National Institute of Standards and Technology (NIST)

Report for CCAUV, September 2017

The National Institute of Standards and Technology (NIST) is one of the United States' oldest physical science laboratories. NIST measurements support the smallest of technologies to the largest and most complex of human-made creations—from nanoscale devices so tiny that tens of thousands can fit on the end of a single human hair up to earthquake-resistant skyscrapers and global communication networks. The organizational structure of NIST includes its headquarters in Gaithersburg, MD and facilities in Boulder, CO. Seven laboratories and several extramural programs comprise NIST. NIST's Physical Measurement Laboratory (PML) develops and disseminates the national standards of:

- length, mass, force and shock, acceleration,
- time and frequency,
- electricity, temperature, humidity,
- pressure and vacuum,
- liquid and gas flow, and
- electromagnetic, optical, microwave, acoustic, ultrasonic, and ionizing radiation.

Calibrations and measurement research related to acoustics and vibration are conducted by the PML Engineering Physics Division's Acceleration, Vibration, and Acoustics (AVA) Project. NIST also coordinates its efforts with the Underwater Sound Reference Division (USRD) to support calibrations related to underwater sound.

The AVA Project has been revitalizing its calibration services and measurement research activities. The project has brought up a new Primary Vibration Calibration System capable of sweeping the vibration frequency from 5 Hz to 50 kHz, as well as low frequency calibration capabilities that extend the range down to 0.2 Hz, while at the same time reducing the uncertainties from the previous services.

The AVA Project has developed and completed testing of a prototype pendulum-based shock calibration capability that is currently capable of producing peak accelerations of over 30000 m/s^2. The system measures the velocity of a test block on which the accelerometers under test are mounted with a laser Doppler velocimeter. After being struck by the pendulum, the test block slides along a v-shaped guide with Teflon surfaces. The analog signal from the velocimeter and the acceleration signal from the accelerometer are sampled at 1MHz with an 18-bit data acquisition system. The acceleration signal from the accelerometer is calibrated by comparison to the derivative of the recorded velocity signal. Both acceleration signals are forward and backward filtered with multipole Butterworth filters set to the same application dependent cutoff frequency. The velocimeter signal is calibrated by integrating it to determine distance and then comparing the results with the distance measured with NIST-traceable calipers and gage blocks. The velocity signal is corrected for dropouts before integration. The difference between 21 measured and calculated displacements of the test block covering the range from 2000 to 32000 m/s^2 has shown agreement to within ±0.2%.

The AVA Project has also been working with US accelerometer manufacturers that produce accelerometers based on microelectromechanical systems (MEMS) technologies, the MEMS and Sensors Industry Group, and the IEEE Standards Association to develop standard terminologies and calibration protocols for digital-based micro sensors of importance to consumer electronics, the Internet of Things (IoT), and automobiles, and other applications. The project has developed a gravity-based inertial calibration method for three-axis accelerometers and has proposed the use of intrinsic accelerometer properties to support comparisons of cross-sensitivity matrix measurement capability by identifying differences caused by errors produced by the measurement apparatus and differences caused by misalignment of the accelerometers during mounting on the measurement apparatus. More detail is provided in the list of publications.

Related work in what we call Motion Metrology is developing stroboscopic interferometry and sub-resolution microscopy for measuring the very fast motion of micro and nano systems. More detail is provided in the list of publications.

Recent efforts regarding microphone calibrations have focused on the pressure response calibration of MEMS microphones by reciprocity. To demonstrate such a calibration, a MEMS microphone was adapted for measurements in the NIST pressure reciprocity calibration system ordinarily used to calibrate triads of Type LS2aP microphones. Because the amplifier in the MEMS microphone package prevented reciprocal operation, this microphone was used only as a receiver of sound for calibrations done with two Type LS2aP microphones included in the triad. Results are reported in a recently published article included in the list of publications. Additional efforts in Acoustics are focused on the development and standardization of techniques used to measure the performance of hearing aid feedback suppression features under simulated conditions of real use. This activity is being conducted within the ANSI/ASA S3 Standards Committee (Bioacoustics) Working Group 48 (Hearing Aids).

Information on underwater acoustics activities is provided in a separate report by the USRD.

Recent Publications

1. J. Geist, M. Y. Afridi, C. D. McGray, and M. Gaitan, Gravity-Based Characterization of Three-Axis Accelerometers in Terms of Intrinsic Accelerometer Parameters, Journal of Research of National Institute of Standards and Technology, Volume 122 (2017). https://doi.org/10.6028/jres.122.032
2. M. Gaitan, M. Y. Afridi, and J. Geist, Analysis and protocol for characterizing intrinsic properties of three-axis MEMS accelerometers using a gimbal rotated in the gravitational field, IMEKO 23rd TC3, 13th TC5 and 4th TC22 International Conference, 30 May to 1 June, 2017, Helsinki, Finland. https://www.imeko.org/publications/tc22-2017/IMEKO-TC22-2017-015.pdf

3. Payne, B.F., Allen, R.A., and Hood, C.E., Improvements in Accelerometer Calibration at NIST Using Digital Vibrometry, Proceedings of the 87th Shock and Vibration Symposium, New Orleans, LA, US, October 2016.
4. C. R. Copeland, C. D. McGray, J. Geist, V. A. Aksyuk1 and S. M. Stavis, Transfer of motion through a microelectromechanical linkage at nanometer and microradian scales, Microsystems & Nanoengineering (2016) 2, 16055. https://www.nature.com/articles/micronano201655
5. C. D. McGray, C. R. Copeland, S. M. Stavis, and J. GEIST, Centroid precision and orientation precision of planar localization microscopy, Journal of Microscopy, Vol. 263, Issue 3 2016, pp. 238–249. http://onlinelibrary.wiley.com/doi/10.1111/jmi.12384/full
6. L. SHAO and J. J. Gorman, Pulsed laser interferometry with sub-picometer resolution using quadrature detection, Vol. 24, No. 15 | 25 Jul 2016 | OPTICS EXPRESS 17459. http://dx.doi.org/10.1364/OE.24.017459
7. Y. Bao, F. Guzmán Cervantes, A. Balijepalli, John R. Lawall, Jacob M. Taylor, Thomas W. LeBrun, and Jason J. Gorman, An Optomechanical Accelerometer with a High-Finesse Hemispherical Optical Cavity, IEEE International Symposium on Inertial Sensors and Systems, (2016).
8. R. P. Wagner, S. E. Fick, “Pressure reciprocity calibration of a MEMS microphone” The Journal of the Acoustical Society of America, Vol. 142, No. 3, pp. EL251-EL257, (05-Sep-2017).