Seafloor Observation Network for Earthquakes and Tsunamis along the Japan Trench (S-net) - Current status of the S-net construction -

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The only real time seafloor monitoring system situated inside the 2011 off the Pacific coast of Tohoku earthquake (the 2011 Tohoku earthquake) source area at the time of the earthquake was the ocean-bottom seismic and tsunami observation system off the Sanriku coast deployed and maintained by Earthquake Research Institute, University of Tokyo. Three seismic and two tsunami observatories were installed on the system. We did not have adequate observatory networks which could measure and monitor earthquakes and tsunamis on the seafloor, even though a lot of earthquakes occur beneath the seafloor around Japan.

NIED (National Research Institute for Earth Science and Disaster Prevention) has launched the project of construction of an observatory network for tsunami and earthquake on the seafloor just after the occurrence of the 2011 Tohoku earthquake. It reflected on the situation that we could not monitor the outspread of the earthquake and the tsunami outbreak on site and in real time due to poor coverage of observation in ocean area. The project has been financially supported by MEXT (Ministry of Education, Culture, Sports, Science and Technology - Japan).

The seismic and tsunami observatory network was named “S-net”. The S-net consists of 150 seafloor observatories and covers the focal region of the 2011 Tohoku Earthquake and its vicinity regions. Each observatory equips two sets of pressure gauge and 4 sets of three component seismic sensors. The 150 seafloor observatories are connected in line with submarine optical cables. And those optical cables are landed at 5 sites (Hachinohe-city, Miyako-city, Watari-town, Kashima-city and Minami-Boso-city) on the Pacific coast of Tohoku district, so then the S-net provides a real-time monitoring of earthquake and tsunami on the seafloor.

Six years has passed since the project started in 2011, the S-net seafloor observatory network is going to reach completion. Some data are being transmitted to Japan Meteorological Agency, and have been already used for surveillance of earthquakes and tsunamis. Full-scale operation of the S-net is expected to start in April, 2017.

We will report the current status of the construction of S-net seafloor observatory network in this presentation.

Keywords: S-net, seafloor observatory network, earthquake, tsunami

Toward a near real-time shaking map using the P-alert seismic network in Taiwan

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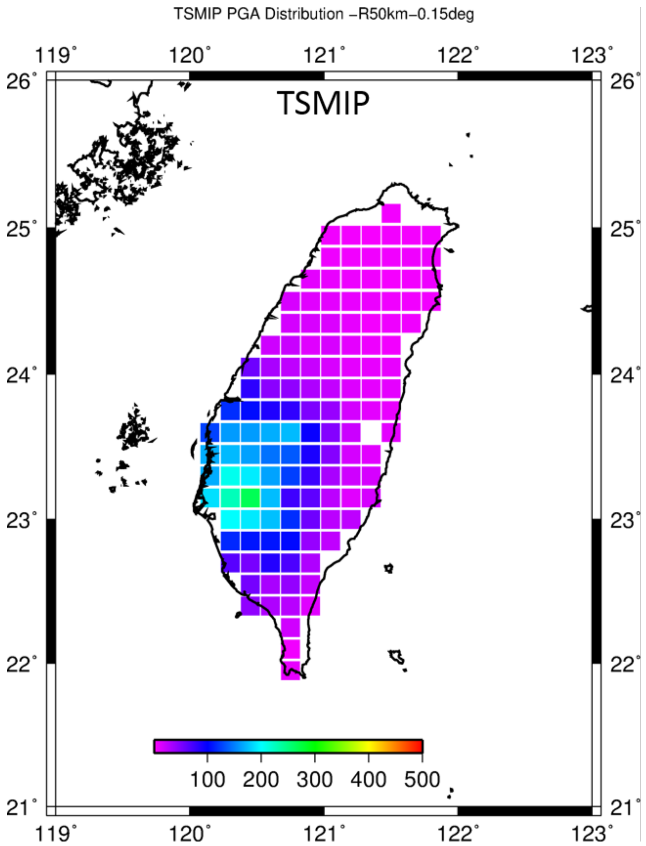
Shaking maps are one of the useful information for hazard assessment after earthquakes occurred. Based on dense and real-time seismic network the detailed and fast shaking maps are available. The Central Weather Bureau of Taiwan (CWB) has operated two strong motion seismic networks. One is the real-time strong motion seismic network, named RTD, consisting of 110 stations. It can provide a shaking map within 15 minutes after an earthquake occurred. The other is the dense seismic network named Taiwan Strong Motion Instrument Project (TSMIP) consisting of more than 800 stations. However, the shaking map generated by the RTD seismic network cannot reveal actual ground motions due to poor station density. The TSMIP seismic network cannot transmit data in real time. Recently, the low-cost Micro-Electro Mechanical System (MEMS) accelerometers has been deployed in Taiwan, named P-alert seismic network, with about 609 stations transmitting data to the center in real time. The P-alert seismic network provides an opportunity to provide quick and real shaking map, but the ground motion records from the P-alert need to be corrected because all P-alert sensors deployed on the wall or pillar of buildings. To obtain real ground motion without building influence, we proposed an approach using TSMIP records to construct a transfer function for the P-alert records. Finally, once an earthquake occurred using the real-time P-alert data streams and corrected by the transfer function, the real ground-motion shaking maps become available.

