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ON THE POSSIBILITY TO ANALYZE AMBIENT NOISE RECORDED BY A MOBILE DEVICE THROUGH THE H/V SPECTRAL RATIO TECHNIQUE

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Abstract. The analysis of the spectral properties of ambient seismic noise has recently turned to be a promising approach in the study of site effects impact on seismic hazard. In the present paper we present some results from our investigation on the possibility to use mobile devices to record analyze seismic noise through the examination of the horizontal to vertical (H/V) spectral ratio. The results were compared to the ones, obtained by the application of professional seismological equipment, a velocimeter of type GBV-316 of the GEOSIG company. Some divergence of the results from the mobile device and those from GBV-316 were identified, revealing that the application of a mobile device in this case is questionable.

Keywords: H/V spectral ratio technique; ambient noise; fundamental frequency

Introduction

It is generally considered that damages, caused by the recent earthquakes are mostly due to local geological conditions affecting the ground motion. The best approach for analyzing ground conditions is through recording and direct observation of the seismic ground motion, but such studies are possible to areas with relatively high seismicity. Reference site methods provide direct measuring of the site effects, but they need the availability of a proper reference site. One of these techniques, the Standard Spectral Ratio (SSR) technique (Atakan, 1995), was originally proposed by Borcherdt, in 1970 for examining the effects of the local geology on the ground motion near San Francisco bay (Borcherdt, 1970). Another method considers the difference between the ground motion from a particular event on the surface and on the bedrock underneath a particular site, which makes it possible to analyze correctly the local site response. This approach, called Surface-Borehole Spectral Ratio (SBSR) technique, was first introduced by Liu in 1992 for site effects evaluation of the Marina District of San Francisco that suffered extensive damage during the 1989 Loma Prieta earthquake (Liu et al., 1992).

Because of restrictions, accompanying reference methods, non-reference site methods have been applied to the site response studies. Ambient noise is a very convenient tool to estimate the effect of surface geology on seismic motion without other geological information.

The horizontal to vertical (H/V) spectral ratio technique, also known as Quasi-Transfer Spectra, is a method, that uses ambient noise and it has received great attention from all over the world for its low price, simplicity and quick information about dynamic characteristics of ground and structures. Although it is considered that the theoretical background of this technique is not clear, there have been many successful experimental studies performed (Atakan, 1995; Kandilarov et al., 2009).

This method is attractive since it gives the ease of data collection and it can be applied in areas of low or even no seismicity. Nakamura (1989) was among the first to suggest this technique. He developed it with relating borehole investigations together with the strong motion records analysis, on the various geological site conditions. It was hypothesized that the vertical component of the ambient noise at the ground surface keeps the characteristics of basement ground, it is also relatively influenced by Rayleigh wave on the sediments and can therefore be used to remove both of the source and the Rayleigh wave effects from the horizontal components. It is effective to identify the fundamental resonant frequency of a sedimentary layer at the examined point, with implied amplification factors that are more realistic than those obtained from sediment to rock site ratios.

The application of this technique still requires the use of professional equipment, which is not easy and cheap to obtain. A lot of modern mobile devices have sensors to record ground motion, these sensors most often being accelerometers. In this study we followed the purpose to verify whether results from the application of the H/V spectral ratio technique on noise records by non-specified sensors on mobile devices are comparable to the results from professional equipment data records. The basic professional equipment we used, was the GBV316 velocimeter from GeoSig and the mobile device sensor was an accelerometer, mounted at a regular mobile phone.

Equipment characteristics and J-SESAME software

The professional equipment measurements were performed with GeoSIG GBV-316 portable seismic station. It is a 3-channel seismic data recorder. This instrument and several others were tested and compared during the SESAME (Site Effects Assessment Using Ambient Excitations) project and the results showed that the GBV-316 sensor was completely reliable and appropriate for seismic noise recording (Atakan, 2002).

a b

Figure 1. Ambient noise recording systems, used in our experiment: a) GBV-316 data acquisition system; b) X-Tremer 45 smartphone accelerometer

The standard GBV (**Fig.1a**) uses a 4.5 Hz geophone in order to achieve low weight, low cost and portability. The GBV is well suited for all typical micro-seismicity studies that require recording of signals above 0.2 Hz as well as for Optionally the GBV-X16 can be equipped with a GPS for full time accuracy. The X-Tremer 45 smartphone accelerometer is a 3-channel device, allowing to record ground acceleration at a point either in m/s^2 or in parts of the Earth acceleration g (we may exclude g, putting all channels under equal conditions.

