Algorithm of Multichannel On-Line Detection of Seismic Signals at Three-Component Station * (Development of Improved Methods of Data Processing for the International Seismic Monitoring System)

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Abstract

In October 1996 the Comprehensive test Ban Treaty (CTBT) was signed at the 51 General Assembly UNO in New York by 129 countries. It's Proposed that verification of the CTBT will be fulfill at the national basis using national technical means supplemented by data from International seismic monitoring system (ISMS). Scientific and technical Concept and the prototype of the ISMS, was developed by the Group of Scientific Experts (GSE) of the Conference, on Disarmament UNO in Geneva at tile period of 1976-1996. Full-scale testing of this concept and prototype of the ISIS was conducted in the course of the Third technical test of the GSE (GSETT-3) in 1,995. Experience, of the GSTEE-3 demonstrated a large number of false detentions per day at many primary (alpha) stations. In this Connection, the fundamental task to improve the efficiency of the ISMS is concerned with development of new on-line methods and algorithms of short period signals detection and rejection of false alarms. The algorithm is presented for on-line detection of regional and teleseismic signals by 3-component stations with the efforts being made to solve the problem of rejection of false detections. The method is proposed for recognition of real signals and false detections, filtered, by 8 single-octave, filters using frequency-time and polarization characteristics of the signals. This method allows to select about 95%, of 1he false detections. Effectiveness of the algorithms was verified

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was estimated on the basis of signal and noise samples at three Russian primary stations included in GSE'Fl'-3 network-: Norilsk (NRT), Zalesovo (ZAL) and Peleduy (PDY).

1 Introduction

In October 1,996 the Comprehensive Test Ban Treaty (CTBT) was signed at the 51 General Assembly UNO in Now York by 129 countries, It's proposed that verification of the CTBT will be fulfill at the national basis Using national technical means supplemented by data from International seismic monitoring system (ISMS). Scientific and technical concept and the prototype of the ISMS was developed by the Group of scientific experts (GSE) of the Conference on Disarmament UNO in Geneva at the period of 1976-1996. Full-scale testing of this concept and prototype of the ISMS was conducted in the course of the Third technical test of the Group of scientific experts (GSE17-3) in 1995,
Experience of the GSETT-3 demonstrated a large number of false detections per day at many primary (alpha) stations. Intensity of false detections even at the end of the experiment at many stations was as much as hundreds per day and sometimes about thousand and more. (IDC Performance Reports, January 1, 199S - January 11,1996; GSE/CR.P.269, 29 March 1.996.).
As a result the procedures of automatic and interactive events processing were conducted at the Experimental International Data Center (EIDC) with high load. This makes modernization of algorithms of automatic signal detection at EIDC still important problem having fundamental significance for increase of efficiency of tile ISMS,
This paper describes a new algorithm of on-line seismic signals detection at three-component (3-Q) station, based on frequency-time (9) method of recognition of signals and false detections. In addition the selection of false detections is carried out with use of distinctions in a rectilinearity level of polarization of signals and noise.
The offered algorithm is development of a method, underlying tile designed earlier program system "SEISMOSTATION" (SEISMO), (Kedrov, Nemytov et. al, 1989; Kedrov and Ovtchinnikov, 1990).
Estimation of efficiency of the offered detection algorithm was made with use of records of earthquakes and noise samples at three primary (alpha) stations of Russian Federation, included in GSETT-3 network: Peleduy (PDY), Norilsk (NRI) and Zalesovo (ZAL) (Kedrov et. al., 1996).

2 Data sources

The regional and teleseismic earthquakes records from various regions of the Earth were used, as well as fragments of noise at three Russian stations PDY, NRI and ZAL. (Tab. 1), received from archive of the Russian National Data Center (NDC) M Dubna.
These stations are equipped with seismic recording systems PARUS-2, which includes short-period (SP). mean-period (MP) and long-period (LP) channels. In this work the only records were used obtained from the SP-channel, that has amplitude frequency characteristic linear by the ground velocity in the range. V11-10.0 Hz at 3dB points (Fig, 1),
In view of velocity sensitivity of seismometers and amplification coefficient of the amplifying and filtering channels, the unit of the lowest order digit of analogue-digital converter makes 9x10-11 m/s or 11.5 counts per 1 nm/s. The data sampling rate is 40 counts/s.
Information on the seismic events sources was extracted from the bulletins PDF and REB, the latter being received from EIDC during the GSETF-3 through INTERNET channels.

3 Basic principles of the method

The program system SEISMO is based on analysis of SP 3-C records of a single station in on-line mode. The system was modernized in order to detect both teleseismic and higher-frequency regional signals. For this purpose 8 one-octave, linear-phase Butterworth filters for each component of the seismic channel were introduced into the system, that cover with overlapping overall velocity linear range. of Frequency-response characteristic of the seismic channel (Fig. 1):

1. 0.5-1.0 Hz;	2. 0,75-1,5 Hz;	3. 1,0-2,0 Hz;	4. 1,5-3,0 Hz;
5. 2,0-4,0 Hz;	6. 3,0-6,0 Hz;	7. 4,0-8,0 Hz;	8. 5,0-10,0 Hz;

Slopes of the filters makes 30 dB/oct.
Tile algorithm of SEISMO is composed in such a manner, that signals detection is carried out independently at each record component (Z, NS and EW), preliminary filtered by the bandpass frequency filter. For the purpose of continuous signal detection, functions of the type:

$$\gamma = \sigma_s^2/\sigma_l^2$$

are calculated. Here σ_s^2 and σ_l^2 are estimates of the seismic oscillations dispersion at short and long time windows, calculated at Z-, NS- and F-W-component records.

Table 1: Earthquakes parameters

Date (d/m/y)	Bulletin	Origin Time (UTC)	Coordinates ϕ^o	λ^o	Depth (km)	Magnitude (m_b)
15/01/1995	PDE	02:40:19	27.51	128.46	47	5.8
24/01/1995	PDE	23:05:49	25.94	128.46	3	4.7
13/02/1995	REB	09:46:18	30.9	131.06	75	3.9
14/02/1955	REB	01:27:49	30.14	130.99	0	4.4
24/02/1995	PDE	20:09:08	27.18	127.39	92	5.4
09/03/1995	PDE	18:36:57	20.94	122.00	42	5.1
22/03/1995	REB	03:30:29	23.66	121.73	88	3.9
02/04/1995	REB	11:09:52	25.27	124.97	64	4.0
02/04/1995	REB	21:27:24	25.21	124.74	63	4.1
05/04/1995	REB	00:20:28	25.25	124.74	94	4.0
05/04/1995	REB	09:32:30	25.58	123.34	135	3.9
03/01/1995	PDE	01:31:15	39.82	78.18	33	4.5
12/02/1995	PDE	10:57:00	33.32	93.38	33	4.8
21/03/1995	PDE	07:44:00	36.45	71.22	235	4.0
07/01/1995	PDE	15:57:59	36.37	70.69	208	4.6
23/01/1995	PDE	01:42:53	36.6	71.48	184	4.5
04/04/1995	REB	15:29:54	28.01	71.54	19	4.5
04/04/1995	REB	14:26:11	30.74	67.48	0	4.0
11/07/1995	REB	23:45:42	29.95	69.32	0	4.4
19/07/1995	REB	23:36:48	29.9	69.43	0	4.6
21/11/1995	REB	02:20:18	29.75	51.48	0	4.7
23/02/1995	PDE	21:03:02	35.04	32.27	33	5.8
31/03/1990	PDE	22:59:48	32.38	-115.24	6	3.4
14/02/1991	PDE	16:37:22	29.68	-113.86	10	5.4
15/02/1991	PDE	04:56:03	29.35	-113.40	10	4.4
18/02/1991	PDE	12:51:22	30.97	-113.26	10	4.2
26/04/1991	PDE	08:20:55	38.06	-112.74	10	3.5
20/09/1991	PDE	00:56:56	29.87	-113.59	10	4.6

