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VERIFICATION THE ATTENUATION RELATIONS FOR SEISMIC WAVES IN THE BOHEMIAN MASSIF

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ABSTRACT
Anti-earthquake design of facilities with high earthquake risk is based on design spectra, which are prescribed on the basis of earthquake hazard to a building site in question. In the Czech Republic, the determination of earthquake hazard, expressed in the units of ground motion acceleration, makes use of acceleration attenuation relations, which had been derived in abroad regions with greater seismic activities. Verification the applicability of abroad formulae must be based on authentic accelerograms of earthquake events in the region of localities in the Czech Republic. Since 2003, four temporarily seismic stations are taken in operation in the N-S profile Šonov – Znojmo towns. For the sake of establishing great number of measuring points in the whole region, automated peak acceleration recorders were constructed. The up to now maps of macroseismic fields could be, step by step, completed by much more objective data.

KEYWORDS: earthquake hazard assessment, design spectra, ground motion acceleration, acceleration attenuation monitoring, seismic profile, acceleration response recorder

1. INTRODUCTION

The earthquake effects on buildings are usually calculated from the response functions. These functions are derived from values of maximum amplitudes of vibrations A of a set of elementary mechanical oscillators forced by seismic ground motion. Oscillators are adjusted on various natural frequencies f_S (Hz) and various damping constants D. Each of response functions $A(f_S,D,R,M)$ is determined for seismic event with magnitude M and epicenter distance R (km). Response functions are plotted in coordinates (f_S, A) for various parameters D. Individual response spectra obtained from worldwide accelerograms were generalized by smoothening. The so obtained empirical functions, called design spectra, are used as input data for anti - earthquake design of buildings. Design spectra in Fig.1 and in Fig.2 are recommended by international authorities to be used for buildings in sites where authentic local strong motion accelerograms are missing. The design spectra are normalized to the value A for f_S >35 Hz, where the acceleration response is practically equal to the Peak Ground motion Acceleration (PGA). The values of PGA are commonly used for evaluating the Earthquake hazard. The spectra in Fig. 1 and in Fig. 2 are normalized for the value PGA = 1 m.s $^{-2}$ = 0.1 g.

The authentic design spectra $A(f_S,R,M,D)$ depending on magnitude M and distance R of cannot be determined in regions of low – moderate seismicity, where the strong – motion accelerograms are missing. The earthquake hazard to NPP Temelin was consulted with the IAEA expert commissions, last time in February and March 2003. The reliability of abroad design spectra, used for the territory of the Czech Republic, is very live in the present time (Buben a Rudajev, 2003).

2. STANDARD DESIGN SPECTRA

The following abroad design spectra functions are used hitherto:

- The Newmark's spectrum and General Response Spectrum (GRS), (Newmark and Hall 1982), Fig. 1.
- The IAEA General Absolute Acceleration Response Spectrum (IAEA 1991), Fig.2.

Sadigh et al. (1986) derived an empirical relation for calculation the design spectra. The design spectra calculated from Sadigh´s relation for values of magnitude M (3.0, 3.5, 4.0 and 4.5) and for distances R (km) from 25 km up to 250 km by steps of 25 km are given in Fig. 3. For verifying the reliability of Sadigh's design spectra for sites in the Bohemian massif, special seismic profile of strong-motion seismographs was established.

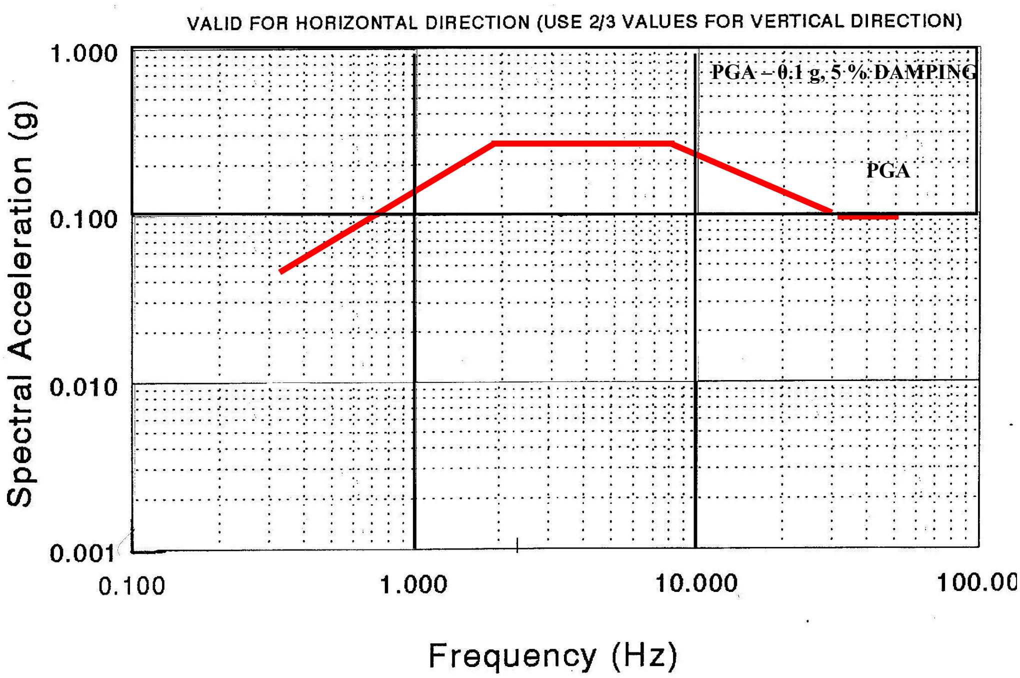

Fig. 1 The Newmark Generalized Response Spectrum GRS.