The outer appearances of both devices are revealed on **Fig.1** and some of their technical specifications are presented in **Table 1**. We could not find certain information about the frequency range of the X-Tremer 45 smartphone accelerometer.

Table 1. Comparison of some technical specifications of the GBV-316 data acquisition system and the X-Tremer 45 smartphone accelerometer

	GBV316	X-Tremer 45 smartphone accelerometer
Sensor	3 geophones	3 accelerometers
Sensor natural frequency	4.5 Hz	Not Available (N/A)
Recording capacity	64 MB	512 MB
Digitizer	16 bit	N/A
Power	12 V battery	3.7 V
Communication	Serial line	USB - miniUSB
Weight	5.2 kg	0.400 kg
Resolution	N/A	0.00390625 m/s^2
Sensor Vendor	GeoSIG	MTK
Max Range:	N/A	32.0 g

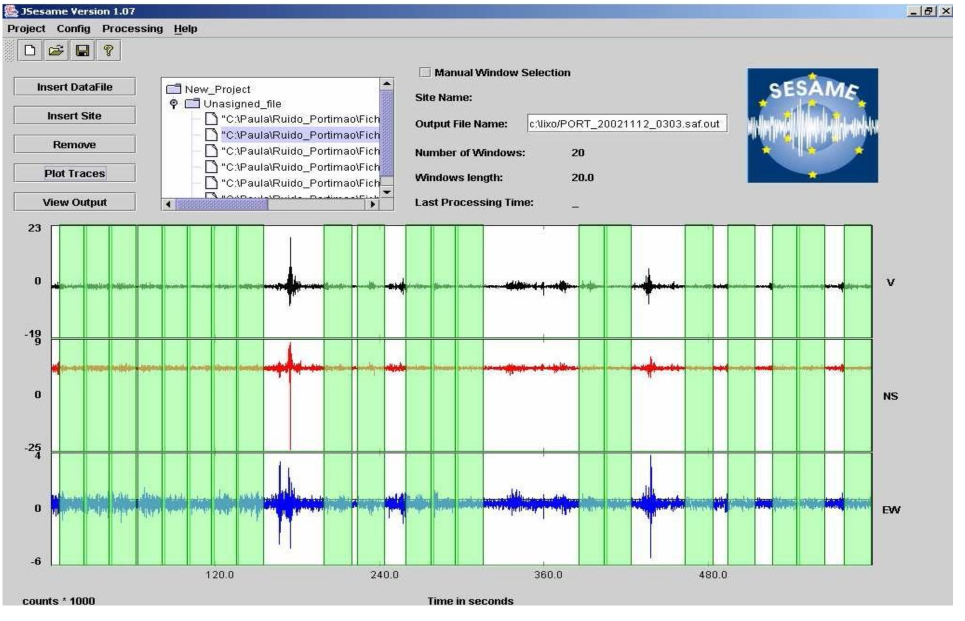

Figure 2. Basic window of the J-SESAME software

After ambient noise is recorded at a chosen point (usually in GSR or ASCII format), the data is subjected to processing through the J-SESAME software to identify the fundamental resonant frequency with the amplification factors of the sedimentary layer at the examined point.

The J-SESAME window (**Fig.2**) allows to open the recorded noise file, to select (automatically or manually) the noise windows to be analyzed and to identify the fundamental frequency at the point of recording.

It is very important that really ambient noise data is processed. One can see on **Fig. 2** that the windows, where known noise sources are active (bigger amplitude) are excluded.

Experimental results

We performed ambient noise recordings at a chosen point next to Plovdiv University "Paisii Hilendarski". Data was recorded by both devices, the GBV-316 data acquisition system and the X-Tremer 45 smartphone accelerometer. Each device recorded three files of 10 minutes each at two point not more than 10 cm apart.

