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Correction of *1/f* noise in SMAC accelerograms

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It has been known that SMAC (Strong Motion Accelerograph Committee) accelerographs give larger amplitude for longer period component than about 5 seconds, when compared with records obtained by other seismographs. In order to certify this tendency, we conducted an experimental study by installing a servo-type accelerograph (referred to SAMTAC) on a foundation on which a SMAC accelerograph was installed. Namely SMAC and SAMTAC accelerographs shared the same foundation and shaking table test and simultaneous observations of actual earthquakes were carried out.

Fig.1 is an example of the record obtained by both accelerographs during an earthquake and we can not recognize the difference in time traces. However, the difference in both records is easily recognized in response spectra as shown in the figure. The reason for this tendency had not been made clear. Then we carried out such anexperiments in addition to observation mentioned above that SMAC accelerograph was mounted on a shaking table to compare with records obtained by SAMTAC and with time traces recorded bypotentio-meter.

SMAC accelerograph is a mechanical type seismometer of which stylus traces on a wax paper. The friction between stylus and wax paper is considered to have no influence on record and it may be true if the friction is small. Through the experiments, however, it was found that the friction between the stylus and wax paper is the cause of the incorrectness in long period range. According to the results of experiments, the stylus is shifted occasionally to only one side by the order of a few gals, which depends on the magnitude of the friction between the stylus and wax paper. The envelope of spectrum of abrupt shift or step function is inversely proportional; namely *1/f* spectrum. This kind of spectrum is known as the "flicker" or *1/f* type spectrum.

On the other hand, SMAC is driven by spring and its driving system produces vibration of the case box. Due to the vibration, the stylus records a fluctuating pattern even if SMAC is at rest (fixed completely). Fig. 2 (a) shows the time trace of a record obtained by SMAC at rest and (b) is Fourier spectrum of the digitized record. The spectra shape of this noise also is *1/f* type.

Trifunac, Udwadia and Brady analyzed errors associated with digitizing process of strong-motion accelerograms. According to their results of analysis, the envelope of Fourier spectrum of average of time trace of five independent traces of straight lines is *1/f* type. Thus, *1/f* noise caused by instrumental error and the human error in digitizing process are observed not only in SMAC records but also in records obtained by other type of **accelerographs**.

Fig.3 (a) is an example of typical Fourier spectrum of SMAC record obtained at Hachinohe during the 1986 Tokachi-oki Earthquake, which is frequently used as an input motion in seismic response analysis of structures, and we can find strong motion records with similar spectral shape. From these facts, we can conclude that the spectral shape of actual earthquakes recorded by SMAC accelerograph is *1/f* type.

Schematic representation of Fourier spectrum of SMAC record is shown in Fig.4. Solid line is the Fourier spectrum of original record and the dashed line is the noise mixed in accelerogram. The high spectral amplitude in low frequency range is representing the noise to be removed. This kind of noise is easily removed by an ordinary cut-off filter but the filtering produces a jump or steep decay of spectrum at cut-off frequency.

Considering the spectral property of noise component particular in SMAC accelerograph, spectral amplitude below the dashed line shown in Fig.4 is noise and this portion should be removed. In other word, the difference between the solid line and dashed line must be spectral amplitude of signal. Eventually, the spectral shape after removing the *1/f* noise must be such that shown by the chain line in Fig.4. However, in case of ordinary high cut filter, only low frequency range lower than the cut-off frequency is removed and the noise component denoted by dashed line is not removed in frequency range higher than cutoff frequency.

Fig. 3 compares the spectra of the 1968 Hachinohe accelerogram ; (a) is before and (b) after the correction mentioned above. If we apply an ordinary cut-off filter at 0.1 Hz of Fig.3 (a), for example, the spectral amplitude in the frequency range just higher than 0.1 Hz is unchanged. However, in case of Fig. 3(b), to which the proposed correction method is applied, spectral amplitude is greatly changed as is shown in the figure.

