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Strong-motion recording and data acquisition – A case study at ERI

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1. Quality of data, design accelerograph and telemetry

The first generation of digital accelerographs, e.g. DSA-1, DCA-333, commonly used a 12-bit A/D converter. An upgraded type with a gain-ranging amplifier, e.g. PDR-1, was also used in strong motion recording. The SMAD-1/2 used in the network of the Strong Earthquake Motion Observation Center, Earthquake Research Institute, has an intermediate dynamic range between the DSA-1 and PDR-1, while the second generation is represented by a 16-bit instrument. When planning an accelerograph array in the Ashigara Valley about five years ago, we decided to use a 16-bit A/D converter together with a gain-ranging amplifier. However, as the reliable resolution of a conventional A/D converter was 14 bits/word at that time, we were able to use the two lowest bits for gain marks (1/4, 1/16). That is, the SMAD-3 has a resolution of 14 bits (78dB) and an apparent dynamic range of 108dB. Figure 1 compares records with similar acceleration levels but different resolutions: the least significant values of acceleration are 0.5 gal(cm/s/s) for the DSA-1, 0.13 for the SMAD-1 and 0.015 for the SMAD-3.

As the quality of records has gradually improved, the analysis of weak motion data has become valuable in predicting seismic strong motion using empirical Green's functions, and in characterizing site response by spectral ratios. A strong motion accelerograph is, as the name implies, designed to record strong motion. However, opportunities to record moderate and weak motions are more frequent than for strong motions. We should continue our efforts to improve a strong motion seismograph so as to record moderate and weak motions with better accuracy and to acquire those data urgently.

In 1988, an upgraded telemetry for strong motion recording was introduced in the array at Ashigara Valley. The telemetry makes use of both low cost private (dedicated) and public telephone lines (50 bits/s). The dedicated telephone lines are used for controlling trigger on/off for all stations, synchronizing the clock at each station, indicating the instrument errors, controlling the order of data dispatch and so on. These functions are executed through the pre-fed program at a specified control station in the Ashigara Valley network. The waveform data are acquired at the central station (SEMOC in Tokyo) or at the control station by using the public telephone line. The maximum transmitting speed for a public telephone line is 4800 bits/s. The necessary time to acquire the waveform data is almost twice the real recording time. The central station supported by a personal computer (NEC-9801) can control the trigger level at each station and specification of triggering by communicating with the local control station using the public telephone line. An outline of the telemetering system is shown in Fig. 2. The major functions of the telemetry system are listed in Table 1.

After three years experience with this telemetering system for the Ashigara Valley recording network, we confirmed the following advantages: quick acquisition of all the data, simultaneous recording of weak motions, accurate timing, and considerable reduction of maintenance tasks. At present, half of the stations in the Ashigara Valley net (consisting of 18) are linked by telephone lines. We hope to extend this system with financial support.

2. Data Acquisition

A digital accelerograph has provided quickness and expediency in data acquisition and processing. However, the recording format is not yet uniform among the strong motion accelerographs so that some complexity or troubles still exist in data acquisition. In order to reduce these we have been attempting to introduce a new system for data acquisition as shown in Fig. 3. The first stage of our data acquisition is managed by using a personal computer (PC-9801). Brief explanations of the major functions follow.

1) Reproducing

SMAR-PF. Proper reproducing software is necessary for magnetic tape recording. SMAR-PF reproduces the magnetic tape recordings of all SMAD-series and the data are stored again on IC-card memory (1Mbyte). One pass of a cassette magnetic tape produces one file on the IC-card memory, even if multiple events are recorded on the tape. The playback speed of SMAR-PF is 2 times faster than the original recording speed. It is so convenient, we are able to reproduce the data with SMAR-PF in the field. The data stored on the IC-card memory are written on a floppy disk or transmitted directly to the main frame (SUN-4/280) through a PC-9801. The communication between SMAR-PF and PC-9801 takes place with GPIB and the PC-9801 is connected with the SUN-4 through the local area network (PC-NFS).

SMAC-DR. This is a device to read the data on IC-card memory using PC-9801. RS232C is used for communication between SMAC-DR and PC-9801. Data transmission by SMAC-DR takes much more time (several times) compared with that of SMAR-PF.

PI-1. It is well known that PI-1 is the reproducing device for DSA-1 and PDR-1 recordings. An open reel IBM-compatible magnetic tape is provided. As the density of the tape is 800BPI and it is not supported by the SUN-4 in SEMOC, we put another digital output into PI-1 so as to get data through RS232C by using PC9801.

