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SOME MAN-MADE SOURCES OF THE SEISMIC NOISE

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ABSTRACT. Short-period seismic noise was observed during various seismic field experiments performed on the territory of the Czech Republic. Analogue as well as digital data were processed with the aim to receive the amplitude–period relationship and the frequency content of seismic oscillations. Regardless of the essential purpose of the above seismic experiments performed in the past and nowadays as well, there are summarized in the present paper. The results of the experiments concerning seismic noise generated by man-made sources only. Traffic and industry were identified in the course of experiments as predominant sources of disturbances having periods and/or frequencies and amplitudes of oscillations closely linked with the character of the respective source, source–receiver distance and basement properties.

KEYWORDS: seismic noise, man-made sources, dynamic parameters

1. INTRODUCTION

It is generally well known that under seismic noise we understand periodic oscillations of the Earth's surface which can have harmonic and/or irregular character. According to the properties of the sources of their origin, oscillations within the essential band of predominating periods and/or frequencies can be distinguished, i.e. $T = 0.01 - 1.0\,\mathrm{s}$ and/or $f = 1 - 100\,\mathrm{Hz}$. As sources of this kind of seismic noise, all man-made activities could be assumed, i.e. different types of traffic and all industrial operations.

In this respect, the most pronounced and wide spreading seismic noise is the noise with frequencies around 2 Hz which was reported, e.g. by Plešinger and Wielandt (1974), Steinwachs (1974) and which was also recorded at the seismic station Kašperské Hory (KHC) as described by Kulhánek (1966) and Fučík (1970).

It is obvious that the level of the seismic noise significantly influences the legibility of the seismograms and, therefore, further measures to improve the interpretation must be taken. With analogue records, the only requirement is to choose the best seismogeological conditions of the recording site by minimizing the influence of the short-period noise. In case of digital data, an improvement can be reached by introducing various mathematical approaches, e.g. by filtering seismic signals to reach a better quality of input data series for further processing and interpretation. The worst situation occurs when the short-period seismic noise coincides with the frequency band of the first onsets of teleseisms and of local events. In this respect, investigations of local man–made sources of disturbances described in this paper are of great importance, mainly the choice of an observation site, which is also closely linked with the seismogeological situation in the environment of the respective site.

The subject of the present paper is to summarize the results of investigations into the properties of different artificial sources of the short period seismic noise. These sources were observed and identified during various seismic experiments and, therefore, this paper does not represent a systematically oriented investigation of the seismic noise on the territory of the Czech Republic.

2. Field Experiments

The measurements of the level of short–period seismic noise described, e.g. by Kárník and Tobyáš (1961), Luosto (1976) and Holub (1994, 1995 and 1996) were combined with the identification of sites having suitable seismogeological conditions for the seismic station erection and/or with the results of investigations of different long–term operating artificial sources of disturbing vibrations in the environment of the seismic station. Further seismic experiments which were performed on our territory for special purposes, became a secondary source of information on the local characteristics of the seismic noise.

A huge amount of analogue data on the seismic noise was gathered during deep seismic sounding experiments along international profiles Nos. VI and VII (Holub 1972 and 1977). Data were available in the wide band of predominant periods observed either before and/or after borehole explosions and which covered approximately the interval of about $T = 0.01 - 0.6$ s. The broadband seismographs used had flat response characteristics within the interval of periods $T = 0.02 - 2.0$ s. For the purposes of the present paper, only those data were used, which gave information related to the vibrations generated by identified artificial seismic sources, e.g. traffic (buses, lorries, trains or freight trains) and industrial installations (compressors, water–work pumps, forging shop operation etc.). The existence of above the mentioned sources operating in the neighbourhood of the respective sites of observation was verified almost simultaneously with the recording.

Another set of data was obtained during seismic experiments performed in 1975 before the construction of the seismic station Ostrava–Krásné Pole. The data used include only vibrations caused mainly by traffic along a road nearby. However, another very intensive source, generating almost regular vibrations having the periods of about $T = 1$ s, was observed. These vibrations were simultaneously recorded at a temporary seismic station situated approximately 800 m eastwards of the above mentioned test site. Later, when the seismic station Ostrava–Krásné Pole (OKC) has been erected, similar vibrations were recorded by short–period seismographs as well (Holub 1995).

In 1983, some seismic experiments in the area of the Mine 1st May (Mine Darkov now) were performed and reported by Veselá (1983) and later by Holub and Veselá (1996) and Holečko and Veselá (1997). These measurements were aimed at investigating the properties of seismic waves generated by large piston compressors. Individual sites of measurement, surrounding the compressor station, were distributed within narrow strips along two short profiles 1000 m and 1400 m long. The data which were at our disposal enabled us to calculate the function of the amplitude–distance decrease. Concurrently with seismic experiments, at two seismic stations of the local seismographic network, there were also recorded 2 Hz almost regular vibrations. These stations were located at the surface and underground at distances of 730 m and 3100 m, respectively.

During 1987, in the area of the Mine Frenštát–West, three one–component seismic stations were in temporary operation so that the conditions for a small local array could be examined. During these measurements, some artificial sources of disturbing vibrations were also identified, i.e. vibrations caused by road traffic and compressor operation (Holub 1994).

Seismic experiments were also carried out in 1989 on the surface in the area of the Mine ČSA in order to determine the seismic noise level prior to the erection of a seismic station. Because of seismogeological conditions of this locality, the basement of which was built by Miocene sediments, the recorded amplitudes were considerably amplified due to a low acoustic resistance. Nevertheless, even the preliminary evaluation of seismograms at this very exposed locality gave evidence of a high level of disturbing vibrations caused especially by near traffic and freight trains.

