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COMPARISON OF SPATIAL VARIATION BETWEEN MICROTREMORS AND SEISMIC MOTION

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ABSTRACT

We examine the feasibility of the prediction of the spatial variation of seismic motion from microtremorts by comparing the estimates of dynamic characteristics from microtremors with those from seismic motion: horizontal component spectral ratios(RH), spectral ratios of horizontal to vertical components(HV) and predominant frequency. We obtain following results from small-array data. (1) The RH of microtremors is in agreement with those of seismic motion. (2) The RH of seismic motion is not in agreement of the HV of microtremors. (3) The predominant frequency from microtremors is in good agreement with that from seismic motions only at sites where spectral peaks are conspicuous. For large-array data, we obtain same results except for the result (1).

KEYWORDS

Special variation of seismic motions; prediction of seismic motion; effects; microtremors.

INTRODUCTION

It is often reported that earthquake damages change greatly even in small areas. Figure 1 shows one example of recorded seismic motions by the array around the Kushiro JMA station, Hokkaido, Japan. The diameter of it is about 500 m. The amplitude of horizontal components changes up to 3 times from site D to site E. This phenomenon of the large spatial variation in amplitude is observed in other arrays (e.g., Muto *et al.*, 1982, Abrahamson, 1985, Kataoka *et al.*, 1990, Horike *et al.*, 1990). It is also reported from the earthquake damage investigation. For example, during the 1993 Kushiro-oki earthquake, approximately 900gal and 700 gal in peak maximum acceleration was recorded only a few tens m apart. The level of the damage of life lines and houses is largely different from area to area within small region enclosed the JMA station (e.g., Kashima, 1993). Therefore, this kind of spatial vibration of seismic motions is thought to be a pretty general phenomenon and should be considered in the plan of urban earthquake disaster prevention measures, large-scale structure construction, and microzonation.

There are three basic approaches to predict and estimate the spatial variation. The first one is direct measurement of seismic motions (e.g., Somerville *et al.*, 1988). The second one is to use numerical simulation (e.g., Lamb, 1904; Horike *et al.*,1990). However, because earthquake does not occur so often and numerical simulation needs subsurface structures, the above two approaches are not practical. The final one is the use of microtremors to cope these problems.

Microtremors are synthesis of slight level vibration generated by human activities such as transportation and natural sources such as tree vibration and sea wave. Because microtremors are recorded anytime and anywhere, and observation is inexpensive and simple, the use of microtremor may be feasible to infer the spatial vibration of seismic motions efficiently.

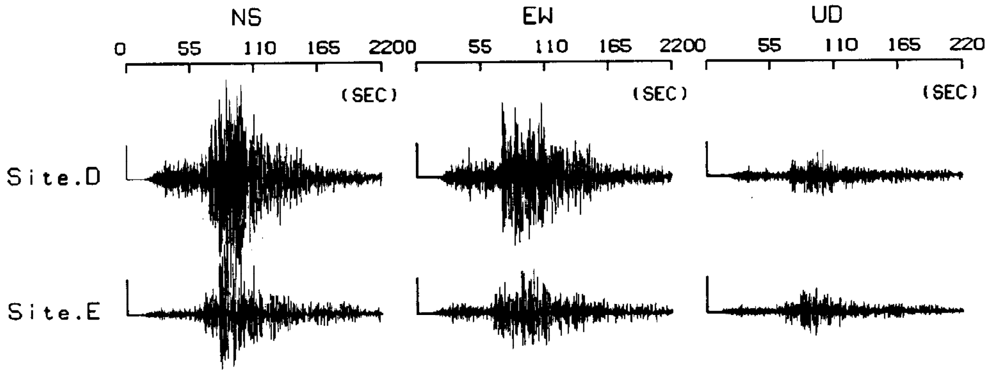

Fig. 1. One example of seismograms generated by the Etorofu-To earthquake.
(M=6.0; △=50 Km; 44503N, 151065E; 03:37:141; AUG. 29,1994)

To use microtremors for the inference responses of sediments, we have to confirm that the responses inferred from microtremors are in agreement with those from seismic motions. However, this kind of study is very few. In this paper we examine firstly the stability of the spectral ratios from seismic motion and then the feasibility of the prediction of the spatial variation of seismic motion from microtremors by comparing directly the estimates of dynamic characteristics from microtremors with those from seismic motion: (1) Spectral ratios between horizontal components recorded at different sites (hereafter abbreviated as RH), (2) Comparison of the ratios of horizontal to vertical components between sites (hereafter abbreviated as RHV) of microtremors with RH of seismic motion. (3) Predominant frequencies inferred from the power spectra (hereafter abbreviated as PP) and from the spectral ratio between vertical to horizontal components (hereafter abbreviated as PR).

ARRAY OBSERVATION

Two array (JSKA and CIKA) were deployed at Kushiro city, Japan. Figure 2 shows the station distribution.

The array JSKA locates in the Kushiro plateau. The diameter of the array is about 500 m around Kushiro JMA, and 8 sites were installed on the plateau, but site D is located at the east side of the Kushiro river. This array was operated from August 2, 1994 till 29th. The shallow portions of the plateau are composed of soft volcanic ashes, and a hard Tertiary formation lies beneath it. The size of the array CIKA size approximately 6 km in east-west direction and , approximately 4 km in north-south direction. Five site of the array CIKA are in the Kushiro alluvium plains west of Kushiro river, and 2 sites are in the Kushiro plateau east of the river. The array CIKA were operated from September 1993 till March 1994. The huddle test for the observation systems showed that spectral responses of all their systems are flat between 0.2-12 Hz and those at JSKA are flat between 0.2-10Hz.

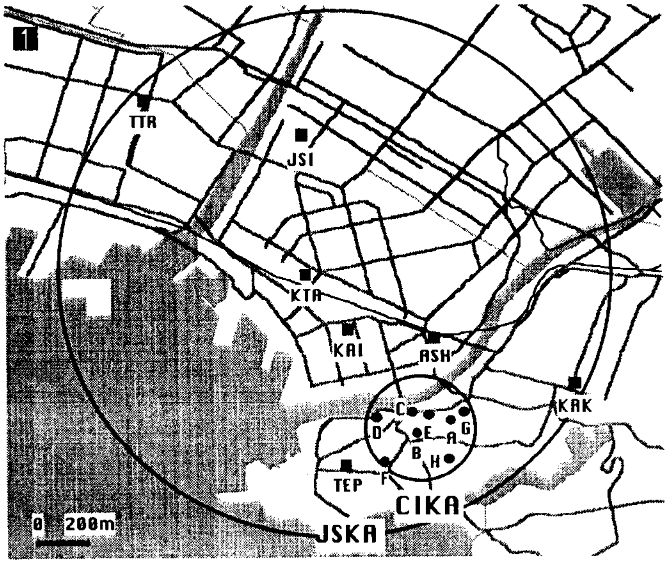

Fig. 2. Array configuration in Kushiro city, Japan.

STABILITY OF THE SPECTRAL RATIOS OF SEISMIC MOTION

In this study we estimate two spectral ratios (RH and HV). We examine whether these two ratios are stable or not; The ratio are independent on seismic events and are dependent on sites. As an example, we discussed the result of the spectral ratio between horizontal components relative to site A in JSKA. The spectral ratios (RH) for 8 events are shown in Figure 3. They are concentrated in the range of 1.5 times to 0.7 times of the average at every site whereas they are changing from site to site. This results show that the horizontal ratios (RH) are stable. It should be mentioned that the ratio HV are also stable and the two ratios of the array CIKA are again stable.

COMPARISON OF SPECTRAL RATIOS

Spectral Ratio RH

Figure 4 shows the ratio RH with reference to site A of the array JSKA. The spectral ratio of horizontal components is computed from rms amplitude of NS and EW-components. The ratios RH from

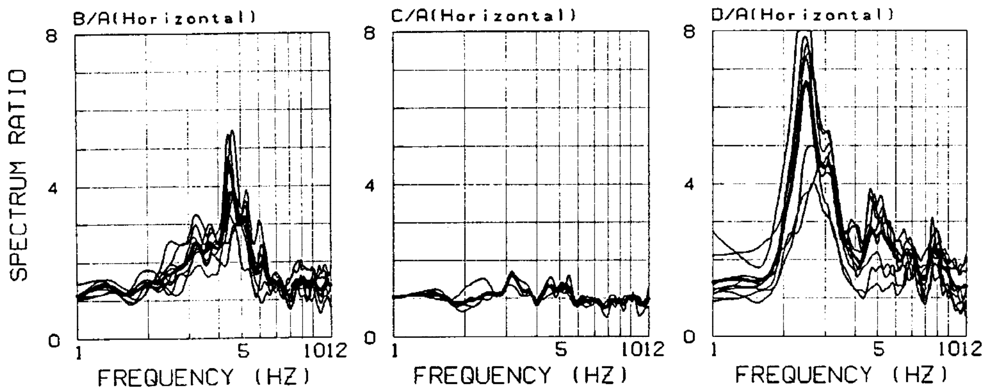

Fig. 3. Results of comparison of the spectral ratios RH between seismic motions relative site A for the array JSKA. Thin and thick lines denote spectral ratios andaverage, respectively.

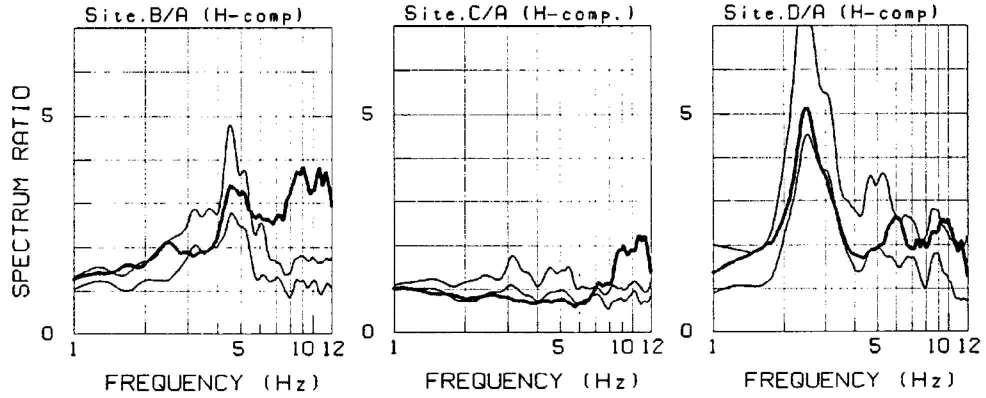

Fig. 4. Results of comparison of the spectral ratios RH with reference to site A for the array JSKA.Thin and thick lines denote average plus and minus one standard deviation of seismic motions and average of microtremors, respectively.

microtremors below 7 Hz are in the range of average plus and minus one standard deviation which are estimated from seismic motions. However, the ratios above 7 Hz are out of range of average plus and minus standard deviation at some sites.

Figure 5 shows the ratios RH in CIKA with reference to site TTR in the west of array. The spectral shape is similar to each other , but the values are is quite different in almost all sites. For example, in TEP/TTR, the ratios from microtremors are ten times larger than those from seismic motions. This result is completely different from the result of the array JSKA and we discuss it in the final section.

Comparison of the Ratios of RHV of Microtremors with RH of Seismic Motion

Nakamura (1987) insisted that the spectral ratios of horizontal to vertical components are almost same as

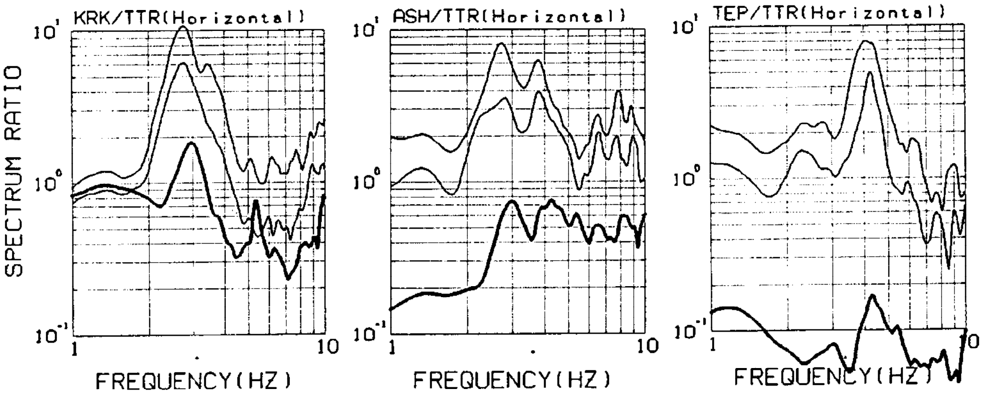

Fig. 5. Results comparison of the spectral ratios RH with reference to site TTR for the array CIKA. Thin and thick lines denote average plus and minus one standard deviation of seismic motions and average of microtremors, respectively.

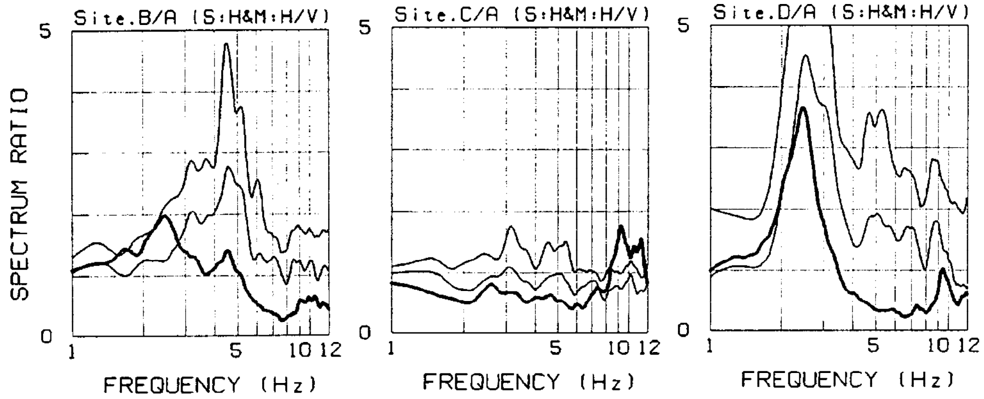

Fig. 6. Results of comparison of the spectral ratios RHV from microtremors and RH from seismic motions for the array JSKA .Thin and thick lines denote average plus and minus one standard deviation of seismic motions and average of microtremors, respectively.

the transfer function of sediments to vertical incident S waves below 10 Hz. However, his explanation does not seem to be reasonable. Therefore, we examine Nakamura's method by comparing the ratio of HV from microtremors with the ratio RH from seismic motions. Figure 6 shows the comparison of the two ratios (RHV from microtremors and RH from seismic motions) for the array JSKA. It is clear that they are different. Furthermore, it should be mentioned that for the array CIKA that the difference of the two spectral ratios are much greater than that for the array JSKA.

COMPARISON OF PREDOMINANT FREQUENCIES

Comparison of Predominant Frequencies PP and PR

The predominant frequency of sediments has been estimated from microtremor (e.g., Kanai and Tanaka, 1961; Kanai,1957; Kanai *et al.*,1 965;) for the simplicity of observation and analysis. However, it was often reported that the predominant frequency does not always reflects that of sediments (e.g., Udiwadia and Trifunac, 1973; Irikura and Kawanaka, 1980; Kagami *et al.*, 1982). In this paper, therefore we compare predominant frequency estimated from seismic motions with the predominant frequency from the power spectra of microtremors and from the ratio HV of microtremors and seismic motion.

Figure 7 shows the power spectra of microtremors and seismic motions. We define the predominant frequency as the peak frequency which appears in the power spectra of all seismic events. It is found that only if microtremor predominant frequency is conspicuous, it is coincident with the predominant frequency of seismic motions (for example see site B).

Figure 8 shows the spectral ratios HV of microtremors and the power spectra of seismic motions. we obtain the similar result: The predominant frequency of the ratio HV is coincident with that of seismic motions only if it is conspicuous. The difference is that the predominant frequency of the ratio HV is more clear than that of the power spectra.

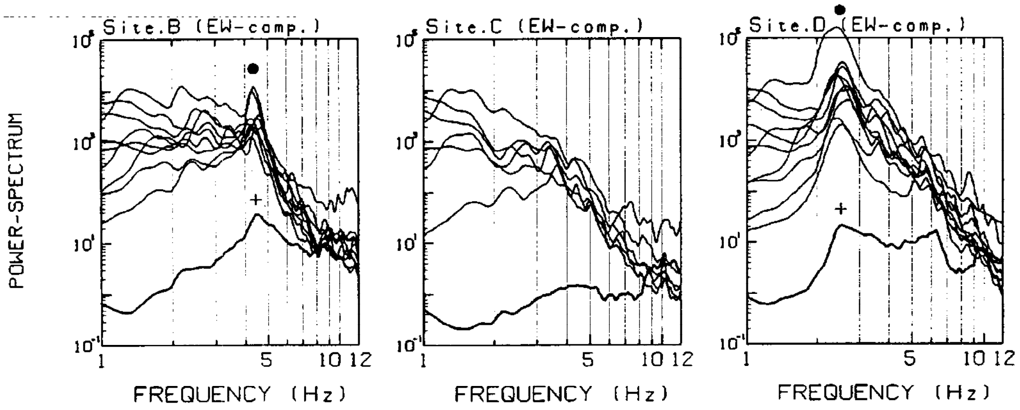

Fig. 7. Results of comparison of predominant frequency PP for the array JSKA. Thin and thick lines denote values of seismic motions and average of microtremors, respectively.

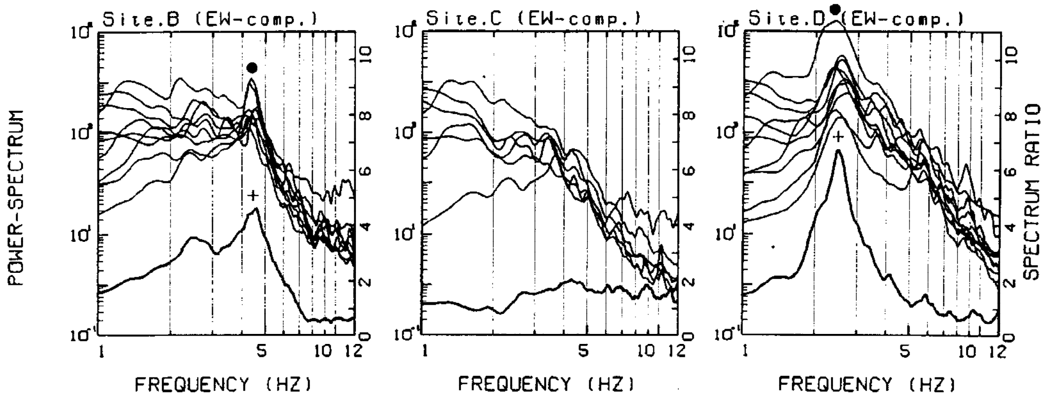

Figure 8 Result of comparison of predominant frequency RP for the array JSKA. Thin and thicklines denote values of seismic motions and average of microtremors, respectively.

DISCUSSION and CONCLUSION

In this study, we compared three estimates from seismic motion and microtremors recorded with small and big seismic arrays. They were deployed at two locations where the geological feature and the basement construction were different. The following results are obtained:

(1) Seismic motion shows strong spatial variations: they change up to 2-3 times in amplitude within small array located on the plateau composed of volcanic ashes and up to 5 times within the large array located on a alluvial layer.

(2) The spectral ratios RH of microtremors obtained with the small array(JSKA) is in agreement those of seismic motions, but the spectral ratios RH obtained with the large array(CIKA) are quite different from those of seismic motions.

(3) The spectral ratios(RHV) of microtremors are different from the spectral ratios(RH) of seismic motion. It means that the method proposed by Nakamura is not suitable for the inference of S wave response of sediments.

(4) The predominant frequencies estimated from seismic motions are coincident with those estimated from microtremor power spectra and the ratios(HV) only if the spectral peaks of predominant frequencies are conspicuous. This conclusion is the case for the large array(CIKA). It should be mentioned that the predominant frequency estimated from the ratios(HV) are more clear than those estimated from the power spectra. The conclusion(2) suggests that if the spatial constants of incident microtremors spectra is not guaranteed, the spectral ratios(RH) of microtremors is not useful for the prediction of seismic motions. The conclusion(4) means that the predominant frequency of seismic motions is possible to estimate from microtremors only in sediments with sharp interface.

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