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COMPARISON OF TWO 120-KHZ SPLIT-BEAM TRANSDUCERS

by

Kenneth G. Foote
Institute of Marine Research
5024 Bergen, Norway

ABSTRACT

The performance of two 120-kHz split-beam transducers is compared through the following measures: relative power level, directivity index, relative source level, and reverberation index or equivalent beam angle. Sidelobe positions and levels are also described.

RESUME: COMPARAISON DE 2 TRANSDUCTEURS 120 KHZ A FAISCEAU SCINDE

Les performances de 2 transducteurs 120 kHz à faisceau scindé sont comparées grâce à: niveau relatif de puissance, index de directivité, niveau d'émission relatif et index de réverbération ou angle équivalent. Les positions et les niveaux des lobes secondaires sont également décrits.

INTRODUCTION

A new 120-kHz split-beam transducer is or will be available for use with the SIMRAD EK500 echo sounding system (Bodholt et al. 1989). Choice of one transducer or another by users of the echo sounder, given sufficient space on the acoustic platform, may be determined by performance.

The simple aim of this work is to compare the performance of two 120-kHz split-beam transducers. This is done through computation of standard performance measures. In the following, the transducer geometries are defined, the method of computation is explained, and results are presented.

This is one of a series of studies broadly directed at understanding the influence of transducer design on current or potential applications in fisheries acoustics.

TRANSDUCER GEOMETRIES

Both transducers are composed of identical, 10-mm-diameter, circular elements that are spaced on a square grid with center-to-center distances

of 11 mm along rows and columns. The arrays are shaded, i.e., the elements are driven by different voltages depending on element position. The voltage- or amplitude-domain weights of the elements in the two transducers are shown in Figs. 1 and 2.

0	0	0	75
0	100	75	100
0	75	100	100
75	100	100	100

Fig. 1. Relative amplitude weights of elements in the upper left quadrant of the SIMRAD ES120 transducer.

0	0	0	57	57
0	0	100	90	90
0	100	100	100	100
57	90	100	100	100
57	90	100	100	100

Fig. 2. Relative amplitude weights of elements in the upper left quadrant of the SIMRAD ES120-7 transducer.

METHOD OF COMPUTATION

The common ingredient of the several performance measures is the beam pattern. Since the arrays described above are planar and composed of identical, if unequally weighted, elements, the farfield beam pattern is

$$b(\theta, \phi) = b_1(\theta) \left| \frac{\sum_{j=1}^n w_j \exp(ik \cdot \underline{r}_j)}{\sum_{j=1}^n w_j} \right|^2, \quad (1)$$

where (θ, ϕ) describes the direction of evaluation of b , b_1 is the beam pattern of a single circular element, w_j is the weight of element j whose center is located at coordinate $\underline{r}_j = (x_j, y_j, 0)$ in the x - y plane, \underline{k} is the wavevector, $\underline{k} = k(\sin \theta \cos \phi, \sin \theta \sin \phi, \cos \theta)$, $k = 2\pi/\lambda$, λ is the acoustic wavelength, θ is the angle between the normal to the array and \underline{k} , ϕ is the angle between the projection of \underline{k} in the x - y , array plane and x -axis. The single-element beam pattern is

$$b_1(\theta) = \left| 2 J_1(ka \sin \theta) / (ka \sin \theta) \right|^2, \quad (2)$$

where J_1 is the Bessel function of the first order, and a is the radius of the circular element.

The power transmitted by a transducer array is equal to the sum of the individual-element contributions. For identical, hence equal-area elements,

$$P \propto \sum_{j=1}^n w_j^2 \quad . \quad (3a)$$

The relative power level of two arrays is thus

$$\Delta P = 10 \log (P_2/P_1) \quad , \quad (3b)$$

where in the present computations P_1 denotes the power transmitted by the ES120 transducer and P_2 that transmitted by the ES120-7 transducer.

The directivity index is defined thus (Urlick 1983):

$$DI = 10 \log (4\pi/\int b \, d\Omega) \quad , \quad (4)$$

where the integration is performed over the 2π steradians of space available to the presumed perfectly baffled array. The DI can be viewed in each of two ways: it measures the concentration of transmitted energy in the axial or forward direction, and it measures the discrimination of the receiver against isotropic background noise. Combined with the transmitted power level, DI gives a measure of the source level of the transducer. In particular, the relative source level of two transducers is

$$\Delta SL = \Delta P + DI_2 - DI_1 \quad . \quad (5)$$

The DI also gives a measure of the signal-to-noise ratio in the receiver.