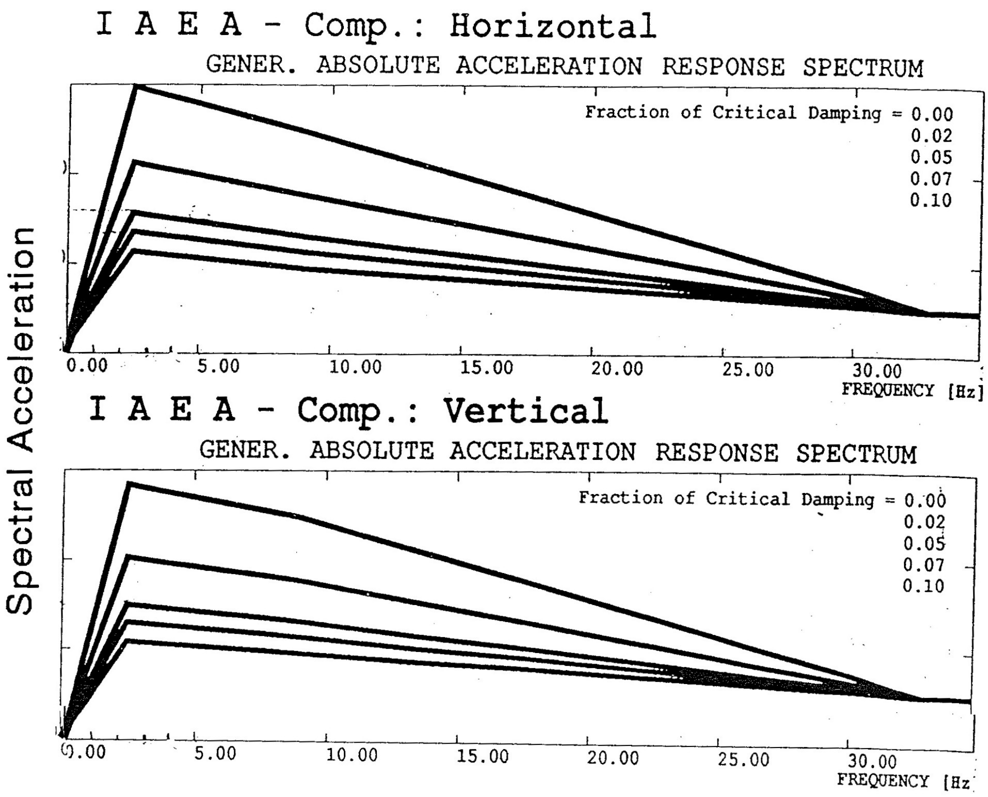

Fig. 2 The IAEA absolute acceleration response spectrum.

