Earthquake Early Warning System

Dr. Shunroku Yamamoto
Laboratory Head
Seismic Data Analysis

Japan is located in one of the areas with the highest earthquake frequency in the world. Under such a natural environment, it is considered to be extremely important to take earthquake countermeasures for the safety of the railways. However, even if full-scale countermeasures such as earthquake-resistant design and anti-seismic reinforcement for railway structures are implemented in advance, it seems to be dangerous for trains to continue running at a high speed during the tremor of an earthquake. If the speed of trains can be reduced as soon as possible at the occurrence of an earthquake, in addition to taking sufficient measures in advance, it will contribute to further improvement of the safety of railways during an earthquake. To that end, an earthquake early warning system for railways was developed.

Seismometers developed for the early-warning purpose are installed at each of the detection points of the Earthquake Early Warning System. These seismometers are composed of sensors and data-processing devices which process the P-wave data detected by the sensors and issue warnings.

Overview of an earthquake early warning system

The earthquake early warning system consists of multiple dedicated seismographs that are connected on a network. In order to be able to output a warning as quickly as possible when responding to an earthquake, each of the connected seismographs are designed to separately perform seismic observation and independently execute warnings. A number of seismographs are placed along railway tracks or in other positions to ensure that a railway network is covered. At the time of an earthquake, a seismograph closest to an earthquake center detects tremors and outputs a warning earlier than the other seismographs.

In addition to having functions to issue a warning after detecting large tremors, each seismometer has a specific function called a P-wave warning function, which can issue a warning by analyzing preliminary tremors (P-waves) that arrive prior to large tremors (S-waves). The greatest feature of the earthquake early warning system lies in its ability to issue P-wave warnings.

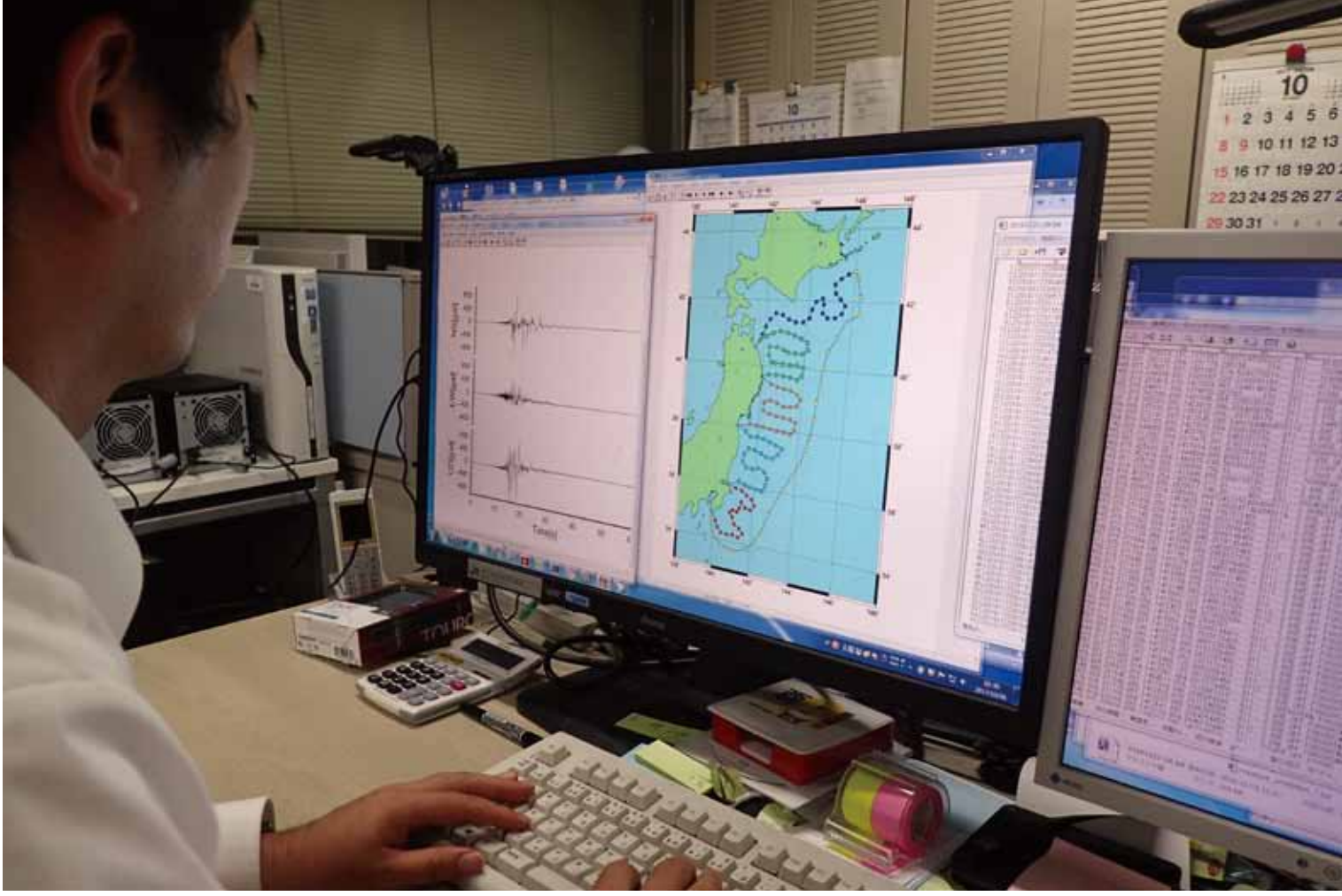
After detecting P-waves, the seismograph estimates epicentral distance, epicenter azimuth and magnitude from the initial motion part of the P-waves, determines the extent of damage and outputs a warning in one second at the fastest rate. In particular, one of the core technologies of the P-wave warning is a method called B-Δ method, which enables epicentral distance to be estimated based on the growth rate of the P-wave amplitude observed in a short period of time. This method was developed through analyzing data on seismic motions. This method is also used by the Japan Meteorological Agency as one of the methods to process Earthquake Early Warning.

