International Council for the Exploration of the Sea

C.M. 1992/B:9
Fish Capture Committee

NOMINAL PERFORMANCE MEASURES FOR TWO 710-KHZ TRANSDUCERS

by

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

ABSTRACT

Two new transducers have been designed by SIMRAD for the EK500 echo sounding system. The nominal operating frequency is 710 kHz. Each transducer is composed of a single, circular, active element, with diameter of 25 or 50 mm. The nominal equivalent beam angle and directivity index are computed for each of these. It is argued that the computed values are more appropriate for ordinary applications in which a transducer is mounted on a large supporting surface, for example, a vessel hull, than are control measurements of the same transducer when minimally mounted or supported.

RESUME: MESURES NOMINALES DE PERFORMANCE POUR DEUX TRANSDUCTEURS 710 KHZ

Deux nouveaux transducteurs ont été mis au point par SIMRAD pour le sondeur EK500. La fréquence nominale d'opération est de 710 kHz. Chaque transducteur se compose d'un élément actif circulaire unique, de 25 ou 50 mm de diamètre. Pour ces deux diamètres, on a calculé l'angle nominal équivalent ainsi que l'index de directivité. Il nous est apparu que les valeurs calculées sont plus adaptées à des usages courants pour lesquels un transducteur est monté sur un grand support (par exemple la coque d'un navire), que ne le sont les mesures de controle lorsque le transducteur est monté sur un support de taille minimale.

INTRODUCTION

Two new transducers are available for application to fisheries. These are the SIMRAD transducer types 710-30-EP and 710-36. Both are resonant at 710 kHz. The geometries are simple, consisting of single integral circular disks of diameters 25 and 50 mm, respectively.

In order to aid discussion on their application, several performance measures are computed here. The task is essentially trivial, as excellent approximations are well known (Urick 1975, Clay and Medwin 1977).

What is less well known or appreciated, however, is that both these expressions, and more general evaluation techniques too, assume baffling. This is usually assumed to be perfect and infinite in extent, which is clearly fictitious. The most common alternative: computation of performance measures based on laboratory measurement of the transducer without the usual mounting or housing, is regarded as even less satisfactory.

Following presentation of the computed measures, therefore, the general issue of applicability is addressed.

METHOD

The basis for computing performance measures is the transducer beam pattern. For a circular disk of radius a with perfect and infinite baffling, the following expression is well known (Clay and Medwin 1977):

$$b(\theta) = \left|2J_1(ka \sin\theta)/(ka \sin\theta)\right|^2 \quad , \tag{1}$$

where θ is the angle between the vector from transducer center to field point and the acoustic axis, which is normal to the disk and passes through the center, k is the wavenumber, and $J_1(x)$ is the cylindrical Bessel function of order one with argument x. The wavenumber is related to the frequency ν and medium sound speed c: $k=2\pi\nu/c$. The above equation applies in the transducer farfield, i.e., for ranges exceeding the Rayleigh distance a^2/λ, where λ is the wavelength. In the evaluations reported below, a=25 and 50 mm, respectively, ν=710 kHz, and c=1470 m/s.

The several performance measures computed here depend on the integrated quantities

$$I_q = \int b^q(\theta)\, d\Omega \quad , \tag{2}$$

where q=1 or 2, and the integration extends over the 2π sr in front of the transducer, for $0 \leqq \theta < \pi/2$.

Directivity index The DI is used both for transmit and receive beam patterns. It measures the concentration of transmitted energy in the forward direction, or the degree of discrimination of the receiver against isotropic background noise. It is defined according to Urick (1975) thus:

$$DI = 10 \log (4\pi/I_1) \quad . \tag{3}$$

Equivalent beam angle or reverberation index The quantity I_2 is just the equivalent beam angle. The corresponding logarithmic measure is

$$\Psi = 10 \log I_2 \quad . \tag{4}$$

The reverberation index is analogous to DI, but specifies the cumulative effects of transducer directivity on discriminating against reverberation noise:

$$J_v = 10 \log (4\pi/I_2) \quad . \qquad (5)$$

Computation The several measures are evaluated by numerical integration and compared against large-ka formulas for DI by Urick (1975) and for Ψ by Clay and Medwin (1977).

RESULTS AND DISCUSSION

The results are presented in Table 1. These agree with the cited large-ka formulas to their indicated level of accuracy, namely to the nearest 0.1 dB. As observed earlier, the formula in Urick (1975) for Ψ is 0.1 dB too high.

Table 1. Nominal performance measures for two circular transducers resonant at 710 kHz, for medium sound speed 1470 m/s, assuming perfect baffling.

Diam (mm)	ka	I_1 (sr)	DI (dB)	I_2 (sr)	Ψ (dB)	J_v (dB)
25	37.9	0.00874	31.58	0.00402	-23.96	34.95
50	75.9	0.00218	37.60	0.00100	-29.98	40.98

The applicability of the approximation formulas is evidently guaranteed by the magnitude of ka. For reference, the two formulas are the following:

$$DI = 20 \log (ka) \quad , \qquad (6)$$

and

$$\Psi = -20 \log (ka) + 7.6 \quad . \qquad (7)$$

The central issue to be discussed is the applicability of theoretically computed beam patterns as opposed to laboratory-measured beam patterns. It is observed at the outset that the differences apparently are not very large, with cumulative effects of the order of 1 dB. In the context of precision measurements of fish density, however, this difference is significant and cannot be tolerated.

Deciding between the two methods of beam pattern determination is simple in principle, for measurement of the beam pattern of a transducer *in situ*, as mounted on the sonar platform of use, is all that is required. In practice, however, this is difficult. Typical platforms, research vessels, are unwieldy, and environmental effects, such as wind and current, frequently exert a major influence on the outcome of measurements.

Recourse might therefore be made to a special series of measurements (Simmonds 1984). These consider in very direct fashion the effect of transducer mounting on Ψ, hence on the beam pattern too. These measurements indicate that the effect of mounting is significant.

This is not at all surprising from acoustic theory. When the extent and nature of baffling employed in fisheries research applications is considered, the use of theory to determine beam patterns may be felt justified.

For more complicated geometries than the simple circular ones considered here - see, for example, Foote (1990) - an additional advantage of computation over that of laboratory measurement is treatment of the beam pattern over the half sphere. Measurement procedures are limited to a finite number of points. These are often arranged along cuts through the transducer axis, sometimes numbering only two, in orthogonal planes. Integration by equation (2) is then not feasible, and an approximate formula must be used. Except in the case of large ka, this may very well lead to erroneous results, from oversimplification.

Further measurement of beam patterns of transducers in situ, as mounted for application, is encouraged to help resolve the question of the sufficiency of theoretical computation vis-à-vis laboratory measurement.

ACKNOWLEDGEMENT

C. Lantuéjoul is thanked for rendering the abstract.

REFERENCES

Clay, C. S., and Medwin, H. 1977. Acoustical oceanography: principles and applications. Wiley, New York. 544 pp.

Foote, K. G. 1990. Designing an improved transducer array geometry. J. Cons. int. Explor. Mer, 46: 129-132.

Simmonds, E. J. 1984. A comparison between measured and theoretical equivalent beam angles for seven similar transducers. J. Sound Vib., 97: 117-128.

Urick, R. J. 1975. Principles of underwater sound. Second edition, McGraw-Hill, New York. 384 pp.