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SIMULTANEOUS TWO-SPHERE TWO-TRANSDUCER CALIBRATION

by

Kenneth G. Foote

Institute of Marine Research

5024 Bergen, Norway

ABSTRACT

When directional transducers are mounted nearby, the central lobes of their beam patterns may partly overlap at ranges typical for standard-target suspension in calibration exercises, e.g., 20 m. According to the proposed technique, two transducers may be calibrated simultaneously by a two-sphere suspension. This will be most workable for split-beam transducers.

RESUME: ETALONNAGE SIMULTANE DE 2 TRANSDUCTEURS SUR 2 SPHERES

Quánd des transducteurs directifs sont montés à proximité l'un de l'autre, les lobes centraux de leurs fonctions de directivité peuvent se chevaucher partiellement à des profondeurs couramment adoptées pour la sphère d'étalonnage, 20 m par exemple. Dans la technique proposée, les 2 transducteurs peuvent être étalonnés simultanément grâce à un dispositif à 2 sphères. Ce montage est mieux adapté pour les transducteurs à faisceau scindé.

INTRODUCTION

Many marine research vessels are equipped with several transducers. These may be hull-mounted or towed in separate vehicles. Insofar as these are scientific instruments per se or components of systems, such as echo sounders and integrators (Mitson 1984), it is important that they be calibrated.

Calibration of a single-transducer system by standard target is an established, high-precision procedure (Foote et al. 1987). Calibration of multiple-transducer systems has been accomplished in a variety of ways. The reciprocity method (Urick 1983) and comparison with standard transducers or hydrophones have been used to calibrate several wideband, plankton-measuring systems (Holliday and Pieper 1980, Holliday et al. in press), with frequency ranges spanning 2.5 and 7 octaves, respectively. A single standard sphere has also been used to calibrate a one-octave system (Simmonds 1986, Simmonds and Copeland 1986).

The problem addressed here is that of calibrating a multiple-transducer system composed of near-lying or clustered transducers with at least partly overlapping central or main beam lobes. Since the solution is based on that of the standard-target method, this is very briefly reviewed, with emphasis on some practical matters. The solution method is then presented and discussed for the case of two transducers.

STANDARD-TARGET CALIBRATION

By definition, this method effects calibration by means of a target of known scattering properties. If these are constant for a specific state of the medium, then the target is a primary standard and the calibration procedure can be repeated under like conditions at any time without reference to other measurements.

A key to using a standard target to calibrate a transducer or single-transducer system is knowing where the target is in the transducer beam. This is usually on the acoustic axis, for changes in position can be readily detected by a fall in the echo level, at least for target spheres. However, other known positions in the main beam lobe may be suitable too.

Knowing where a suspended target is in a transducer beam is essentially a matter of trigonometry, although with some interesting practical twists. These include (1) knowing the target suspension precisely, (2) being able to suspend the target from three known points, without lines coming in contact with the hull or transducer mounting and without their effective mass hindering the true suspension of the sphere, and (3) knowing the transducer orientation, both in mounting and due to the trim of vessel or transducer-carrying vehicle, especially because of the narrowness of beamwidths of typical scientific transducers.

The importance of these factors is underlined by citing some typical dimensions involved in calibrating hull-mounted transducers. For Norwegian ocean-going research vessels, these are a transducer depth of about 5 m, target depth of about 25 m, suspension points at different heights in the range 5-10 m above the water surface, with baseline of about 10 m, and transducer beamwidths measured between opposite -3-dB levels of 5-8 deg.

That an off-axis calibration can be effected from purely trigonometric considerations has been demonstrated by the work of, among others, Reynisson (1985, 1986, 1987), who has used extended outriggers on R/V ARNI FRIDRIKSSON and R/V BJARNI SAEMUNDSSON. Other beam-mapping exercises have also shown the feasibility of working off axis, although some, e.g., that by MacLennan and Svellingen (1989), have inferred the target position in the beam from the sum-beam signal of a split-beam echo sounder.

Clearly, transducers with the split-beam function (Ehrenberg 1983) are very convenient for defining off-axis positions. This assumes, of course, that their angle measurements are correct, which is not to be taken for granted (Reynisson 1987, Degnbol 1988, Kieser and Ona 1988, MacLennan and Svellingen 1989).

