THE BELGIAN PC-BASED SEISMIC NETWORK

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A B S T R A C T

A new data acquisition system based on PC-technology has been developed at the Royal Observatory of Belgium. It improves effectively the performance of the previously designed system. The resolution and dynamic range has been extended to 18 bits, each channel has its own analog to digital converter ensuring a strictly synchronous sampling rate; a hard-ware digital decimation filter reduces anti-aliasing circuit complexity. The PC flexibility allows many combinations: stand-alone stations with continuous storage, or with diverse detection algorithms, with or with out gain-ranging, with data storage on a hard-disk and/or tape-streamer (120 Mbytes), or video-tape cartdridge (2 Gbytes), or also on magnetooptical CD (1/2 Gbytes). The adding of a modern extends the possibilities still further: telemetry on switchel lines, without interruption of the acquisition, with hierarchical access to the DOS on the remote side, depending on the user password (privilege); or telemetry on point-to-point leased lines: up to 4 stand-alone stations can be connected in real time to a central PC. The collecting computer handles the communications and detects the events by coincidence on a time window. At the present time, more than 15 PC-seismic stations are running in Belgium. They have proved their reliability and will replace most of the older stations of the network in a near future. The low cost of this installation type, the easy realization and the high flexibility make it the solution for data recordings and exchange.

ΤΟ ΣΕΙΣΜΟΛΟΓΙΚΟ ΔΙΚΤΥΟ ΤΟΥ ΒΕΛΓΙΟΥ ΒΑΣΙΣΜΕΝΟ ΣΕ PC

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Π Ε Ρ Ι Λ Η Ψ Η

Ενα νέο σύστημα καταχώρησης δεδομένων, που βασίζεται σε τεχνολογία P.C. έχει αναπτυχθεί στο Βαοιλικό Αστεροσκοπείο του Βελγίου. Βελτιώνει ικανοποιητικά τις επιδόσεις του προηγούμενου συστήματος. Η ακρίβεια και το δυναμικό του εύρος έχει επεκταθεί στα 18 bits, κάθε κανάλι έχει το δικό του αναλογικό προς ψηφιακό μετατροπέα, υποσχόμενο ένα (αυστηρά) σύγχρονο ρυθμό δειγματοληψίας, ένα ψηφιακό φίλτρο αποκοπής στο Hardware μειώνει την πολυπλοκότητα του αντιπαρασιτικού φίλτρου. Η ευελιξία του PC επιτρέπει πολλούς συνδυασμούς: Μεμονωμένη ύπαρξη σταθμών με συνεχή αποθήκευση ή με διαφορετικούς αλγόριθμους ανίχνευσης, με

ή χωρίς μεγεθύνσεις, με αποθήκευση των δεδομένων σ' ένα σκληρό δίσκο των 120 Mbytes, ή σε κασέττες video ταινίας (2 Gbytes) ή επίσης σε μαγνητοοπτικό C.D. (1/2 Gbytes). Η προσθήκη Modem επιτρέπει ακόμη: τηλεμετρία σε συνδεδεμένες γραμμές, χωρίς διακοπή της εγγραφής, με ιεράρχηση προς το DOS του απομακρυσμένου σταθμού, ανάλογα με τη προτεραιότητα που δίνει ο χρήστης. Επιτρέπει επίσης τηλεμετρία μεταξύ δύο σημείων μισθωμένων γραμμών: μέχρι 4 μεμονωμένοι σταθμοί μπορούν να συνδεθούν σε πραγματικό χρόνο με το κεντρικό PC. Ο κεντρικός υπολογιστής χειρίζεται τις επικοινωνίες και ανιχνεύει τους σεισμούς που καταγράφονται ταυτόχρονα σ' ένα παράθυρο χρόνου. Στην παρούσα φάση, περισσότεροι από 15 PC-σεισμολογικοί σταθμοί λειτουργούν στο Βέλγιο. Εχουν αποδείξει την αξιοπιστία τους και θα αντικαταστήσουν τους περισσότερους από τους παλαιούς σταθμούς του δικτύου στο προσεχές μέλλον. Το χαμηλό κόστος αυτού του τύπου της εγκατάστασης, η εύκολη υλοποίησή της και η υψηλή ευελιξία λειτουργίας το καθιστούν λύση για την εγγραφή και ανταλλαγή δεδομένων.

INTRODUCTION

The particular seismicity and geological structure of Belgium (Fig.1.) requires various strategies for data acquisition systems:

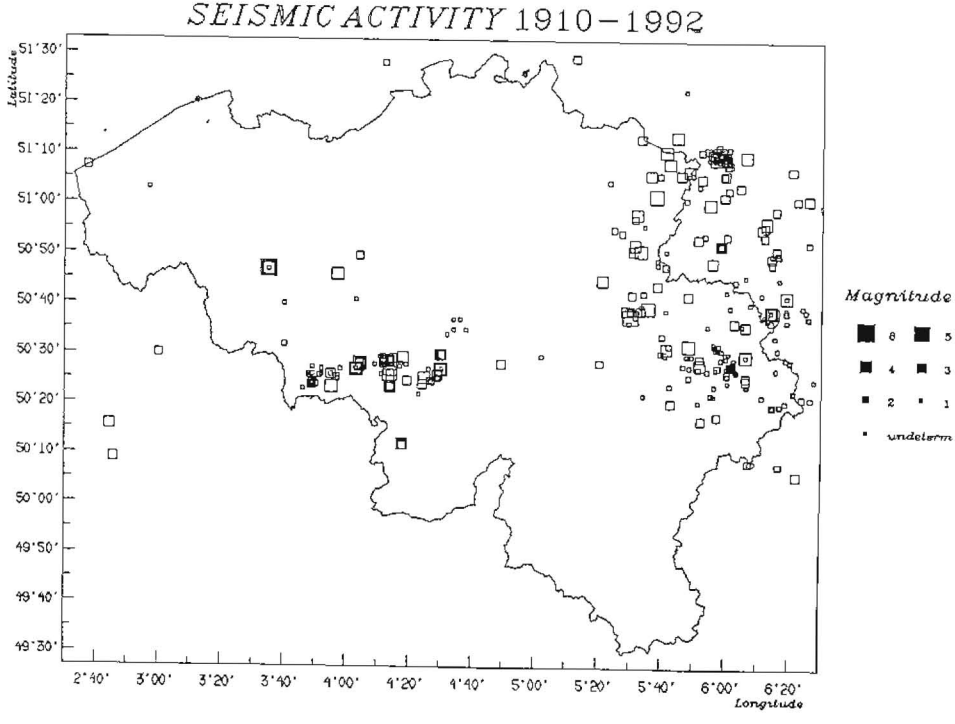

Fig.1. Seismic activity in Belgium.

Earthquake-prone areas, where shallow swarm activities occur with precursors (German and French border): High density subnetworks are necessary to detect and locate precisely the sources, in order to follow the swarms evolutions since their beginning. Due to the high quantity of data to sort, it is necessary to work with a triggering algorithm. These stations can be stand-alone. In this case a tape-streamer or a magneto-optical disk should be used to collect the data.

Areas with very long periodicity activity but with significant earthquakes (Brabant Massif): Here the density of the network is lesser critical, but stations must exists, and their data should be immediately accessible (modems) in case of major earthquake, with a view to help the authorities (Civel Protection).

Zones where the human activity and the seismic risk coexist (liege, Charleroi): It is necessary to multiply the stations to decrease the number of false alarms or hidden events. The stations must be linked to a central substation that manages the redundant signals. It should be preferable that the central substation could be immediately accessible to any user.

Areas with a high level of microseismic noise (North Sea Coast, Flanders, Limbourg): As detection algorithms are unefficient here, the seismic signal should be recorded continuously with a high capacity mass-starage device (Video tape recorder). Due to the bad quality of data in this zones, they are normally disregarded, exepted in case of significant earthquakes.

SPECIFICATIONS

A digital aquisition system necessarily consists of a microprocessor, memories and a mass-storage device. It is all what is found inside a low cost Personal Computer. If an acquisition board and some software is added around, we have enough to build a versatile seismic data acquisition system.

So we have started our experience with the most simple case: a one-channel acquisition on a PC-XT with a common detection algorithm, keeping in mind the above-mentioned requirements. Step by step the possiblities of the system where extended, to reach (without being a final point) the following specifications.

PRINCIPLES OF THE SYSTEM

Handware

The present success of compact-disks has allowed to decrease the price-efficiency ratio of analog-to-digital so that now it is possible to imagine a system where each channel is supplied with its own converter. Moreover, the factories have developed hardware anti-aliasing filters. It must be mentioned that all those components are designed in CMOS technology, allowing very low power dissipation.

We have choosen A/D converters (dual in line) giving 18 bits of resolution/channel, with a serial output so that the converter can be exiled near the seismometers if necessary.

HARDWARE SPECIFICATIONS		
Resolution & dynamic	:	18 bits
Max. number of channels	:	4
Fundamental Sampl. rate	:	any rate $\leq$ 16 kHz, internal, programmable
Power supply	:	No external needed (PC bus provided)
Time service	:	External clock (DCF, GPS or other)
Instr. amplifier	:	outside board, PC bus powered
Digital A.A filters	:	on board, 8 times oversampling decimatiou
COMPUTER REQUIREMENTS		
Computer	:	8086-8088 processor family, XT or AT
Memory	:	512 K or lesser following the applications
Graphic screen	:	Hercules or VGA monochrome
Mass storage device	:	20 to 40 Mbytes hard disk
Options	:	60 to 120 Mbytes tape streamer
		2 Gbytes video tape recorder
		300 to 600 Mbytes magneto-optical disk, or others
		Modem for remote control and data exchange
		X.25 card for packet switching network
SOFTWARE		
Operating system	:	DOS 3.0 or higher
Acquisition	:	Interrupt routine controlled by the sampling rate
		- Gain ranging if needed
		- Data buffer $\rightarrow$ no data loss
		- Each sample has a bit devoted to a time code
Trigger	:	STA/LTA based, band-pass filters
	:	Coincidence sum on time window
	:	All this parameters are user selectable (menu)
Communications	:	Real time pt-to-pt link (1 pair of wires):
		- 4800 Baud
		- 2 data bytes +1 control byte / sample
		- Up to 4 stations can be connected
		- coincidence sum, time window, and weights
	:	On switched lines :
		- **Acquisition is running during communication**
		- Hayes protocol compatibility
		- 1200/2400/4800 Baud (modem dependant)
		- Fast transfer protocol with checksum
		- DOS emulation on remote side
		- Read/write/exec/del privilege (username)
		- Remote files visualization during communication

A decimation filter permits to use an 8 times oversampling technic, reducing the difficulties met with high order analog anti-aliasing filters. This filter has a finite impulse response (FIR) circuit using a high number of coefficients. The data sheets guarantee causality and anti-aliasing protection on all the dynamic range if the input signal respects the Shannon-Nyquist theorem on th eoversampled data.

The output of the FIR is written on a 20 bits serial word, so that we have the advantage to reduce (theoreticaly) the quantization noise.

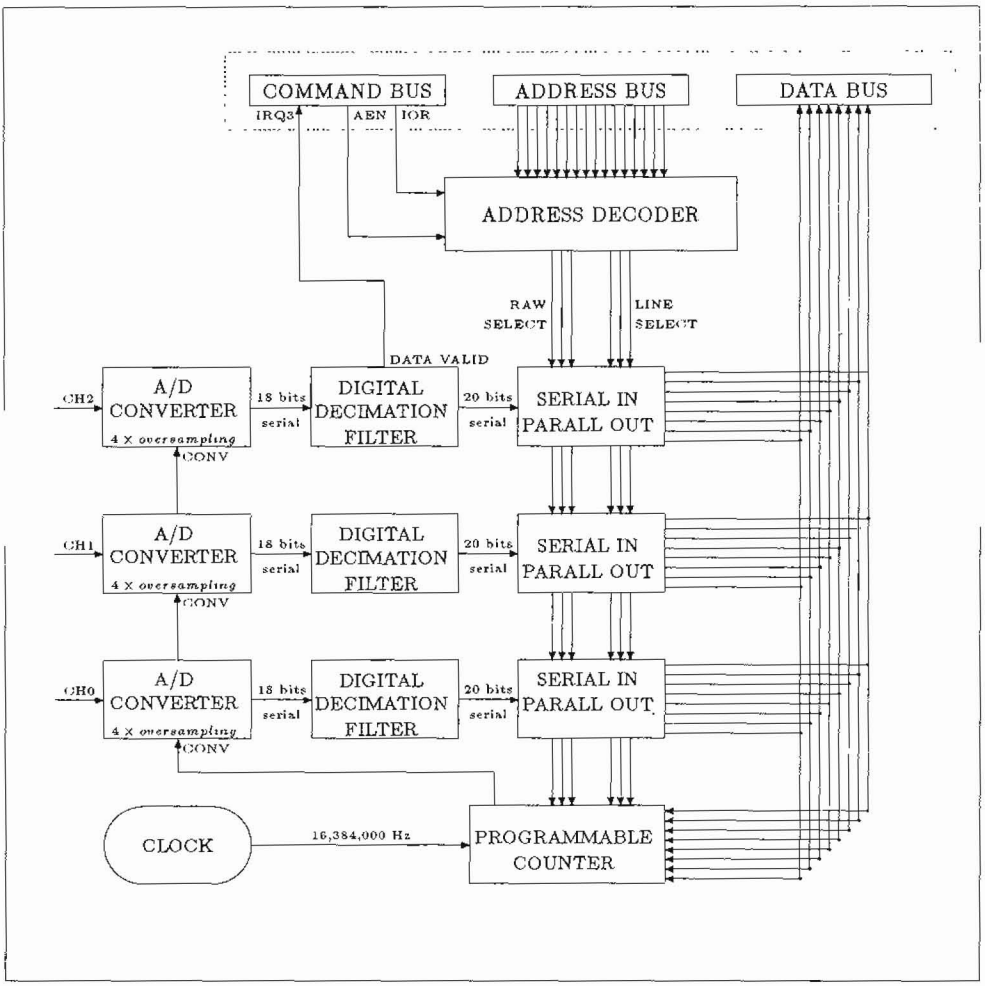

Fig.2. The new acquisition board diagram.

This 20-bits serial flow goes inside three serial-in/parallel-out circuits which are read during the interruption procedure.

The convert command, derivated from the system clock frequency via a programmable divider, is given to all the converters at the same moment, so that all the channels are synchronized.

When the convertions are performed, the converter issues a signal (Interrupt Request) to inform the processor of a valid data presence.

Software

When the processor receives the request from the converter, it freezes its current activity and jumps inside an interrupt routine where the sample is read and treated by an anti-aliasing filter in order to reach the final sampling rate (user selectable). Then the analog channel address is incremented. When all this is done, the processor returns to its preceeding activity, or waits for the next sample if there is nothing else to do.

A fast event detection algorithm is applied to each sample at the output of the channels. It consists of:

1. A high-pass and a low pass-filter, needed to select a current working band-width.
2. A short term (STA) and a long term (LTA) averages obtained by computing the mean value of the refined signal on different shifting time windows.
3. An alarm flag is set if the STA/LTA ratio becomes greater than a user-prscribed value.
4. If the alarm flag is set, the data are stored on the hard-disk with a pre- and a post-event time length or sent to an ethernet link.

The cut-off frequencies, the integration intervals and the trigger level are accessible to the user via a menu window. If needed, a continuous storage regime may be switched on.

During the operating time, each sample is displayed on the screen along 3 traces. The plotted signal can be the pure input, or any step of the detection algorithm. The screen parameters like the traces speed, the fullscale, the offiset of each channel are menu-driven.

The data file structure is based on the principle of channels separation. Data in each file consists of blocks of 2048 bytes. A 48 bytes header contains the necessary information about date and time of record, the station code, the sampling rate and the type of channel/seismometer. The following 200 bytes contain 500 samples of 4 bytes each (long word) or 100 (2000) incremental data of 2(1) bytes if it is possible. A flag in the header indicates the structure of each block.

Communications

On point-to-point lines

Up to 4 stand-alone stations can be connected in real time to a central PC with 4800 Bauds asynchronous modems. The collecting computer handles the communications and detects the events by coincidence on a time window. The triggered files are sent on the X-25 packet-switching network, so that they can be immediately processed by the main frame (μVAX) in Brussels.

On swiched lines

A moderm card or an external modem can be added to the system. In this case, it is possible to call the remote size and to exchange files.

A communication interrupt routine based on the interruption generated by a change on the signals CTS, RTS, RING, DCD (available on the pins of the modem connector) is added to the general program for stand-alone stations.

A fast transfer protocol with data compression reduces the transfer time. Binary files are sent with a checksum protocol.

The data acquisition runs continuously during the communication and transfers. The calling station may visualize directly the sent files.

A restricted DOS-gateway is provided on the remote side. The trigger parameters can be modified by the calling station. Following the username privileges, it is possible to read, write, execute or delete on the remote side, to modify the program, or to send a new batch file.

The reader can find more details in Snissaert (1989).

The figure 2 summarizes the general architecture of the PC-based network of the ROB.

An example of records of an aftershock of the Roermond earthquake (April 13, 1992, M_L=3.4) is shown at figure 3.

OTHER APPLICATIONS

This type of PC-based station was the departure of a common project between the European Centre for Geodynamics and Seismology (ECGS), the Royal Observatory of Belgium and the International Institute of Earthquake Prediction Theory and Mathematical Geophysics (IIEP). The main objective is the improvement of the knowledge on the deep structure of intracontinental areas by the study of the teleseismic surface waves polarization and dispersion. For this purpose it has been decided to install a profile of stations along a great circle crossing all Europe from Great-Britain to Caucasus. This profile has been choosen because it points to areas where major earthquakes may occur: New Zealand, Indonesia, Iran and Afganistan at the East or Central America at the West (Levshin et al., 1991). This profile crosses accessorily also high seismicity areas of Romania, Georgia and Armenia.

Four stations of this type have already been installed in Belgium (Membach-ROB), Great-Britain (Hartland-British Geological Survey), in Germany (Moxa-Universitat Jena) and Ukraine (Uzhgorod). Contacts have been established in Crimea (Simplheropol-Ac.Sciences of Ukraine), the Czech Republic (University of Brno), and the state of Georgia (Institute of Geophysics).

The broad-band signal is decimated again at 1 Hz and saved continuously after compression (Long period files).

This procedure is repeated at 0.1 Hz and 0.01 Hz to produce very long periods and tidal files. Figure 4 shows a recording of an aftershock of the Roermond earthquake obtained with this system.

A gain ranging technic is used to increase the dynamic of the system: 2 channels are devoted to each seismometer; when an overflow is detected on the highest sensitive channel, the lowest sensitive is taken into account and pushed on the data stream after multiplication. This way permits to extend the dynamic range to 120 dB.

The data are oversampled at 125 Hz and decimated at 25 Hz after an anti-aliasing finite impulse response filter. This branch gives the pure broadband signal. If an event is detected, the data are stored on the hard disk with a pre- and a post-event time.

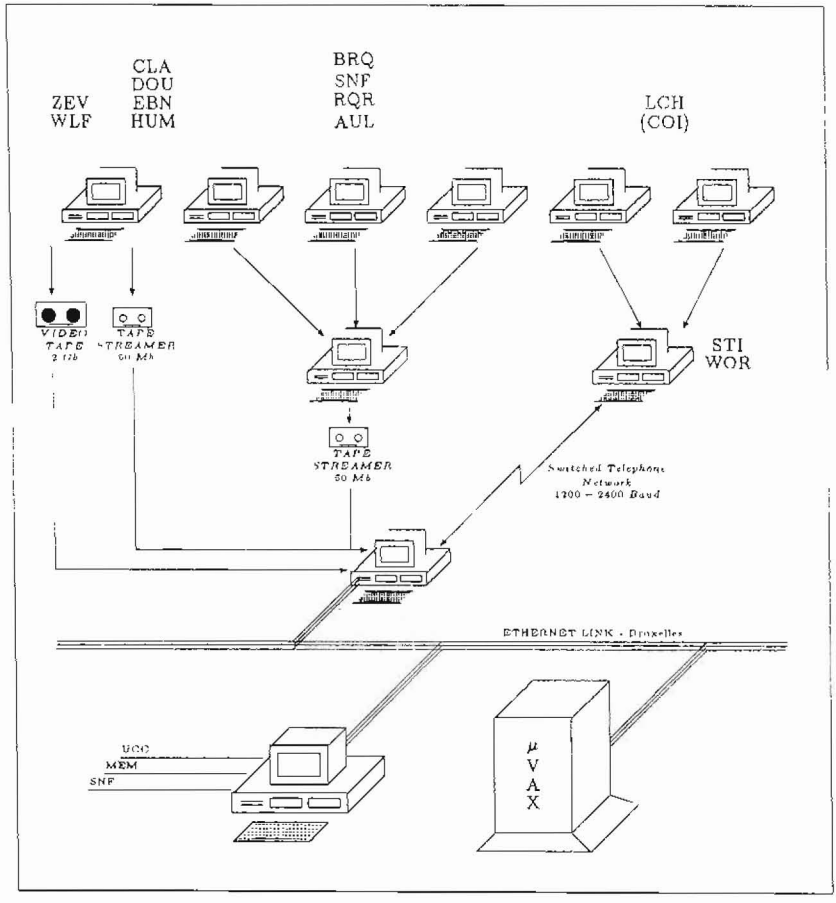

Fig.3. General architecture of the PC-based network of the Royal Observatory of Belgium.

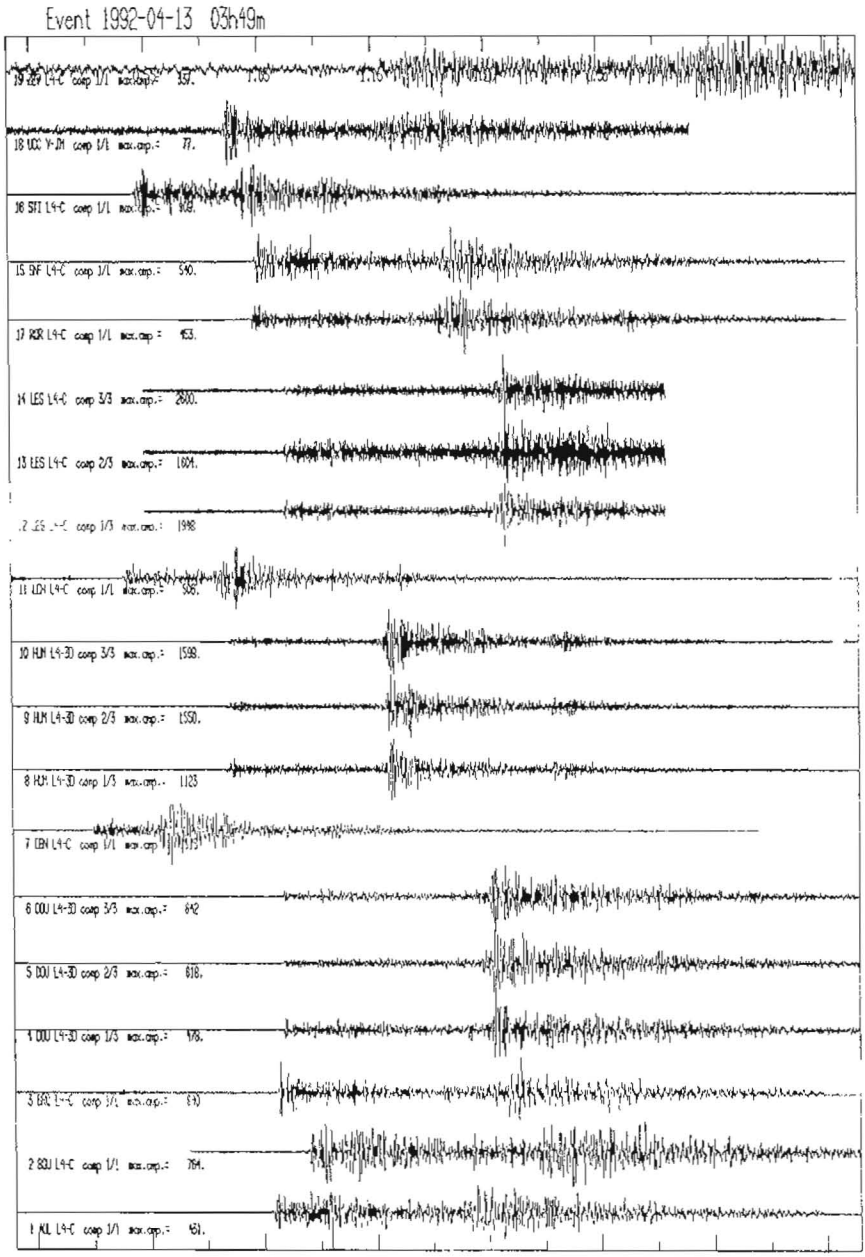

Fig.4. Records of the event 1992-04-13.

LIMITATIONS AND RELIABILITY OF THE SYSTEM-SOLUTIONS

1. The most important problem met was the time service: although this issue doesn't depend on the acquisition system, it is always distressing to have a wonderfull seismogram with no time marks or with suspicious clock indications. The DCF receiver we used worked "practically" well in Belgium. It signifiles that troubles where met coinciding with some atmospheric conditions, or inside underground stations. The ennoying thing is that the time code was missing for some beautiful records.
2. Up to now, few hard-disk failures were observed in our system. Nevertheless, some precautions can be taken to avoid problems:

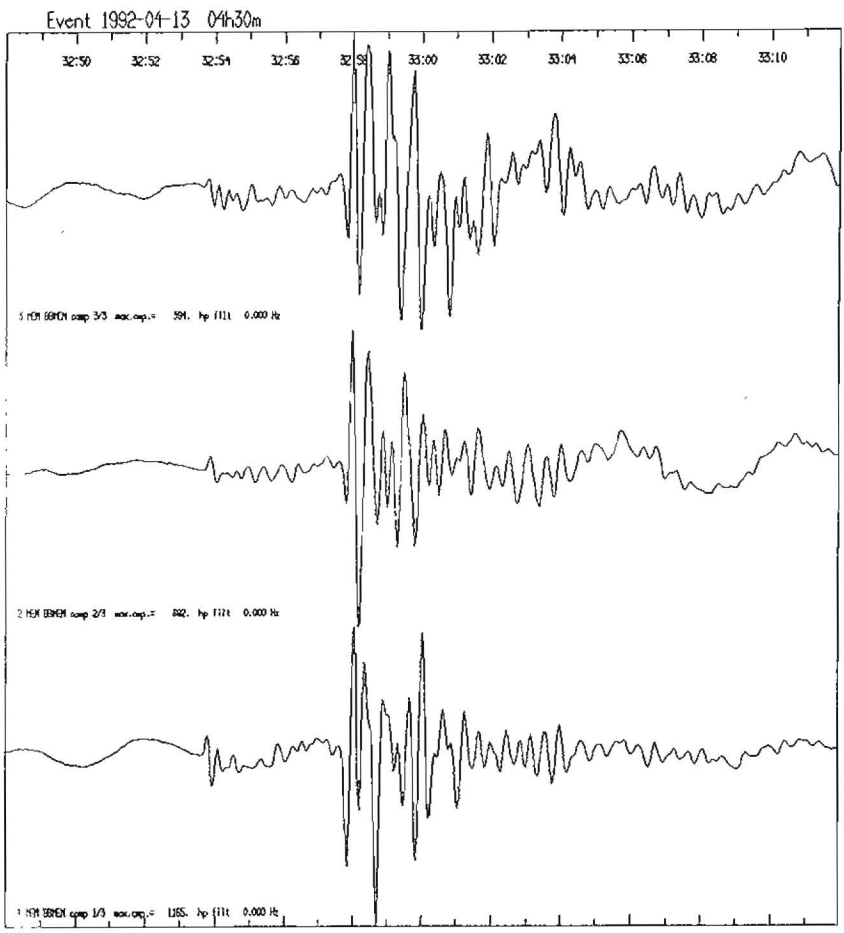

Fig.5. A record of an aftershock of the Roermond earthquake.

* handle with care and don't forget to lock the head,
* choose preferably an autopark disk,
* limit the head movements by increasing the detector efficiency,
* choose a hermetic hard-disk in dusty environment.

The two first remarks are obsolete with the present PC's.

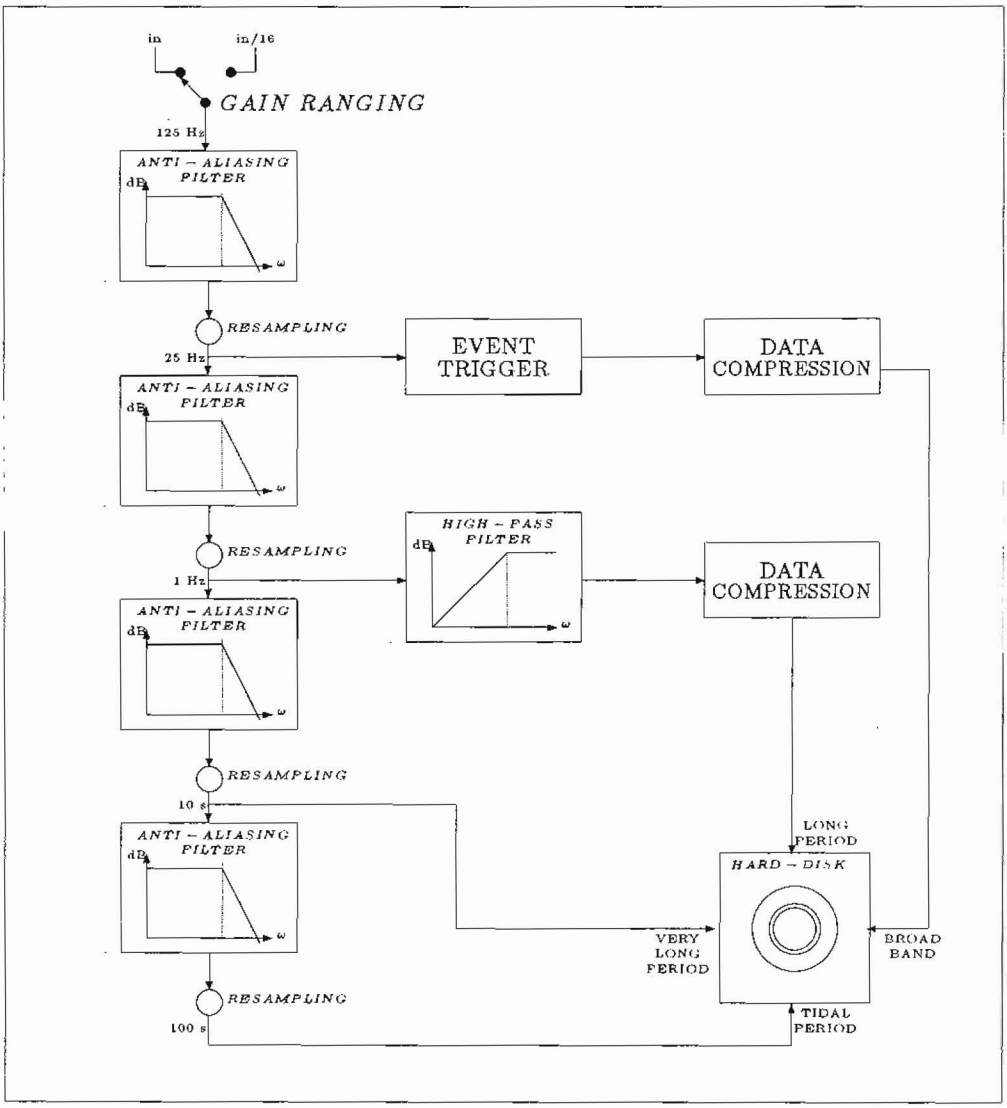

Fig.6. Flow-chart of the ISP stations.

CONCLUSION

The evolution of the market permits to produce a new card answering to all the objections met with the first model. This card will be more compact, with more dynamic and resolution, without power dissipation. The price of the components is so low that their effect on the total price of the system is marginal.

This system has been installed successfuly in 8 countries. A broad-band system is planned in Tanzania to study the seismicity of the East-African rift. Many other projects are under consideration.

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