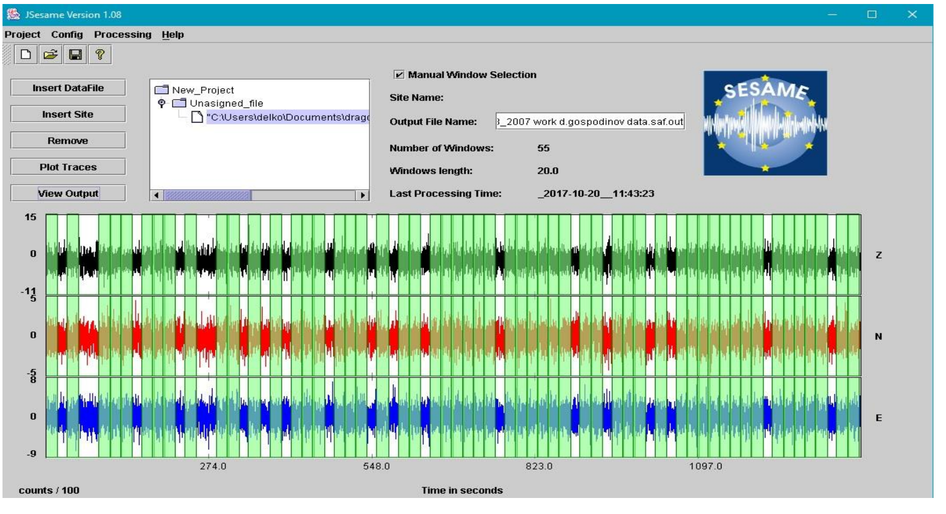

Figure 3. J-SESAME window for one of the records, made by the X-Tremer 45 smartphone accelerometer

One can see on **Fig.3** that the noise level is low for all three components (east-west, north-south and vertical). The results from the J-SESAME application (**Fig.4**) reveal no specific peak of the H/V spectral ratio i.e. no fundamental frequency is identified by these data.

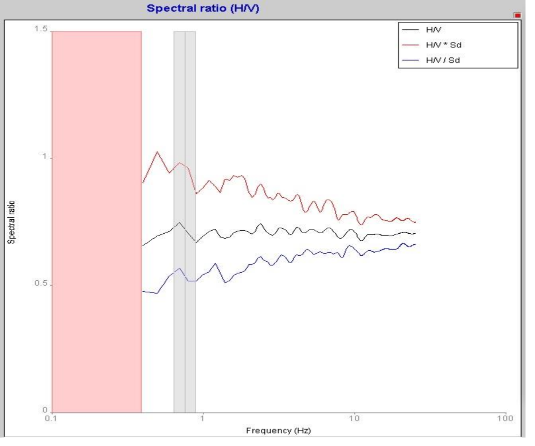

Figure 4. H/V spectral ratio of the data, revealed on Fig.3. No specific peak can be identified

The H/V spectral ratio curve (curve in the middle on **Fig.5**) follows nearly equal values with a slight variation. What is more, this curve shows, that the amplification factor values (vertical axis on **Fig.5**) are very small (less than one).

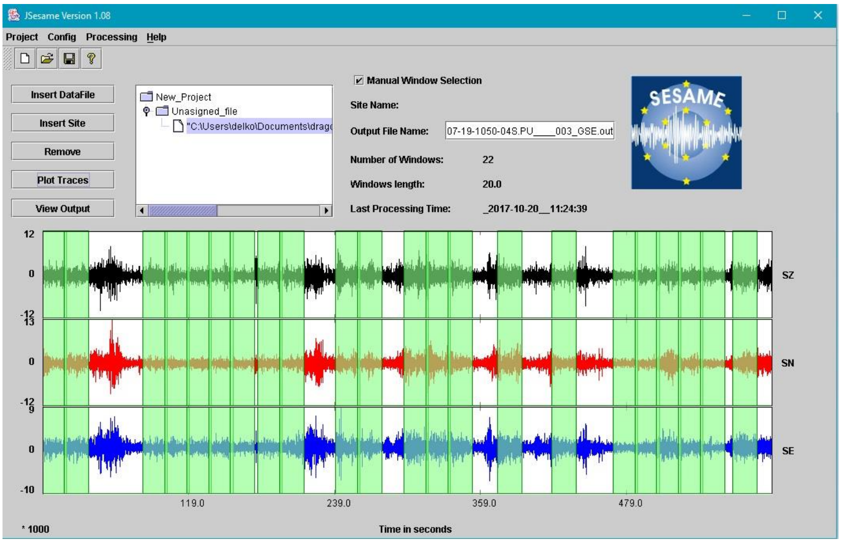

Figure 5. J-SESAME window for one of the records, made by the GBV-316 data acquisition system