While the data mentioned above were of analogue form only, the data obtained in 1995 through 1997, were digital ones. During the course of special seismic measurements, a modified digital instrumentation was applied (Holub 1997). The waveforms recorded were digitized at a sampling rate of 100 Hz and the processing of digital data was performed using the "WAVE" PC program .This program comprises, e.g. as procedures for spectral analysis, i.e. Fast Fourier Transform (FFT) and method of Determining Harmonic Components (DHC algorithm), as polarization analysis (see Toth 1991 and Kaláb, Gruntorád 1992).

"Nová huť" metallurgical works in Ostrava–Kunčice with various sources of disturbing vibrations were of our interest, too. Therefore, this area was chosen for field experiments. There were investigated the following vibration sources: a forging shop, a plant for the forming of raw ingots and crankshafts, a compressor station and other installations in the acetylene mill, a diesel engine and freight train.

The above digital instrumentation was also used for seismic vibration recording at various discrete sites of observation, where an influence of road and railway traffic was observed. As a special case study, the manifestation of cupola motion at astronomical observatory to recordings at the seismic station Ostrava–Krásné Pole (OKC) situated nearby was investigated.

3. Amplitude–Period Relationships

The processing of the original analogue records obtained was quite simple and was based on the measurements of peak–to–peak trace amplitudes and the respective periods of oscillations. Both parameters measured on records in mm, were converted into displacement amplitudes given in nm or μm and periods in s. Displaying peak–to–peak displacement amplitudes and/or their halves, on the bilogarithmic scale, clusters of points were obtained which could be enveloped by a continuous curve denoted ECMA (Envelope Curve of Maximum Amplitudes) smoothing the maximum values observed (Holub 1977). In this way for each site of observation such an amplitude–period dependence was prepared with a distinction between the measurements performed in the daytime ($05^h - 20^h$ UT) and at night ($20^h - 05^h$ UT). Moreover, individual graphs took into account the appropriate component of displacement amplitudes, i.e. vertical (V) and horizontal (H) ones, as well.

The set of all ECMA graphs corresponding to the sites distributed along both DSS profiles were qualitatively evaluated and the intervals of seismic noise background were defined. Part of this noise background was caused by artificial sources with specific properties of generated seismic waves which are of our interest now.

On the basis of a detailed analysis of the individual ECMA and the identified sources of seismic waves, one essential difference between a stationary and a moving source was proved. This difference consists first of all in the fact that the stationary source generates oscillations with a relatively constant amplitude and period. On the other hand, a moving source with changing source–receiver distance implies unavoidable variations namely in amplitudes. In both cases, a significant role for displacement amplitudes as well as periods of oscillations have the physical–mechanical properties of the basement at the test sites and in the environment of the sources of seismic noise. Thus at sites located on bedrock, lower amplitudes and shorter periods are in general observed. On soils and unconsolidated sediments, greater amplitudes and longer periods are usually observed. In Fig. 1 several examples of amplitude–period graphs of the seismic noise level generated by man–made sources are given.

4. Seismic Noise Sources

a) Identified Sources

As mentioned above, various man–made sources were examined simultaneously with their manifestations on seismograms during field experiments. As soon as some specific vibrations were detected, the appropriate source and/or sources had to be determined. Moving sources (road and railroad traffic) were identified more easily than some weak stationary sources or sources operating at greater distances. Since a part of this paragraph is related to the results obtained earlier during DSS experiments, one can find more details in Holub (1972 and 1977).

The influence of **highway** and **road traffic** recorded at various test sites in Central Bohemia could be characterized by vibrations having periods within the interval of $T = 0.06 - 0.14$ s and minimum amplitudes at night as well as in daytime of about $A \approx 2$ nm. Larger amplitudes were observed, e.g. in Southern Moravia near the road E 84 where vertical amplitudes attained values of $A \approx 6$ nm with periods $T = 0.16 - 0.19$ s. Horizontal amplitudes were almost at the same level but periods of oscillations increased up to $T = 0.25 - 0.28$ s.

The same vibration sources in the Ostrava–Karviná industrial agglomeration were investigated at test sites situated in the areas of the planned seismic stations Ostrava–Krásné Pole and Frenštát–West (Holub 1995 and 1996). At the test site

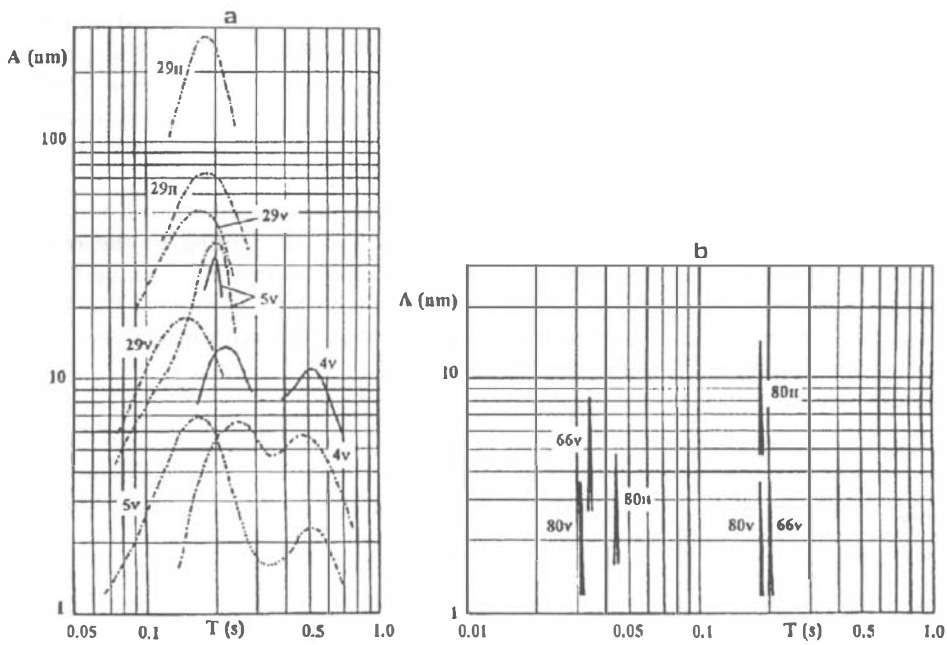

FIG. 1. Level of seismic noise generated by man–made sources. **a** – moving source (train), **b** – stationary source (water–work pump). ——— daytime observation, _ . _ . _ night observations, 4, 5, 29, 66 and 80 denotes no. of the site along the respective profile, V or H (vertical or horizontal component) (after Holub 1977).

