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# AN INTELLIGENT EARTHQUAKE OBSERVATION SYSTEM REMOTE-CONTROLABLE VIA PUBLIC TELEPHONE LINE

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## SUMMARY

A compact system has been developed in order to ensure high quality observation of micro- to moderate-earthquakes, even when observation stations are quite distant from an observation center. The motive of the development of this system is to investigate the seismicity of distant area of interest without laborious efforts. The system is capable of not only monitoring but also remote-control of seismometers situated at the local stations via public telephone line. The system also has some intelligent function such as to discriminate earthquake signals from electric noise, and to detect arrival times of P- and S-phases.

## INTRODUCTION

Strong ground motion observation has been done in the field of earthquake engineering in order to study strong motion with a main focus on great damage to life and property. The present system has been developed to observe micro- to moderate-earthquakes which cannot be detected by strong earthquake observation networks. Micro-earthquakes may provide us with useful information not only seismicity of the area of interest but also local ground conditions. But practical use of data on micro-earthquakes is left to future study.

Maintenance is the most important and difficult element for any earthquake observation system especially for a system at a distance. A telemetry system has gradually become used these days. But even such a system usually costs much time and money for it's maintenance. One of the purposes to develop the present system is to reduce as much efforts as possible in earthquake observation in a distant area.

## LOCATION OF THE SYSTEM

At present, total system consists of three local observation stations and two observation centers which control the local stations. The location of the system is shown in Fig.1. The observation stations are installed at three dam sites in the Hokuriku area late November, 1985 (Ref.1). They constitute a triangle whose side length is about 30 km. Observation stations are located about 300 km distant from observation centers.

There are two observation centers, one is at the Nagatsuta campus, Tokyo

Institute of Technology, Yokohama, Japan, and the other is at an office of Power Development Co. Ltd., Chigasaki. The center at Chigasaki was added to the system late November, 1986.

## STRUCTURE AND CHARACTERISTICS OF THE SYSTEM

**Hardware** At present, total system consists of three local observation stations and two observation centers which control the local stations. The structure and specification of the system are shown in Fig.2 and Table 1 respectively. A hard disk of the micro-computer at a local station is used to store not only control programs but also earthquake data. The hard disk can store about 200 sets of earthquake data. The earthquake data in the hard disk are usually copied onto a disket by manual operation to be sent to an observation station. But, when necessary, they also can be sent to an observation center directly via public telephone line by a request from the center. An example of an earthquake data indicated on CRT of an observation center is shown in Fig.3.

The whole system of a local station except a sensor unit and a pre-amplifier is compactly built in a 60x180x70 cm rack. To protect the system against lightning and power cut, the system is equipped with a isolation transformer and a backup power supply. An observation center system consists of only a set of a micro-computer and a telephone unit. Public telephone line is used for communication between a station and a center. The telephone unit functions as a modem and a network control unit.

**Software** An observation center has two major functions. One is data communication, and the other is data management. Data communication is divided into two types. One is ordinary communication from each local station to a center once a day, and the other is occasional communication which can be sent anytime from a center to each station. They are shown in Table 2.

The occasional communication includes seven major items of request. These items are selected in order not only to control functions of remote stations but also to detect any trouble in the remote systems. When a seismograph is needed to be sent immediately to a center, it can be done by requesting to " Send a set of seismograph ". But this request will take rather long communication time, say 400 seconds to receive a set of seismographs, because of the 1200 bps transmission rate of telephone line. The data management function includes usual processing of observed data as well as indication of the present status of each local station such as remaining capacity of the hard disks and trigger levels of the seismometers as shown in Fig.4. and Fig.5. respectively.

Each local observation station has three major functions, that is; earthquake observation, communication, and control of seismometers as shown in Fig.6. Among these, the first priority is naturally placed on earthquake observation. Thus, when earthquake occurs during the time under communication, the system will interrupt communication for a while. Only a short time interval is permitted for the communication routine, otherwise a local station cannot engage itself in earthquake observation. If the data communication needs a longer time interval, it is divided into some segments and executed little by little. In addition, to avoid any trouble caused by a wrong call and a malfunction of telephone, the system will hang up in case it does not receive appropriate passwords.

