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SEISMIC NOISE MEASUREMENT IN THE REGION AROUND KAIGA ATOMIC POWER PROJECT

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ABSTRACT

Measurement of background seismic noise in three provinces around the region of Kaiga nuclear power plant site in Karnatka has been made using an indigenously developed portable field seismic monitoring system incorporating a wide band cassette magnetic tape recorder and a band limited helical chart recorder. Several noise samples obtained during May 23-25, 1989 and spectral analysis of these data show that the high frequency noise that interferes in signal detection is practically absent in Kulgi area, moderate at Idagundi and comparatively largest in Kumbarwad province. Although the relatively long period oceanic microseismics have comparable energy in all the three provinces, Kulgi among them is found to be overall quietest locality which qualifies to have a sensitive microearthquake monitoring station

INTRODUCTION

There is a proposal for setting up initially three to four sensitive seismic stations in the region around Kaiga atomic power project located along the course of Kali river, about 35 km east of Karwar coast in Karnataka, where it is planned to monitor regional seismicity as part of seismotectonic investiggations in that region. It is expected that these seismic stations would detect within about 100 km all microtremors down to a local magnitude -2. Hence, they will have to be sited at relatively noise free locations so that their operational magnification is 1-1.5 million in the frequency range 5-10 Hz, which provides reasonably good signal to noise ratio.

It is noted that KPCL (Karnataka Power Corporation Limited) are operating in the region of their hydroelectric power stations along the Kali river four independent seismographic stations with helical paper recording at Khanapur, Supa, Kirvatti and Karwar. But these are relatively less sensitive stations with maximum magnification around 1000,000 at 2 Hz. It is planned to upgrade these stations such that they match in operational characteristics with the proposed Kaiga seismic stations when their data can be well utilized along with those of other sensitive stations for seismicity studies. Possibly, at a later stage, all these regional seismic stations will be radio telemetered to a centralized data acquisition facility at Kaiga for more efficient seismic monitoring.

In a reconnaissance survey conducted earlier, the three provinces of Kulgi, Idagundi and Kumbarwad were considered logically suitable to have seismic stations for the Kaiga net. This was followed by an experimental survey in the month of May 1989, to measure the level of background microseismic noise due to artificial and natural sources that interferes with the detection of local earthquake signals. In Kulgi province compact hard rock surface was available for emplacement of seismic sensors. However, small pits had to be excavated and their base concreted at sites in Idagundi and Kumbarwad provinces where unconsolidated weathered material was found covered with soil.

Actual noise samples were taken at several places in the above three provinces over sufficiently long time intervals ranging from one to five hours during May 22-25, 1989. In each run, analog recordings were organised both on helical paper charts and cassette tapes using a portable field system designed and fabricated indigenously and tested at Gauribidanur seismic array station. In the seismic laboratory equipped with a computerised data acquisition system, the cassette tape records were digitised at the rate of 200 samples per second per channel and the data acquired on floppy diskettes as well as on computer compatible tapes for futher processing. The main analysis to which the digital data was subjected relies on the estimation of power spectral density that revealed the nature and intensity of the microseismic noise.

TOPOGRAPHICAL FEATURES OF THE SITES

The geographical locations of Kulgi, Idagundi and Kumbarwad provinces, the Kaiga project site and the existing KPCL seismic stations are shown in Fig. 1. However, the main topographical features of the three provinces surveyed are as follows :

(a) Kulgi

Situated between an abandoned quarry and thick forest (tall trees at distances of 60-70 m), this province has generally granitic terrain with solid metamorphites or compacted paleozoic sediments at places. It is isolated from human activities except the forest nursery garden at a distance of about 1 km and the main road about 1.5 km away. A composite masonry rock filled dam of small height (29 m) is situated at about 10 km from Kulgi. The reservoir behind this dam has a capacity of 85 Mcum, which supplies water to the power house located about 15 km downstream. There is a deep valley about 3 km away from Kulgi village.

(b) Idagundi

With mainly weathered rock up to 1-2 m underneath the top soil, thick forest consisting of tall trees covers this province where some areas are converted into paddy fields. A dam of height about 60 m and the associated power house are situated about 9 km away from the village. Two different types of rock structures are exposed near the roadside at distances of 200-300 m.

