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THE SUBSURFACE STRUCTURE INFERRED FROM MHVRS AT THE BOUNDARY OF THE BASIN EDGE IN UJI, JAPAN

S. Matsushima[(1)]

[(1)] *Professor, DPRI, Kyoto University, matsushim@sds.dpri.kyoto-u.ac.jp*

Abstract

In this study, microtremor horizontal-to-vertical spectral ratios (MHVRs) are used to estimate the subsurface structure at the boundary of the basin edge in the northern part of the city of Uji, Japan, around the Uji campus of Kyoto University.

Within the Uji campus of Kyoto University, directional dependence has been clearly seen in the observed MHVRs. Uji campus is located close to the basin edge, which is formed as a result of the reverse fault movement of the Obaku fault, in the south-eastern part of the boundary of Kyoto basin. Previous studies found that the observed directional dependence of MHVRs are a result of the effect of the two-dimensional basin structure from the numerical MHVRs, calculated based on the diffuse field assumption (DFA). Based on DFA, MHVRs are calculated from the ratio of the imaginary part of Green's functions for a coinciding load and response for the horizontal and vertical components, so it is not limited to a flat-layered media, and can be derived for any kind of heterogeneous velocity structure.

In order to investigate MHVRs in a wider area outside of the Uji campus, microtremor observations were conducted surrounding the Uji campus. The spatial variability of the directional dependence of MHVRs from the data obtained from stations that were extended to sites further away from the basin edge, i.e. closer to the central part of the basin, and sites up the hills to the hanging wall side of the Obaku fault, and sites along the fault. The observed MHVRs showed that if the site is further away from the basin edge, it does not show much directional dependence, where we can assume that the subsurface structure can be considered as flat-layered. On the other hand, if we go up the hills, the peak diminishes as predicted by numerical calculations by Matsushima et al. (2014).

The information obtained from observed MHVRs are used to specify the detailed shape of the three-dimensional basin edge structure and construct a velocity model. As a result, the

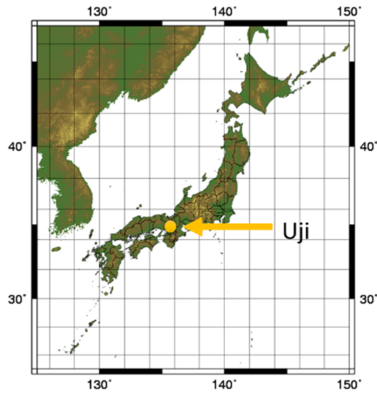
Keywords: Microtremor, Horizontal-to-Vertical Spectral Ratio, Subsurface Structure, Basin Edge, Uji

1. Introduction

In this study, microtremor horizontal-to-vertical spectral ratios (MHVRs) are used to estimate the subsurface structure at the boundary of the basin edge in the northern part of the city of Uji, Japan, around the Uji campus of Kyoto University.

Within the Uji campus of Kyoto University, directional dependence has been clearly seen in the observed MHVRs [1]. Uji campus is located close to the basin edge, which is formed as a result of the reverse fault movement of the Obaku fault, in the south-eastern part of the boundary of Kyoto basin. The observed directional dependence of MHVRs were found to be a result of the effect of the two-dimensional basin structure from the numerical MHVRs [1], calculated based on the diffuse field assumption (DFA) [2]. Based on DFA, MHVRs are calculated from the ratio of the imaginary part of Green's functions for a coinciding load and response for the horizontal and vertical components. This indicates that calculation of MHVRs does not need to be limited to a flat-layered media, but can be applied to any kind of heterogeneous velocity structure if the Green's functions can be derived.

In order to investigate MHVRs in a wider area outside of the Uji campus, microtremor observations were conducted surrounding the Uji campus [3]. The predominant frequency of MHVRs are used to estimate the distribution of the bedrock depth in the region.



(a) Location of Uji, Japan

(b) Topography surrounding the Uji campus (plotted on Google Map)