on the outskirts of Ostrava which was about 400 m from the highway, the following effects of traffic were defined. The passage of buses generated vibrations with periods within the intervals of $T_Z = T_H = 0.08-0.15$ s and amplitudes $A_Z <$ 20 nm and $A_H < 35$ nm. The passage of lorries generated vibrations with periods $T_Z = 0.17-0.24$ s, $T_H = 0.09-0.13$ s and amplitudes $A_Z = 50$ nm, $A_H < 25$ nm, respectively. It was also observed that during night measurements with no transport of goods, no vibrations of this kind were recorded.

Likewise, at the test sites in the area of the Mine Frenštát–West, the vibrations generated by cars, buses and lorries passing along the road and highway, comprised oscillations of periods of $T = 0.06-0.15$ s. These oscillations recorded at a minimum distance of 130 m from the road, reached maximum amplitudes of less than 150 nm. The level of these disturbances depends mainly on actual density of the local traffic and is quite independent on the time of observation.

According to the measurements at the sites of observation in the Mine 1 May, the influence of road traffic could be also generally characterized by certain periods of oscillations, i.e. lorries ($T = 0.06-0.30$ s), freight trains ($T = 0.2-0.3$ s) as reported by Veselá (1983).

During seismic measurements on the surface in the locality of the Mine ČSA, as important sources of local disturbances there were identified automobile freight traffic and different types of transport and technical services (e.g. cars, lorries, bulldozers and mobile cranes). It was ascertained that automobile freight traffic and bulldozer operation generated, at a minimum distance of 130 m oscillations of $T = 0.09 - 0.15$ s with maximum amplitudes $A \approx 210$ nm.

At the seismic station Ostrava–Krásné Pole (OKC) the level of seismic noise was investigated in detail on the basis of digital data, too. According to the results of spectral analysis (FFT and DHC), the influence of road traffic is manifested by expressive peaks in the range of frequencies from about 15 to 20 Hz, i.e. $T = 0.04 - 0.07$ s, as seen in Fig. 2. The maximum particle velocities within analyzed time window attain almost the value $v = 8.5 \cdot 10^{-8}$ m/s.

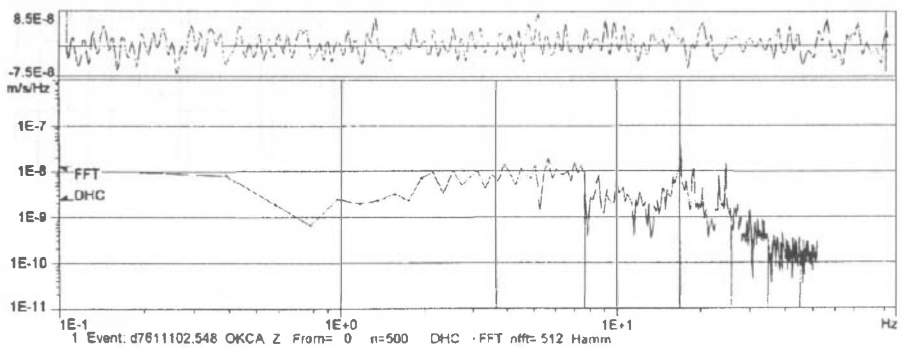

FIG. 2. Seismogram section (vertical component) of vibrations induced by local traffic and recorded at the station Ostrava–Krásné Pole (OKC) (top) and the corresponding frequency spectra (FFT and DHC algorithm) (bottom).

The influence of the **railway traffic** was investigated at several sites. In Central Bohemia, the measurements revealed that the train passing at a distance of approximately 1 km, generated vibrations with periods $T = 0.24 - 0.26$ s and amplitudes of more than 30 nm. Near the town of Písek, in Southern Bohemia, the recording was performed close to a railway station. The diesel engine of the train stopping at this station, generated almost regular vibrations with predominant periods of $T \approx 0.2$ s and constant amplitudes of about $A = 30$ nm. Close to this site, another seismometer was situated at a distance of less than 1 km from the railroad. There, a passage of a train in daytime caused vibrations with periods of $T = 0.21 - 0.23$ s and variable amplitudes attaining the maximum values of about $A \approx 15$ nm (see curves 4 and 5 in Fig. 1). Contrary to that, in Northern Bohemia at a site placed on the alluvium of a stream, approximately 1 km apart from a railroad, the passage of a train at night generated oscillations with the following parameters: $T = 0.15 - 0.18$ s, $A_Z = 18 - 50$ nm and $A_H = 70 - 270$ nm (see curves 29 V and 29 H in Fig. 1a). In this case, the amplification of the observed amplitudes was probably influenced by the unconsolidated basement.

The railroad freight traffic at the Mine ČSA proved to be the most serious source of disturbing vibrations. The seismic vibrations generated during its passage at the distance of about 300 m could be characterized by a very narrow band of periods $T = 0.19 - 0.22$ s and approximate amplitudes $A \approx 450$ nm. By making use of these results, an admissible amplification of the seismograph deployed at this site was determined (Holub 1996).

The manifestations of various types of railway traffic, i.e. passenger, fast and freight train were investigated at a site situated in the outskirts of Ostrava town. On the basis of the spectral analysis it was ascertained that frequencies of vibrations caused, e.g. by the passage of a freight train were observed within the range of about $f \approx 2 - 10$ Hz, i.e. $T \approx 0.10 - 0.5$s. Particle velocities on vertical component reached the maximum value $v = 3.8 \cdot 10^{-6}$ m/s, as seen in Fig.3; in contrast to it, it amplitudes on the transversal component attained the value of about $v = 4.6 \cdot 10^{-6}$ m/s.

