Advances in developing a high-frequency sonar calibration facility

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Abstract- **Advances in developing an acoustic calibration facility at the Woods Hole Oceanographic Institution are documented in the course of giving a brief overview of the calibration venue: a sea well on Iselin Dock, and previously described systems for transducer-mounting and rotation, and target suspension. New instrumentation consisting of a precision target-positioning system and external triggering system to synchronize transducer rotation and sonar pinging is described.**

I. INTRODUCTION

Quantitative users of acoustics appreciate the need for calibration. Qualitative users nominally concerned with imaging may also appreciate the need for calibration. In fact, calibration is essential for both classes of applications.

In principle, calibrations are most applicable when performed *in situ* under the actual conditions of use. Such conditions may involve the transducer mounting, depth of application, sea area, and water temperature, among other things.

In practice, calibrations may have to be performed under different conditions from those of use. The sea state or currents may be too high to achieve proper conditions of stability; manipulation of the transducer platform at the depth of deployment may be unwieldy; and time may be too precious to undertake a calibration exercise, for example. Thus, development of an acoustic calibration facility can be justified.

A particular calibration facility is described here. This has been designed for absolute calibration by the standard-target method [1-3]. The facility serves two overall goals: to provide a properly equipped venue (1) for the calibration of high-frequency sonars, and (2) for the development of calibration protocols for the same. The facility has been described previously [4]; advances in this development are emphasized in the following overview.

II. VENUE

The venue is a sea well on Iselin Dock of the Woods Hole Oceanographic Institution (WHOI). The sea well, in Woods Hole, is defined by an opening in the wharf built on pilings. The opening of the sea well is 6x13 m, oriented east-west, but it can also be accessed from the east at a range of 22-24 m from the western end of the opening. The approximate depth of the well below the rectangular opening is 15-16 m. The tidal current is mostly rectified, flooding strongly eastwards but ebbing with only imperceptible flow.

A shipping container outfitted as a laboratory is placed beside the well on an ad-hoc basis. This provides housing for the electronic instruments and a place to work.

The well is equipped with a stationary crane for lifting, access to larger, mobile cranes for bigger items, and a portable platform than spans the width of the opening. The platform serves as a bridge for access to the well, as well as for deployment of some target-suspension and -positioning apparatus.

III. TRANSDUCER MOUNTING

Plates have been prepared for each sonar transducer. Each plate is welded to a standard flange for coupling to a vertical aluminum shaft that is centered in a 6-m-long steel, trussed tower. To reduce flexure in the tidal current, the plates have been stiffened by welding angle irons to the back sides. The tower is used upside-down, with its wider base section attached to a massive I-beam by means of a gravity lock to hold it securely in place, but allow easy lifting, as for changing the transducer.

IV. ROTATION APPARATUS

A precision turntable has been developed from a commercial apparatus used to turn satellite dishes. The manufacturer is M2-Antenna Systems, Inc. The turntable can generate both radial and axial thrusts sufficient to hold the central shaft, weighted by the transducer, in place. The turntable is controlled by software from a personal computer (PC). Its accuracy is better than ±0.1 deg and is repeatable at least over a period of days-weeks or more. This has been confirmed by means of a laser pointer affixed to the top of the shaft.

V. TARGET SUSPENSION AND POSITIONING SYSTEMS

A total of three systems have been developed for suspending and positioning standard targets.

In its simplest form, the target is suspended from the portable platform bridging the well. The target may be weighted, either by a free weight or by a tensioned line threaded through a block attached to a massive weight sitting on the bottom.

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In another form, the target is suspended by three lines, each of which is attached to and controlled by a motorized, remotely controlled fishing reel, as designed and built by J. Klaet at the Institute of Marine Research, Bergen, Norway. Again, the target may be weighted or tensioned to reduce its range of motion in the rectified tidal current.

A third suspension system consists of a central supporting line, as in the first system, but with five additional lines providing tension. One applies a vertically downwards force, the other four act obliquely upwards toward the corners of a square at which tension is applied to each line by means of a block and weight.

All lines are made of monofilament nylon. These are recognized to stretch under tension and deform with time, also because of the influence of the immersion medium.

Positioning is controlled by running the vertical supporting line through a block attached to the platform to a motorized fishing reel mounted on the wharf proper. The monofilament line passes over a 1-m-long ruler. By marking the line, the depth of the target can be controlled by reading the ruler to within amillimeter accuracy. However, the actual depth will also be affected by the current. This makes possible angular control of the target out of the horizontal plane of the transducer to within 0.0001 rad, or 0.34 sec of arc, for a target range of 10 m. Thus, for a fixed transducer mounting, the different sections of the transducer beam can be sampled with high precision by simple adjustment of the line.

VI. TRIGGERING SYSTEM

An electronic system has been designed, built, and tested for control of both scientific echo sounders and multibeam sonars. The particular systems belong to the series of Simrad scientific echo sounders, e.g., EK500 [5] and new EK60, and Kongsberg Simrad Mesotech multibeam sonars. Admittedly, control of the multibeam sonar is difficult, but only for want of adequate specification of the trigger signal and the possibility of over-riding the hard-wired internal logic of the particular units.

VII. STANDARD TARGETS

A variety of standard targets have been used in the calibration of the mentioned scientific echo sounders, with operating frequencies of 38, 120, 200, and 714 kHz, and multibeam sonars, with operating frequencies of 90 and 200 kHz.

Two classes of standard targets have been used. (1) Solid, elastic, homogeneous spheres made of electrolytic-grade copper, tungsten carbide with 6% cobalt binder, and aluminum have been used. The respective diameters have been 23 and 60 mm for the copper spheres; 20 and 38.1 mm for the tungsten carbide spheres; and 60 mm for the aluminum spheres. (2) Focusing spheres have been used to achieve enhanced target strengths for the particular diameter. The spherical shells have been composed of high-silicon bronze of diameter 101.6 mm and nominal thickness 3 mm, and rubber of nominal diameter 88.9 mm and presently unknown thickness. Both spheres have been filled with the environmentally neutral fluorocarbon liquid FC-5, with tradename Fluorolube [6].

VIII. TESTS

The calibration apparatus has itself been calibrated or verified. (1) As mentioned above, the turntable has been calibrated by means of a laser pointer attached to the top of the rotation shaft. By measuring the deflection of the beam and relating this to the range, the angle can be gauged. (2) The trigger signal has been measured by means of a digital oscilloscope when the trigger unit has been coupled to one or two echo sounders or to a multibeam sonar. (3) The target strengths of the mentioned standard targets are known *a priori* by calibration [1], but have also been measured directly, although the results have yet to be reported.

IX. USES OF THE FACILITY

A number of high-frequency acoustic systems have been calibrated at the facility, and calibration protocols continue to be developed both for scientific echo sounders and multibeam sonars [7,8]. Another application has involved calibration of an acoustic positioning system used in conjunction with the autonomous underwater vehicle (AUV) REMUS.

The potential of the facility for use in performing calibrations and in developing calibration protocols for other high-frequency sonars may be apparent.

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