the array, one for each transducer. A four-channel Wavetek 650 Synthesizer was used to apply phase and time delays. The directivity patterns were measured using a rotating station at a water depth of 30.5 m. At this depth, the sound speed was 1418 m/s as determined using a Falmouth Scientific 2" Micro CTD.

The radiation pattern shown in Fig. 4 was produced by driving the two center array elements 180° out of phase. At 1640 Hz the spacing between the elements was 0.47λ. This dipole-like pattern had a beamwidth of 94° and a sound pressure level 8 dB higher than that of a single element.

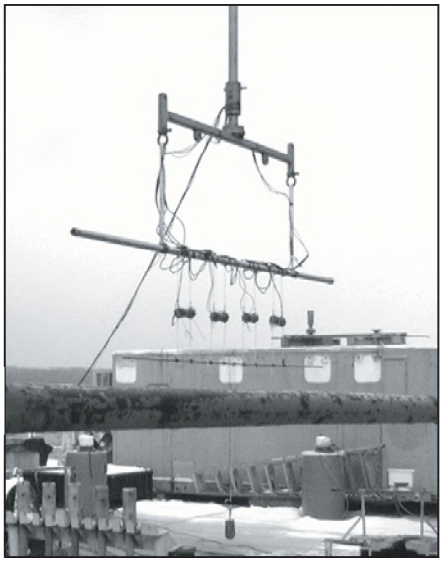

Fig. 3. The four-element line array of barrel-stave transducers at the Seneca Lake Sonar Test Facility.

Cardioid patterns were produced using the same two center elements. By driving the two elements 96º out of phase at 800 Hz, the cardioid in Fig 5 was realized. Note that the inter-element spacing was 0.23λ at this frequency. The beamwidth was 166º, front-to-back ratio was 46 dB and the sound pressure level was 6 dB higher than that of a single element. By switching the relative phase to -96º, the cardioid direction changed to 270º with a front-to-back ratio of 53 dB.

When all four elements were driven in phase at 1640 Hz, the measured radiation pattern was the solid curve in Fig. 6. The inter-element spacing was 0.47λ and the beamwidth of the main lobes on the 0º-180º axis was 29º. The four side lobes are not fully developed. At frequency f, the main lobes were steered to angle θ_0 by applying phase shift ϕ according to

$$\phi = 0.102\ f\ \sin\theta_0 .$$

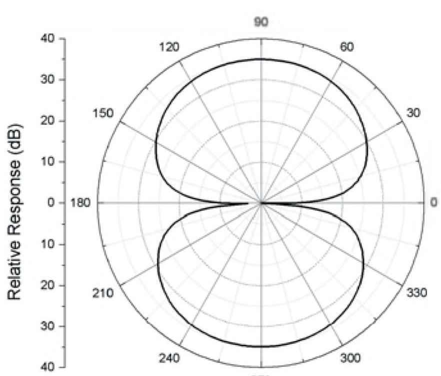

Fig. 4. Two elements driven 180º out of phase at 1640 Hz with a 0.47λ spacing. The array is collinear with the 90º-270º axis.

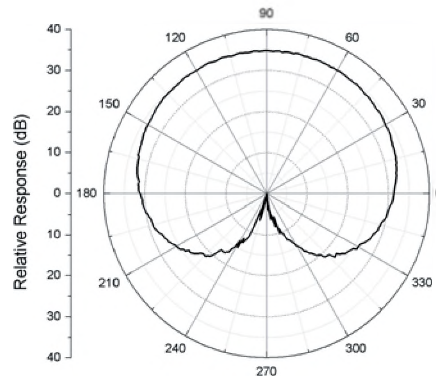

Fig. 5. Two elements driven 96º out of phase at 800 Hz with a 0.23λ spacing. The array is collinear with the 90º-270º axis.

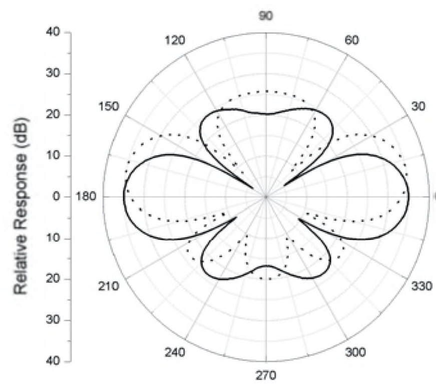

Fig. 6. Four elements driven in phase (solid) and 30º out of phase (dotted) at 1640 Hz with a 0.47λ spacing. The array is collinear with the 90º-270º axis.

Thus, by applying a phase shift of 30º, the main lobes were steered 10.3º as shown by the dotted curve in Fig. 6. Note that the same steering angle can be achieved using a time delay of 50μs.

4. CONCLUSIONS

In this work it was shown that a 1.3 m long line array of four barrel-stave flextensional transducers could produce a variety of radiation patterns. An omnidirectional pattern could be created by exciting a single element. Cardioid and dipole-like patterns resulted from driving two elements out of phase. When all four elements were driven, the main lobes were steered using phase shifts or time delays.

REFERENCES

[1] Jones, D.F. (1989). Low-frequency flextensional projectors. Proceedings of the Annual Meeting of the Canadian Acoustical Association, Edited by A.J. Cohen, 18-23.

[2] Jones, D.F. and Lindberg, J.F. (1995). Recent transduction developments in Canada and the United States. Proceedings of the Institute of Acoustics, 17(3), 15-33.