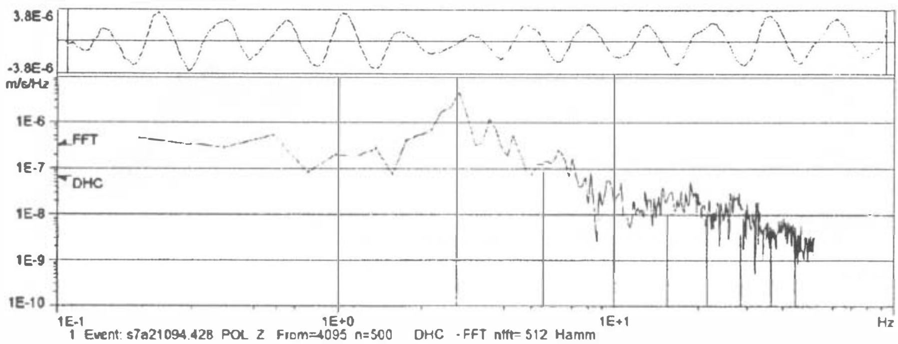

FIG. 3. Seismogram section (vertical component) of vibrations caused by a freight train passage recorded at the distance of about 800 m near village Polanka (top) and the corresponding frequency spectra (FFT and DHC algorithm) (bottom).

In the area of "Nová huť" metallurgical works in Ostrava, where various technical sources of vibrations were investigated, the passage of a freight train drawn by diesel engine at a minimum distance of about 80 m was also observed. In Fig. 4 a cut of three–component seismogram and the respective FFT and DHC spectra are given. When comparing the amplitudes of individual components it is obvious that amplitudes on the vertical component reached the value of about $5.5 \cdot 10^{-5}$ m/s, while the level on horizontal ones is approximately twice lower. Based on spectral analysis, the prevailing frequencies which were characteristic for this source of vibrations, fluctuated within the range of $f = 6 - 7$ Hz, i.e. interval of $T = 0.14 - 0.17$ s.

Another important source of disturbing vibrations in Ostrava agglomeration is represented by the operation of various **industrial installations** (plant and equipment). When solving some tasks of engineering geophysics, the influences of these

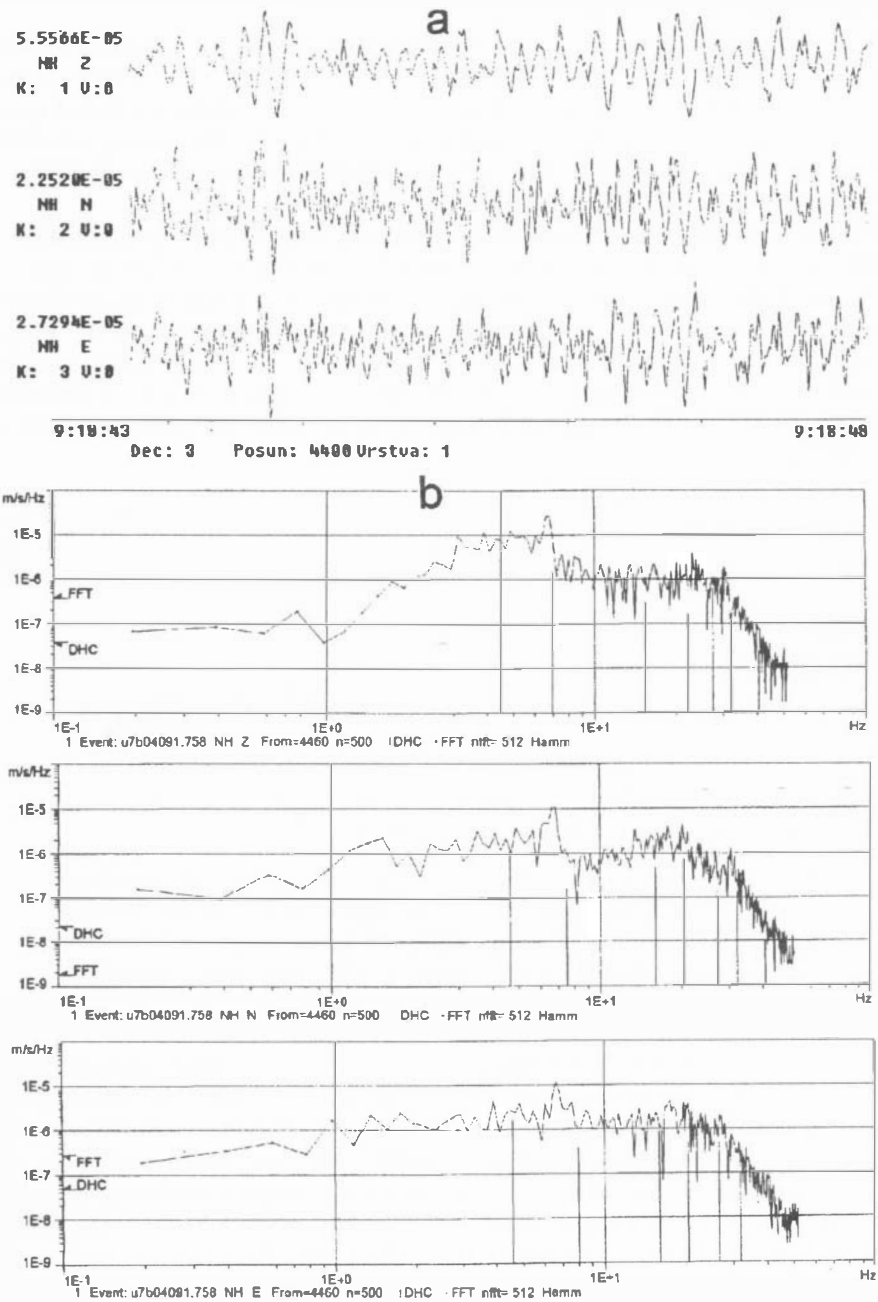

FIG. 4. Three component seismograms of vibrations generated by a freight train passage (**a**) in the Nová huť area and corresponding FFT spectra (**b**).

disturbing sources have been very often investigated. For instance, special seismic measurements conducted in the vicinity of the forging shop at Nová huť works were aimed at the estimation of the influence of its operation on the surrounding buildings at the distance of about 300 m. The vibrations caused by the forging shop operation were characterized by "beats", the spectral analysis of which reveals predominant frequencies of about 4.5 Hz and 8.5 Hz, i.e. $T = 0.22$ and 0.12 s, respectively (see Kaláb and Knejzlík, 1996). The same source of vibrations was investigated later at another site of observation at the distance of about 175 m. The duration of the individual "beats" was from 1 to 2 s and the maximum particle velocities in the investigated time window (see Fig. 5) reached the value on the vertical component almost $2.1 \cdot 10^{-4}$ m/s, while the velocities on the horizontal ones were approximately $5 - 10$ times lower. Using spectral analysis algorithms, prevailing lower frequencies within the range from 2.5 up to 8 Hz were observed, as shown in Fig. 6. An example of particle motion trajectories of the investigated time window is given in Fig. 7, from which follows that the essential particle motion takes place in the vertical plane.

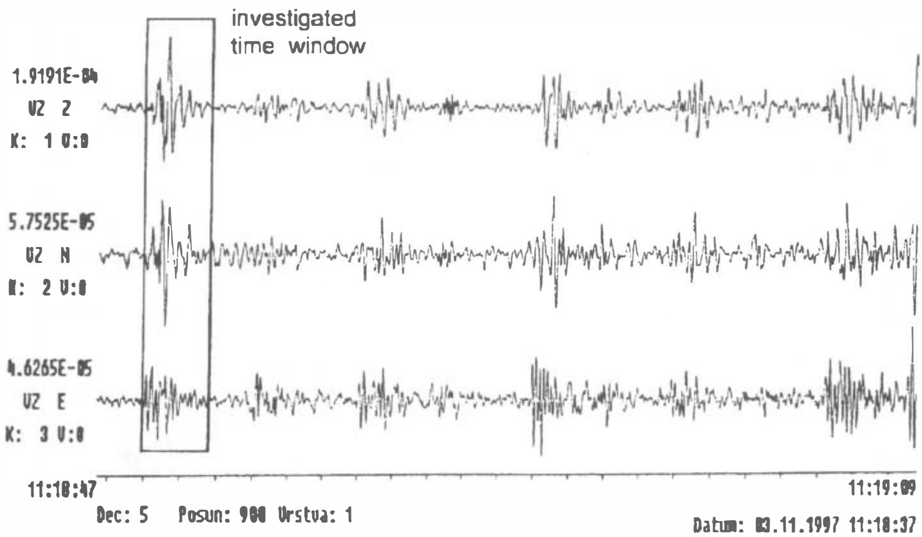

FIG. 5. Three component seismograms of vibrations induced by a forging shop operation made at an epicentral distance of $r \approx 175$ m.

Besides vibrations of an irregular character discussed above, also regular and/or almost regular vibrations caused by **rotating sources** were observed. Such a type of vibrations was recorded at two sites in Southern Moravia, the amplitude-period graphs of which are given in Fig. 1b (see curves 66 and 80). Both sources, i.e. pumps of local water works used for watering the fields, were identified. At the first site, two predominant groups of periods were recorded. The first group with periods of $T_V = 0.20$ s was superimposed on oscillations of $T_V = 0.034$ s with the respective