Detection of asserted if the level γth is exceeded at any of three seismograph component during some fixed period of time.
Processing of each defected signal is conducted with minimal time delay in interrupt mode in such a way, that provides the real-time mode priority for the procedure of new signals detection. The block-scheme, describing the sequence of 3-C information processing with the program SETSMO is shown at fig, 2
As far as the algorithm and the results of operation with the program SEISMO at the seismic station BOROVOE (131W) were considered earlier in details in the paper (Kedrov and Ovtchinnlkov, 1990). we consider in this work only briefly the main parameters, which are estimated by this program.
For each detected signal the following parameters are calculated:
- arrival time (t_{arr}), - wave type classification (P, S or X), - maximal amplitude ($A_{\max}$) - period corresponding to $A_{\max}$ ($T_{\max}$), - delay time of the moment of $A_{\max}$ (relative to t_{arr}), - signz:d to noise ratio (SNR), - azimuth (Az) and apparent angle of incidence (i) of P- and S-waves according, to polarization analysis, - rectilinearity of oscillations ($\varepsilon = b/a$, where b is the intermediate semi-axis and a is the major one of the polarization ellipsoid), - delay time of the moment of the maximal rectilinearity of the wave (in seconds relatively to (t_{arr})
Those detections which had polarization that did not match neither P- nor S-waves were denoted as X-waves.
Parameters Az, i and e are estimated with -use of polarizafion analysis of the initial fragment of the detected signal.
Arrival time of the signal is estimated with use of the following procedure.
- the interval. of the γ-function record is searched when the condition gi = gth was reached first,
- at the interval in the vicinity of γth γ-function is approximated by the straight line using the least square technique, which intersection with the time axis is asserted as t_{arr}.
The SNR is the maximal value of $(\gamma_i)^{1/2}$ at the moment of the signal detection.
Analysis of operation of such detector showed that at $\gamma\mathrm{th} = 4.2$ it allows to detect reliably at the station BRV weak teleseismic and partly regional signals, which have the ratio S/N ¿ 2 when using the range of preliminary frequency filtering 0.7-2.7 Hz at 3 dB points.
Experimental estimates showed that the errors of the automatic estimates tarr are compared with the visual determinations of the operating personnel within ±0.5 c in 70% of cases, for SNR ¿ 10 s and within ±1.0 s for SNR. ¡ 10. The limiting estimate errors t_{arr} for weak signal and those with non-pulse shape do not exceed ±3 s.
However operation of such detector produced a lot of false detections at each component Z, NS, W (about 40;1, of the all detections), Moreover, using of the single pre-detection filtering did not meet, the condition of equal probabilities of detecting signals with different spectral content over the whole range of registration

0.7-10.0 Hz.
In this connection a new version of the program SEISMO is offered, that is referred below as SEISMOI, and it is based on using eight one-octave filters.
A set of one-octave filters is used already long time for detecting signals among noise in automatic mode. In view of convenience to compare results the same set (if filters was chosen in the frames of the response range of the recording system Parus-2, which was used at the EIDC during the GSETT-3.
However introducing 8 filters, for automatic analysis of information by the components Z, NS, EV causes many times increase of the detections rate compared with filtering by one filter. Most of these detections are false signals.
As false detections will be considered those, which are, stipulated by random bursts of noise oscillations. Probably, such random peak- variations of noise are result of superposition of oscillations, arriving, to the station from various directions. They are characterized by relatively small ratio SNR and by low level of polarization rectilinearity.
Besides we assume to qualify as false the signals, which have relatively large SNR and high level of polarization rectilinearity, but represent shear waves from local sources.
Analysis of large sample of data has shown that as an effective tool to prevent false detections of such type with a multichannel detector may serve a method, based on comparison of detections in time-frequency domain.
The typical difference between signals and random noise in time-frequency domain is that detection of signals occurs practically in the same time at several subsequent filtered channels, at least at two of them, if the signal is weak, In most cases of noise some single entries are observed, which are not correlated in time on subsequent filters.
Thus, this method of identification of signals in f-t plane may be named as spectral-time correlation (STC) method.
These distinctions of signals and noise in the f-t plane are well seen at the diagram of the spectral-time analysis (STAN) (fig. 3).
This figure shows the raw records of the earthquake in Japan (a.), (14.02.95; To = 01:27:51; ϕ = $29,27^oN, \lambda$ = $131,14^oE$; H = 29 km; mb = 4,5; D = 46,30 - according to PDE) at the station NRI and envelopes of this signal records by 8 filters, obtained as a result of STAN in a range of frequencies 0,7.5-10,0 Hz (b).
Alongside with such arrivals the detector identifies a lot of secondary body phases in the coda of the earthquake records. These phases contain some useful information, which can be used during processing at the EIDC. Usually such secondary phases are also found out at least at two subsequent filters and this is base for their identification among a plenty of S-type detections, generated by weak local Sources.
The level of the polarization rectilinearity may be also used for selection of that part of false detections, which are generated by a superposition of random oscil-

lations from various sources arid have a lower level of polarization, than signals, generated by single point sources (fig, 4).
Fig 4 shows projections of the ground particle motion at three orthogonal planes for 3-seconds intervals record of a false P-type detection at the moment of time 04:35:30 (a) and real P-wave (b) shown at fig. 3. Preliminary this record was filtered in the range of 1,0 - 2,0 Hz.
Thus, to use these attributes for elimination of false detections during automatic processing the following rule-s are offered.
1. The signal fixed at least at two adjacent filters (k = 2), is identified as a real signal; the signal, found out only at one filter is qualified as a false alarm.
2. The signal is classified as real, if it has parameter $\varepsilon < \varepsilon$th.
3. The signals, which are identified as P-waves according to their polarization characteristics, are considered as real, while signals of type X and S - as false detections.
However hereinafter the signals of type X and S will be considered in this work with the purpose of estimate of their contribution into the whole flow of false detections.
Basically, a weak signal, which has the ratio SNR close to the chosen value gth, can be found out only at one of filters, however processing, of such signals is reasonable to conduct at the stage of interactive analysis.
Another way is to assemble such arrivals of P-, S- and X-type at any one filter in a separate archive, which may be addressed automatically when composing, the preliminary alpha-beta event list (ABEL.).
In view of difference in arrival times of a signal it adjacent filters some critical value Δt_1 is chosen, that provides detection of weak signals at least at two adjacent filters.
Also the second interval of search for signal arrivals Δt_2 is introduced in connection with the detection problem of secondary phases of regional signals, which have greater time spread of tarr at different filters in comparison with the first arrival of P-wave.
Besides it is possible in such a way to exclude a situation of rnissinz-1 a channel with Maximum SNR value. For example, If the signal is found out at 1st, 3rd and 4th channels, and the maximum SNR value is noticed at the 1st channel, then to find 1st channel, the secondary inspection is necessary of the arrival times of the signal at all filters after it was already found at two subsequent (3rd and 4th) channels.
The rectilinearity level of P-waves depends ¡in station conditions of registration, on the SNR value and does not practically depend on the bandpass frequency of the filter.
Fig. 5a shows a record of the earthquake from Japan at the NRI (see fig. 3 a) and fig. 5b shows the scheme, at which arrows indicate entries of phases P, S, and X, found out automatically by the program SEISMOI with the following values

Table 2: results of processing of the earthquake record from Japan on 14.02.95 at the station NRI by the program SEISMO1

Filter with SNR_{max}	Wave type	t_{arr}	A_{max}, nm	T, s	SNR	ε	Number of filters with detections
2	S	4:34:45	0,3	0,8	2,5	0,19	3
2	S	4:35:48	0,3	0,7	2,8	0,20	2
3	P	4:36:02	2,4	0,7	3,3	0,29	2
1	P	4:36:10	1,7	1,1	7,2	0,25	3
3	X	4:36:20	2,2	0,7	3,9	0,25	3

of the initial parameters:

$$\Delta t_1 = \text{I,1 s ii } \Delta t_2 = \text{2,5s; } g_{\text{II}}(1) = \text{4,5, } \gamma\text{th}(2) = 4, \gamma\text{th}(3) = \text{4,5, } \gamma\text{th}(4) = \text{5,0,}$$
$$\gamma\text{th}(5) = \text{5,0, } \gamma\text{th}(6) = \text{5,0, } \gamma\text{th}(7) =\text{- 5,5, } \gamma\text{th}(8) = \text{5,5 and } \varepsilon\text{th} \leq \text{0,35,}$$

It's seen from the last figure, that total 22 signals are detected at the given fragment (13-P. 7-S and 2-X), among which only 2 ones (first arrival of P-wave at 04:36:10,2 and one secondary phase in the P-coda .) correspond to the earthquake from Japan, and ill other have smaller intensity and distributed in casual manner at the If-I plane,

Use of STC and eth criteria allows to reduce number of detection down to -5 showed in a circle. Parameters of all these signals are shown it) table 2. In the last column the number of filters is specified, at which an appropriate phase was l6und- out in the given time windows Δt_1 and Δt_2.

