Improvement of Seismic Parameters Estimation and Noise Discrimination for Earthquake Early Warning

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1. Introduction

Running trains need to be stopped immediately when earthquakes occur that are large enough to affect the safety of railway facilities and running trains. For this purpose, seismographs are placed along railway lines in Japan to issue warnings by estimating seismic parameters at an early phase of earthquakes by detecting feeble-amplitude of initial P-wave. In the current earthquake early warning system, the epicenter location and seismic magnitude are estimated based on the initial P-wave information in several seconds obtained at a single–station, and warnings are issued if necessary. However, the system needs to prevent issuing false warnings by accurately discriminating between seismic motions and train-induced vibrations. In this research, we have improved the algorithms for estimating the seismic parameters and the noise discrimination in order to further enhance the performance of the earthquake early warning system.

2. Improvement of the algorithm for estimating seismic parameters

In this project, the current method of estimating the epicentral distance has been replaced by a newly-developed one, and consequently the time to analyze the data has been reduced to one fourth. In addition, with this algorithm:

1) the estimation is started at the phase when somewhat strong motion arrive in P-wave, instead of the phase just after the arrival of P-wave, and
2) in order to estimate the back-azimuth, the developed algorithm uses variable time window to analyze the data of the half-wavelength of the displacement onset of P-wave. (The current system uses a fixed time window.)

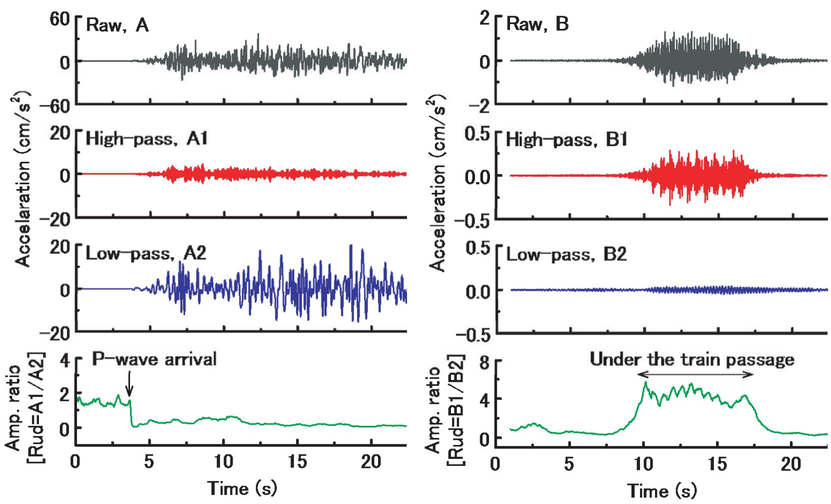
As the result, the accuracy and rapidity of estimating the epicenter location have been improved. Also, acceleration data has been introduced as a parameter to estimate the seismic magnitude, because it has been confirmed that, on average, the maximum amplitude can be detected earlier in the acceleration than in the displacement. However, if we focus on acceleration data for estimating seismic magnitudes, the accuracy is lower compared to focusing on displacement. Accordingly, the author proposes the OR operation including both acceleration and displacement data.

3. Improvement of the algorithm for the noise discrimination

Currently, the maximum of the ratio of vertical and horizontal vibration amplitudes (VHmax) is used to discriminate between seismic ground motions and train-induced vibrations. However, by comparing the frequency characteristics of both the seismic and the train-induced vibrations, it was found that, in vibrations caused by running trains, the high-frequency vibrations are dominant over the low-frequency ones. Therefore, we proposed a method of obtaining two sets of data obtained by high-frequency and low-frequency band pass filtering. We then calculated the ratios of their absolute amplitudes to moving averages (Rud) as shown in Figure 1. As a result of reviewing the performance of the discrimination method, it was found that good results were obtained by the method of combining the logarithms of VHmax and Rud in a linear equation.

4. Conclusion

With the improvements described in this article, not only the accuracy for estimating seismic parameters is expected to be improved, but the minimum time necessary to issue warnings can also be reduced from current 2.0 s to proposal 1.0 s. Furthermore, the reliability of warnings will be improved. Currently, we have developed and have been inspecting a prototype seismograph equipped with the upgrade algorithms described in this article so as to apply this device to practical applications.



(a) Seismic motions (b) Train-induced vibrations

Fig. 1 Typical case of Rud time-series data