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DIRECT MEASUREMENTS OF EQUIVALENT BEAM ANGLE ON HULL-MOUNTED TRANSDUCERS

by

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ABSTRACT

Measurements for checking the equivalent beam angle on a hull-mounted transducer have been made on a standard 38-29/25-E SIMRAD transducer on the Norwegian research vessel "ELDJARN". The measurements were made during a controlled trimming of the vessel above a previously centered calibration sphere. Comparisons with laboratory measurements of the transducer and theory suggest an effect of the hull mounting of less than 0.2 dB in the equivalent beam angle.

INTRODUCTION

To obtain reliable acoustic estimates of fish density, the fish detection or sampling volume must be known precisely. This is given through the directivity pattern of the transducer,

$$\psi = \int_{o}^{2\Pi} \int_{-\frac{\Pi}{2}}^{\frac{\Pi}{2}} b^2(\theta,\phi) \cos \theta d\theta \; d\phi \ ,$$

which is often simplified by using an ideal beam with a flat response inside the beam and no response outside (URICK 1967).

In order to calculate ψ from the integral expression, a detailed investigation of the beam pattern has to be made. Usually, only two normal sections through the acoustic axis of the directivity pattern are available from the manufacturer, and simplified equations are used to find the equivalent beam angle.

URICK (1967) has given simplified expressions for such calculations:

$$10 \log \psi = 20 \log \left(\frac{\lambda}{2\Pi a} \right) + 7.7 \text{ [dB]}$$

and

$$10 \log \psi = 10 \log \left(\frac{\theta_A \ \theta_B}{4} \right) - 31.6 \text{ [dB]}$$

where

λ = wavelength
a = transducer diameter, or actually effective diameter $\langle a \rangle_{eff}$.
θ_{A}, θ_{B} = one-way half-intensity beamwidth.

In both expressions above it is assumed that the directivity is ideal, approximated through the directivity of a circular piston:

$$b(\theta) = \left[\frac{2J_1 \; (ka \; \sin\theta)}{ka \; \sin\theta} \right]^2$$

where J_1 is the first-order Bessel function:

$$J_1 \; (z) = \frac{z}{\Pi} \int_0^{\Pi} \cos(z \cdot \cos\theta)/\sin^2\theta \; d\theta$$

If this is the case also for unshaded multiple-element transducers, measurements of the half-intensity angles should give a fair estimate of the equivalent beam angle.

Reports of changes in directivity pattern from the mounting medium itself (SIMMONDS, 1984), indicate that the transducer must be mounted in its operational site when measured. Direct measurement on the hull-mounted transducer was therefore considered essential.

METHOD

The measurements were made on a standard 38-29/25-E SIMRAD transducer mounted on the hull of R/V "Eldjarn". The transducer is composed of 70 ceramic elements packed to maximum density as shown in Fig. 1. Nominal beamwidth is $8^{\circ} \times 8^{\circ}$.

After a general echo-sounder and integrator calibration, a diver fastened the adjustment lines for the calibration-sphere to eyebolts mounted near the transducer. The sphere was then centered on the acoustic axis by trimming the vessel in the fore-and-aft plane, Fig. 2.

During continuous echo-integration, but with rapid printouts of mean echo energy, the vessel was slowly trimmed down 10° both to starboard and to port. The angle measurements were made by two specially arranged, spirit level-meters, giving an accuracy in the fore-and-aft and athwartship angles of 0.05 degrees.

RESULTS

A total of 76 distinct points were measured along the main lobe of the transducer beampattern in the athwartship plane, Fig. 3.

Both measurement series, of port-to-starboard and starboard-to-port rollings, specified an opening angle of 8.3° $\pm 0.05^{\circ}$, as measured across the beam between the -6 dB levels, representing the two-way-sensitivity loss due solely to beam directivity.

The fore-and-aft angle was constant to within 0.09° during the roll measurements. The second cut through the main lobe is 0.2 dB lower on the acoustic axis than is the first.

Measurements in the fore-and-aft plane were also made, but only a small part of the directivity pattern could be sensed. The pumping of 340 tonnes of fuel from the stern center tank to the bow center tank produced a tilt of only 2.5°.

DISCUSSION

The laboratory measurements from the manufacturer on this specific transducer, Fig. 4, indicated a half-intensity angle of about 9°, but as seen from the directivity plots, low accuracy in the pen-plotter may have flattened the top of the main and side lobes. Assuming a general hyperbolic shape of the top of the main lobe, the corresponding half-intensity opening angle is measured as 8.3°, which is similar to the measurements made on the transducer when hull-mounted.