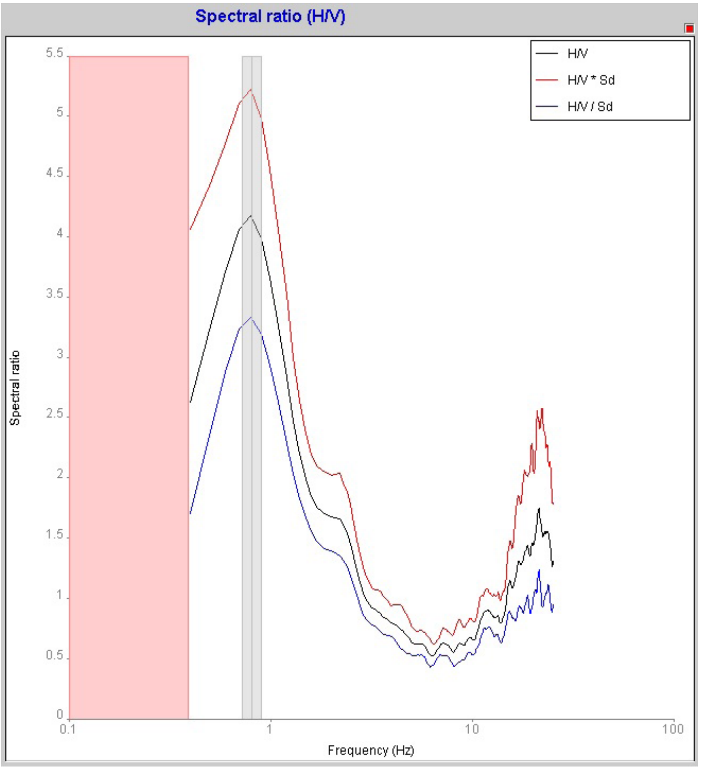

Figure 6. H/V spectral ratio of the data, revealed on **Fig.5** (see comments in text)

The situation is quite different when we examine the results from the analysis of the GBV-316 data acquisition system. The noise level is low (**Fig.5**) with some random peaks, probably caused by vehicles, which are excluded from consideration (no windows are selected to cover them). The processing of these data through the J-SESAME software allowed to identify a fundamental frequency of 0.9 Hz and an amplification factor of more than four (see **Fig.6**). A second peak can be seen at a frequency of about 20 Hz (**Fig.6**), most probably caused by fact that the recording points were at a site, covered by thin concrete tiles. It is easy to see that latter results are quite different from the ones, obtained by the X-Tremer 45 smartphone accelerometer data.

Conclusions

In this paper we present the results from an experiment, we performed using two sets of equipment, the GBV-316 data acquisition system and the X-Tremer

45 smartphone accelerometer. We used these sensors to record ambient noise at nearly one and the same point (two points, 10 cm apart). The recorded data were analyzed through the H/V spectral ratio technique by applying the J-SESAME software on both of them. The purpose was to estimate the fundamental frequencies on each set of data and to see whether the obtained values are comparable.

Although the recording points are very near to each other the results from the different datasets diverge substantially. We estimate a fundamental frequency of 0.9 Hz and an amplification factor of more than four for the data, recorded by the GBV-316 data acquisition system. The value of the fundamental frequency is related to the depth of the sediment layer (up to the bedrock).

For the data provided by the X-Tremer 45 smartphone accelerometer no fundamental can be identified at all. We guess the reason for this difference in the obtained results is due to the different frequency ranges of both sensors. There is not enough information about the X-Tremer 45 smartphone accelerometer, but it is probable that its frequency range is quite narrow and part of the information about the sediment layer is lost.

The outcome of our experiment reveals that the X-Tremer 45 smartphone accelerometer is not applicable to provide ambient noise data with characteristics, needed to estimate the fundamental frequency at a certain point.

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