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# Frequency and distance changes in the apparent P-wave and S-wave radiation pattern

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## Introduction

When earthquake occurs in a homogeneous medium, the spatial variation of maximum amplitude (apparent radiation pattern) of S waves is characterized by four-lobe pattern, which has larger S waves in the direction of fault strike and its normal direction. However, some studies pointed out that the apparent S-wave radiation pattern is significantly distorted for frequencies higher than 3-5 Hz and showing almost isotropic pattern rather than four-lobe pattern (e.g., Liu and Helmberger, 1985; Takemura et al., 2009). Recently, by using dense Hi-net waveform data, Kobayashi et al. (2014, SSJ) reported that the apparent P-wave radiation pattern is also distorted at high frequency. In this study, to investigate the differences of propagation features between P and S waves, we examined frequency and distance changes in both apparent P- and S-wave radiation patterns based on the method proposed by Kobayashi et al. (2014).

## Data and Method

We used 755 velocity seismograms recorded at Hi-net stations with hypocentral distances of 0-150 km during 10 shallow crustal earthquakes that occurred in Chugoku region, southwestern Japan. Earthquakes in this study were characterized by strike-slip faulting mechanism. Based on a method of Kobayashi et al. (2014), we evaluated the azimuthal change in amplitude fluctuations of P and S waves, which were calculated by fluctuation of amplitude from master attenuation curves estimated by the coda normalization method (e.g., Yoshimoto et al., 1993). We also evaluated the theoretical fluctuation by calculating fluctuation of theoretical radiation pattern coefficient from its average at a certain hypocentral distance (Aki and Richards, 2002, Ch. 4). To quantify how the apparent radiation pattern is distorted, we calculated the cross-correlation coefficient (CCC) between observed and theoretical amplitude fluctuations for each frequency and distance. The frequency bands in our analysis were 0.5-1 Hz, 1-2 Hz, 2-4 Hz, 4-8 Hz, and 8-16 Hz.

## Frequency and distance changes in the apparent radiation pattern

Data analysis demonstrated that the four-lobe P- and S-wave apparent radiation patterns were preserved at low frequency (0.5-1 Hz), but those were gradually distorted with increasing frequency and distance. The cause of such observation might be the seismic wave scattering due to the small-scale velocity heterogeneity along propagation path. At high frequency (8-16 Hz), the apparent radiation pattern was significantly distorted even for short hypocentral distances (40 km). It might be suggested that this observation reflects the effects of scattering due to localized strong heterogeneities around source region and/or the complexity of source rupture process.

The distortion of the apparent S-wave radiation pattern was stronger than P wave for all frequencies and distances. Furthermore, even for source region, the CCC values of S waves were obviously smaller compared with P waves. The values of CCC of P and S waves at distance of 0 km for frequency 2-4 Hz were 0.75 and 0.55, respectively. These results imply that the effects of localized heterogeneities around source region and/or source rupture complexity on P and S waves might be significantly different.

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