Using a general equation for an ideal circular piston, the effective radius (in the athwartship plane) has been calculated from:

$$k \cdot a \sin\theta = 1.616$$

Substituting $k = 1.48\ cm^{-1}$ and $\theta = 4.15^{o}$ gives:

$$\langle a \rangle_{eff} = 13.8\ cm$$

Agreement of measurement and theory, based on an ideal circular piston with this effective radius is shown in Fig. 5.

Considering the actual dimensions of the transducer, it can be concluded that the fore-and-aft beamwidth must be less than the athwartship beamwidth. The laboratory measurements show a difference of 0.2^{o}, and if this is valid also when the transducer is hull mounted, the estimated fore-and-aft beamwidth is 8.1^{o}.

The measured and estimated beamwidths were used to calculate the equivalent beam angle given in Table 1.

Table 1. Summary of nominal, laboratory-measured and <u>in situ</u> measured equivalent beam angles.

Source	θ_A (deg)	θ_B (deg)	ψ (ster)	$10 \log \psi$ (dB/ster)
Nominal	8	8	0.0110	-19.6
Producer	9	8.5	0.0132	-18.8
Hull mounted	8.3	(8.1)	0.0116	-19.4
Theory (circular)	8.3	(8.3)	0.0117	-19.3

For different research vessels with this transducer type, the nominal value of ψ is used when establishing the instrument constant C_I. The measured beamwidths of this transducer is $\theta_A = 8.3^{\circ}$, $\theta_B = 8.1^{\circ}$, giving $10 \log \psi = 19.4$ dB. Consideration of the various error sources suggests an accuracy of ±0.2 dB. Thus the equivalent beam angle of the 38 kHz transducer on R/V "ELDJARN" is 0.0116 ±0.0005 ster.

Whether the simplified equations will give an exact estimate of the equivalent beam angle is not considered in this report. More detailed measurements of the directivity of hull-mounted transducers, using additional acoustic systems for sphere-positioning, are planned.

REFERENCES

SIMMONDS, E.J. 1984. The effect of mounting on the equivalent beam angle of acoustic survey transducers. ICES. CM. 1984, B 32: 1-9.

URICH, J.R. 1967. Principles of underwater sound for engineers. New York, McGraw Hill Book Co., 342 p.

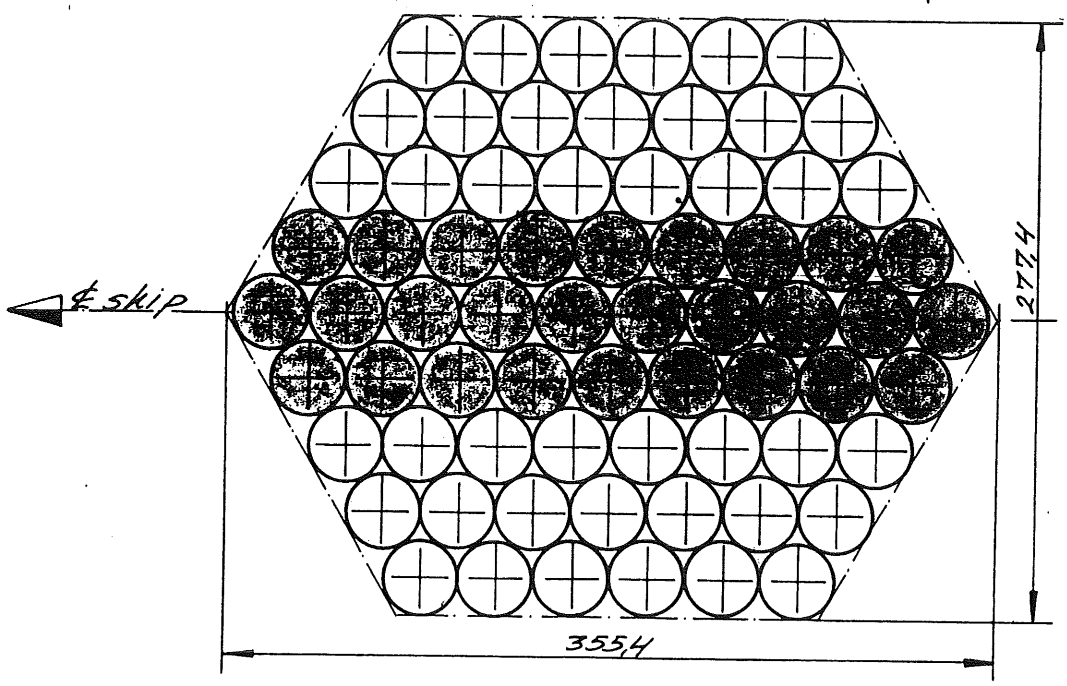

Fig. 1. Transducer shape and distribution of the 70 ceramic 35 mm Ø - elements. The actual dimension of the element area is given.