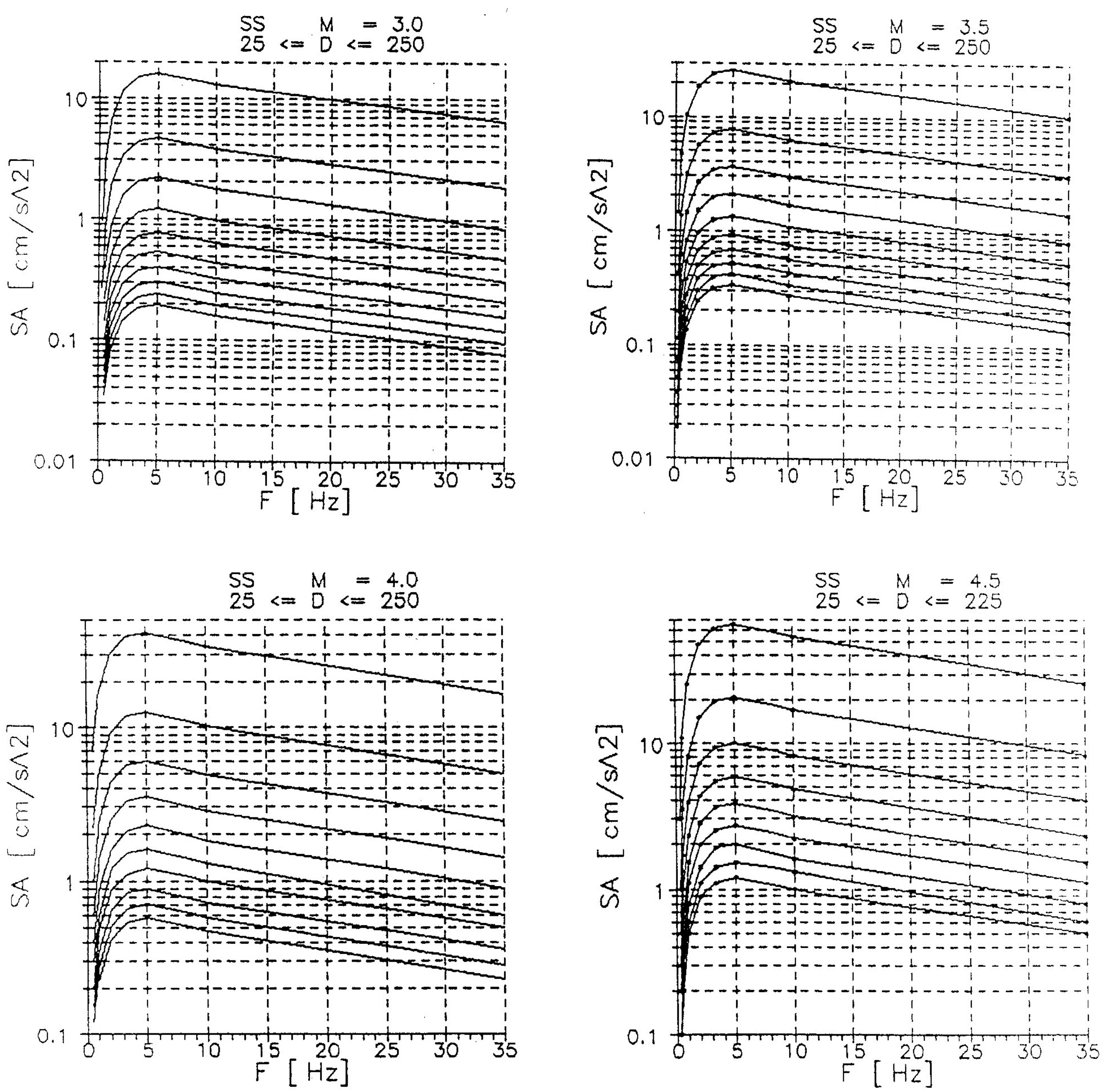

Fig. 3 Design spectra calculated from the relation of Sadigh.

Table 1 The coordinates of seismic profile stations

Seismic station	Latitude [°N]	Longitude [°E]
Šonov near Broumov	50.614	16.396
Potštejn	50.079	16.306
Skalka	49.445	16.277
Znojmo-Konice	48.834	16.021

3. SEISMIC PROFILE

During the year 2003, four engineering seismographs type MR 2002 Syscom, Swiss, were installed on rocky outcrops in the profile of direction NS. This profile was namely designed for monitoring the earthquakes in the Vienna basin and rockbursts in the copper mine Lubin near Legnica (Poland). The earthquakes in the Viennese source zone and the mining induced seismic events in copper mine Lubin, contribute substantially to the volume of the data for determination decrease function PGA(R,M). Seismic events in Lubin (51.463° N, 16.119° E) appear with high repeating frequency (tenths events per year) and moderate magnitude M, (e.g., the event $M_L = 4.1$ from 5.10.2003 or $M_L = 4.5$ from 24.3.1977). The coordinates of seismic profile stations are given in Tab.1 and their positions are shown in Fig. 4.

Events recorded during the operation of instruments from 1 July 2003 to 1. February 2004 are given in Table 2 (earthquakes and rocbursts) and Table 3 (explosions). As an illustration, records of rocburst in Lubin from 5. 10. 2003 are shown in Fig. 5. For obtaining the necessary volume of data we await the period of operation to be some years at least and the greater number of stations will be used (distance steps between stations should be shorter). To this purpose, more dense set of special low-cost instruments, recording only the spectral response for f = 18 Hz, seems to be well helpful. The construction of this recorder (G18) is described in following paragraphs.

4. RESPONSE RECORDER G18

The apparatus was worked up as an extremely easy and low-cost tool for monitoring the PGA values in a great number of measuring sites. The quality of recorded of data will be far higher than that obtained up to now by macro-seismic observations. The apparatus does not record the time history of forced vibration, but only the peak absolute amplitude. Due to these features, the recorders can be made in good-sized series and their sitting and operating in terrain is easy executable.

The prototype of apparatus consists of a PC Pentium1 (actual cost not exceeding 30 Euro) and of a geophone with natural frequency f_S, manufactured originally for seismic prospecting and monitoring the seismo-acoustic emission. A selective amplifier adjusts the selective amplitude frequency characteristic of recorder. The values of maximum forced amplitudes are stored on the disc commonly with the date and time of individual seismic events.

