

Frequency response evaluation of broadband seismometer in primary calibration using laser interferometer

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Broadband seismometers have wide measurable frequency range, and are used for analysis of hypocenter mechanism by monitoring nearby and far seismic waves. Since the broadband seismometer has a bandpass characteristic with a low cut-off frequency of 0.01 Hz or less in the low-frequency range, in order to evaluate its frequency response, it is necessary to use a vibration exciter which precisely oscillates at low frequency and the measurement system. Therefore, a broadband seismometer was evaluated using low-frequency calibration facility developed by AIST.

This low-frequency calibration facility consists of a vibration exciter and a laser interferometric measuring system, and vibrates an accelerometer to be evaluated with a vibration exciter and measures its vibration displacement with the laser interferometric measuring system. The vibration exciter is a specific-manufactured dynamoelectric type with air bearing which has a stroke length of 0.4 m and the maximum loading capacity that can be excited with less than 30 kg. On the other hand, the laser interferometric measuring system equips a two-phase detection type homodyne laser interferometer with a stabilized He-Ne laser source (wavelength 632.8 nm), and detects quadrature signal with the difference of orthogonal phase each other in relation to the vibration displacement. The quadrature signal is recorded at a sampling frequency of 10 MHz, the vibration displacement is calculated from phase angles normalized by 2π per half wavelength obtained by arctangent and phase unwrapping in the signal processing program. Simultaneously, from the broadband seismometer, the voltage signal of the velocity is also recorded at a sampling frequency of 200 kHz with 24 bits high resolution. By applying sine approximation to both the displacement and voltage signals, then the sensitivity of the seismometer is obtained from the ratio of the velocity and the voltage amplitudes. Furthermore, from the initial phases of both sine approximated, the phase lag of the seismometer is also calculated. In this way, obtaining the output quantity of electricity per input acceleration of the accelerometer using the laser interferometer with the length standard, is called primary calibration and is internationally documented as ISO 16063-11.

AIST, a national metrology institute (NMI), is responsible for ensuring the reliability of the measurement of the low-frequency calibration facility, international equivalence and its traceability in order to supply the acceleration standard to the industry. Therefore, also in the calibration of the seismometer, the velocity is the assembly quantity of the length and the time, and the output signal is the electric quantity, so these quantities shall be traceable to the national standard. The stability of the He-Ne laser wavelength is guaranteed on the basis of CIPM recommendation and the time standard is secured by the JCSS calibrated rubidium time base. The electric standard also secures its traceability using a JCSS calibrated DC voltage generator. Regarding measurement reliability and international equivalence, in the international comparison of low-frequency vibration (CCAU.V-K3) where NMIs compare the calibration and measurement capability mutually, the world's best uncertainty of 0.15% and international equivalence.

Information on the frequency response of broadband seismometers is given by cut-off frequencies or the table of pole and zero described in the test report by the manufacturer. Since observation data of seismic waveform is corrected and analyzed using that information, the reliability of frequency response is significant, but there are few cases reported on its accuracy and stability. In this study, since we calibrated the frequency response of Guralp CMG-3T using a low-frequency calibration facility and verified the

consistency with the test report by the manufacturer, the results will be presented.

Keywords: primary calibration, laser interferometer, broadband seismometer, frequency response