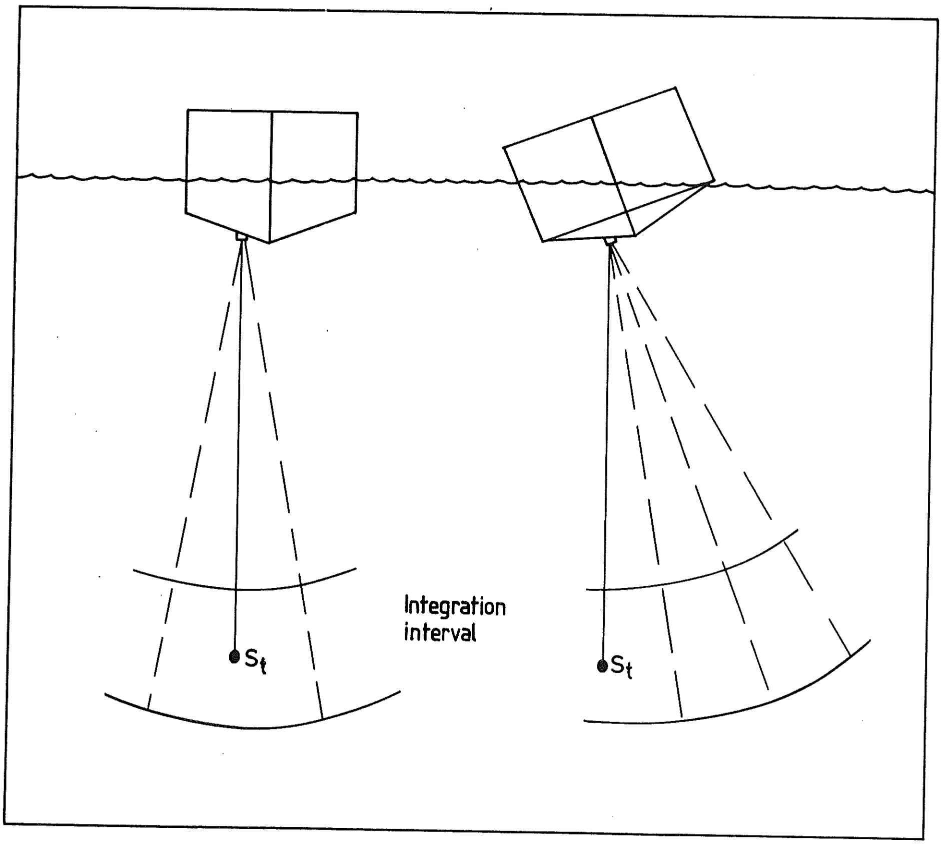

Fig. 2. Trimming the vessel in the atwartship plane while integrating on a standard calibration sphere.