The first two arrivals in table 2 with polarization of S-waves have small intensity and are stipulated by local sources. The third detection of P-wave is stipulated by the source, information about which is absent in the PDE bulletin.

Fig 6 shows the record of the earthquake from California at the station Albuquerque (ALQ), (16.04.1991; T_0= 08:20:54,8; ϕ = $38,06^o$N, λ = $112,74^o$W; H = 10 km; mb = 3,5, ML = 3,2; , - I,I; Δ = $5,9^o$ - according to PDF) and the results of processing this 4-minute fragment by the offered algorithm. Overall 20 arrivals are detected at this fragment by the program SEISMOI (6 - P-waves, 12 - S-waves, 2 -X-waves). Table 3 gives parameters of signals detected by the program SEISMOI.

Thus, consideration of the given signal at the f-t plane allows to eliminate from the further analysis practically all false detections, having left only the first arrival and two secondary phases of the earthquake.

It should note that the automatic classification of regional phases Is essentially more complex procedure compared with the analysis of teleseismic signals. Nevertheless, in general, result of automatic detection of the given and some other

Table 3: Results of the processing of the record of the earthquake from California 26.04.1991 at the station Albuquerque by the program SEISMO1

Filter with SNR_{max}	Wave type	t_{arr}	A_{max}, nm	T, s	SNR	ε	Number of filters with detections
4	X	8:22:26	0,4	0,5	8,6	0,10	4
5	P	8:23:59	0,2	0,3	4,1	0,16	3
1	S	8:24:04	0,8	1,3	3,1	0,32	2

regional signals may be considered satisfactory, as far as despite some errors of identification (the first arrival identified as X instead of 111., wave and second detection classified as P instead of S phase).

4 Algorithm

Algorithm of 3-C seismic data processing by multichannel detector is developed on the basis of the program. SEISMO designed earlier (Kedrov et al, 1989, Kedrov and Ovtchinnikov, 1990.).
Block-scheme of the processing by the offered method (SEISMO) is represented at fig.7.
Three-component data to be entered into computer are, Filtered by set of 8 one-octave linear-phase filters and are analyzed then in order to detect signals, at all 24 channels with use of the program SEISMO as a standard modulus.
All the major constants of the detector of the program SETSMO are frequency dependent and are entered separately for each filter,
Such constants are:
- conversion's coefficients from amplitudes to nanometers;
- the value of γ;
- long- and short.-time windows of the detector;
- minimal time of signal's registration above the threshold;
- the window of the covariation matrix calculation at polarization analysis;
- the window of searching maximal value of rectilinearity in. the detected wave.

The arrivals of P, S and X waves detected in specified time interval at all 24 filters were verified to meet the condition $\varepsilon < \varepsilon$th and then were analyzed at the f-t plane in order to find such signals which have at any two adjacent filtered channels the difference in arrival times $\Delta t_1 < \Delta t_{1\mathrm{th}}$.
To count the errors of the automatic finding tarr by the detector that is especially important in case of secondary phases from regional signals, additional searching is conducted of all the filters in more wide window Δt_2.

From k channels at which signal is found, one is chosen as the resulting at which the t value of SNR is fixed.
The set of parameters of the detected signals by the program SEISMO1 is practically the same as that mentioned above in the format of data output of the program SEISMO.
Additionally only those parameters are introduced which indicate the number of filter with SNR_{max} arid interval of time relative to tarr when the mammal value of the polarization rectilinearity was found.

5 Efficiency of the method

Efficiency estimation of the offered multichannel detector was made with use of seismic events from various regions of the Earth and samples of noise which were recorded at the stations NRI, ZAL and PDY. (Table 1)
Analysis of noise was made by 60-minutes fragments of 3-C records on January 1, 1994 at NRI and ZAL and on March 1, 1994 at PDY.
As a result of such analysis distributions of minimal intervals between detections at adjacent filters for records of earthquakes at PDY, ZAL and NRI were determined (Table 4). In brackets the number of observations at each station is indicated.
As limiting values were selected $\Delta t_1 < 1.1$ and $\Delta t_2 < 2.5$.
Table 5 shows distribution of polarization rectilinearity ε for P-waves of earthquakes and false detections, obtained after processing the signals and fragments of noise at ZAL, NRI and PDY.
Conducted analysis shows, that e does not depend on the filter's frequency content, but does depend on the conditions under station. Besides, it is known, that ε depend on the value of the SNR (Kedrov et al, 1990). Distributions of ε by signals and noise are totally overlapped, which does not allow to choose effective limiting value for updating noise with probability of signal missing equal to zero. Perhaps, more effectively this criterion may be applied if individual values of ε are chosen at each station.
In this work however for exception of obvious noise by the given criterion the common value εth $\leq 0,35$ is chosen for all three stations.
Analysis of records of earthquakes and noise was conducted by the program SEISMO1 with the values of the main entered constants, dependent on the central frequency of each filter (Tab. 6).
The data processing with various gth and (SNR)min values has allowed to find dependence between these two parameters:

$$(\mathrm{SNR})_{\mathrm{min}} = 0{,}4\ \gamma\mathrm{th} + 0{,}7 \text{ - for channels 1-5,}$$
$$(\mathrm{SNR})_{\mathrm{min}} = 0{,}6\ \gamma\mathrm{th} \text{ - for channel 6.}$$

These equations allow to evaluate what signals with minimum SNR value it is possible to detect with various values γth at each channel.

Table 4: Distribution of the number (in %) of the minimal values of P-wave arrives at adjacent channels (Δt_1)

$\Delta t_1, c$	ZAL (29)	NRI (18)	PDY (21)
$< 0,3$	96	89	95
$< 0,5$	100	100	95
$< 0,7$	-	-	100

Table 5: Distribution of the parameter ε for signals and noise (in %)

Intervals	ZAL		NRI		PDY	
ε	signal (29)	noise (63)	signal (19)	noise (84)	signal (20)	noise (164)
0,0 - 0,1	54	8	66	10	22	10
0,1 - 0,2	41	41	23	43	48	55
0,2 - 0,3	4	39	11	38	21	29
0,3 - 0,4	1	12	5	9	9	5

Table 6: List of constants of the program SEISMO1

Filter	f_c, Hz	γth	Detectors' windows		Polar analysis window	Search window of ε, s
			long, s	short, s		
1	0,7	4,5	28	1,7	2,1	4,2
2	1,1	4,5	19	1,1	1,4	2,8
3	1,4	4,5	14	0,85	1,1	2,1
4	2,1	5,0	9	0,55	0,7	1,4
5	2,8	5,0	7	0,4	0,5	1,0
6	4,25	5,0	5	0,3	0,4	0,7
7	5,65	5,5	4	0,25	0,2	0,5
8	7,1	5,5	3	0,2	0,15	0,4

Table 7: Results of the processing the records of the chemical explosion on 22.09.93 at the NTS by the program SEISMO1

Station	Filter number	Wave type	t_{arr}	$A_{\max}$, mn	T, s	SNR	ε
NRI	1	P	07:12:29,1	1,0	1,1	2,8	0,28
	2	P	07:12:28,3	1,5	0,8	3,5	0,19
	3	P	07:12:28,1	1,5	0,8	4,0	0,17
	4	P	07:12:28,3	0,4	0,5	3,5	0,24
	5	P	07:12:28,2	0,2	0,4	3,0	0,43
PDY	1	P	07:12:46,1	3,9	1,2	4,9	0,27
	2	P	07:12:46,5	2,7	0,9	4,5	0,17
	3	P	07:12:48,2	2,1	0,6	3,3	0,24

In this work the identical threshold values γth for all three stations (Tab. 6) were used. However at different channels different γth values were selected. It will be shown below, that, on the average, with these setting comparable detection rate at all three stations is observed.
The chosen values of γth and of other constants of the program SEISMOl, allow certainly to detect rather weak teleseismic P-waves. This is confirmed, in particular, by the results of detection of signals from 1 kt underground chemical explosion, conducted at Nevada Test Site on September 22, 1993 (GSE/RF/65, 1994) at NRI and PDY (fig. 7, 8) . Table 7 gives results of processing of this explosion.
The data listed in table 7 show that at NRI ($\Delta = 73^o$) and PDY ($\Delta = 76^o$) the P-waves from The given explosion are detected by the program SEISMO1 with permissible values of parameters Dt1, Dt2 and e, enabling certainly to identify them is signals.
Overall list of the number of detection, obtained after processing of 60-minute fragments of noise at stations PDY, ZAL and NRI before and after application of the false entries selection criteria is listed in table 8.
These estimates testify that the criterion Dt and e allow to select about 95%, of noise of any type and about 98%, if noises of type S and X to consider as obvious false detection. At the same time the method allows to detect arrivals of secondary phases in the coda of the teleseismic and regional signals.
The main contribution of false alarms selection is made on the basis of the f-t criterion. Important criterion of elimination of weak false detections is also identification them as S- and X-wave. Polarization rcetilinearity level can be applied as an effective criterion of elimination of false detection only in view of individual features of the station.