## INTELLIGENT FUNCTION

**Signal Discrimination** In some cases, electric noise produced by an induced current is likely to appear in signals from sensors. An example of such a electric noise is shown in Fig.7. If the noise often appears, noise reduction is indispensable. For this purpose, the following function to discriminate earthquake signals from indicated electric noises is provided for the local systems.

On detecting signals exceeding a trigger level, a station micro-computer tries to discriminate earthquake signals from electric noise. This is effectively done by calculating cross correlation between each component of the signal, because the electric noise always shows higher correlation. To save calcuration time, cross correlation between N-S and U-D components is only used for discrimination in the system. Examples of cross correlation are shown in Table 3.

**Arrival Time Detection** Arrival times of P- and S-phases are necessary to determine location of an earthquake focus. Amplitude of vertical component is superior to that of horizontal component at a P-phase arrival, and that is reversed at a S-phase arrival. On this basis, an amplitude ratio of horizontal and vertical components is useful for detection of arrival times of P- and S-phases. The amplitude ratio is calcurated as the following (Ref.2).

$$V/H(i\Delta t) = \sqrt{V(i\Delta t)/H(i\Delta t)}$$
$$V(i\Delta t) = X_{UD}(i\Delta t)^2+\alpha V((i-1)\Delta t)$$
$$H(i\Delta t) = X_{NS}(i\Delta t)^2+X_{EW}(i\Delta t)+\alpha H((i-1)\Delta t)$$

$X_{NS}$,$X_{EW}$ and $X_{UD}$ are velocity amplitude of NS, EW, and UD components respectively, $\Delta t$ is a time interval, and $\alpha$ is a coefficient for smoothing.

Fig.8 shows an example of the seismogram and amplitude ratio. By detecting transitional point in a curve of amplitude ratio, the micro-computer can determine arrival times of P- and S-phases.

## CONCLUSIONS

The present system has proved to be very helpful and effective in observation of micro- to moderate-earthquake. By use of many remote control functions of this system, it has become easy to assess seimicity of the area distant from an observation center. In addition, the system can automatically discreminate earthquake signals from electric noise, and detect arrival times of P- and S-phases, which reduces lavorious tasks from routine jobs.

## ACKOWLEDGMENTS

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## REFERENCES

1. Tanaka, S., "Source Parameters Determination System for Micro-Earthquakes of Distant Area," Master Dissertation, Tokyo Institute of Technology, (1986)
2. Nakamura, Y. and Saito, A., "Automatic Detection of P- and S-Onset Times and Direction of Epicenter by Data at An Observation Station," Proceeding of 17th Technical Meeting on Earthquake Engineering, 95-98, (1984)

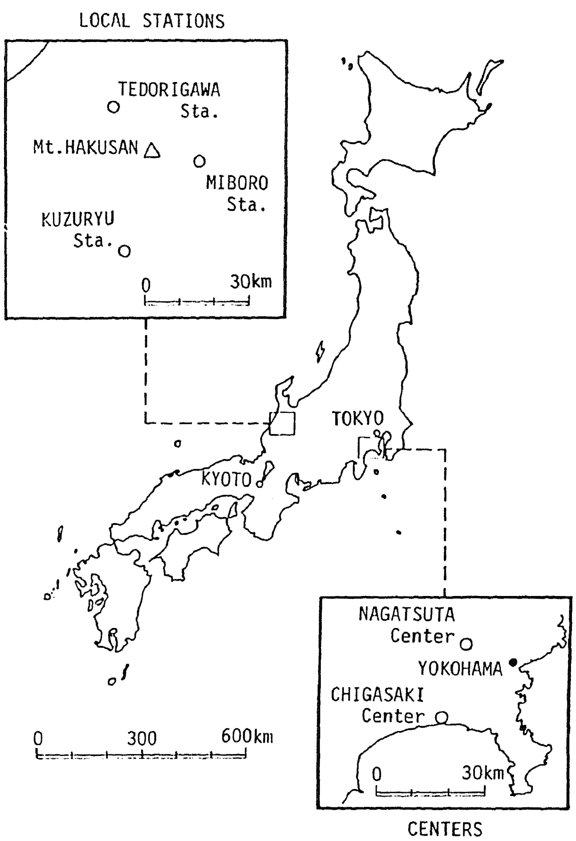


Fig.1 LOCATION OF THE SYSTEM

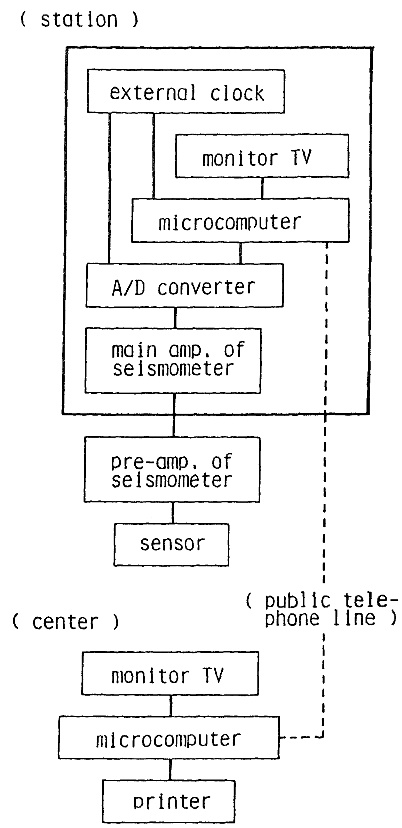


Fig.2 STRUCTURE OF THE SYSTEM

Table 1 SPECIFICATION OF THE SYSTEM

| Components | Specification |
|---|---|
| seismometer:<br>velocity meter | gain; 0.5, 2.5, 5 or 10 V/kine<br>low-pass filter; 20 Hz or 70 Hz<br>sensor; 3 pendulums with natural frequency 1 Hz buit in<br>calibrator; 10 Hz sinusoidal signal of 0.1 kine equivalent |
| microcomputer<br>(NEC PC-9801F3) | internal memory; 256 kB RAM<br>external memory; 10 MB hard disk and 5 inch MFD |
| A/D converter | resolution; 16 bits for ±5 V<br>sampling rate; 200 Hz<br>delay and auxiliary memory; 10 sec and 3x16 kB RAM |
| external clock | precision; $10^{-8}$<br>calibration; automatically done by radio time signal |
| telemetering | circuit; public telephone line<br>data transfer rate; 1200 bps (half duplex) |

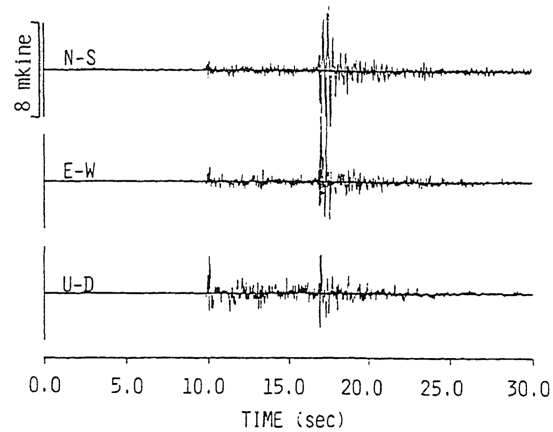


Fig.3 AN EXAMPLE OF THE EARTHQUAKE DATA

Table 2 DATA COMMUNICATION FUNCTIONS

<u>Ordinary Communication</u> ( from station to center )

Frequency: Once a day

Informations: Header files only which includes;

| | |
|---|---|
| 1. Station name. | 2. File name. |
| 3. Trigger channel. | 4. Trigger time. |
| 5. Filter frequency. | 5. Attenuation gain. |
| 7. Trigger level. | 8. Maximum amplitude. |

<u>Occasional Communication</u> ( from the center to stations )

Request items:

1. Send data files. ─ 1. Send the latest header files; 2. Send header files in sequence; 3. Send a set of seismograph.
2. Change attenuation range.
3. Change filter frequency.
4. Change trigger levels.
5. Delete data files.
6. Measure background noize.
7. Calibrate seismometers and send results.

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[ INDEX.NAM ]                      88 07/23 10:24 24.00sec
                                 ( 88 07/19 09:28 02.00sec )

STATION NO.  A        CAPACITY  9297920 byte(227files)
FILE COUNT ON DISK  3A
WAITING FILE COUNT   0   0  NEWFILE.NAM : A000406D.DAT
```

Fig.4 INDICATION OF STATION STATUS

| STATION | GAIN | FILTER Hz | COMPONENT | TRIGGER_LEVEL m.kine(about) |
|---|---|---|---|---|
| A | 1 | 30 | NS | 1.000 |
| | | | EW | 1.000 |
| | | | UD | 1.000 |

Fig.5 INDICATION OF OBSERVATION STATUS

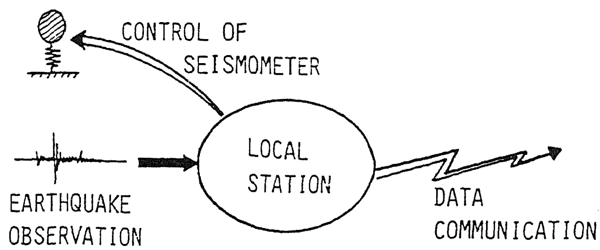


Fig.6 FUNCTIONS OF THE LOCAL STATION

Table 3 EXAMPLES OF CROSS CORRELATION

| SAMPLE NO. | CROSS CORRELATION | |
|---|---|---|
| | EARTHQUAKE | ELECTRIC NOISE |
| 1 | -0.303 | 1.000 |
| 2 | 0.698 | 0.999 |
| 3 | -0.407 | 1.000 |
| 4 | -0.513 | 1.000 |
| 5 | 0.061 | 0.998 |

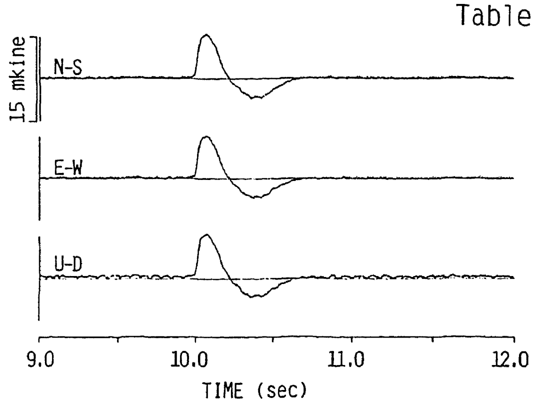


Fig.7 AN EXAMPLE OF THE ELECTRIC NOISE

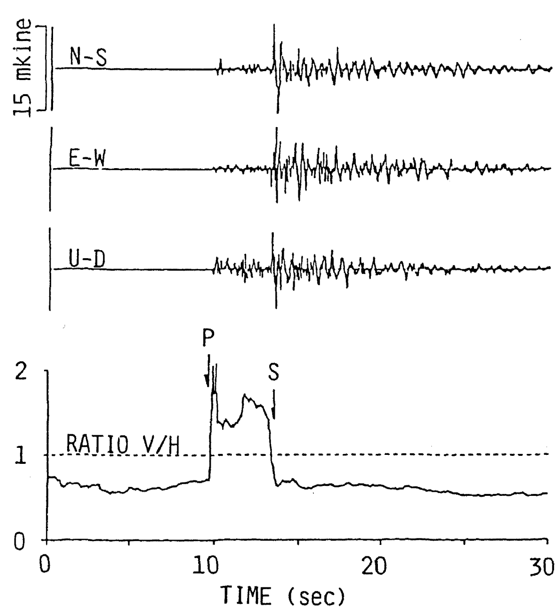


Fig.8 AN EXAMPLE OF THE SEISMOGRAM AND AMPLITUDE RATIO