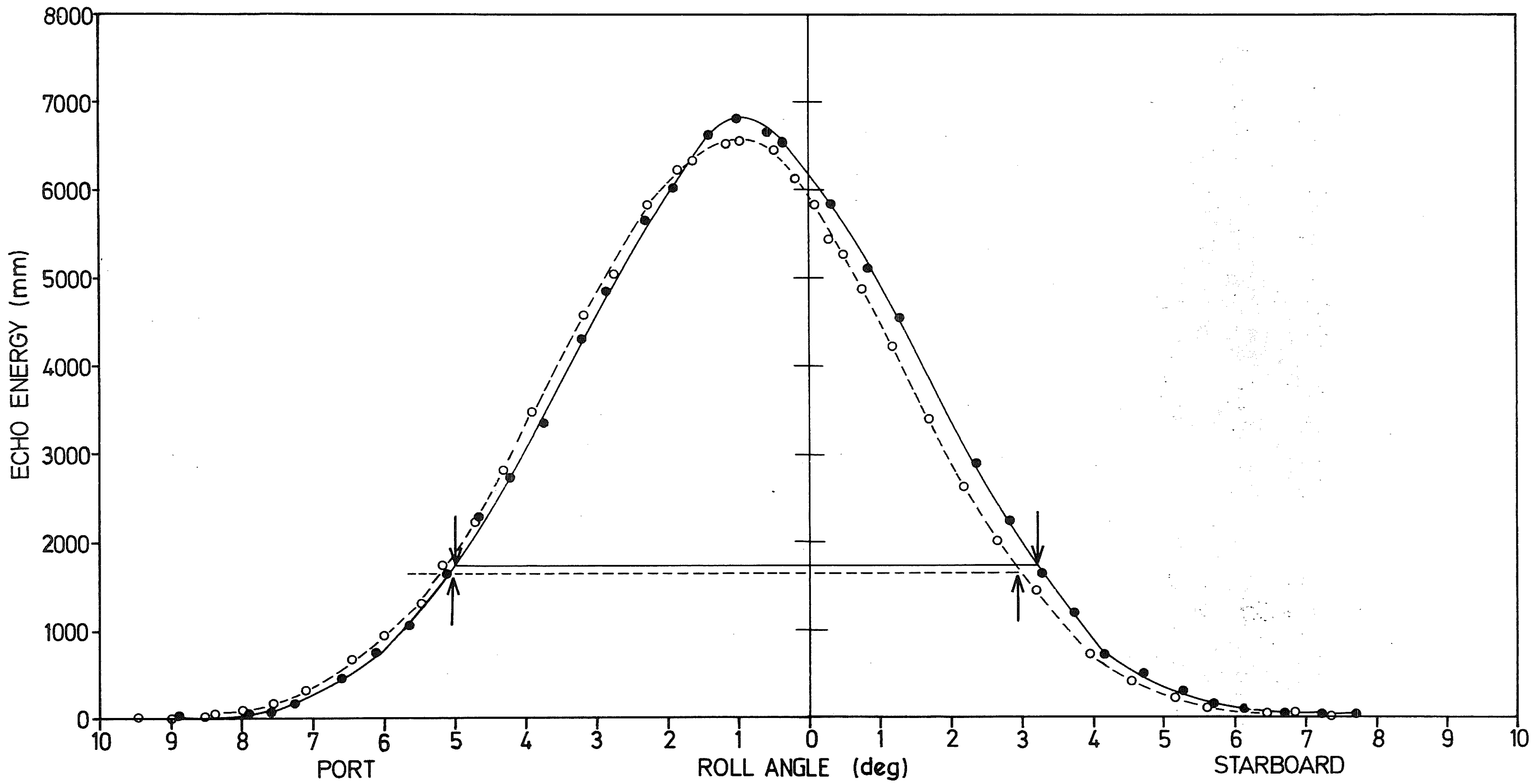

Fig. 3. Two-way directivity pattern of the transducer in the athwartship plane, measured while trimming the vessel above the calibration sphere. Half-intensity points for one-way propagation are indicated.