Fig. 1 – Map of Uji campus, Kyoto Universit8

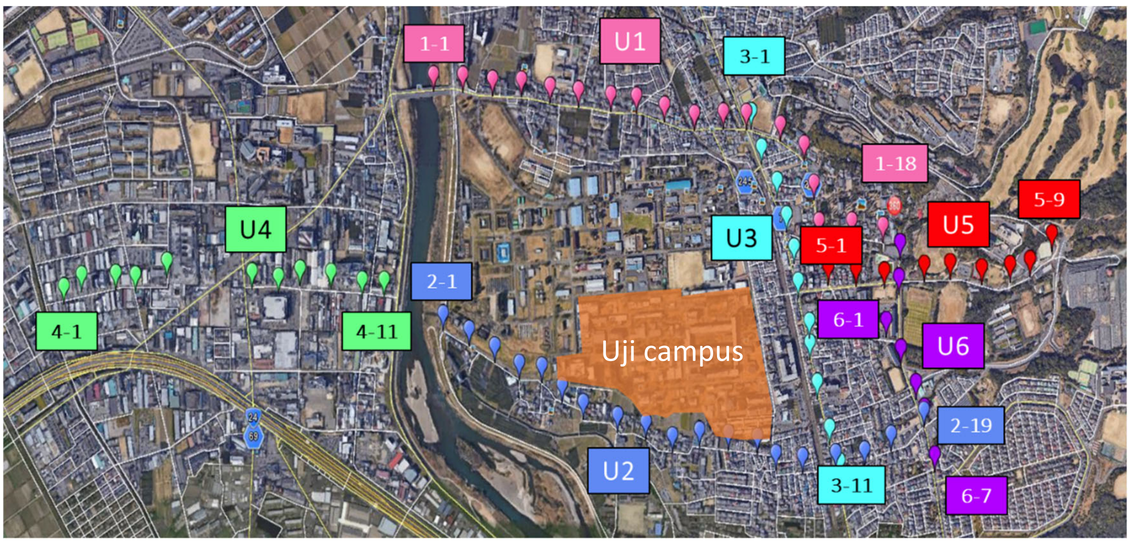


Fig. 2 – Distribution of microtremor observations sites surrounding the Uji campus (plotted on Google Map)

2. Microtremor MHVRs

2.1 Overview of observation plan

Microtremor observations were conducted in the target area of this study, in Uji, Kyoto, Japan (Fig.1). The observation sites were distributed along six survey lines surrounding the Uji campus of Kyoto University (Fig. 2). For the observation, portable 3 component accelerometer SMAR-6A3P were used. The microtremor was observed for 30 minutes at each site, with the condition of 100 Hz sampling, 1000 times amplification, time calibration by GPS and analog filter of 30 or 50 Hz.

Line U1 and U2 were deployed along the roads going east-west, located north and south of Uji campus, respectively. Line U3 and U6 was deployed along the roads going north-south, running along the Obaku fault. Line U4 was deployed west of the Uji river that flows north-south in the western side of Uji campus. Line U5 was deployed in the east-west direction in the most eastern part of the observed area, going up the hill to the footwall side of the Obaku fault. The observation sites were deployed about 100 m apart.

2.2 Observed MHVRs

For the data processing of observed microtremors, firstly 40.96 second time windows overlapping half of the time window is take out from the 30-minute microtremor data. Secondly, the average MHVRs for each time window is calculated for NS and EW components separately, and the two horizontal components is not averaged as done in conventional MHVR studies. Finally, MHVRs are averaged by all the time windows taken out from each measurement. The spectrum was smoothed by Parzen window with bandwith of 0.1 Hz. MHVRs for all survey lines U1 to U6 are shown in Figs. 3 to 8, respectively. The theoretical MHVRs that will be explained in the next chapter, are also shown in the figures.

The Observed MHVRs around Uji campus show directional dependent characteristics, i.e. NS/UD and EW/UD has different amplitude and/or different predominant frequency. For line U1, the directional dependence can be seen in most of the sites, but the peak at around 0.4 Hz is clear from sites U1-1 to U1-12, except U1-5 and U1-6 which does not show any peak because of poor data quality. The peak around 0.4 Hz shift to higher frequency as the sites move eastward. For sites east of line U3, U1-15 to U1-18, the peak is not clear, which can be assumed that it is because the sites are close to the boundary of the basin edge. These phenomena were seen in the numerical calculations by Matsushima et al. [1]. Sites U1-1 to U1-12 were deployed along a road with much traffic, so the overall quality of the data is low.

For line U2, since it was observed in much better condition compared to line U1, the peaks are very clear from U2-1 to U2-13 and shifts to higher frequency as the sites move eastward, but after crossing line U3, the peaks become unclear. Also, sites from U2-4 to U2-13 as clear directional dependence but for sites U2-1 to U2-3, the difference becomes smaller. For sites U2-14 to U2-19, the directional dependence is not clear. For line U3, sites U3-1 to U3-3 shows directional dependence, but sites south of U3-4 (U3-4 to U3-11) does not show clear directional dependence.

For line U4 which is the only survey line west of Uji river, there is a second peak around 3 to 5 Hz in addition to the predominant peak at around 0.3 Hz. Both peaks do not show directional dependency and the peak at around 0.3 Hz is stable along the line. For line U5, the first three sites, i.e. U5-1 to U5-3, show clear peaks around 0.8 Hz and some directional dependency. For sites U5-4 and U5-5, the peak is flat and unclear. For sites beyond U5-6, the peaks shift to 3 Hz and above. As for line U6, the peak frequency does not change from site to site, but the difference between NS/UD and EW/UD becomes smaller. From these figures, we can understand that the characteristics of the directionally dependence of MHVRs seems to show relation with the local lateral heterogeneity close to the basin edge.

