

## On the timing of maximum amplitude -for rapid estimation of magnitude in earthquake early warning-

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Earthquake early warning, EEW, aims at issuing the warning of strong ground shaking before its arrival by analyzing seismic waveform data obtained near the hypocenter. Rapid estimation is important as well as precise anticipation of strong shaking. At present, Japan Meteorological Agency (JMA) anticipates the strong shaking using magnitude, attenuation relation and site amplification factors, and the anticipation is performed repeatedly at a given time interval. The lapse time to the final anticipation depends strongly on the timing of the estimation of magnitude. Magnitude is estimated from maximum displacement amplitude of P wave and S wave portion in the current EEW of JMA, so the timing of maximum amplitude is the main factor of the rapid and precise issue of EEW. For the estimates of M, acceleration, velocity, and real time seismic intensity (Yamamoto, 2008) can be used as well as displacement. In this analysis, we investigate the timing of maximum amplitude of acceleration, velocity, displacement and real time seismic intensity of P wave and S wave portion. We also investigate the ratio of S wave amplitude to P wave amplitude.

For the analysis, strong motion data of JMA of 1997-2007 and KiK-net data of NIED of 2000-2008 are used. We focus on the short hypocentral distance of large earthquake considering the importance of strong ground shaking in EEW, so that we analyze the data of hypocentral distance less than 100km and earthquakes of larger than M5.0. For information of earthquake origin time, P and S wave arrival time is obtained from JMA integrated hypocenter catalog.

Velocity waveform and displacement waveform are obtained from acceleration waveform, and real time intensity is evaluated by using Kunugi et al.'s(2008) method. For the acceleration, velocity, displacement, and real time intensity, time of maximum amplitude are obtained. Here we exclude the noisy waveform data, and also waveforms which are contaminated by the other earthquakes occurred just before or just after the earthquake.

At first, timings of maximum amplitude of acceleration, velocity, displacement, and real time intensity are compared for S wave portion. There are some variations for each waveform, but generally peak of acceleration is first, and then that of velocity and real time intensity follows it, and finally peak of displacement is observed. Also for P wave portion, peak of acceleration is first, and the velocity and real time intensity, and then peak of displacement is observed. Peak of acceleration of P wave portion is often observed just after the P wave arrival, but that of displacement is often just before S wave arrival. Peak arrival time depends on magnitude: peak arrival time generally becomes late with increasing magnitude.

The ratios of S wave amplitude to P wave amplitude are compared. It decreases with increasing hypocentral distance, and that of displacement is generally larger than that of acceleration. Difference of real time intensity of S wave portion and P wave portion has weak dependence of distance, and the difference increases with magnitude.

Maximum amplitude of acceleration or velocity is earlier than that of displacement. This tendency is observed not only S wave portion, but also P wave portion. This means that high frequency wave such as acceleration or velocity is useful for rapid determination of magnitude. On the other hand, saturation of acceleration at near field of large earthquake is known: peak acceleration does not depend on magnitude. Combination of magnitude estimation from displacement and that from high frequency (acceleration or velocity) is important for rapid and precise estimate.

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