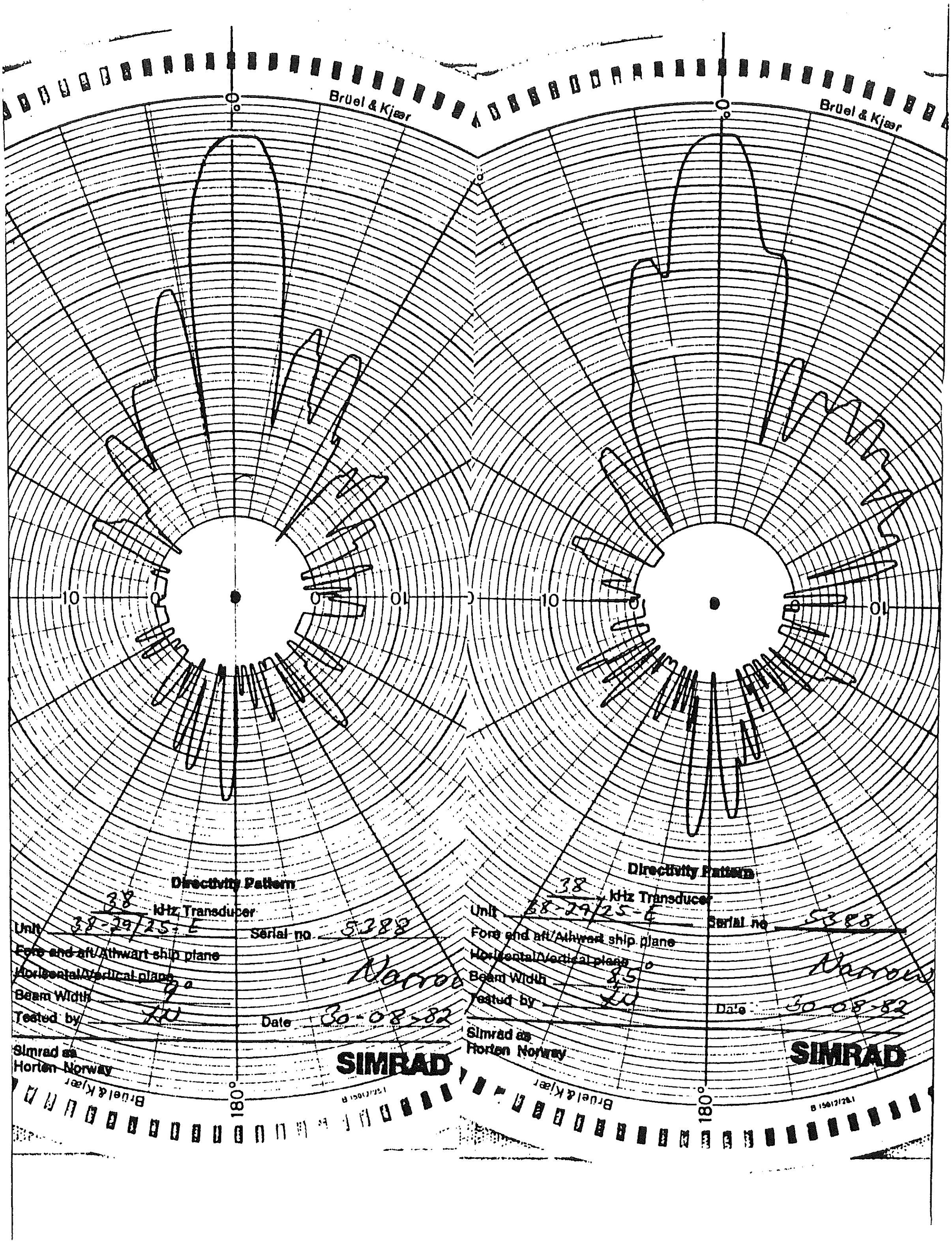

Fig. 4. Laboratory measurements of the transducer.

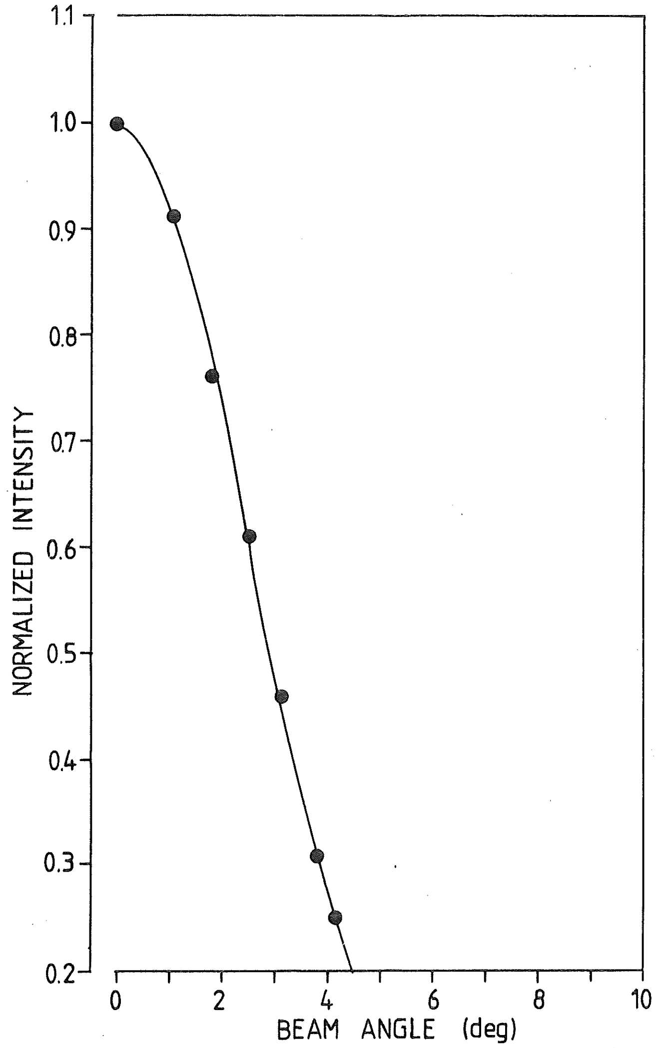

Fig. 5. Comparison of theoretical athwartship beam pattern, solid line, with measurements.