Keywords: seismic network, shaking map, low-cost seismometer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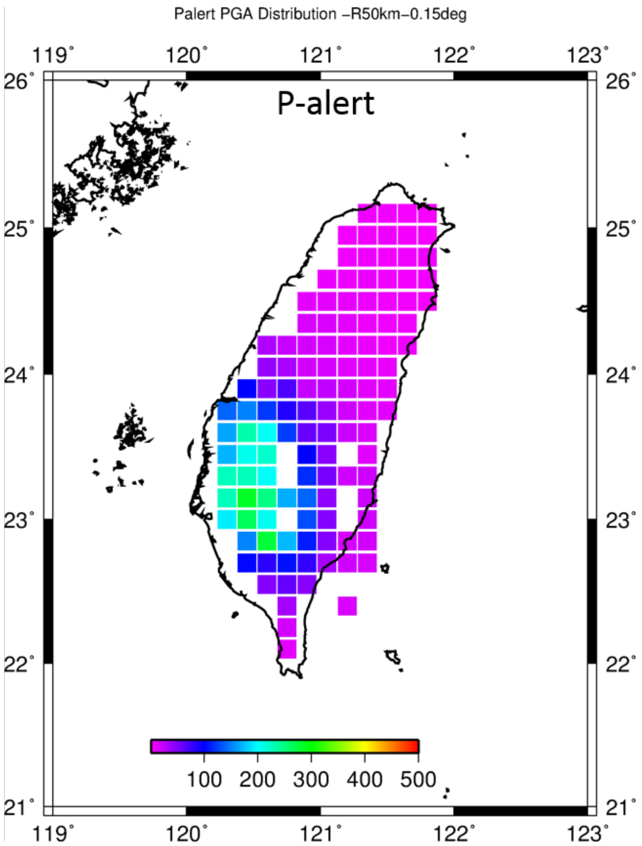
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Frequency response evaluation of broadband seismometer in primary calibration using laser interferometer