Me results submitted in this work testify that use of frequency-time and polarization characteristics of real and false detections can be a powerful tool of suppression of false alarms after automatic on-line detection algorithm at 3-C stations. At first glance paradoxical result, when the flow of false detections at 24-channel detector appears to be essentially less than at the single-channel one, In effect once again emphasizes importance to use in full spectral content and polarization of characteristics of registered oscillation.
The algorithm can be recommended for use in seismological centers, where large flows of digital seismic information are processed in on-line mode.

6 Conclusions

In this work an algorithm of a multichannel detector is proposed, enabling, in realtime mode effectively to distinguish real and false detections in frequency-time domain at 31-C station. Recognition of signals and noise is reached by spectral-time correlation of detections at 8 channels with one-octave filtering in the whole (0,7-10 Hz) frequency band of data registration, which provides short-period seismic channel of the recording system Parus-2.
As two additional criteria of discrimination of false detections polarization characteristics of signals are used (type of polarization and polarization rectilinearity level of oscillations). The programs SEISMO1, realizing this algorithm, represents the new version of earlier developed program system based on single-channel detector at 3-C station.
The estimate of efficiency of the offered algorithm of recognition of signals and false detections is conducted on samples of records of earthquake and 60-minwe fragments of noise, at three Russian alpha-stations PDY, ZAL and NRI, included in GSEIT-3.
Analysis of data has shown, that with careful choice of γth and other input constants of the program SEISMO1 for each filter, the algorithm allows to detect weak regional and teleseismic signals, providing selection of about 98% of false detections,
The program SEISMO1, made presently for the research purposes, can be easily transformed for on-line mode operation in thc International Data Center of the ISMS where large flow of digital seismic information are processed in own-fine mode.

7 References

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Table 8: Results of selection of false detections by the program SEISMO1 at 60-minute fragments of noise at PDY, ZAL and NRI

Station	Filter frequency range, Hz	Overall number of detections				Number of detections after application of the criteria Δt and ε			
		P	S	X	Total	P	S	X	Total
PDY	0,5 -1,0	10	16	6	32	1	-	-	1
	0,75-1,5	8	12	7	27	2	-	-	2
	1,0 -2,0	19	8	2	29	-	1	-	1
	1,5 -3,0	16	27	4	47	-	2	-	2
	2,0 -4,0	17	32	7	56	-	2	-	2
	3,0 -6,0	13	23	7	43	1	2	-	3
	4,0 -8,0	4	13	2	19	-	-	-	-
	5,0-10,0	2	6	1	9	-	-	-	-
Total		89	137	36	262	4	7	-	11
NRI	0,5 -1,0	4	7	4	15	1	1	-	2
	0,75-1,5	20	20	3	43	1	-	-	1
	1,0 -2,0	24	13	6	43	-	2	-	2
	1,5 -3,0	9	17	3	29	-	-	-	-
	2,0 -4,0	2	5	1	8	1	-	-	1
	3,0 -6,0	2	2	-	4	-	1	-	1
	4,0 -8,0	3	6	-	9	-	-	-	-
	5,0-10,0	-	2	-	2	-	-	-	-
Total		64	72	17	153	3	4	-	7
ZAL	0,5 -1,0	3	16	-	19	1	-	-	1
	0,75-1,5	5	24	4	33	1	-	-	1
	1,0 -2,0	10	27	2	39	-	1	-	1
	1,5 -3,0	5	23	5	33	-	-	-	-
	2,0 -4,0	2	28	3	33	-	1	-	1
	3,0 -6,0	4	30	11	45	-	1	-	1
	4,0 -8,0	8	17	2	27	1	-	-	1
	5,0-10,0	2	7	1	10	1	1	-	2
Total		39	172	28	239	4	4	-	8

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Kedrov O.K., A.I.Nemytov, N.N.Kalinina, O.P.Willemson (1989): Method and program realization of automatic detection and localization of seismic phenomena a separate three-component station in real time mode (In Russian), Proceedings of the Acad. of Sci. of the USSR, 307, (1), 67-73.

Kedrov O.K., V.M. Ovtchinnikov (1990): An on-line analysis system for three-component seismic data method and preliminary results, Bull, Seismol, Soc. Am, 80 (part B), 2053-207l.

Kedrov O.K., L.A, Polikaxpova., G.M. Steblov (1996.): Algorithm for detection of weak short-period seismic signals based on frequency-time analysis 43-component records in real-time mode (In Russian), Physics of the Earth, Russ. Acad. Sci. (in print).

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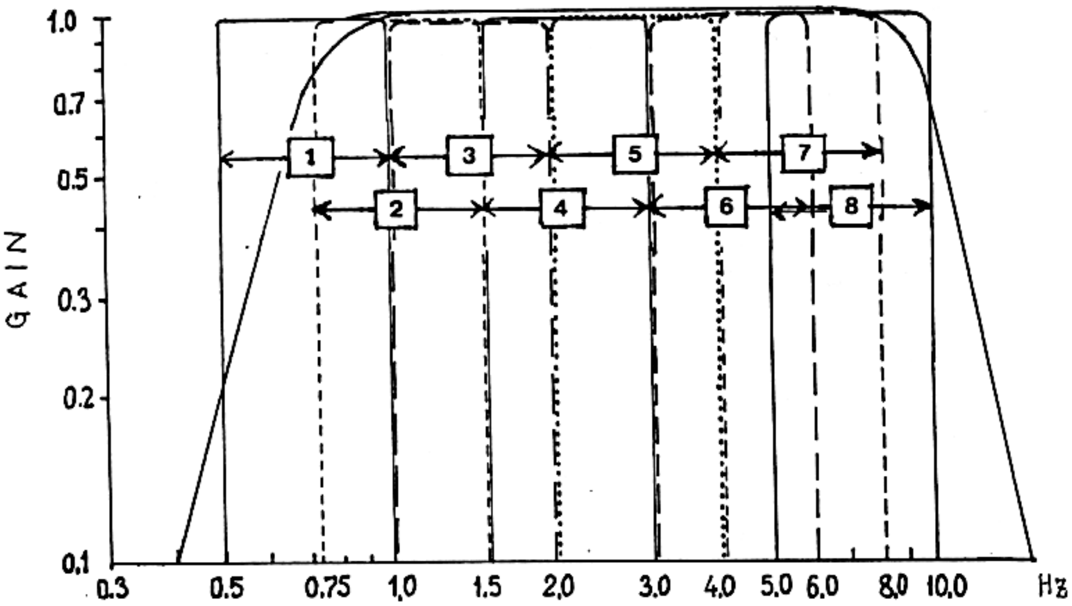


GAIN
1.0
0.7
0.5
0.3
0.2
0.1
0.3
0.5
0.75
1,0
1.5
2,0
3.0
4.0
5.0
6.0
8,0
10,0
Hz
1
2
3
4
5
6
7
8

Figure 1:

