Development of the Earthquake Early Warning System for Railway in Japan

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Since Japan is located in one of the highest seismicity zones, to improve countermeasures against earthquake is a significant issue for railway. An earthquake early warning system is one of those countermeasures, particularly for high-speed trains. The first EEW system was in operation in 1982. This was a front-detection system, in which a seismometer located along coastlines remote from the rail monitors a large shaking from subduction zone earthquakes. The second system called Urgent Earthquake Detection and Alarm System (UrEDAS) had been installed since 1992. UrEDAS estimates magnitude and epicenter of an earthquake in several seconds by the initial phases of P-wave observed at single station, and issues a warning signal when a large shaking is expected along the rail. The present system, which has upgraded algorithms for a warning using single station data, has been operated since 2004. At present all the high-speed trains in Japan use this EEW system.The present EEW system consists of track-side seismometers, front-detection seismometers and a central server. Basically each seismometer can issue warnings by itself, but at the same time it can issue warning by using the information from other seismometers. The seismometer has two kinds of warnings, which are a S-wave warning and a P-wave warning. The S-wave warning is issued by threshold excess of acceleration and the P-wave warning is issued by analyzing the P-wave data. In order to issue the P-wave warning, the seismometer firstly estimates epicentral distance by the B-D method from 2-second P-wave data and also estimates back-azimuth to the epicenter by the Principal Component Analysis from 1.1-second P-wave data. Secondary it determines magnitude by using the epicentral distance and observed amplitude. Finally P-wave warning is issued for the potential damaging area which is determined from an empirical relation using the estimated epicenter and magnitude.The present system is reported to have worked well during large earthquakes. A successful train control by the EEW system during the 2011 Great Tohoku earthquake (Mw=9.0) is one of those examples. However to improve the rapidness, accuracy and reliability of the warnings is expected so as to enhance the safety of railway during earthquakes. Now all the high-speed trains in Japan use EEW information from JMA as an additional EEW source. Further, two other approaches are considered for safety. One is improvement of P-wave warning algorithms, the other is usage of external data such as data from ocean bottom seismometers. For the former approach, the C-D method and variable time window method are developed. These methods shorten the data length for estimation to 0.5-1.0 second and improve the estimation accuracy at the same time. For the latter approach, a simple warning logic using ocean bottom seismometers is proposed though an advanced study to understand the characteristics of OBS data is still necessary. The redundancy of warning logics as well as redundancy of system configurations is essential for a reliable EEW.

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