The reverberation index is analogous to the directivity index, but measures the cumulative effect of transmission and reception:

$$J_v = 10 \log (4\pi/\int b^2 \, d\Omega) \quad , \quad (6)$$

where, as before, the integration is performed over the half space in front of the transducer array. The denominator of the argument, or antilogarithm, is called the nominal equivalent beam angle

$$\psi_o = \int b^2 \, d\Omega \quad , \quad (7a)$$

whose common logarithmic measure is

$$\Psi_{\circ} = 10 \log \psi_{\circ} \quad . \quad (7b)$$

Other measures of performance are given by the sidelobes of the transducers. Since these are not circular, the structure cannot be described by a single slice or cut through the axis; rather it must be defined over a surface. For convenience, the sidelobes are described here by a succession of slices through the axis, but differing in azimuth ϕ . Since the transducers do possess eight-fold symmetry, it is enough to examine the directivity structure over the azimuthal range $[0, \pi/4]$.

RESULTS AND DISCUSSION

The several performance measures presented in Tables 1 and 2 are accurate to within one-half part of the next, unshown digit. Only the first three sidelobes are presented in Table 2.

Clearly there is a difference in performance of the two transducers. This is to be expected from their different geometries. In particular, the larger size and greater degree of shading in the ES120-7 transducer, compared to that of the ES120 transducer, implies a higher power level and source level, increased directivity, and smoother or more regular beam pattern. These several characteristics are evident in Tables 1 and 2, which moreover quantify the differences.

In the light of Simmonds's study on the effect of transducer mounting on the beam pattern (Simmonds 1984) and usual manufacturer practice of measuring transducers with quite simple mountings and without much baffling, the present values are believed to be more applicable to hull-mounted transducers than those specified by the manufacturer. Other arguments for choosing computed values over manufacturer-supplied values have previously been mentioned (Foote 1990).

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Table 1. Performance measures.

Transducer	n	Σw_j^2	ΔP (dB)	$\int b d\Omega$ (sr)	DI (dB)	ΔSL (dB)	$\int b^2 d\Omega$ (sr)	J_v (dB)	Ψ_o (dB)
ES120	44	37.00	0	0.0340	25.67	0	0.0135	29.69	-18.70
ES120-7	76	62.16	2.25	0.0186	28.29	4.87	0.0082	31.88	-20.89

Table 2. Sidelobe positions θ and levels $B=10 \log b$ for a range of azimuthal values ϕ . Both ϕ and θ are given in degrees and B in decibels.

Transducer	ϕ	θ_1	B_1	θ_2	B_2	θ_3	B_3
ES120	0	14.2	-20.8	24.5	-20.1	43.4	-22.5
ES120	5	14.2	-20.7	24.3	-21.3	43.6	-26.4
ES120	10	14.3	-20.2	23.7	-25.6	33.2	-58.9
ES120	15	14.4	-19.7	22.9	-36.1	30.6	-29.5
ES120	20	14.5	-19.2	30.2	-23.2	42.7	-23.7
ES120	25	14.5	-18.9	30.7	-21.8	43.1	-28.0
ES120	30	14.5	-18.8	22.9	-41.9	31.7	-24.2
ES120	35	14.4	-18.8	23.8	-27.1	33.7	-33.2
ES120	40	14.3	-18.9	24.7	-21.8	52.3	-45.3
ES120	45	14.3	-19.0	25.1	-20.3	90.0	-36.6
ES120-7	0	11.3	-18.4	18.6	-32.9	24.6	-38.5
ES120-7	5	11.3	-18.4	18.6	-31.7	24.8	-39.5
ES120-7	10	11.2	-18.5	18.6	-29.3	25.1	-40.7
ES120-7	15	11.2	-18.6	18.5	-27.0	25.6	-38.2
ES120-7	20	11.1	-18.7	18.4	-25.4	25.9	-33.5
ES120-7	25	11.1	-18.8	18.3	-24.6	25.9	-29.8
ES120-7	30	11.1	-18.8	18.2	-24.4	25.7	-28.0
ES120-7	35	11.1	-18.8	18.1	-24.5	25.5	-27.5
ES120-7	40	11.1	-18.8	18.0	-24.6	25.2	-27.7
ES120-7	45	11.1	-18.8	18.0	-24.7	25.1	-27.9