2) Filing and standard format data

All raw binary data are transmitted to the SUN-4 (which is a main frame data processing device in SEMOC) from a terminal PC-9801. A directory "phase1" in Fig. 3 is provided to hold raw binary data. These raw binary data consist of a series of 2-byte data. However, the bit compositions of the data are different for each type of accelerograph. In addition, data from the cassette magnetic tape recordings generally include more than one event so that we have to make data files by identifying event by event.

We have prepared the editing program on the SUN-4 to deal with the diversity of raw data. Figure 4 displays the entire time series of one component from a cassette MT in which the amplitudes are artificially clipped at a level of 10 gal(cm/s/s). This stage is provided for identifying each event and for separating events manually. By clicking the mouse at the beginning and end of the selected data, shown by small open triangles in Fig. 4, we will obtain multi-filed data. Figure 5 shows the time history of one file (12th event in Fig. 4). **We can see the details of the record by** zooming up as shown in Fig. 6, which is the enlarged part of the square box in Fig. 5, and we can then assign the P-wave arrival. By setting another window, we are able to identify the S-wave arrival.

We sometimes face data errors in cassette magnetic recordings. Our editing program facilitates such data correction. By zooming up a boxed area in the figure, we can correct the missing part of the data.

Data from DSA1 and PDR1 are processed in a similar manner. For other accelerographs, the editing is simple. The final stage of editing is to confirm the file name, station, channel and trigger time. This editing program will end after restoring the processed data in a standard format under the directory of "phase2". Our standard format consists of a header and individual channel data files. The header file includes the file name, station number (code), trigger time, earthquake name (region of epicenter), channel information, data number, sampling time, maximum acceleration and P- and S-wave arrival times. Each channel data file consists of a header of two lines and the time history. These data files are written in ASCII with 80-byte record lengths so as to make the data compatible with other computers.

3) Database

The data distribution should become an easy task after the completion of the database. We are working on the database in the following manner.

The strong motion database should be composed of a set of earthquake source data, a station table and recorded strong motion data. The known strong motion data files, from almost all organizations, include these fundamental data. The same style will be followed, but added to this we are planning to make a user-friendly database system. We introduced a relational database application software: "G-base, Richo Company, Ltd.", on the SUN-4 computer. The first stage is to register the three kinds of data: earthquake source, station (instruments) and strong motion data. The necessary earthquake source data are copied from the monthly report of the Japan Meteorological Agency. For strong motion data, "G-base" can hold the header data which consist of file name, earthquake name, trigger time, component and its maximum acceleration, sampling time, data number, P- and S-wave arrival times, epicentral/hypocentral distances, azimuth and back-up MT number.

At this moment the number of events is not large but it will become difficult to handle without the help of a database. The description here is an outline of our ongoing database construction. Ideas and criticism from seismologists and earthquake engineers will improve our ongoing database.

Table 1 Major functions of telemetry system used in SEMOC

Public telephone line use
1. File header display (maximum acceleration, duration, time)
2. Acquisition of complete data set
3. Remote calibration
4. Manual start of recording
5. Setting trigger level and selecting stations for triggering
6. System reset
7. Status display
8. Initializing
9. Delete files at observation station
Dedicated telephone line use (continuous)
1. *Synchronizing clock at each station by master clock*(Control st.)
2. Controlling start/stop of recording for all stations
3. Controlling the order of data dispatch from each station
4. Transmitting commands: Change the triggering level, system reset, selection of data dispatch mode
5. Error or event flag: seismograph, telemeter interface, status of communication, power supply, door open/close

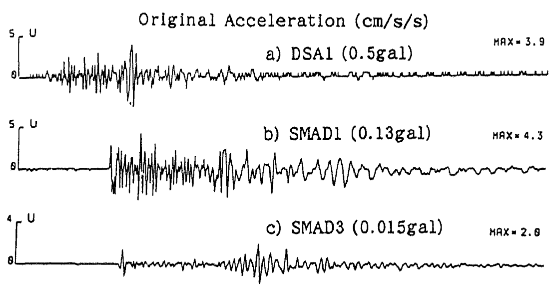

Fig.1 Comparison of weak motion records obtained by three accelerographs of different resolution. a) DSA1 (0.5gal), b) SMAD1 (0.13gal), c) SMAD3 (0.015gal)

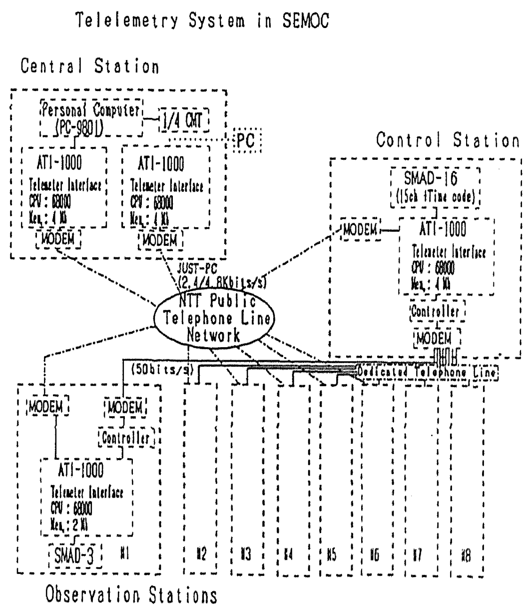

Fig.2 Telemetry system used in the Ashigara Valley Strong Motion Accelerograph Array.