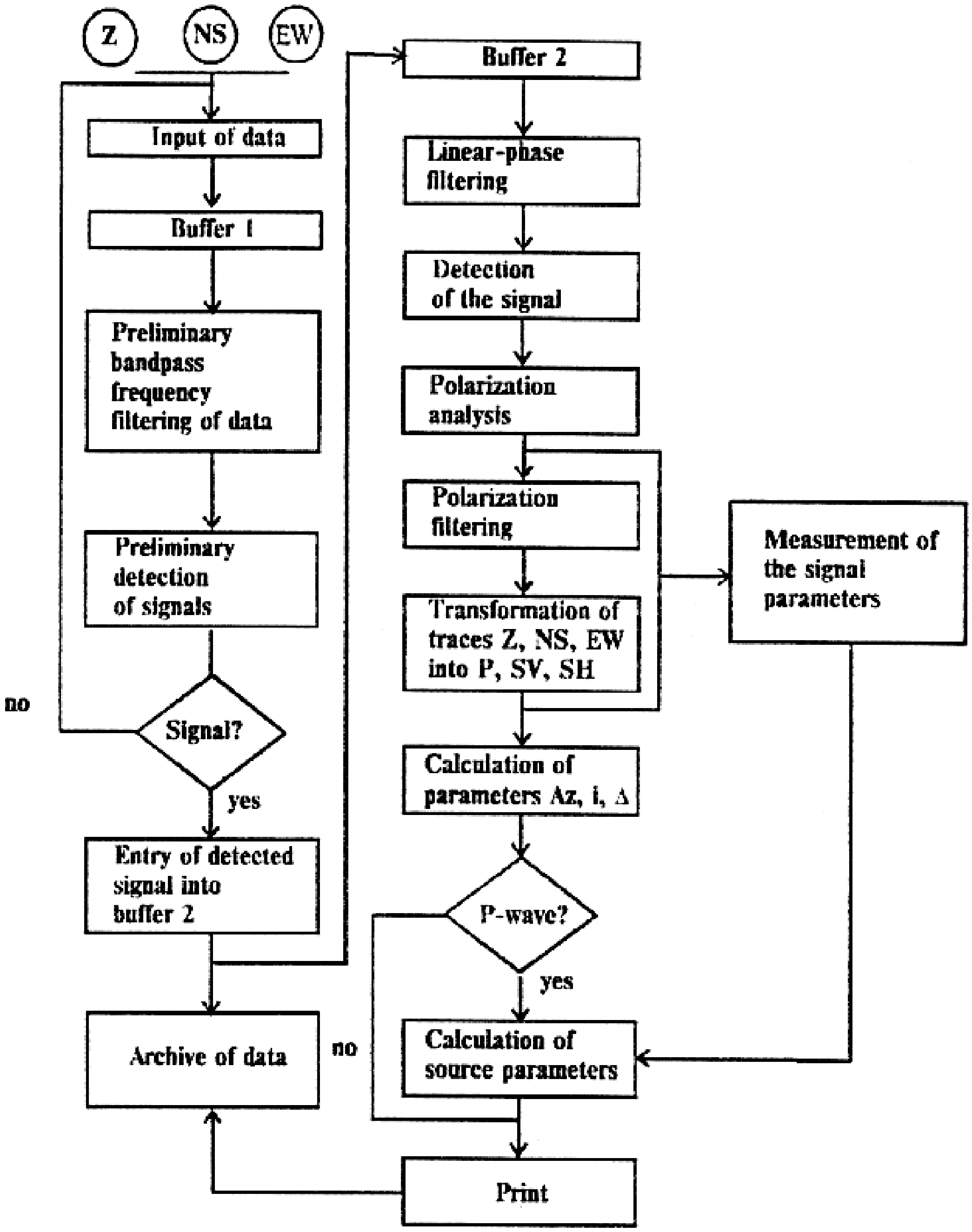
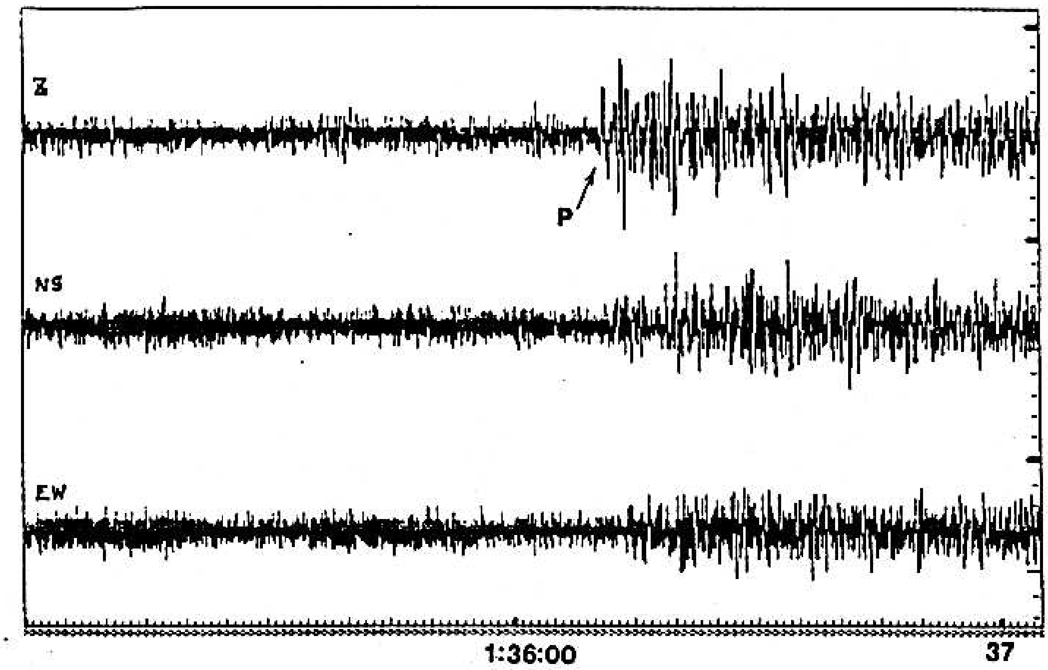
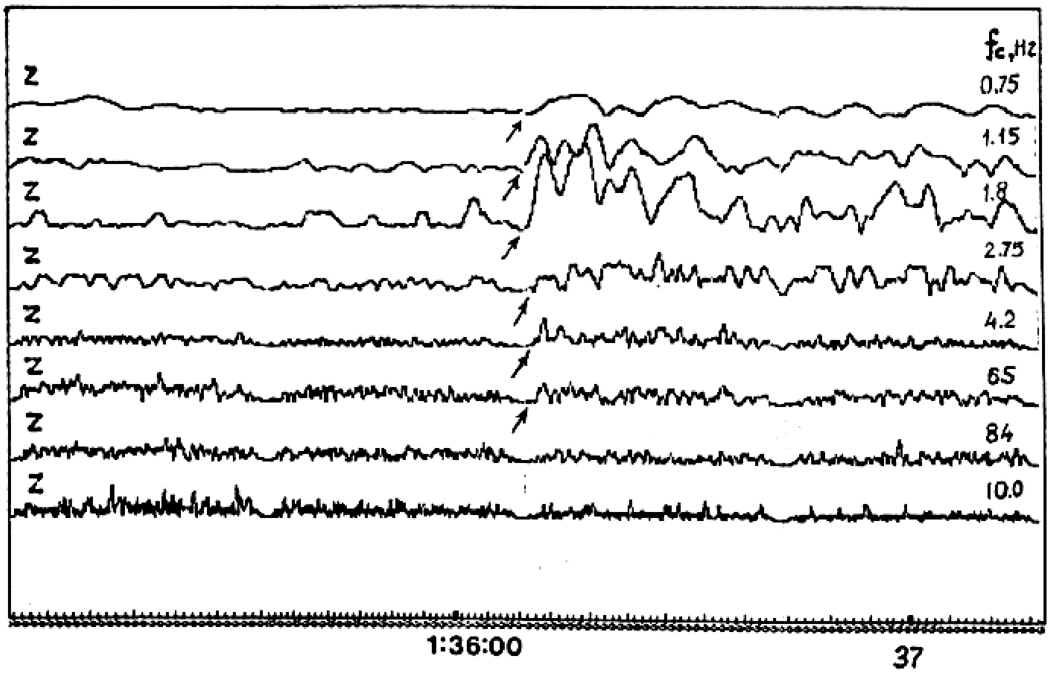

Z
NS
EW
Input of data
Buffer 1
Preliminary bandpass frequency filtering of data
Preliminary detection of signals
no
Signal?
yes
Entry of detected signal into buffer 2
Archive of data
Buffer 2
Linear-phase filtering
Detection of the signal
Polarization analysis
Polarization filtering
Transformation of traces Z, NS, EW into P, SV, SH
Calculation of parameters Az, i, Δ
P-wave?
yes
no
Calculation of source parameters
Print
Measurement of the signal parameters

Figure 2:

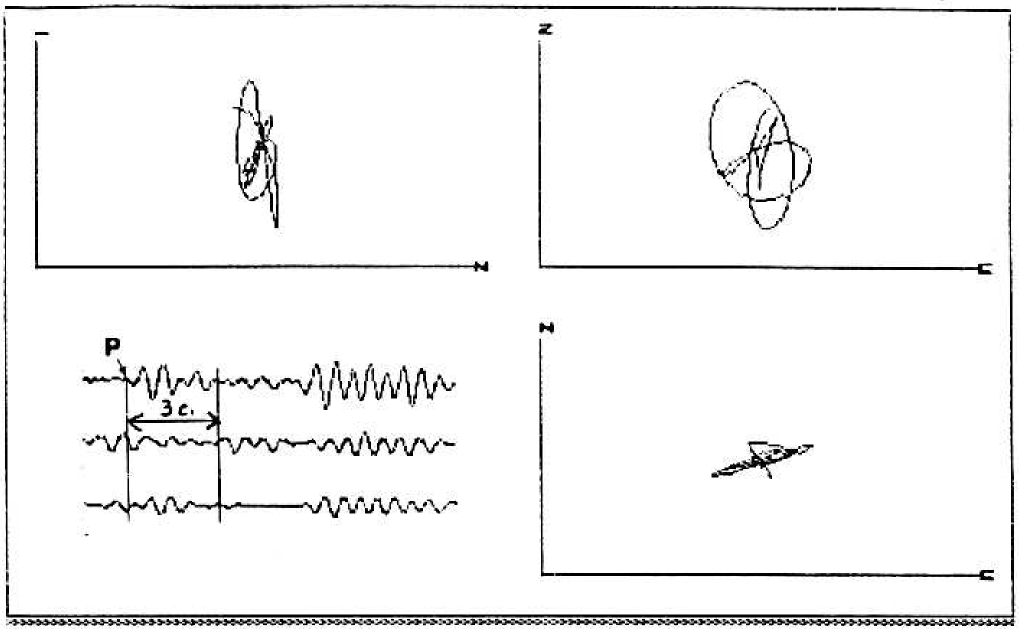


(a)



(b)

Figure 3:



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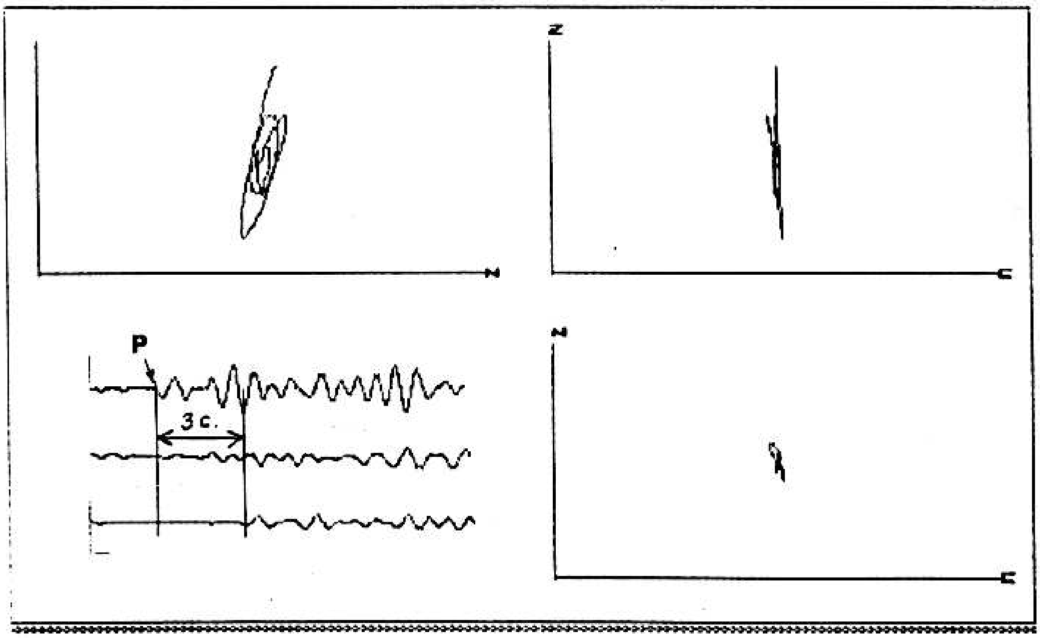
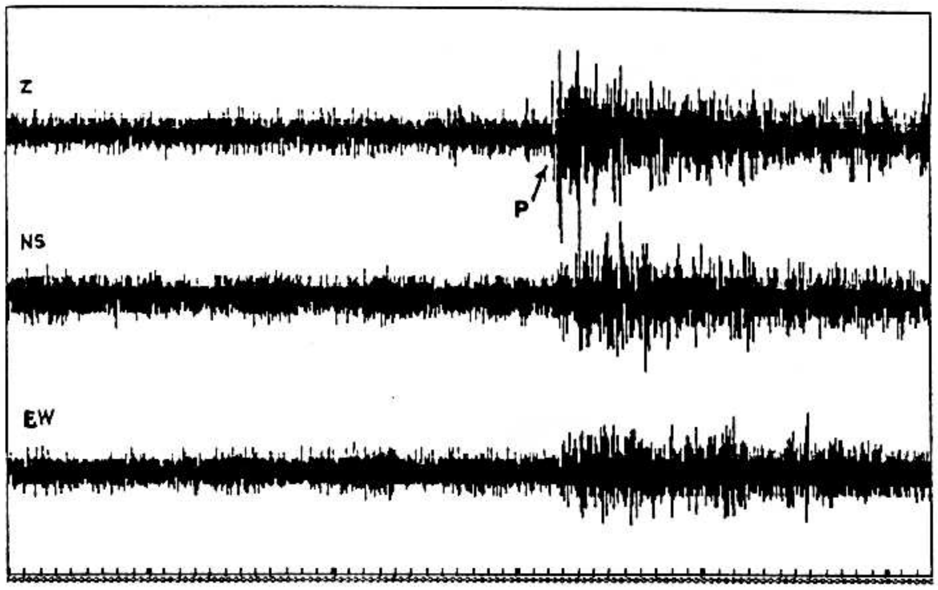
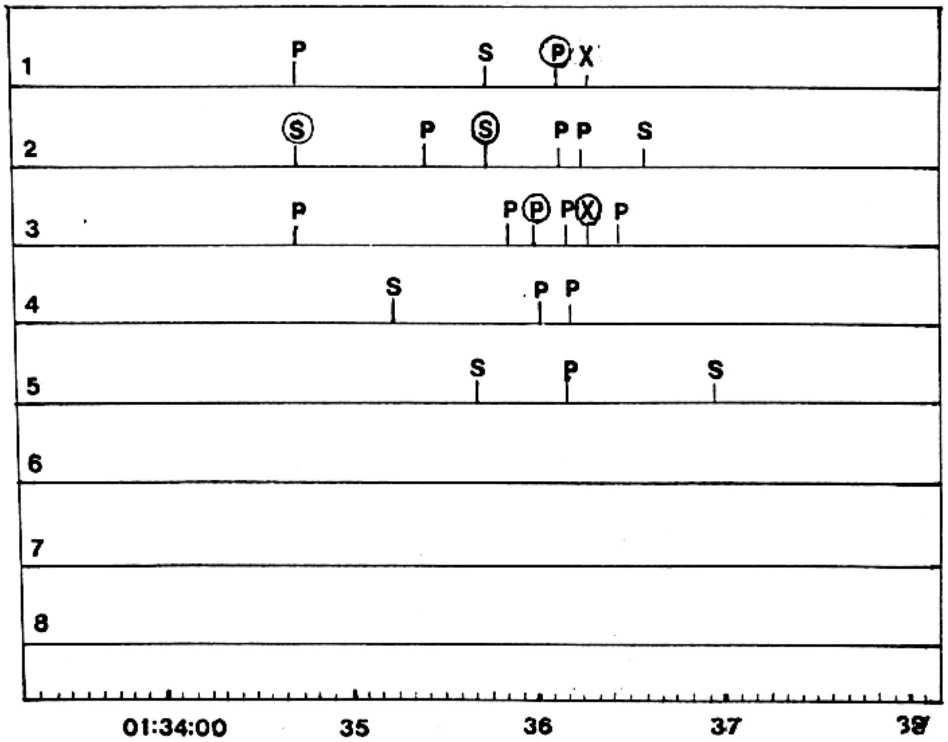


(b)

Figure 4:

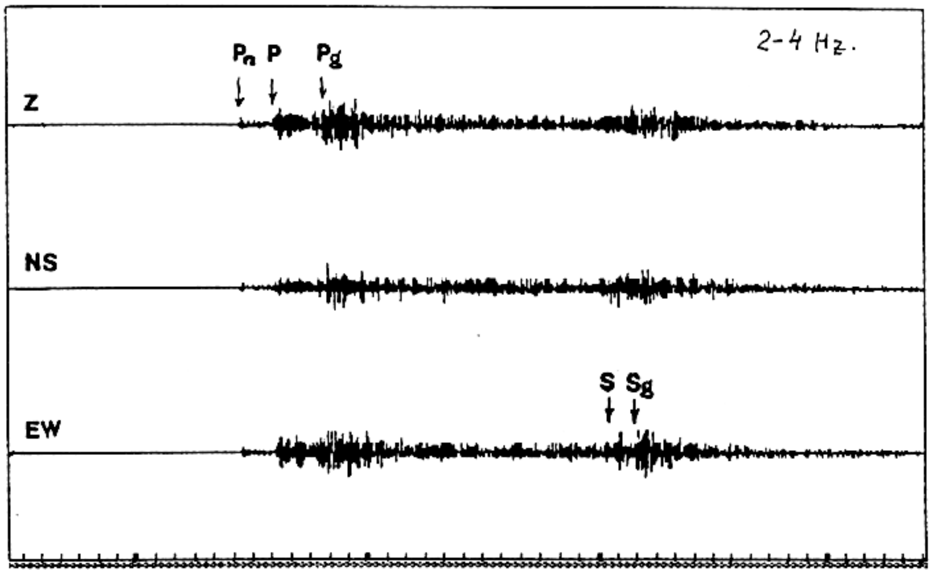


(a)

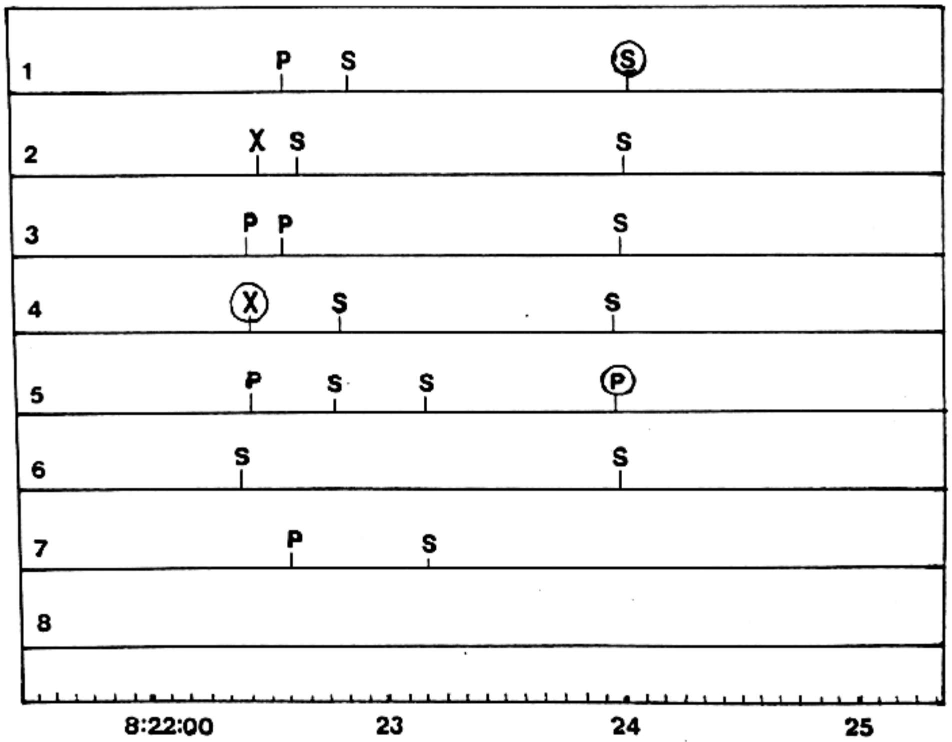


(b)

Figure 5:


2-4 Hz.
Pn P Pg
Z
NS
S Sg
EW

(a)


1 P S S
2 X S S
3 P P S
4 X S S
5 P S S P
6 S S
7 P S
8
8:22:00
23
24
25

(b)

Figure 6:

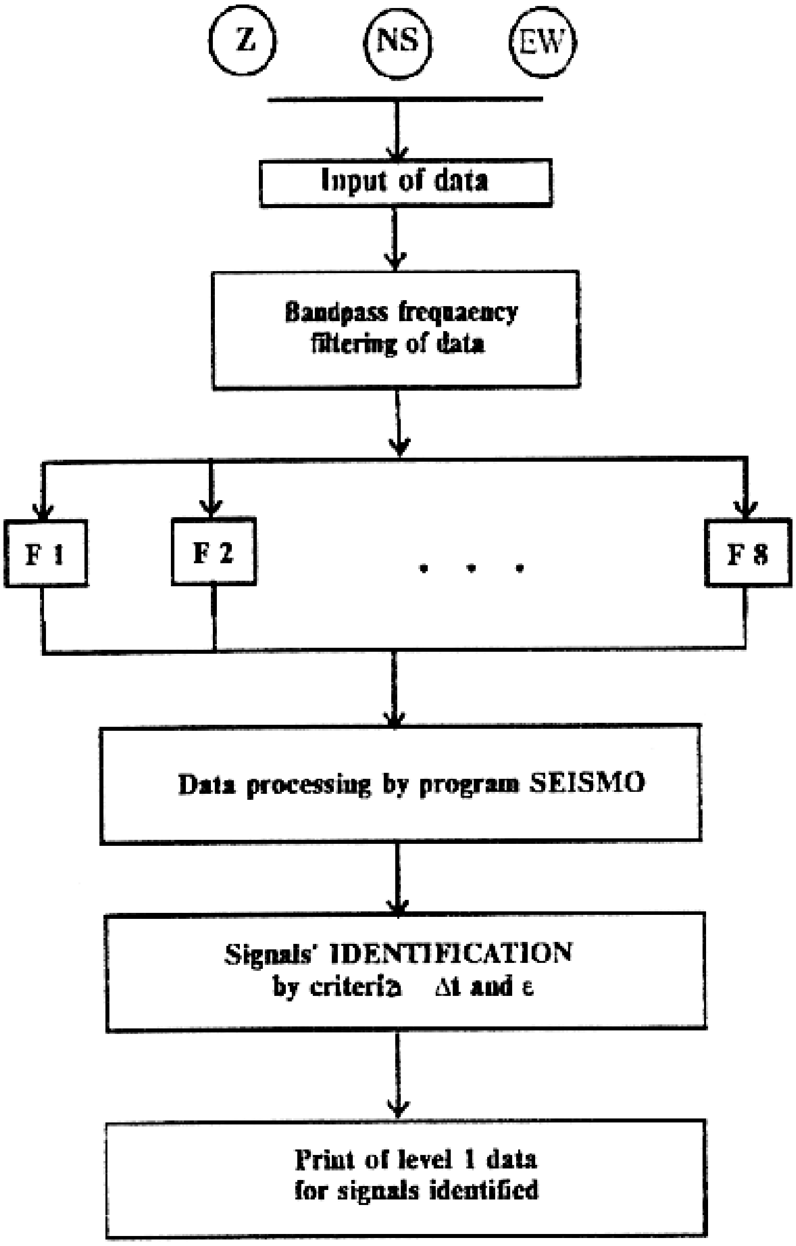
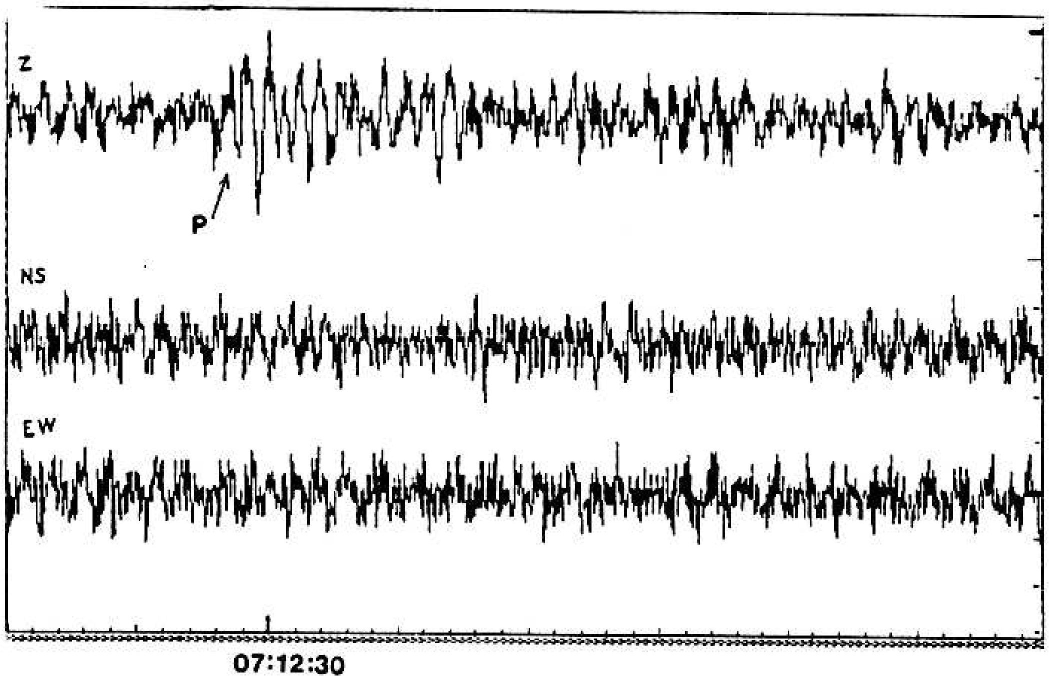
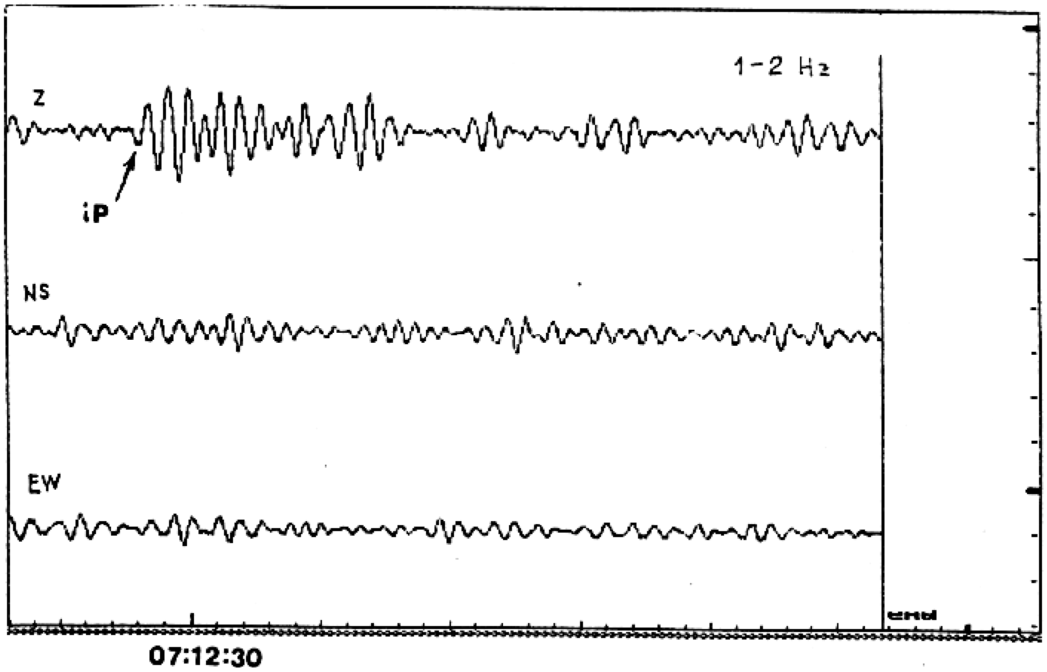