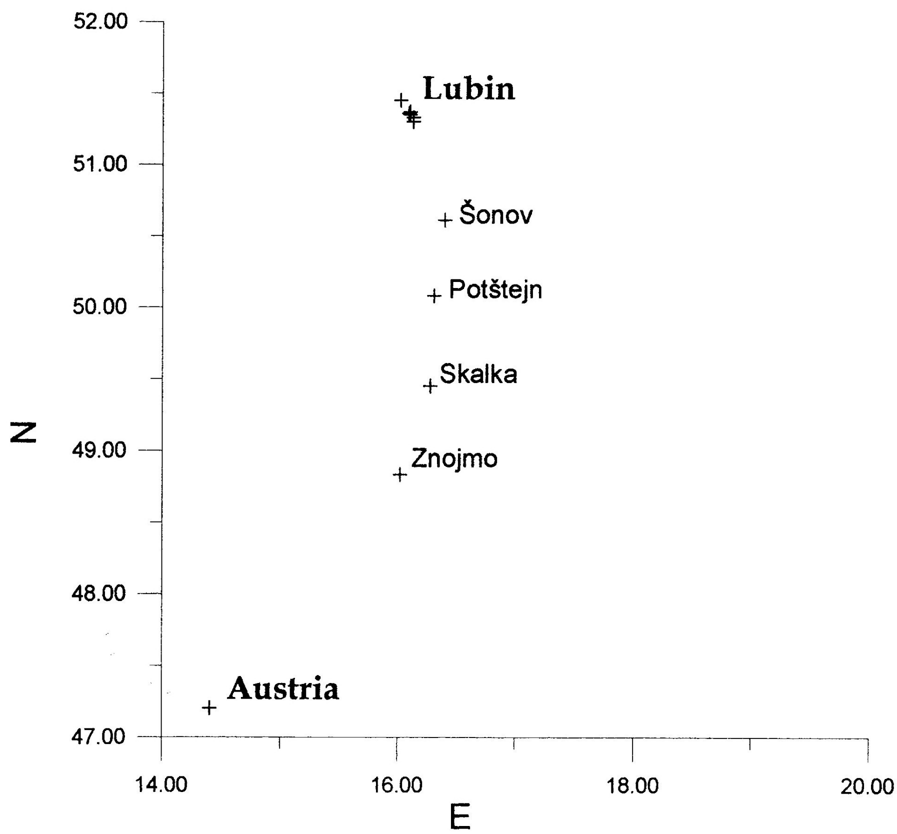

Fig. 4 Position of seismic stations on the NS profile

Table 2 Recorded seismic waves generated by earthquakes and rockburst

			Data	G F U		Šonov				Potštejn				Skalka				Znojmo			
Datum	Čas	Lokace	N	E	ML	X	Y	Z	vzdál.	X	Y	Z	vzdál.	X	Y	Z	vzdál.	X	Y	Z	vzdál.
	UTC		stup.	stup.	m	Amax µm/sec.			km	Amax µm/sec.			km	Amax µm/sec.			km	Amax µm/sec.			km
21.7.2003	13:15	**Austria**	47,200	14,400	**4,3**					14	6	8	345,3					12	11	10	230,2
24.7.2003	4:25	Poland	50,310	18,670	3,1					4	3	2	237,5								
24.7.2003	16:04	Lubin	51,564	16,009	3,3	15	15	18	102,6	9	5	4	151,4								
25.7.2003	7:34	Lubin	51,515	16,084	3,2	11	6	18	95,0	7	5	5	145,3								
25.7.2003	15:10	Lubin	51,470	16,080	2,8	6	3	13	99,2												
31.7.2003	15:33	Lubin	51,450	16,119	2,9					4	3	2	138,4								
4.8.2003	8:17	Lubin	51,451	16,167	3,5	17	20	27	83,7	18	17	13	137,9					5	5	5	262,1
4.8.2003	12:25	Lubin	51,485	16,094	3,1	8	4	18	92,2	5	3	3	142,2								
4.8.2003	12:52	Lubin	51,482	16,098	3,0	8	4	12	91,8	3	3	3	141,8								
9.8.2003	13:31	Poland	50,290	18,610	3,3	9	4	8	216,8	6	6	4	204,5								
9.8.2003	22:01	**Austria**	47,080	16,650	**3,5**													6	4	5	186,3
27.8.2003	1:02	Lubin	51,564	16,008	3,1	10	10	12	102,6	6	4	3	151,5								
14.9.2003	21:42	**Northen Italy**	44,700	11,500	**4,9**					2	4	2	721,3					3	4	4	612,6
16.9.2003	3:41	Poland	50,050	18,260	2,8					3	3	4	195,4								
19.9.2003	3:54	Lubin	51,480	16,070	2,9					4	1	2	142,1								
22.9.2003	2:33	Lubin	51,484	16,100	3,2	8	5	17	91,9	5	4	4	142,0								
27.9.2003	2:13	Lubin	51,540	16,057	3,1	8	9	16	98,6	4	3	2	148,2								
28.9.2003	3:49	Lubin	51,483	16,098	3,3									6	5	5	205,1				
2.10.2003	23:34	Lubin	51,481	16,101	3,3	11	8	22	91,6	8	8	6	141,9	5	5	5	204,4				
3.10.2003	16:01	Lubin	51,480	16,100	3,1	13	4	27	91,5	3	3	4	141,6								
5.10.2003	3:52	Lubin	51,510	16,100	3,8	25	38	34	94,4	32	16	28	144,6	18	17	16	207,3				
16.10.2003	15:34	Lubin	51,477	16,115	3,2	11	5	8	90,8	7	8	4	141,1								
19.10.2003	3:52	Lubin	51,480	16,100	3,2	7	5	17	91,5	5	4	3	141,6								
24.10.2003	16:53	Lubin	51,481	16,071	3,2	14	6	20	92,6	11	6	8	142,2	7	9	6	204,9				
29.10.2003	7:15	**Austria - Tirol**	47,300	12,100	**3,5**					3	3	3	504,1	6	6	4	469,6				
30.10.2003	4:52	Lubin	51,480	16,110	3,0					4	3	2	141,5								
4.11.2003	16:46	Lubin	51,466	16,138	3,1					8	5	5	139,7	7	5	4	201,5				
8.11.2003	22:01	Poland	50,230	18,550	3,5					6	7	4	224,9								
10.11.2003	19:50	Lubin	51,451	16,122	2,8					3	3	1	138,4								
11.11.2003	19:19	Lubin	51,510	16,063	3,0	9	4	15	95,6												
4.12.2003	23:47	CS - Hronov	50,430	16,040	2,7									5	6	6	101,3				
11.12.2003	1:38	**Austria**	48,350	15,240	**2,9**					6	6	6	203,1	21	36	15	150,8	46	32	28	91,9
23.12.2003	17:26	Lubin	51,515	16,127	3,3					7	5	3	144,7								
31.12.2003	4:31	Lubin	51,500	16,140	3,2					5	2	2	143,1								

Table 3 Recorded seismic waves, generated by near production blasts (stations Šonov, Potštejn).

Datum	Čas SELČ	Lokace	Data GFU N stup.	E stup.	Šonov X Amax μm/sec.	Y	Z	Potštejn X Amax μm/sec.	Y	Z
16.7.2003	13:20	lom Rožmitál	50,62	16,38	24	44	39			
16.7.2003	14:11	lom Rožmitál	50,62	16,38	80	49	91			
18.7.2003	11:14	lom Rožmitál	50,62	16,38	173	201	348			
31.7.2003	12:16	lom Litice/Orl.	50,09	16,36				13	11	17
6.8.2003	13:40	lom Rožmitál	50,62	16,38	129	149	185			
8.8.2003	13:43	lom Rožmitál	50,62	16,38	134	168	240			
14.8.2003	12:50	lom Čer.skála	50,08	16,29				103	94	98
23.8.2003	12:13	lom Rožmitál	50,62	16,38	155	234	301			
28.8.2003	12:13	lom Litice/Orl.	50,09	16,36				12	14	18
29.8.2003	14:10	lom Rožmitál	50,62	16,39	69	78	70			
4.9.2003	12:16	lom Litice/Orl.	50,09	16,36				4	4	5
12.9.2003	17:35	lom Rožmitál	50,62	16,39	80	95	187			
16.9.2003	12:10	lom Rožmitál	50,62	16,39	162	157	255			
26.9.2003	13:41	lom Rožmitál	50,62	16,39	107	99	184			
30.9.2003	13:36	lom Litice/Orl.	50,09	16,36				12	10	11
13.10.2003	13:26	lom Rožmitál	50,62	16,39	66	112	147			
16.10.2003	12:01	lom Litice/Orl.	50,09	16,36				10	11	10
30.10.2003	13:05	lom Čer.skála	50,08	16,29				127	130	203
3.11.2003	12:40	lom Rožmitál	50,62	16,38	57	78	99			
5.11.2003	13:02	lom Rožmitál	50,62	16,38	54	63	121			
17.11.2003	13:39	lom Rožmitál	50,62	16,38	147	125	179			
18.11.2003	14:23	lom Rožmitál	50,62	16,37	62	64	72			
8.12.2003	14:00	lom Čer.skála	50,08	16,29				86	113	106

4.1. VIBRATION SENSOR

The seismic ground motion is sensed by the geophone GP3 which is produced by the firma Geotest, Uhřínov, Czech Republic. The State Institute of Standards and Weights, Prague, calibrated a choice example of serial number AB025/95. The stated technical parameters of product are as follows:

- Natural frequency of system f_S =18 Hz.
- Resistance of induction coil R_g = 620 Ω.
- Electro-dynamic constant B = 19.7 [V.s/m].
- Damping constant D = 0.15 without any external rezistor.

This sensor can now be used as a secondary standard for determination parameters of all others sensors.

4.2. BLOCK OF ELECTRONICS

The whole electronics consists from following circuits:

- Amplifier and selective filter, the two-way (full-wave) rectifier.

The selective amplifier consists of two operational amplifiers OA1 and OA2, see wiring schema in Fig.6. The values of RC feedback and coupling elements are adjusted for desired selective amplification with maximum value at 18 Hz. The amplification factor is adjusted by resistors 2 kΩ.

The rectifier uses operational amplifiers OA3 and OA4 with circuit elements that generate the absolute value of output signal to be the triple of the input amplitude. The rectified signal is filtered by a passive low-pass network R=10 kΩ and C7= 2μF, (Fig.4).

As an example, Fig.7 shows the course of rectified signal on the output of OA4 (lower curve) and the course of the filtered output signal (upper curve). This output is fed to the AD converter.

In Fig. 8 the graph GA shows the dynamic magnification of mechanic system of the geophone GP3. The voltage sensitivity of GP3 is illustrated by graph GB. Graph GC illustrates the amplitude-frequency characteristic of amplifier. The amplitude-frequency characteristic of whole apparatus is presented by graph GD.

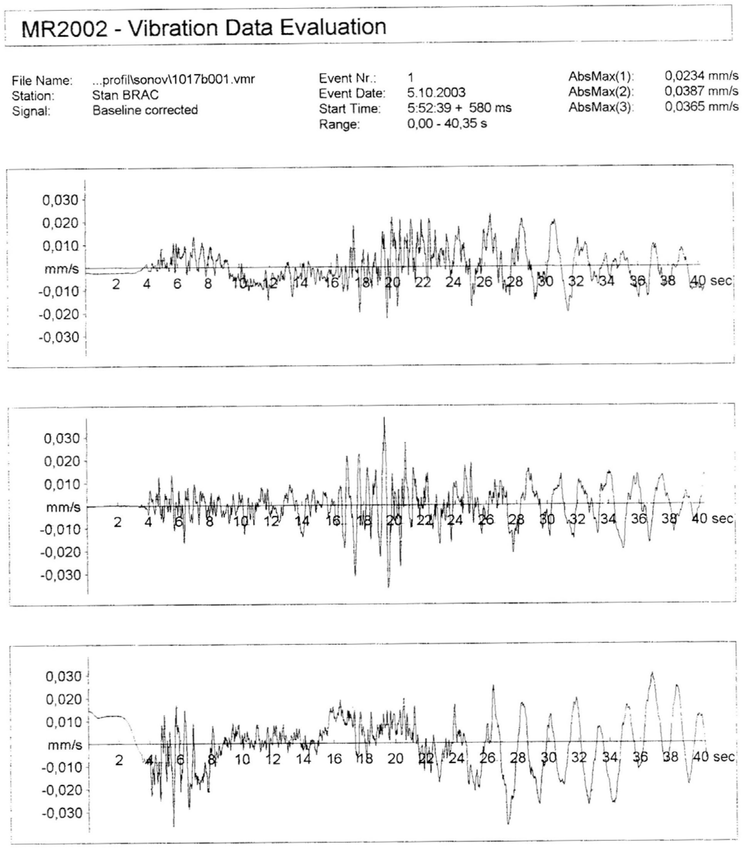

Fig. 5a Seismic station Šonov – Record of rockburst

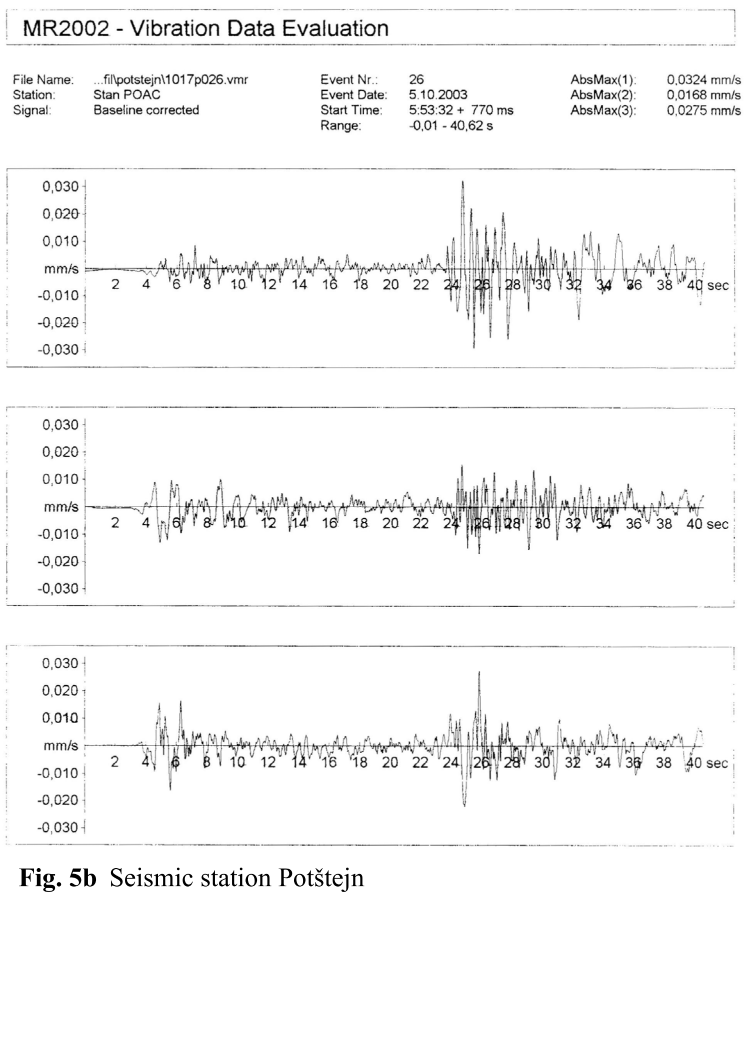

Fig. 5b Seismic station Potštejn

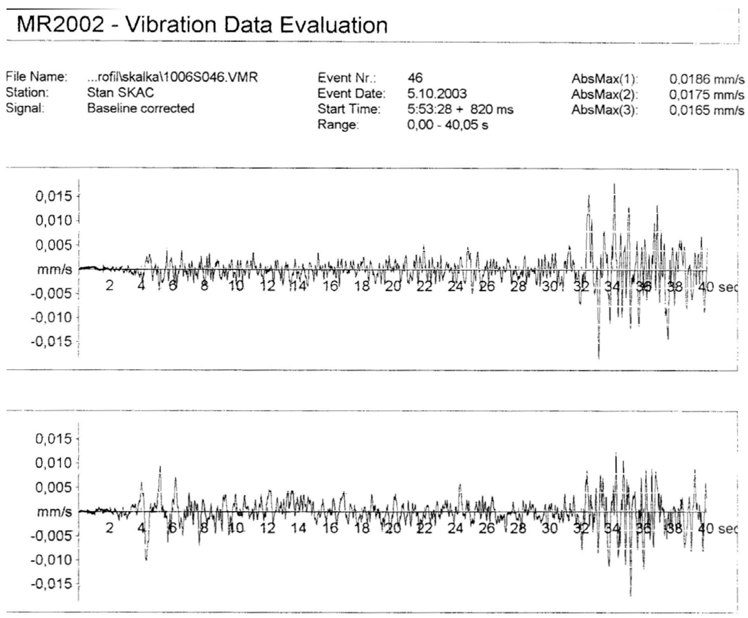

Fig. 5c Seismic station Skalka

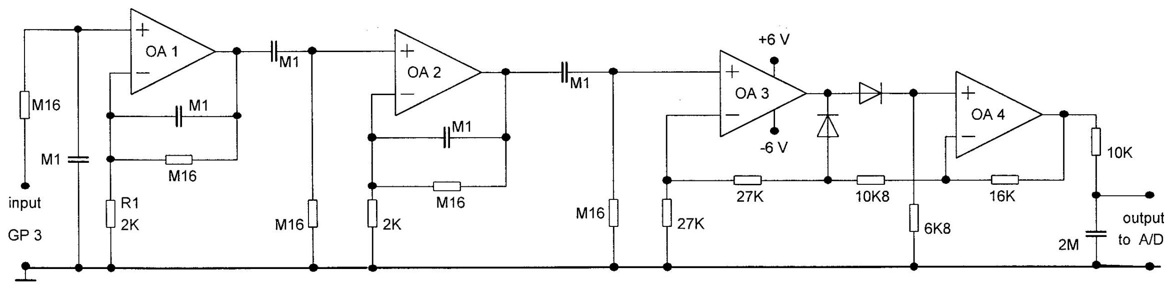

Fig. 6 Wiring schema of electronics

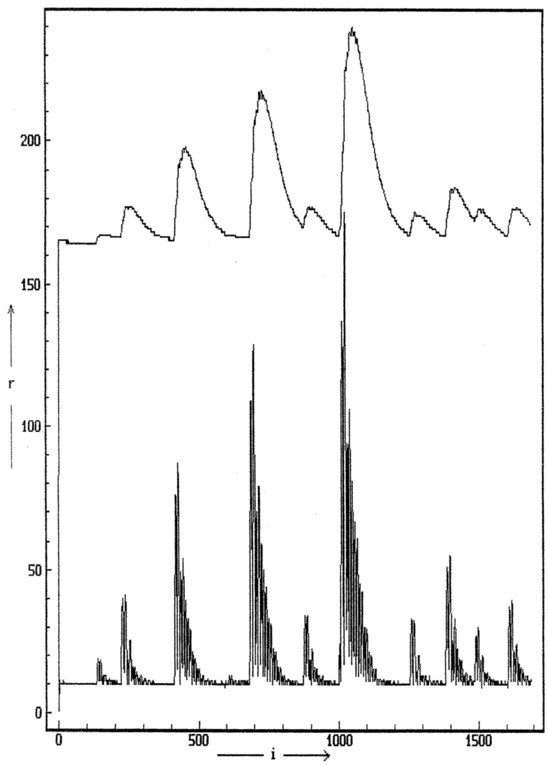

Fig. 7 Illustration of a rectified and filtered signal

- Analog-to-digital converter (A/D).

The A/D converter AD232 is a product of firm Janas Card, Ltd., Prague. This converter can be connected to a serial port (COM1 or COM2) of any standard PC. Sampling frequency (10Hz) does not have to be as high as in standard seismic recorders, because the output pulses are sufficiently wide. Discrimination of AD232 is about 15 bits, range ± 0.5 Volt, noise 15 μV and input impedance 1.1 MΩ.

The date and time of events are taken from the timing system of PC. The corrections of the internal PC clock are performed automatically on the basis of receiving the station DCF77.The receiver of and appropriate software mark RPC-B-UP-200-DOS is produced by firm Procon, Česká Lípa, and distributed by firm OMNIPRES, Prague.

4.3. SOFTWARE G.EXE.

The storage of data on hard disc starts when the amplitude exceeds a preset triggering level. This can be achieved automatically with respect to local seismic noise. The first amplitude of onset need not be the maximum value of the whole wave train. Therefore a number of values that have exceeded the triggering level are stored in the output file in ASCII code.

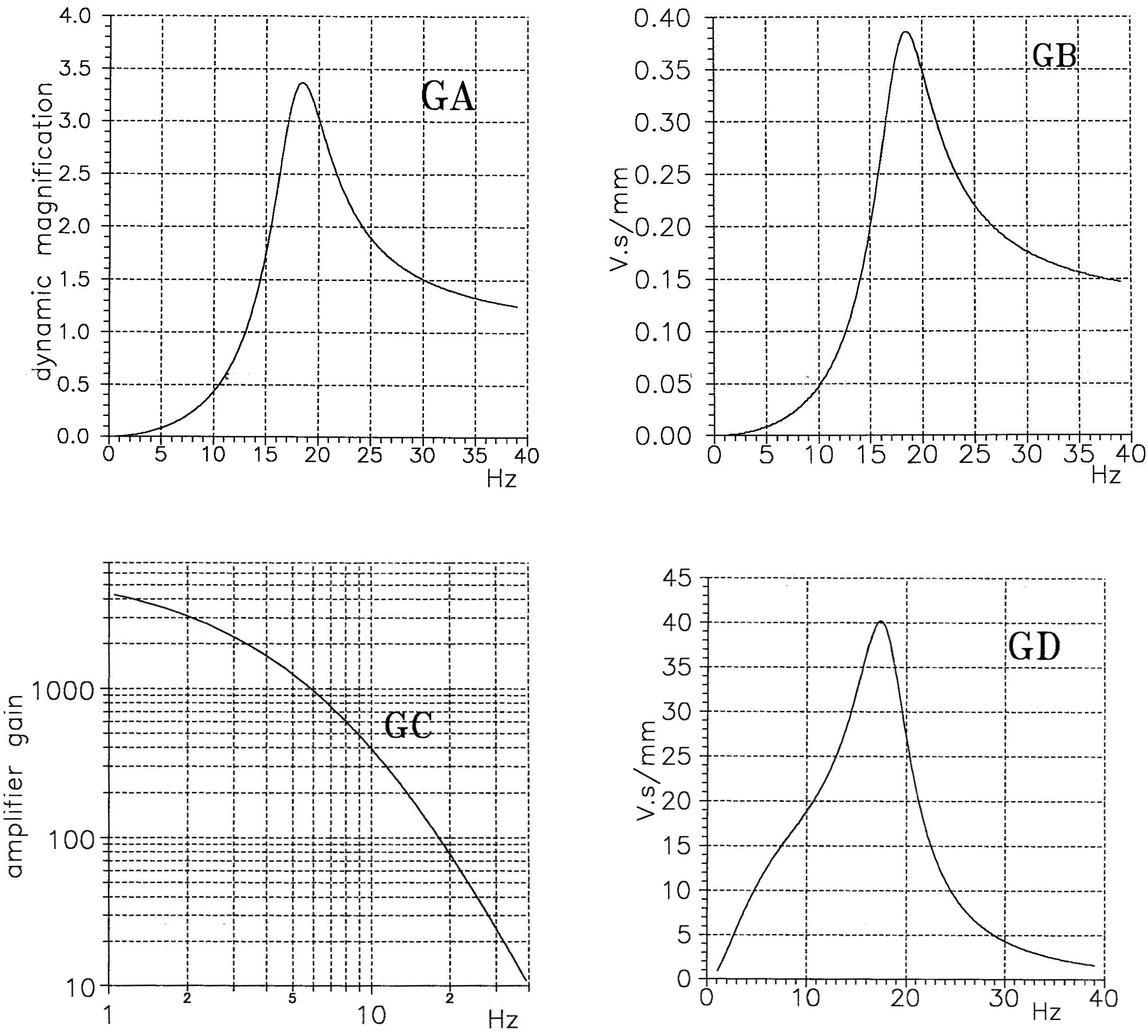

Fig. 8 Amplitude frequency characteristics
GA - Dynamic magnification of the geophone
GB - The voltage sensitivity of geophone
GC – Characteristics of amplifier
GD – Transfer function of recorder G18.

A new file is opened for each trigger. The file-name consists of the number *ddd* of day in the year + the name of station (*g*) + the hour *hh,* + minute *mm* in the current day. The seconds *ss* are quoted in the file extension. Due to this labeling, the time of stored data can be easy determined from their file-names *dddghhmm.ss.* When the recording condition goes off, the output file is closed. Therefore the failure of power supply does not give rise to damage all of previously stored files. When the instrument is switched on again, the recording software G.EXE does automatically start up.

4.4. PERSPECTIVE APPLICATIONS

Hitherto, the prototype of response recorder operates in the seismic vault of the IRSM building - Prague. The first operating sites are planned in the NS profile Broumov – Znojmo. The foreseeable application is monitoring the spatially distribution of ground motion amplitudes in as numerous as possible (some tenths) of sites in the Czech Republic. In this way, the up to now maps of macro-seismic fields should be - step by step- completed by much more objective isolines in the future.

ACKNOWLEDGMENT

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