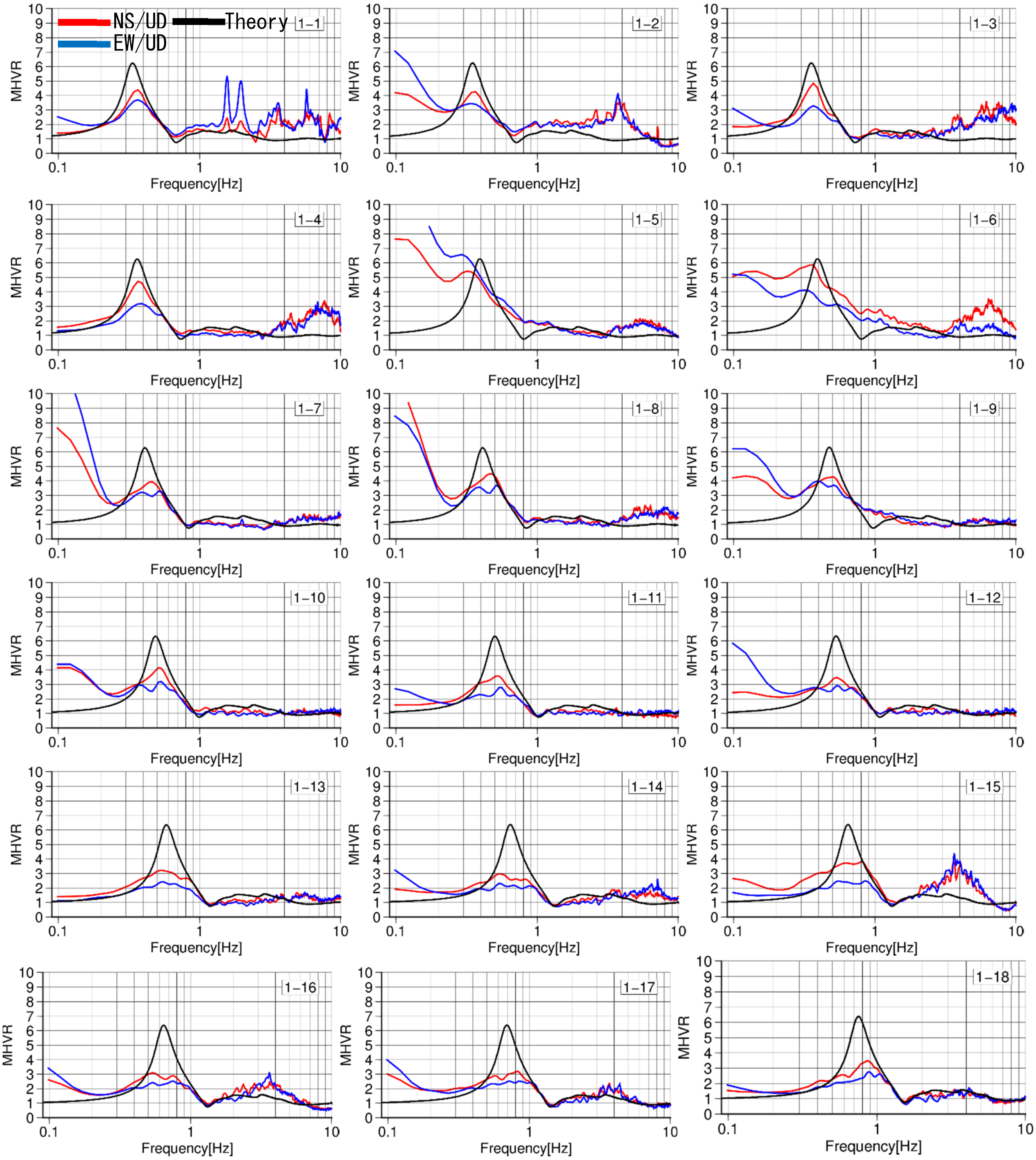


Fig. 3 Observed MHVRs (red and blue lines) compared with theoretical MHVRs (black line) for Line U1