Z
NS
EW
Input of data
Bandpass frequaency filtering of data
F 1
F 2
. . .
F 8
Data processing by program SEISMO
Signals' IDENTIFICATION by criteria Δt and ε
Print of level 1 data for signals identified

Figure 7:

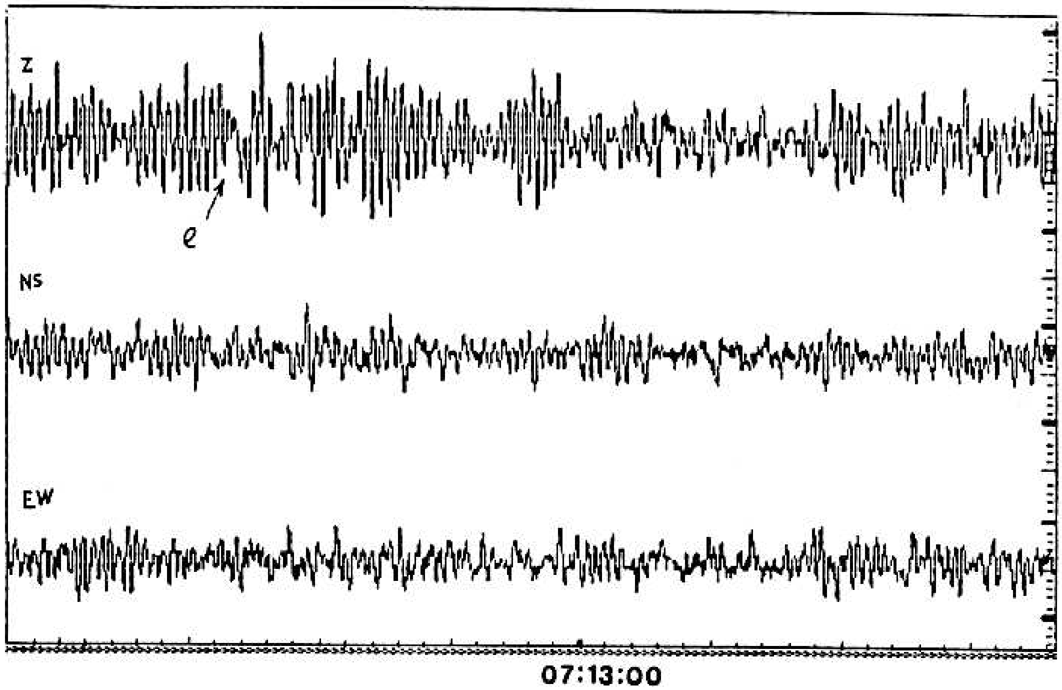


(a)

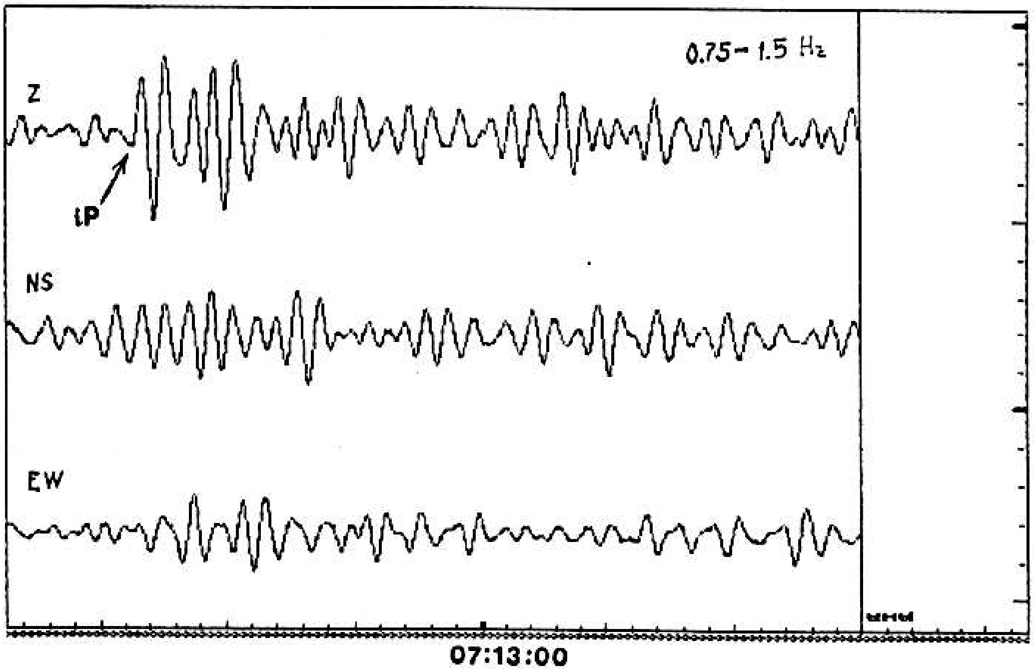


(b)

Figure 8:



(a)



(b)

Figure 9: