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Beamforming Reliability of DAS Ambient Noise Data and Wave Modes Identification

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Ambient noise generated by the anthropological activities in the urban environments may contain both Rayleigh and Love waves. Due to the differences in the physics of Rayleigh and Love waves, a pre-knowledge of the wave modes in the cross-correlogram is essential for an accurate inversion of the subsurface velocity model. Several studies (Martin and Biondi, 2017; Martin et al., 2017; Luo et al., 2020) demonstrated that only Rayleigh waves can be extracted by cross-correlation if the virtual source is colinear with the DAS array based on the assumption that the ambient noise sources are random and uniformly distributed. However, in realistic cases, ambient noise sources may come from a certain direction (e.g., Dou et al., 2017; Zhang et al., 2019). Moreover, the source propagation direction should be resolved and used to correct the apparent dispersion curves. Zhao et al. (2020) and van den Ende et al. (2020) proposed that beamforming results are not always reliable due to the measurements of DAS.

Based on the synthetic DAS ambient noise data recorded by a near “L” shape array (Source-West corner of the Stanford DAS-1 array), we prove that beamforming can resolve the source direction when the ambient sources are mainly coming from one direction. Two important processing procedures are that: check the polarity in the data and apply polarity flip on one part of the data; apply amplitude normalization on the data if strong amplitude difference exits in the data. Based on the source direction, the coordinate of the DAS array, and amplitude ratio of the data recorded by the two segments of the DAS array, we propose an inversion method to calculate the amplitude ratio of the Rayleigh and Love waves generated by the ambient sources.

We apply the method to two 100-second DAS ambient noise data recorded by the Stanford DAS-1 array. We first resolve the source propagation direction from the two data. The results indicate that the ambient noise in the data were mainly generated by the motor vehicles running on the Campus Drive in the northwest of the array. Then we invert for the Rayleigh and Love waves amplitude ratio using the proposed method. The ratios for the two data are 0.2 and 0.13, respectively. The results suggest that the ambient noise generated by motor vehicles running on the northwest corner of the Campus Drive mainly contain Love waves.