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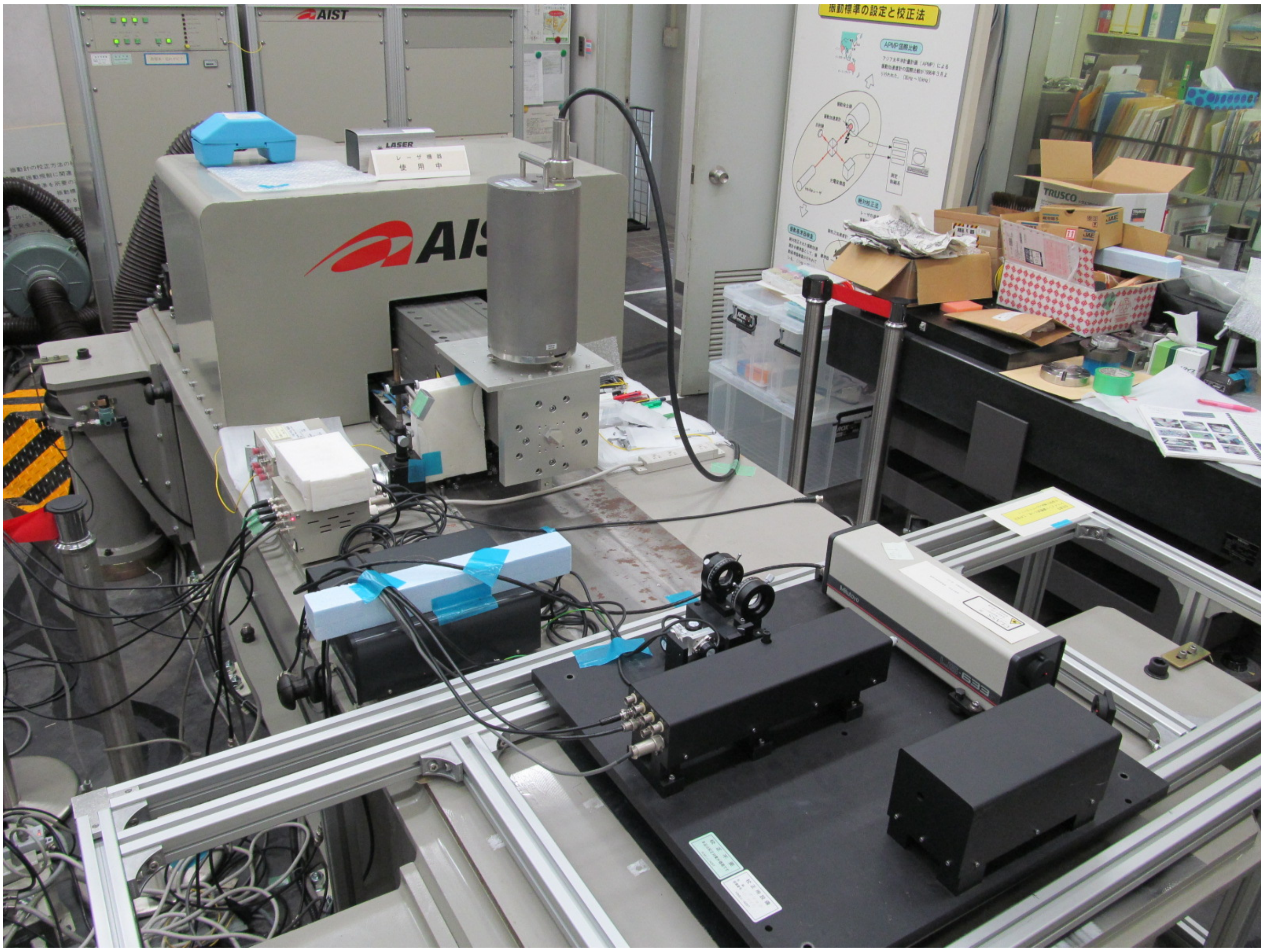
Broadband seismometers have wide measurable frequency range, and are used for analysis of hypocenter mechanism by monitoring nearby and far seismic waves. Since the broadband seismometer has a bandpass characteristic with a low cut-off frequency of 0.01 Hz or less in the low-frequency range, in order 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 (wavelengh 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 2p 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 (CCAUV.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



Progress of Seismic Monitoring System using Optical Fiber and DAS Technology

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1. Schlumberger

During the JpGU 2016, I introduced that DAS (Distributed Acoustic Sensing) technology has been used since 2011 for the demands of pipeline monitoring and intrusion detection in Oil & Gas business, and the latest optical fiber sensing technology using ‘differential phase’ data now allows DAS to record seismic signal including VSP (Vertical Seismic Profiling). The system is called ‘hDVS’ (heterodyne Distributed Vibration Sensing). Now, new tier-3 hDVS system has introduced in H2 2016.

Unlike conventional seismic recording system, which usually use electro-magnetic sensor or Geophone, hDVS/DAS uses optical fiber as vibration sensor. It measures dynamic strain of the optical fiber, either SMF (Single-Mode Fiber) or MMF (Multi-Mode Fiber) for entire length or a section defined by the user. In case of SMF, the maximum length of the optical fiber is around 40km with tier-2 hDVS system, while the maximum length is reduced to around 10km for MMF, depending on the level of optical signal loss and optical sampling frequency. With using new tier-3 hDVS system, it would be able to record longer (50km or longer) the length of SMF (100km is theoretical maximum length for hDVS/DAS). In addition, the S/N ratio of the data was improved by 15dB in Lab environment.

There are several advantages of hDVS/DAS system compare with current seismic monitoring system such as:

a)Able to use existing optical fiber installations as seismic sensor.
b)One system can measure line sensor over 50km rather than dot sensor.
c)Easier to expand as monitoring network by using existing optical fiber network.
d)Spatial resolution and gauge length can be set as parameters.
e)Core part of optical fiber is made of high-silica glass which can be installed at harsh environment over 200 degC where conventional sensors cannot be used.
f)Optical fiber is a passive component and no high risk of failure.
g)In the case sensing fiber is broken by earthquake/tsunami, seismic monitoring can still be continued from the damaged point.
h)Using WDM (Wavelength Division Multiplexing), there is a potential to use one fiber for both communication and seismic monitoring.

There would be more benefits can be identified.

Keywords: DAS, hDVS, optical fiber, seismic monitoring, earthquake, tsunami