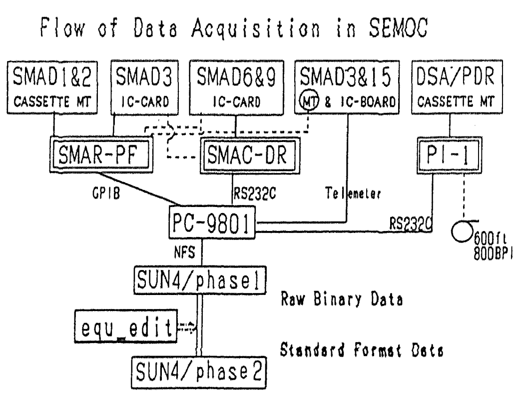

Fig.3 Flow of the data acquisition system used in SEMOC.

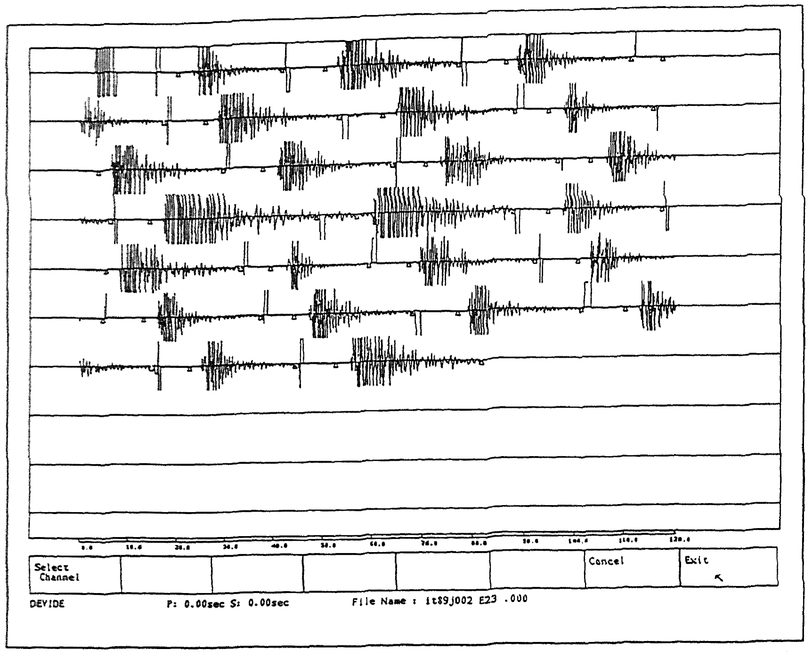

Fig.4 A display of multi-events reproduced from cassette tape recording to identify the individual events. Open triangles are assigned manually. The data between triangles are only stored for the following processing.

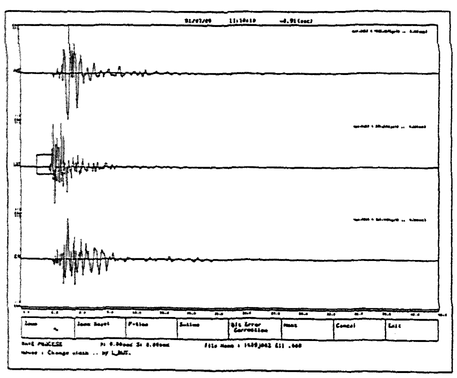

Fig.5 An example of identified solitary event(12th event in Fig.4). Asqure box shows the area to enlarge.

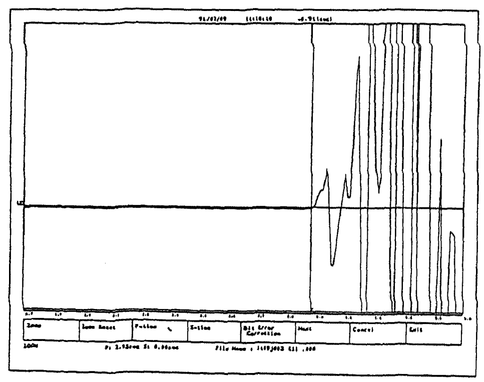

Fig.6 An enlarged display of the part in Fig.5 for identifying the P-wave arrival time.