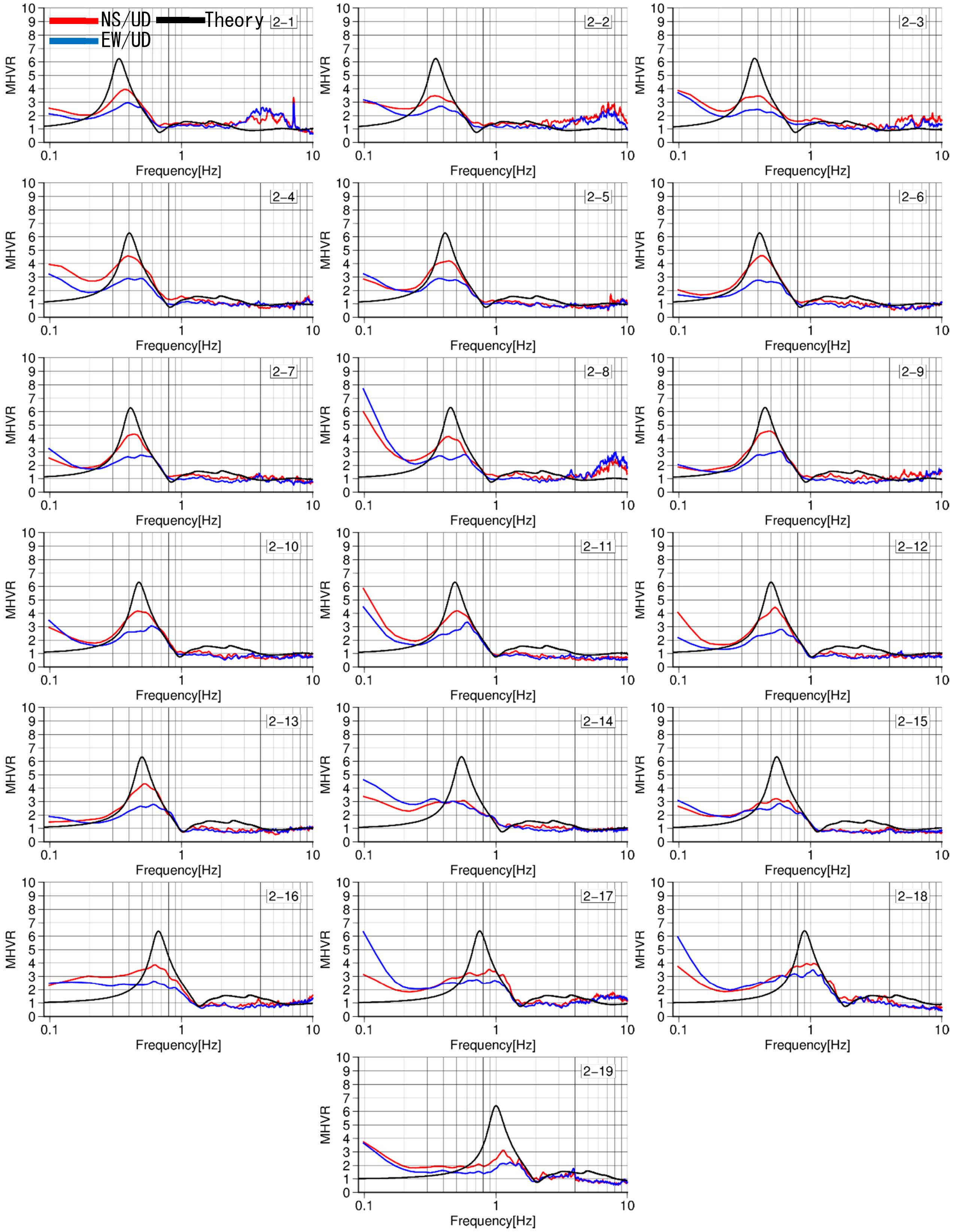


Fig. 4 Observed MHVRs (red and blue lines) compared with theoretical MHVRs (black line) for Line U2