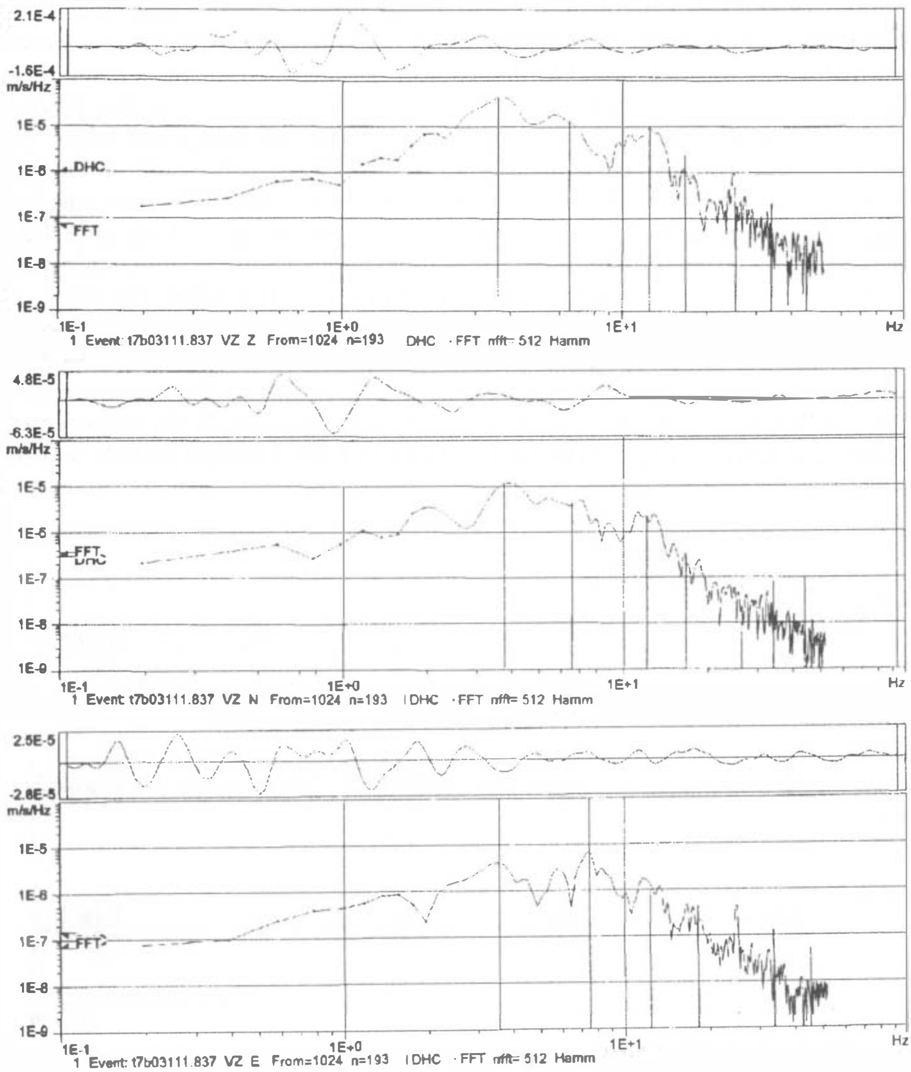

FIG. 6. FFT and DHC spectra of vibrations on the seismogram section defined by the time window (see Fig. 4.).

amplitudes of $A = 8.3$ nm and 3.6 nm. At the other site, very close parameters of vibrations were observed, i.e. $T_V = 0.18$ s and 0.031 s with amplitudes equal to $A_V = 3.6$ nm. Predominant periods of vibrations on the horizontal component $T_H = 0.18$ s and 0.043 s with amplitudes less than $A_H = 4.8$ nm, only exceptionally achieving values $A_H = 14.4$ nm.

In connection with the investigation of the influence of regular oscillations of

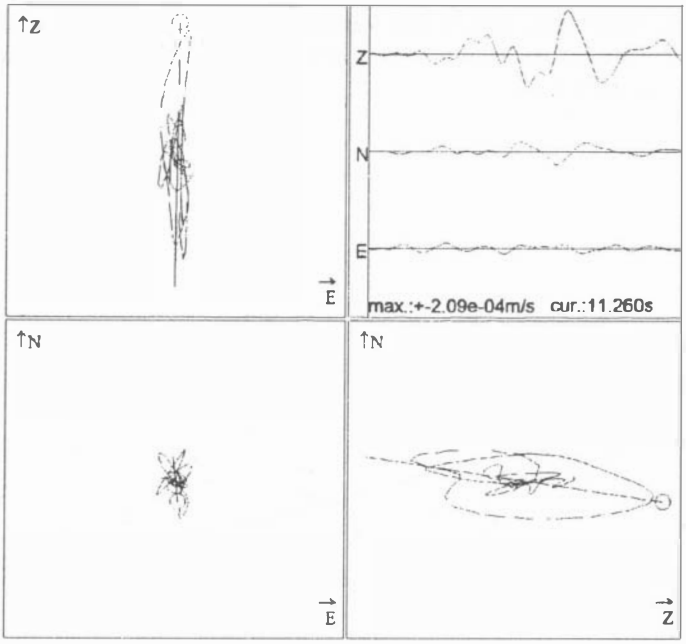

FIG. 7. Particle motion trajectories within the time window (see Fig. 4).

$T = 0.2$ s generated by large piston compressors operating in the Mine 1st May several experiments were carried out. Regular oscillations were also recorded at the surface seismic station in the Mine 1st May ($h = +270$ m m.s.l.) showing displacement amplitudes up to $A \approx 1\,\mu$m. At the underground seismic station in the Mine Doubrava ($h = -510$ m m.s.l.) amplitudes of up to $A \approx 100$ nm were measured. These seismic stations, which are part of the local seismographic network, were situated at epicentral distances of 730 m and 3000 m from the piston compressors, respectively.

On the records obtained at localities close to the compressor station (several tens of metres,) mains interference of 50 Hz occurred. All sites of observation were spread within two stripes in northeastern and southern directions from the compressor station. For both profiles, the displacement amplitude–distance graphs were investigated, however, only for the northeastern profile the data displayed a relatively small scatter and enabled us to perform approximation with a power function. The respective relationship reads:

$$\ln A = 3.816 - 0.526 \ln r\,.$$

The law of displacement amplitudes decrease fits very well the approximation of surface waves data in the form of a power function where the exponent is usually assumed equal to be -0.5. The corresponding amplitude vs. epicentral distance graph for the northeastern profile is given in Fig. 8. Along the southern profile, a great scatter of amplitudes due to the variability of the basement quality was ascertained and, therefore, the results of a power function approximation were not reliable and were omitted here.

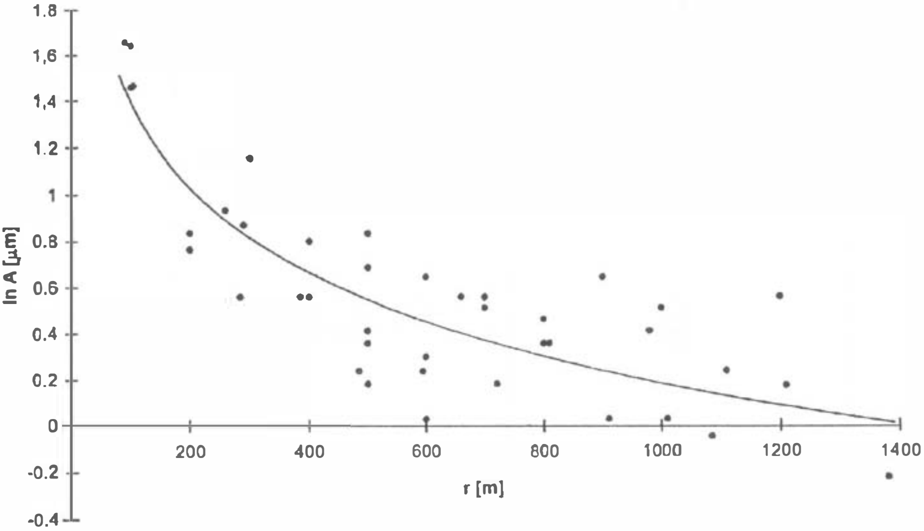

FIG. 8. Experimental amplitude–distance curve of the vertical component of vibrations with periods of $T \approx 0.5$ s generated by large piston compressors.

Besides the influence of piston compressors in the Mine 1st May, other local sources of regular oscillations in the Ostrava–Karviná region were considered, too. For the first time, we met regular compressor induced vibrations induced by the compressors operation near the Mine Frenštát–West which were reported by Holub (1994). These vibrations recorded by the vertical seismograph at the distance of about 150 m could be described with the following parameters $T = 0.10 - 0.12$ s and approximate amplitudes $A = 7.5$ nm.

On the other hand, regular and/or almost regular vibrations were observed at three sites inside the acetylene mill which was situated in the area of "Nová huť" metallurgical works. The oscillations caused by various technological installations differed by frequency and particle velocity on the records of individual components made at discrete sites of observation. While the frequencies calculated fluctuated in the range from 5 up to 11 Hz, the amplitudes at the nearest site, 30 m apart the rotating source, attained the value of $4.5 \cdot 10^{-3}$ m/s approximately. The results of spectral as well as particle motion analyses of vibrations generated by the operation of the compressor in the acetylene mill are given in Figs. 9 and 10. Typical of these vibrations is almost constant frequency $f = 6$ Hz and vertically oriented polarization diagram of induced seismic waves.

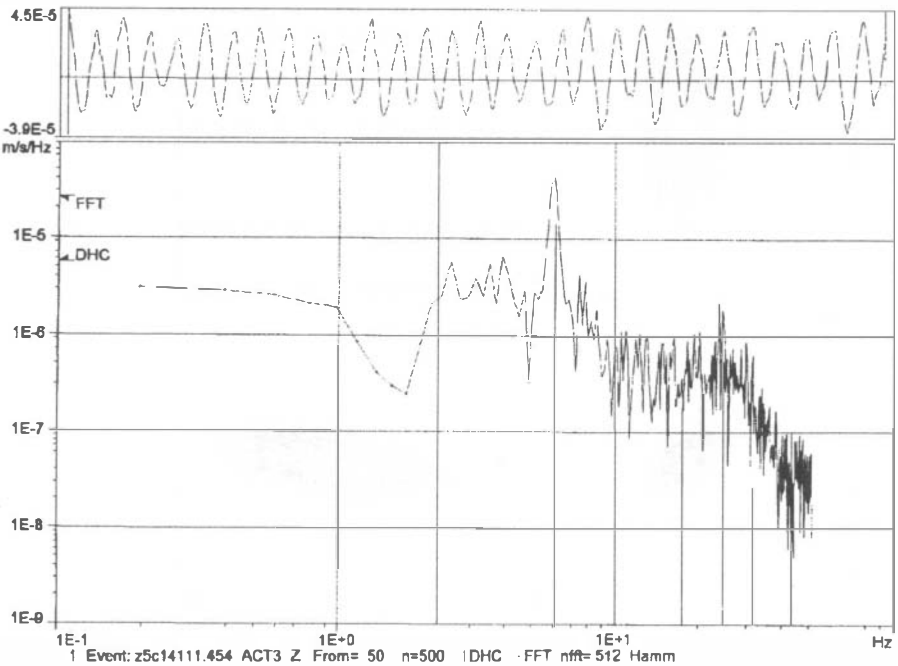

FIG. 9. Spectral analysis of the vertical component of vibrations induced by the compressor operation.

As a part of our experiments at the seismic station Ostrava–Krásné Pole, a trial frequency spectra determination using spectral analyser B & K was performed. The resulting FFT spectrum was calculated automatically as a linear average of 32 spectra summation. In one special case, the influence of the rotary motion of the cupola of an astronomical observatory onto the content of noise frequency content was investigated. Spectral analysis performed after the averaging of six FFT spectra proved the existence of a to sharp peak at the frequency of 5.82 Hz.

b) Unidentified Sources

In spite of all our efforts to identify each of the man-made sources of disturbing vibrations which occurred during our field seismic measurements, we were not able to avoid some speculations concerning the identification of an ambiguous seismic source. This is due to lack of objective data for a reliable specification of the sources which may have existed during field tests.

At two sites, located near Trnava and Nitra towns (Slovak Republic), very distinct and regular seismic oscillations with periods $T \approx 0.50\,\mathrm{s}$ and displacement amplitudes $A = 36\,\mathrm{nm}$ and $A = 92\,\mathrm{nm}$, respectively, were recorded (Holub 1972). The source of these oscillations was not reliably identified. It could have been the operation of generators in the local power plant but there is no evidence for an unambiguous explanation.

