Towards new UK underwater acoustical measurement standards in the 21st century

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Abstract: The importance of establishing common measurement standards to support underwater acoustical calibration and testing in the UK, and the need to demonstrate calibration traceability, has progressively grown over the last few years. In the UK, the National Physical Laboratory (NPL) provides traceability for most physical quantities through the establishment and dissemination of primary standards of measurement. This paper outlines the progress made so far in establishing the UK’s underwater acoustical measurement standards, and looks at plans to extend the capability to cover the whole frequency range of interest and over the range of temperature and hydrostatic pressure found in real ocean conditions.

OVERVIEW

Measurement plays an increasingly important role in almost all industrial practices as the drive towards improved technical performance and more rigorous quality assurance increases. In the UK, NPL develops and disseminates measurement standards for most physical quantities and is also responsible for ensuring that the UK’s measurement standards are harmonised with those of other countries. Dissemination of measurement standards is either directly to equipment manufacturers and end users through calibration services provided by NPL or indirectly through calibration laboratories accredited by the United Kingdom Accreditation Service (UKAS). In underwater acoustics, there are now two UKAS-accredited laboratories. This paper reviews progress made to date in establishing the UK’s underwater acoustics measurement standards, and looks forward to plans to extend the capabilities.

PRIMARY STANDARDS OF MEASUREMENT

For underwater acoustic field measurements, the most important basic physical quantity that is measured is acoustic pressure, using a calibrated hydrophone. Hence, to achieve traceable calibrations, the requirement is to establish primary standards of measurement for acoustic pressure. To date, this has been achieved at NPL over the frequency range 2 kHz to 60 MHz. In the frequency range above 0.3 MHz, the primary standard is a laser interferometer measuring acoustic particle displacement, from which the acoustic pressure is derived (1). Typical overall uncertainties (95% confidence level) of between ±3% and ±5% in the range 0.3 to 20 MHz and between ±5% and ±25% in the range 20 to 60 MHz are achieved. In the frequency range 2 kHz to 300 kHz, the primary method of calibrating hydrophones is three-transducer spherical-wave reciprocity with typical overall uncertainties (95% confidence level) of ±6% (1). These primary standards are then used to calibrate reference or measuring hydrophones, thereby establishing a means of disseminating the standards to users.

For frequencies below 2 kHz, the coupler reciprocity method is under development at NPL as a primary standard for the calibration of reference hydrophones. As the technique involves the use of a closed chamber, small compared with the acoustic wavelength, it will be possible to establish the primary standard over the ranges of hydrostatic pressure and temperature appropriate to ocean conditions.

CALIBRATION AND TEST FACILITIES

Two open tank facilities have been established at NPL, in a controlled laboratory environment. The first is used for frequencies in the range 5 kHz to 1 MHz and consists of a tank 2.5 m long by 1.5 m wide by 1.5 m deep,
made of polypropylene with a steel framework. It has a positioning system with two independent carriages: one has X, Y and Z linear motion and rotation about the Z-axis, the other has X, Y and Z linear motion and rotation about the Z- and X-axes. Carriages can travel to any part of tank and employ linear and rotary encoders, and are operated under computer control. Resolution in the X, Y and Z axes is 10 μm and in rotation is 0.01°. Absolute accuracy of X, Y and Z stages is 0.05 mm and in rotation is 0.02°. Maximum handling weight of the carriages is 20 kg. All carriages under computer software control. The facility is well instrumented for a whole range of acoustical measurements and is fully controlled by computer.

The second recently installed open tank is used for the frequency range 2 kHz to 300 kHz. It consists of a 5.5 m diameter, 5 m deep wooden tank with a positioning system with three independent carriages. Two carriages with load capability of 20 kg in air have X, Y and Z motion over 1 m with a resolution of 0.1 mm and rotation about the Z-axis through 360° with resolution of 0.1°. Extended travel in the Y direction up to 4 m is provided. All carriage axes are under remote computer control enabling simultaneous movement on all axes. A third carriage with a load capability of 50 kg in air has Z motion and rotation about the Z-axis. Mechanical handling is available for loads up to 500 kg. This new tank offers a unique capability for mapping the spatial distribution of the magnitude and phase of acoustic pressure fields, and is therefore ideal for developing and validating far-field prediction methods based on near-field measurements.

To date, no UK facilities have existed to enable measurement standards to be established over the ranges of ambient hydrostatic pressure and temperature corresponding to those in the ocean. However, NPL has now secured a large anechoic pressure vessel 2.5 m diameter and 7.6 m long, which will provide the basis for enabling standards to be established over a range of hydrostatic pressure up to 7 MPa (depth equivalent of 687 m) and temperature 2 °C to over 35 °C. Traceable testing facilities will be established over the range of operating conditions for transmit current and receive voltage responses, electrical impedance, directional response, noise level and near field measurements. This will permit measurement of the acoustical performance of systems under the same environmental conditions as are experienced in practical use.

VALIDATION OF STANDARDS

Although the development of primary standards involves a critical assessment of measurement uncertainty, the independent validation of the UK’s standards is undertaken through intercomparisons at an international level. NPL has organised and executed two such projects. To date, intercomparisons have been undertaken predominantly within Europe, although NPL hopes to see these extended world-wide in future. Examples are the EC intercomparisons of hydrophone calibrations between 0.5 MHz and 15 MHz (2) and 15 kHz and 300 kHz (3). In both cases, the overall agreement between the UK’s measurement standards and the grand means of the results of all participants was well with the measurement uncertainties. Typically, the r.m.s. differences between NPL’s results and the grand means was 2% at megahertz frequencies and 5% at kilohertz frequencies.

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