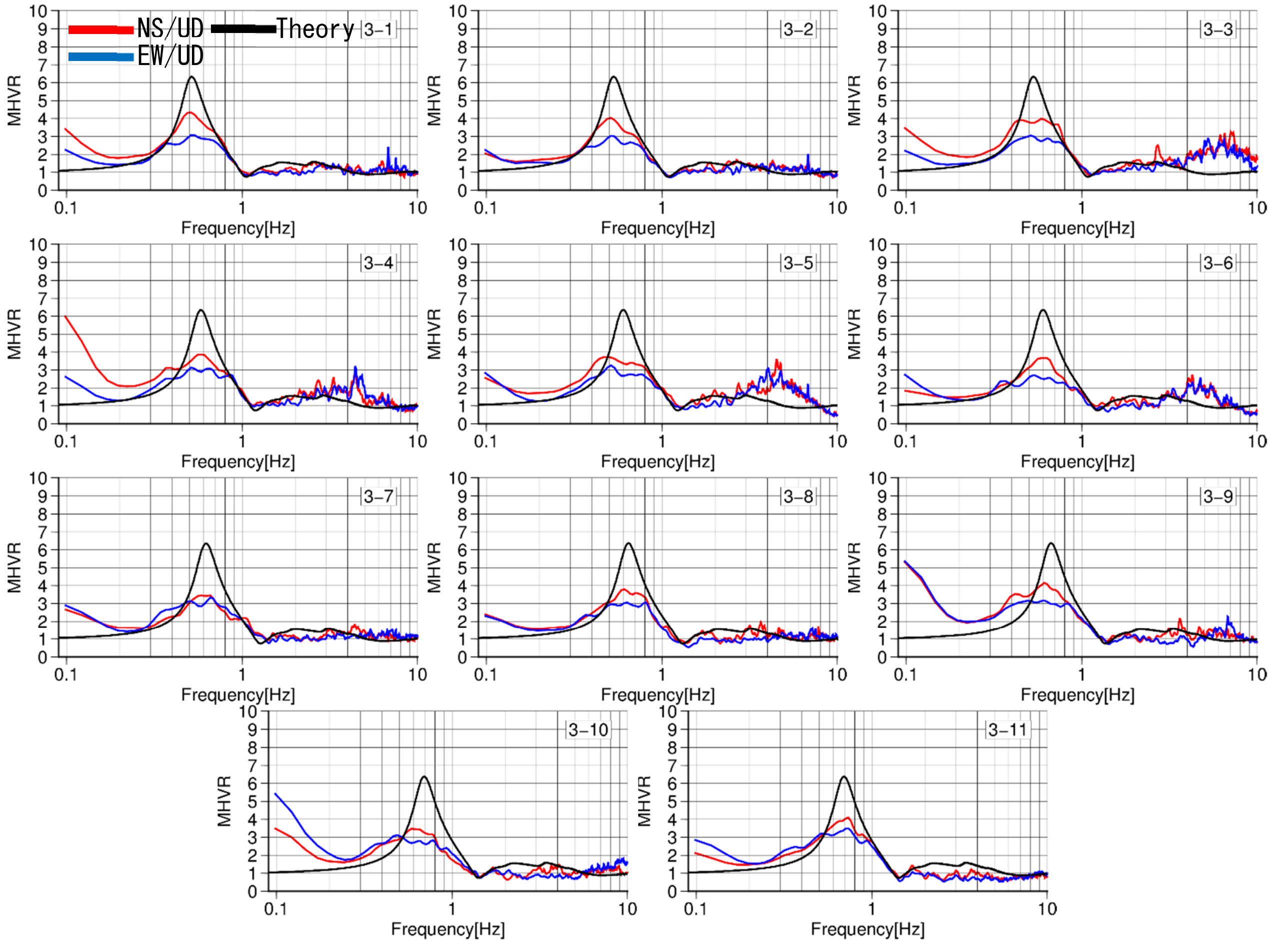


Fig. 5 Observed MHVRs (red and blue lines) compared with theoretical MHVRs (black line) for Line U3

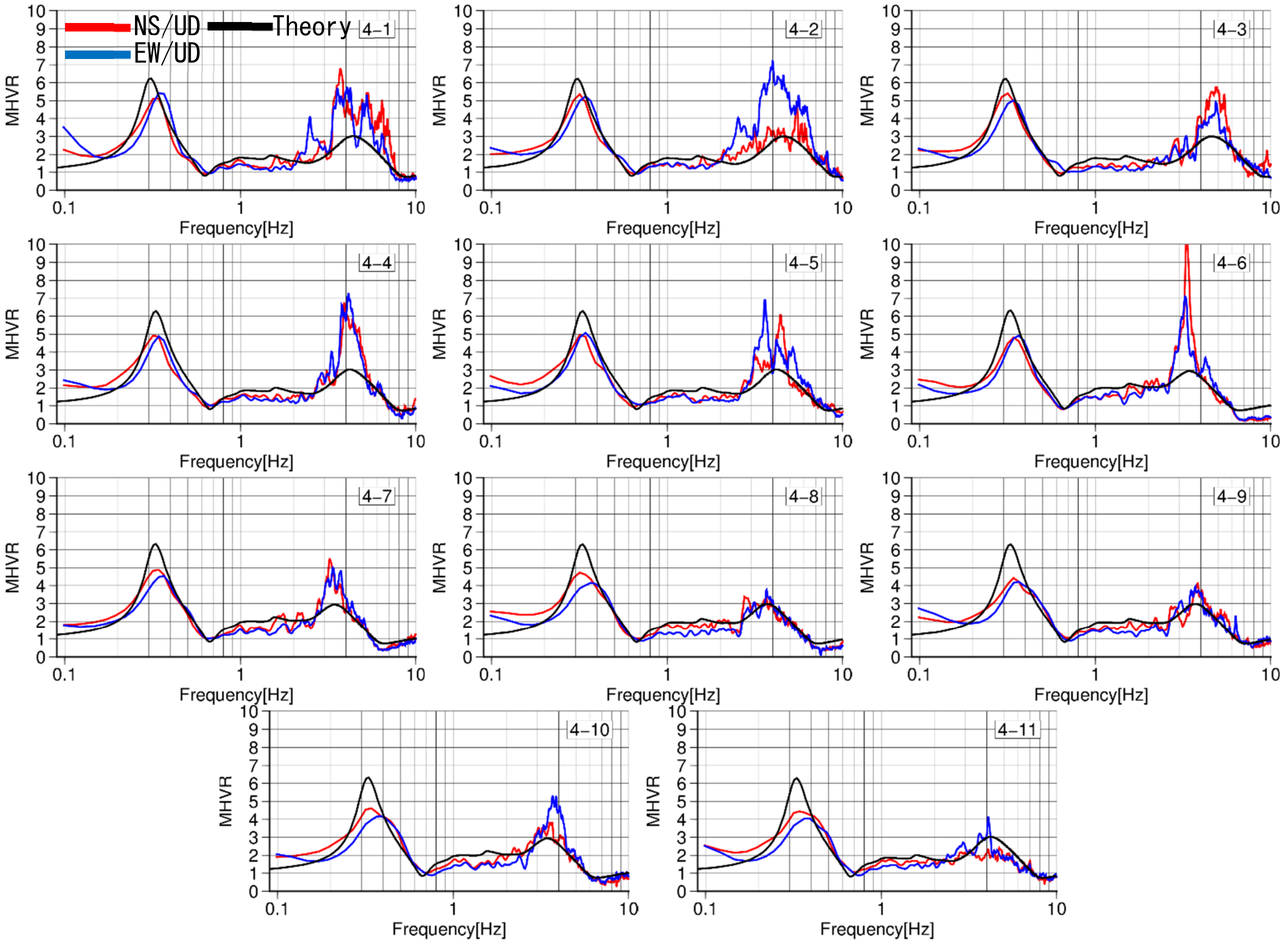


Fig. 6 Observed MHVRs (red and blue lines) compared with theoretical MHVRs (black line) for Line U4

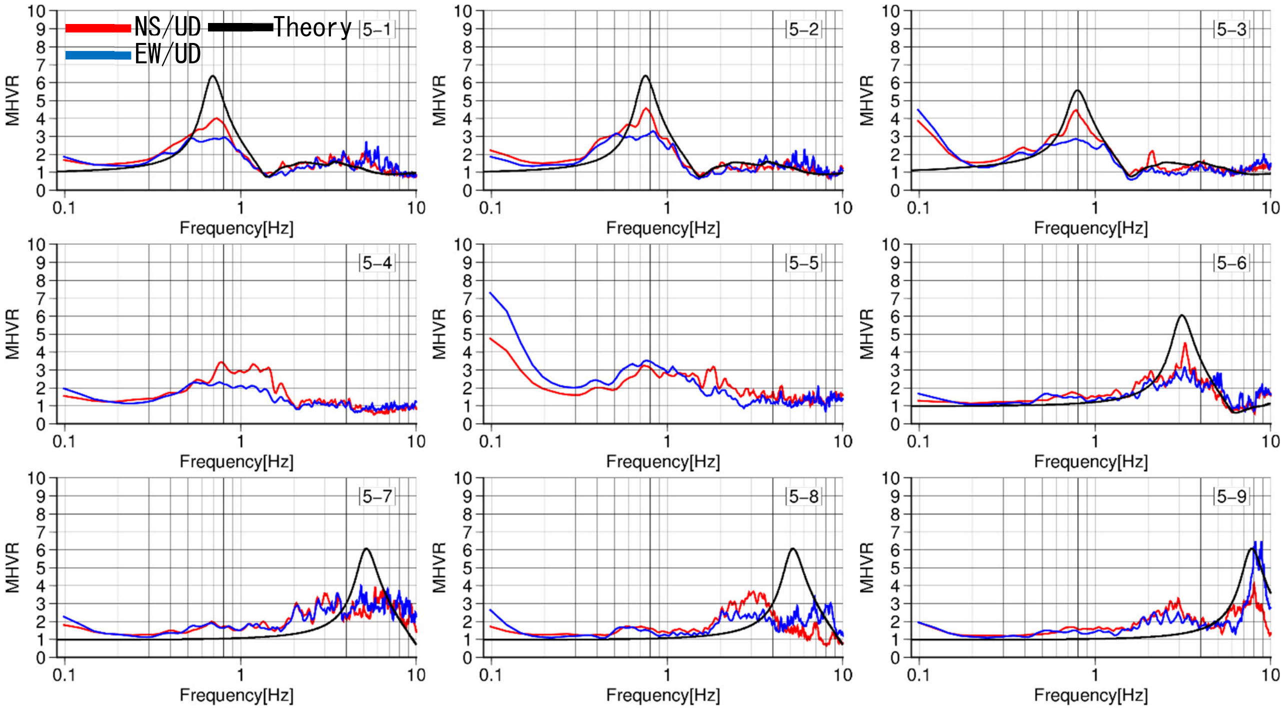


Fig. 7 Observed MHVRs (red and blue lines) compared with theoretical MHVRs (black line) for Line U5

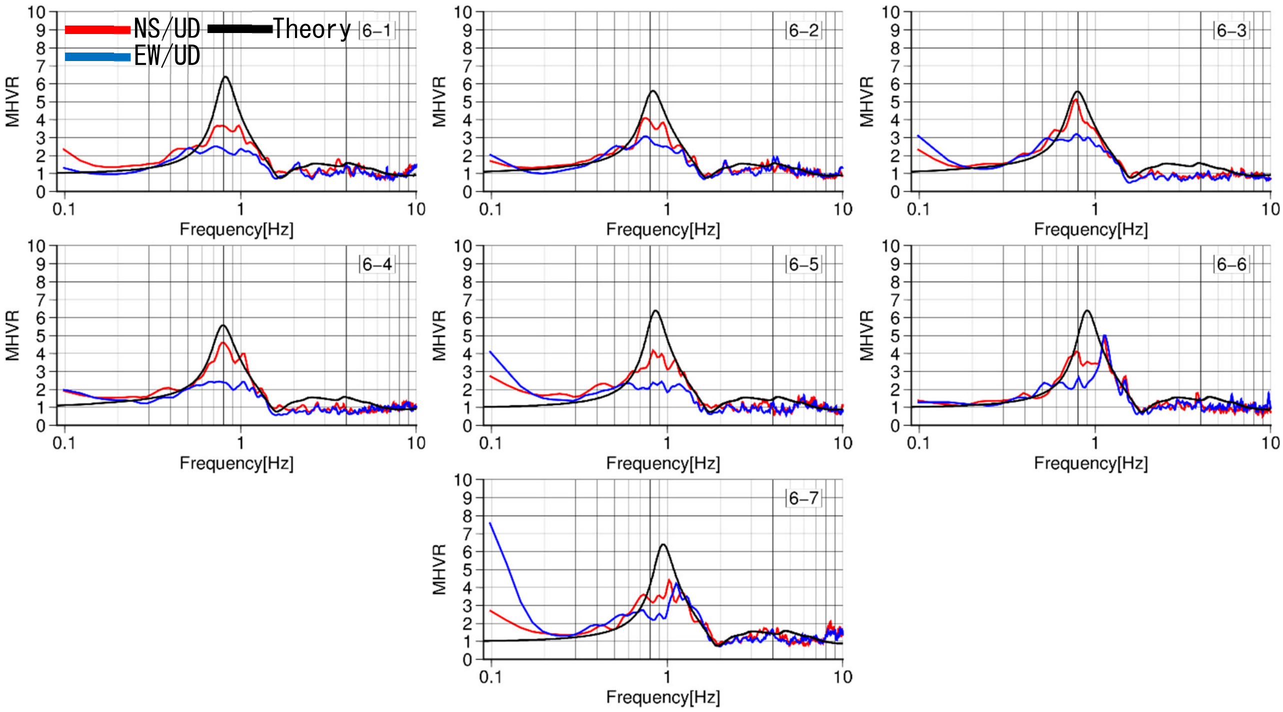


Fig. 8 Observed MHVRs (red and blue lines) compared with theoretical MHVRs (black line) for Line U6

3. Estimated Subsurface Structure

In order to estimate the subsurface velocity structure at each observation sites, the peak frequencies of observed MHVRs are fit by the theoretical MHVRs. The theoretical MHVRs are calculated using the subsurface velocity models of Tables 1 and 2, and the thickness of layers are determined assuming a one-dimensional model just beneath the observation site. Figs. 9 to 14 show the estimated velocity structure for each survey line.

Table 1 – Subsurface velocity model [1] for lines except U4

	Vs [m/s]	Vp [m/s]	Density [g/cm^3]
layer 1	406	1117	1.90
layer 2	638	2029	1.90
layer 3	1450	2950	2.10
bedrock	2348	5083	2.60

Table 2 – Subsurface velocity model for line U4

	Vs [m/s]	Vp [m/s]	Density [g/cm^3]
layer 0	167	557	1.74
layer 1	406	1117	1.90
layer 2	638	2029	1.90
layer 3	1450	2950	2.10
bedrock	2348	5083	2.60

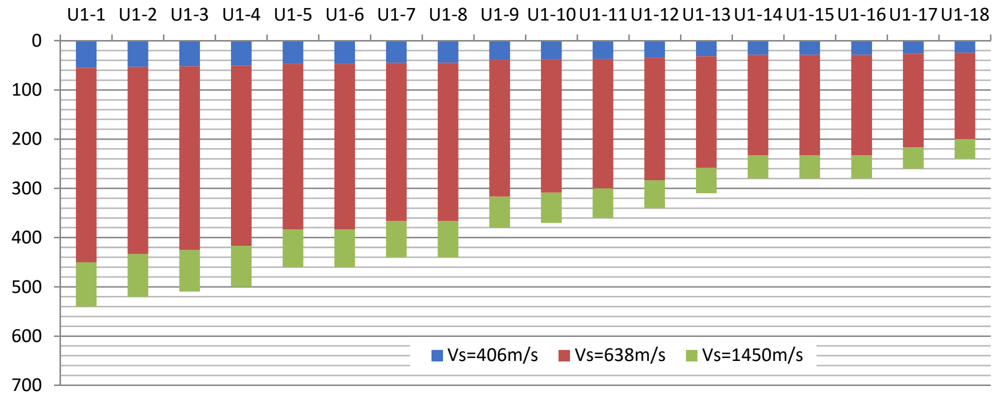


Fig. 9 Velocity structure determined from the MHVRs for line U1

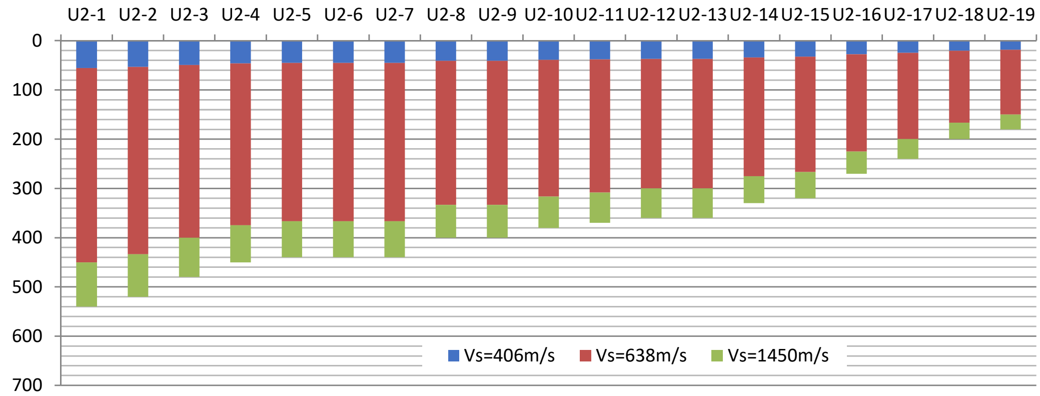


Fig. 10 Velocity structure determined from the MHVRs for line U2

Fig. 11 Velocity structure determined from the MHVRs for line U3

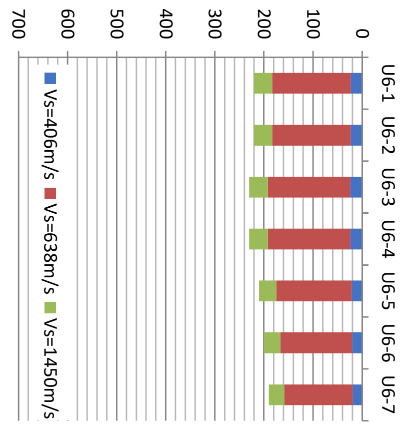


Fig. 12 Velocity structure determined from the MHVRs for line U6

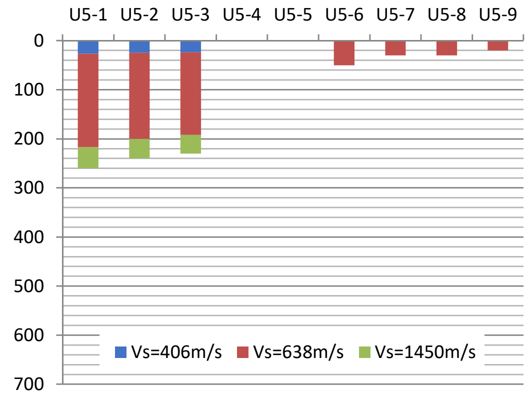


Fig. 13 Velocity structure determined from the MHVRs for line U5

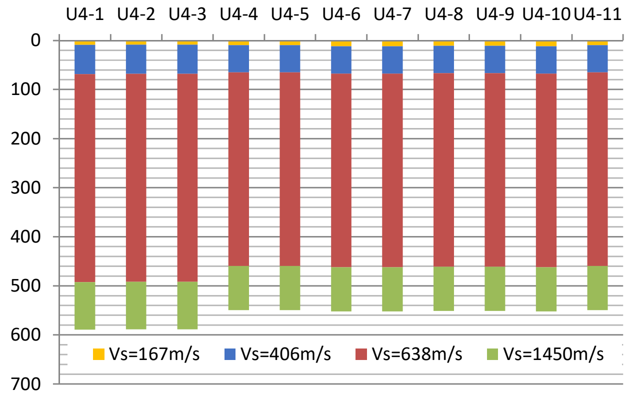


Fig. 14 Velocity structure determined from the MHVRs for line U6

For lines U1 and U2, the bedrock depth gradually gets shallower to the east as the sites get closer to the boundary of the basin. For line U3, the bedrock depth gradually gets shallower to the south, but for line U6, the depth does not change much within the survey line. For line U5, there is a transition zone at U5-4 and U5-5 and sites west of this zone is in the basin side and the site east of this zone is in the mountain side. As for sites of line U4, the bedrock depth does not change drastically and it seems that it can be considered as an one-dimensional structure along the survey line U4.

4. Summary

Microtremor observation was conducted in the area surrounding the Uji campus of Kyoto University to estimate the subsurface structure. The observed MHVRs in and around Uji campus showed directional dependent characteristics (NS/UD vs. EW/UD) and the characteristics of the directional dependence of MHVRs seems to be related with the local lateral heterogeneity close to the basin edge. By assuming a three- and four- layered one-dimensional model just beneath the observation stations, the subsurface velocity structure was estimated.

The observed MHVRs showed that if the site is further enough from the basin edge it does not show much directional dependency, where we can assume that the subsurface structure is flat-layered. On the other hand, if we go up the hills, the peak diminishes as predicted by numerical calculations by Matsushima et al. (2014). The location where the bedrock gets flat and the location of the end of the basin were able to be estimated by the observed MHVRs.

5. Acknowledgements

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6. References

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