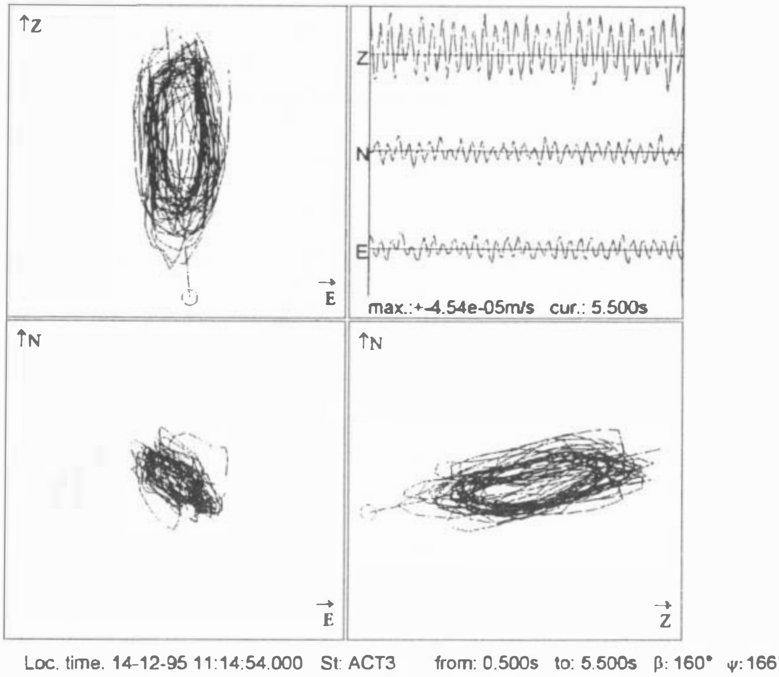

FIG. 10. Particle motion diagrams of vibrations generated by the compressor operation in an acetylene mill. Upper right corner three component record sections.

A more serious problem of identification of the seismic source arose from the existence of a "long period" seismic noise with periods $T \approx 0.7 - 1.1$ s. This type of seismic noise was recorded at two sites during the preparation phase for the erection of the seismic station Ostrava–Krásné Pole (OKC) and in the course of its regular operation as well. The appearance of this seismic noise at OKC made it often impossible to interpret reliably the seismograms (see Fig. 11). The determining of suitable triggering criteria for automated recording of teleseisms and local seismic events, especially mining induced ones, would be a problem, too. However, at present, this type of seismic noise has not been recorded at all at the seismic station OKC.

5. FINAL REMARKS

The results of observations of the seismic noise level and its frequency content performed at the reported sites showed some essential features which can be characterized as follows:

(i) Traffic and industry are the original and serious sources of the short–period seismic noise.

(ii) Road traffic (cars, buses and lorries) generates vibrations with periods within

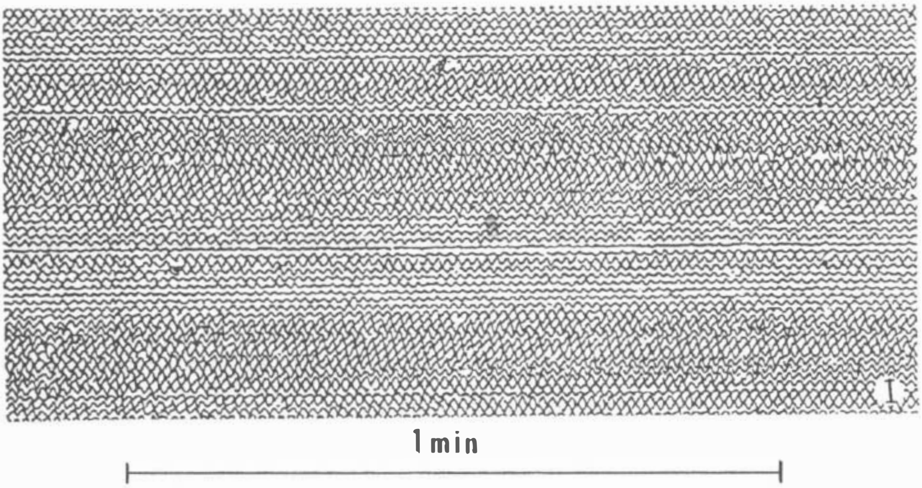

FIG. 11. Wave pattern recorded by the vertical short–period seismograph at the seismic station Ostrava–Krásné Pole (OKC). The bar in the right lower corner represents the displacement amplitude of $A = 100\,\mathrm{nm}$.

the interval $T \approx 0.04 - 0.30\,\mathrm{s}$ and/or $f \approx 3 - 25\,\mathrm{Hz}$ and with variable amplitudes. In the same category of disturbances also vibrations caused by bulldozers and mobile cranes could be included.

(iii) Railway traffic induces vibrations with periods of about $T = 0.10 - 0.45\,\mathrm{s}$, i.e. approximately $f = 2 - 10\,\mathrm{Hz}$. Stationary sources exhibit minimum amplitude changes and almost stable periods, while amplitudes caused by moving sources vary.

(iv) Individual industrial sources generate vibrations within various bands of periods and/or frequencies, e.g.:

- pumps of local water works – $T = 0.18 - 0.20\,\mathrm{s}$ superimposed with oscillations of $T_V = 0.031\,\mathrm{s}$ and/or $T_H = 0.043\,\mathrm{s}$ both with almost constant amplitudes
- compressors – $T = 0.10 - 0.12\,\mathrm{s}$ and $T \approx 0.17\,\mathrm{s}$, i.e. approximately $f = 5 - 11\,\mathrm{Hz}$
- cupola motion at the astronomical observatory – $f = 5.8\,\mathrm{Hz}$
- piston compressors – $T \approx 0.5\,\mathrm{s}$
- forging shop operation – $f = 2.5 - 8.5\,\mathrm{Hz}$, i.e. $T = 0.12 - 0.40\,\mathrm{s}$.

(v) Amplitudes of vibrations due to man–made activity vary considerably and depend on the source–receiver distance, the source intensity and the seismogeological conditions of the environment. Changes in the amplitude level of the artificial noise do not depend on the time of observations during the whole day.

(vi) The law of the decrease of displacement amplitudes which were generated by piston compressors ($T \approx 0.2\,\mathrm{s}$) and recorded up to the distance of 1400 m can be described by the power function in the form:

$$\ln A = 3.816 - 0.526 \ln r\,.$$

(vii) Besides identified sources also some unspecified sources were observed, e.g. sources of regular oscillations with periods of $T \approx 0.5$ s caused probably by generators of local power plants and a "long period" noise having periods $T \approx 0.7 - 1.1$ s. This type of noise was previously observed in wider neighbourhood of the seismic station Ostrava–Krásné Pole, however, its origin has not been identified yet.

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