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On the generalization of the SPAC method and the development of a CCA method

CHO, Ikuo[1*]

[1] National Institute of Advanced Industrial Science and Technology

Introduction

Microtremor array methods refer to techniques for estimating subsurface velocity structures from the dispersion of Rayleigh-wave phase velocities obtained through array analysis of microtremors. Methods for analyzing Rayleigh-wave phase velocities include two major constituents: the spatial autocorrelation (SPAC) method [Aki, 1957] and the frequency-wave number spectral (FK) method [Capon, 1969]. SPAC method excels the FK method in the overall analysis efficiency, when account is taken of the requisite number of seismic sensors and the breadth of the wavelength ranges eligible for analysis [Okada, 2003]. The SPAC method, in addition, is intrinsically usable with a two-sensor seismic array [Aki, 1957], a potential that has received reappraisal during the past decade. Given this context, the SPAC method in recent years has not only come to be used more often, but has also seen progress in theoretical studies of its applicability.

Generalization of the SPAC method and the development of a CCA method

In our case, Cho et al. [2006] generalized the Aki's theory following Henstridge[1979], describing generic formulae to analyze a circular array of three-component microtermors on the basis of the theory of stationary random processes. The generic theory provided a basis for constructing various methods to efficiently analyze Rayleigh- and Love-wave phase velocities, Rayleigh-wave ellipticities, and power partition ratios of Rayleigh to Love waves. It also provided a theoretical foundation to examine applicability conditions and optimal observation durations for two-sensor SPAC methods.

The centerless circular array (CCA) method [Cho et al., 2004] represents one method on the basis of the generic theory to analyze phase velocity of Rayleigh waves. The CCA method is characterized, among other things, by its applicability to an array of three seismic sensors in irregular configuration. It is also characterized by superior analytic performance in long-wavelength ranges. Methods have been proposed to evaluate noise levels, which can negatively impact its analytic performance, in terms of signal-to-noise (SN) ratios and to compensate for the effects of noise.

In the first half of the presentation, the above history will be described after a simple explanation of the general features of microtremor array explorations.

Development of miniature array analyses for shallow surveys

In the second half, the situation on the miniature array analyses based on the CCA method will be reported. "Miniature array analyses" involves 15-min microtremor measurement sessions using very small seismic arrays, 1 m or less in radius, to obtain the dispersion of Rayleigh-wave phase velocities corresponding to depths of several tens of meters, and sometimes more than 100 m, beneath the surface. In addition to this feature, the analysis results are accompanied with quality control factors. In the last year, we dealt with the following problems so as to put the miniature array analysis into practical use: (i) What is an appropriate way to deal with analysis results of limited quality and dubious reliability in general? (ii) What is a better way to pursue the efficiency of surveys, including the step of estimating subsurface structures after the dispersion curve is obtained?

In the presentation, I will report the solution for this problem on the basis of the experience, the automatization of the analysis procedure (Cho et al., 2014; Senna et al., 2014), and a plan to release a new BIDO package (https://staff.aist.go.jp/ikuo-chou/bidodl.html) to draw 2D S-wave sections by miniature array analysis.

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Keywords: Microtremor, velocity structure, surface waves, phase velocity, exploration method, array