

Preliminary Design of a Very Low Frequency Vibration Calibration System

Dick Rhorer and Bev Payne
National Institute of Standards and Technology
Gaithersburg, MD 20899-8220

Measuring vibration is important to many precision-engineering enterprises. For example, accelerometers are often used to measure and analyze the vibration of precision machine tool structures. As with any measurement, the calibration of the vibration transducer is a key component of the overall measuring process. The National Institute of Standards and Technology (NIST), originally the National Bureau of Standards, has been calibrating reference level accelerometers for over half a century.

This paper is an overview of the preliminary design for a new motion generating and measuring system for the NIST vibration laboratory. The goal of this project is to develop the capability for the high accuracy calibration of vibration transducers in the low frequency range—down to 0.1 hertz (Hz) or below. This will extend the current frequency range for NIST calibration of accelerometers by at least one order of magnitude.

The calibration of vibration transducers usually involves placing the transducer on a motion generating system—often called a shaker—and comparing the transducer output to a standard motion measuring system. The design of both the shakers and the motion measuring systems involve the application of precision engineering principles to achieve the levels of accuracy necessary for NIST level calibrations. Measuring the displacement of the accelerometer as a function of time with a laser interferometer can be used to perform an absolute calibration. The second derivative of the displacement signal is compared to the accelerometer output signal for calibration. The uncertainties of the calibration measurement results depend on many factors, including the purity of the motion imparted by the shaker during calibration. An ideal situation is to have pure rectilinear harmonic motion of a carriage that supports the accelerometer. Specifying the maximum allowable deviations from pure rectilinear motion, needed to produce the required level of accuracy in the acceleration, is an important part of the design specification for the shaker.

The current lowest frequency capability at NIST is 2 Hz for acceleration levels 2 to 20 m/s² (or 0.2 to 2 g). For a harmonic vibration of 2 Hz at an acceleration level of 2 m/s², the displacement required is 12.6 mm and the maximum velocity is 159 mm/s. To lower the frequency and maintain the same level of acceleration the length of motion and velocity capability will increase. To produce a motion with the same acceleration of 2 m/s² and a harmonic frequency of 0.1 Hz, a displacement of 5.06 m would be required (a total stroke of about 10 m) with a maximum velocity of 3.18 m/s. Because of the difficulties and expense of such a large shaker, the preliminary designs being considered will limit the stroke to about 1 m, which would allow the calibration of transducers to an acceleration amplitude of 400 mm/s² at 0.1 Hz. Maximum velocity would be approximately 630 mm/s. This range would cover many of the instruments designed to measure earthquake motions. Also, it is interesting that these length of travel and velocity requirements for the shaker are similar to parameters for modern high-speed precision machine tools.

Key Words: precision motion, accelerometer calibration, vibration measurement