There is another problem. to be solved in determining the noise level. It is how to set the amplitude of the *1/f* filter because the resulting spectral shape depends on the setting level of this filter. In order to find a reasonable level, we used the records obtained by seismographs of the Japan Meteorological Agency, namely, JMA records. First, we assume the level of *1/f* filter and this gives a constant value of acceleration because acceleration is constant along the dashed line in Fig.4.

Then, assuming the noise level for spectrum of each original SMAC record, *1/f* noise component was removed from spectrum of original record and the response spectrum was computed to compare with spectrum for JMA record. After that, the difference between two spectrum for the period range between 5 sec to 10 sec was determined. The best fit filter level was determined by an iterative method in such way that the difference between two spectrum is minimized. This level is referred to the noise level by JMA on abscissa in Fig.5

On the other hand, Fourier spectrum of records is smoothed by a moving average with variable window width. Then, the *1/f* filter which comes in contact with a minimum value of the smoothed spectrum is defined as the noise level by smoothed spectrum, which is plotted on the ordinate of Fig.5. The procedure above mentioned was applied to 26 components of the strong motion records which were recorded by both of SMAC and JMA seismograms which have been installed within a few hundred meters from the observation station of SMAC. This figure implies that the rough estimate of the best match filter between SMAC and JMA records is given by the *1/f* filter of which level is determined from the smoothed Fourier spectrum.

The proposed method is applicable not only to SMAC records but also to accelerograms recorded by other type of accelerographs because *1/f* type noise or flicker is inherent in recording and driving devices and digitizing process. To eliminate this kind of error, the proposed method might be better than the cut-off filter and/or Ormsby filter which are frequently used in data processing of strong-motion accelerograms.

REFERENCE

Trifunac, M.D., Udwadia, F.E. and A.G. Brady : Analysis of Errors in Digitized Strong-motion accelerograms, Bull. Seismological Society of America, Vol. 63, No.1, pp.157-187, Feb. 1973.

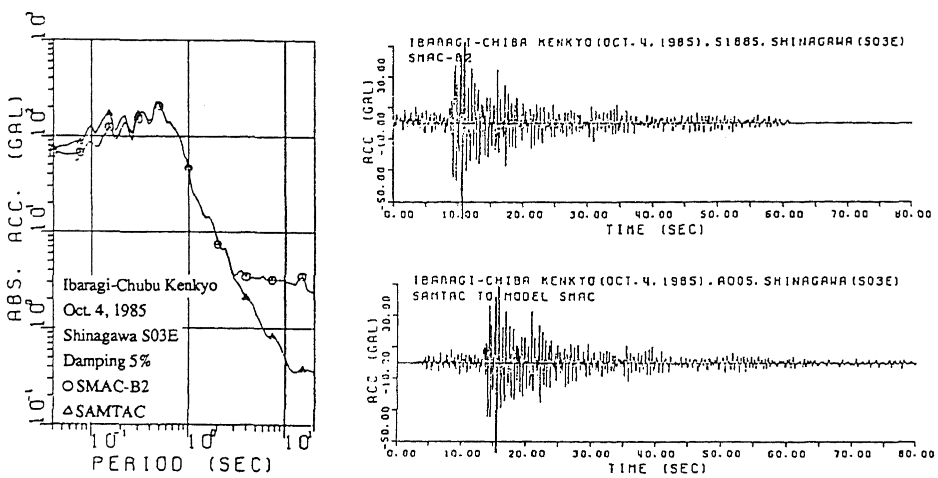

Fig.1 Comparison of time trace and spectrum of records obtained by SMAC and SAMTAC

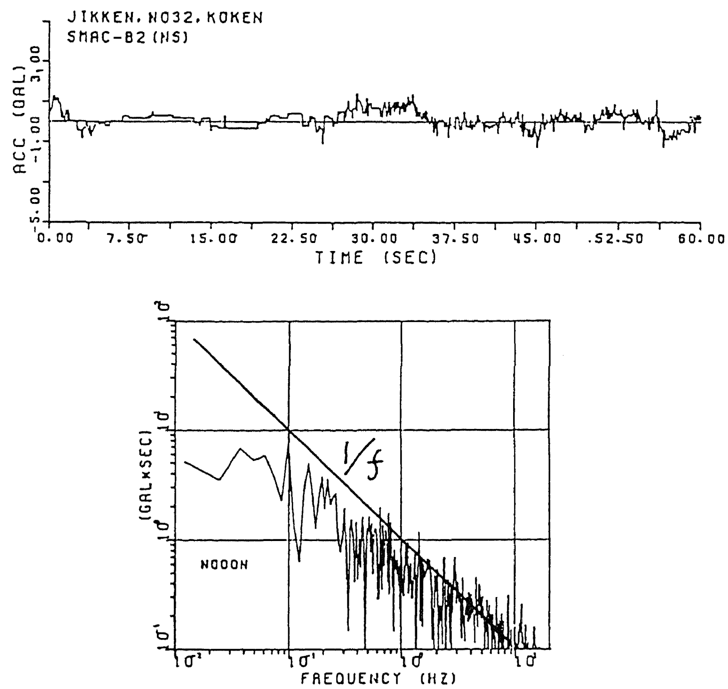

Fig.2 Time trace and spectrum of record obtained by SMAC at rest

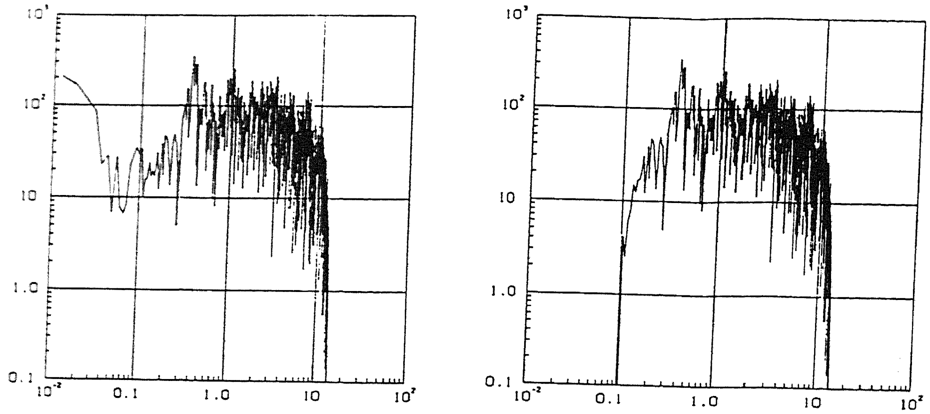

Fig.3 Example of spectra of SMAC records

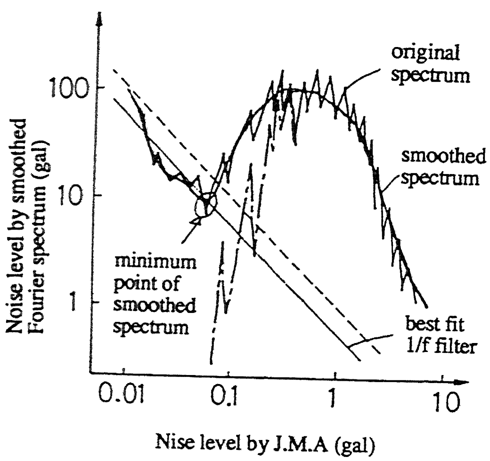

Fig.4 Schematic representation of spectrum of SMAC record

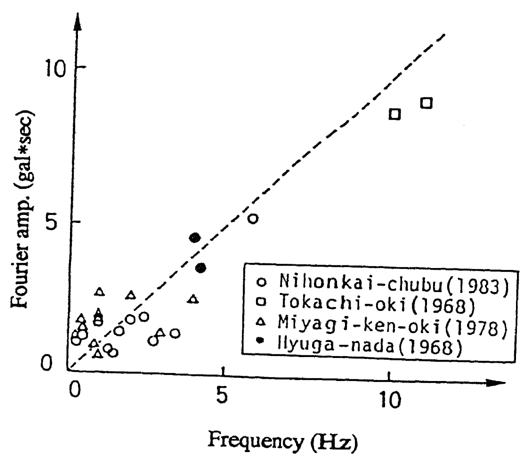

Fig.5 Comparison of low-frequency noise level