To prevent false alarms, it is also important for the system to have a function to distinguish seismic motions from vibrations. The seismographs incorporate an algorithm to identify seismic motions by the characteristics of observed waveforms.

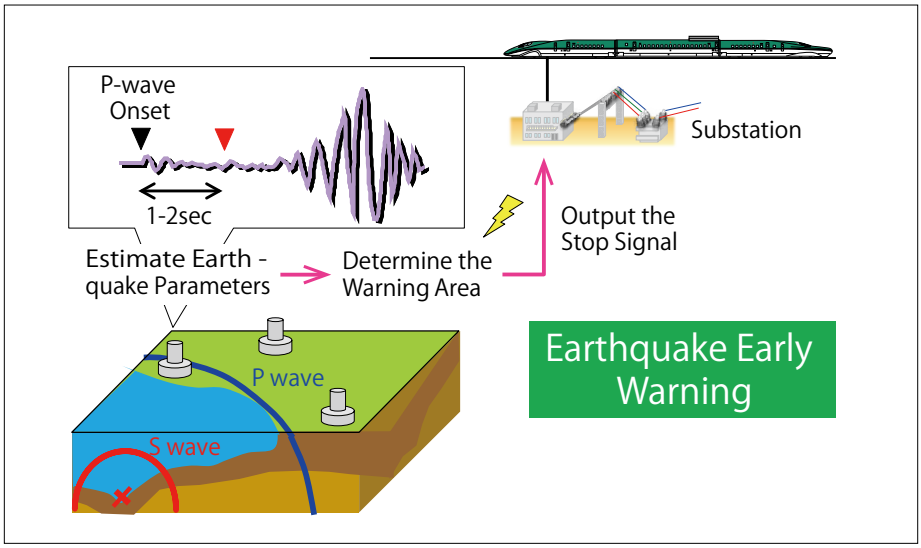
Utilization of the earthquake early warning system

The earthquake early warning system has been installed in the Kyushu Shinkansen since 2004, and presently it is being utilized in the Shinkansen throughout Japan. At the time of the 2011 off the Pacific coast of Tohoku Earthquake (moment magnitude:

Detection points are located along railway tracks or quiet places distant from tracks. Constant temperature and humidity are maintained inside the buildings housing seismometers in order to ensure stable operation of the seismometers over a long period.



RTRI is also developing an early-warning system directly using the data of ocean-bottom seismometers placed by governmental organizations so that warnings can be issued as quickly as possible at the time of major ocean-bottom earthquakes.



This system instantly estimates the epicenter and the areas expected to suffer damage by analyzing the data of initial tremors of P-wave and issue warnings immediately to the areas.

9.0), this system successfully output a warning before a large tremor reached the Shinkansen.

Currently, the system is being utilized as an important system to protect the safety of railways in Japan. At the same time, great expectations have been placed on its performance improvement. In response to such expectations, RTRI will proceed with technological developments to further improve the accuracy and promptness of the earthquake early warning system.