In the following, it is assumed that the means are available for determining where a standard target is in the transducer beam. The beam pattern can thus be known and its effect on the echo level measured. Since the target strength is known, comparison of the recorded performance with this reference quantity allows adjustment of the transducer electronics or other definition of the transducer or transducer-coupled-system performance, thus effecting the calibration.

DOUBLE-TARGET CALIBRATION

If the main beam lobes of two transducers overlap at least partially, then each transducer can be calibrated separately by using the respective sphere of a two-sphere assembly suspended from the same point. The two spheres are thus imagined to be attached to the same line, which is attached to the suspension system at the junction of the three lines. To avoid interfering echoes from the two spheres, the distance between them must in principle be at least one-half the total pulse length of the longest pulse to be used. In practice, it should be several times this distance. Calibration of the two transducers or attached systems can then be effected simultaneously by appropriate time-gating of the several echoes.

Under noisy or other difficult conditions it may be advisable to use only measurements whose echo amplitude or beam pattern value exceeds some threshold. A companion paper (Foote 1990a) expresses this operation mathematically for the example of an echo integrator calibration. Expressions required for calibrating other acoustic equipment may be derived by analogy.

DISCUSSION

The outlined double-sphere method for calibrating two transducers or transducer-coupled systems is quite simple, depending as it does on ordinary standard-target calibrations. An essential condition for this is that the central beam lobes overlap or intersect at a range convenient for suspending the two-sphere assembly in the farfields of the respective transducers. If the respective positions of the sphere in the two beams are additionally known, as with split-beam transducers, performance of the calibration is immediate.

Several advantages, both direct and incidental, accrue from the simultaneous use of two spheres. The first is the expedient use of time. More often than not during survey cruises, there is scarcely time for calibrating one transducer, much less two. Even where there is sufficient time, bad or deteriorating weather or tidal conditions makes rapid execution of calibration exercises desirable.

A related, important advantage of being able to calibrate two transducer-coupled systems simultaneously is that of confirming the correctness of simultaneous two-transducer operation. For widely differing transducer frequencies there is little chance of cross-talk, except when something fails or is lacking in the receivers, which is another good reason for calibrating acoustic systems.

Use of a two-sphere assembly confers a third advantage: that of inertia. The lower sphere acts as a weight on the first, reducing the effect of the suspension lines on positioning of the upper sphere in its transducer beam. Pendular movement of the assembly is a hazard, but is not expected to have serious effects, except possibly in bad weather. Under poor conditions, calibration of split-beam or dual-beam transducers can still be performed (Foote 1990a), as long as the spheres spend at least some time in the respective main beam lobes and there is no consistently excessive absorption due to air bubbles between transducer and target.

If the sphere can be used with each of the two transducers, then a two-sphere calibration offers the possibility of redundancy. What is achievable with one sphere can be achieved with each of two spheres, albeit at different ranges. Are the results the same? If they differ, are the results significantly different? If not, combination by a weighted average may be advisable. The degree of variation about this will give a measure of the precision of the overall calibration.

A candidate system for application of the described two-sphere two-transducer calibration method is the SIMRAD EK500 scientific echo sounding system (Bodholt et al. 1989), when employing split-beam transducers. The procedure was found to be feasible during an exercise performed on R/V MICHAEL SARS in Olderfjorden in west Finnmark in March 1990. In the course of investigating a number of problems, it was discovered that the numbers for the target strength distribution that were being printed on the echogram were incorrect. Later investigation by the manufacturer confirmed the incorrectness of the printing. Target strength data sent to external processors, such as the Bergen Echo Integrator (BEI) (Knudsen 1989), were, however, found to be correct. Users of the EK500 in the version current in March 1990 are thus warned about using single-scatterer target strength data as printed on the echogram, whether from standard targets or fish. The attempted two-sphere calibration consequently could not be realized without making recourse to BEI-stored data.

A further difficulty with any off-axis calibration, which must inevitably be the modus operandi for a simultaneous two-transducer calibration, is that of variability in beam pattern compensation, observed by, among others, MacLennan and Svellingen (1989). It may be hoped that manufacturers or researchers will extend the meticulous work by Simmonds (1984) to the new transducers that are so critical in fisheries research applications. If beam patterns can be mapped accurately, then the compensation process should also be improved, to the benefit of the calibration scheme proposed here.

This work aims at calibrating two transducers or two transducer-coupled systems simultaneously, where two spheres are used, for convenience or by necessity. It is thus a contribution to the general problem of calibrating multiple-frequency multiple-transducer systems (Foote 1990b).

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