(c) Kumbarwad

This province has a relatively thick cover of soft soil which extends to a depth of 5-8 m. It is surrounded by thick forest containing tall trees and has a small village about 4 km away. A big tunnel (6.5 m wide and 3 km long) upstream of the large Supa dam is situated close by (200 m), which is charged with water during rainy season. There was no water flowing through this tunnel at the time of the present noise survey.

MAJOR DETAILS OF INSTRUMENTATION

As shown in schematic block diagram (Fig. 2), the indigenously fabricated seismic noise monitoring system has three essential components. These are sensor, sender unit or signal conditioner and recording system.

(a) Sensor

A 1-sec vertical component seismometer having velocity sensitivity of 350 volts/m/sec at 60 percent critical damping was used. In addition, a 7 Hz geophone of 30 volts/m/sec sensivity at 70 percent critical damping was also used.

(b) Sender

This unit consists of a dual two-state low noise differential amplifier set to an effective gain of 6000 and a flat frequency response between 0.5 Hz and 20 hz (3 db points). It is followed by a dual frequency modulator (voltage controlled oscillator or VCO). The two VCO's are operated at two different centre frequencies of 270 Hz and 2160 Hz with frequency deviation of ± 33.33 percent corresponding to ± 2 volts input. Normally, the seismometer is connected to the 2160 Hz channel and the geophone to the 270 Hz channel. The two frequency modulated (FM) seismic signals are mixed at the next stage constituted by a mixer. The mixed signals are transmitted through a split wound transformer and cable to a recorder kept farther away (typically 75-100 m). The power required for driving the sender unit is sent through the same cable.

(c) Recording system

The mixed FM signals (2160 Hz and 270 Hz channels) are recorded directly on a cassette tape after attenuating the signal to a level of about 30 mv (above which the signal distorts) by using a resistive network. The tape recording system was modified to accommodate signal frequencies up to 10 KHz. At the tape speed of 7 inches/sec, about an hour's data from each site could be accommodated in a single cassette tape reel. In parallel, the mixed FM signals are separated by a suitable filter unit, shaped and attenuated to a level of 200 mv to avoid any signal distortion at the next stage of FM demodulators that retrieve the seismic signal. The FM demodulators have a sensitivity of 5 volts output for input variation of ± 33.33 percent in the carrier frequency. Thus, there is an increase in gain by 2.5 times, which brings up the total electronic gain of the system to 15000.

The demodulated signals along with time are displayed for visual inspection on a helical paper chart recorder driven at a linear speed of 240 mm/min and a sensitivity of 2 volts/cm for signals from seismometer and 125-250 mv/cm for geophone signals.

SYSTEM CALIBRATION

The monitoring system was calibrated using a standard sine wave generator. The tape recording system was set to have a wide passband of 0.5-45 Hz (both 3 db points) with a uniformly flat response in the band 1-30 Hz. In comparison to this, the visual recording system has a relatively narrow passband of 1-12 Hz (both 3 db points; Fig. 3). For both kinds of system, however, the frequency response outside the passbond rolls off at the rate of about 20 db per octave.

While the wide band tape recordings and replays are used by us for only spectral analysis of the noise samples, it is the visual seismic monitoring system that is actually used here in the direct measurement of ground motion due to seismic noise. Hence we have reproduced frequency response curve for this system (generally referred to as the overall system in this paper) and computed its dynamic magnification in the useful range of signal period.

The displacement magnification of the seismic system at different signal frequencies is calculated using the following relation (Arora et al., 1973; see also Arora et al., 1983) :

$$d(f) = 2\pi * g_o * G_e * f * R_o(f) / V_r \quad (1)$$

where,

g_o = velocity sensitivity of the transducer (seismometer or geophone) p expressed in volts/cm/sec,

f = signal frequency in Hz,

G_e = electronic gain of the system,

V_r = recorder sensitivity expressed in volts/cm, and

$R_o(f)$ = overall system response factor (normalised to unity) at signal frequency f.

The above expression (1) for d(f) readily follows by assuming some value of true ground displacement amplitude (say, z cm) whose particle velocity equivalent at frequency f is $2\pi fz$ cm/sec and which, after detection by the sensor (velocity transducer) and appropriate electronic amplification, produces an output signal of strength $2\pi fzg_oG_e$ volts. Such signal would register a visual trace of amplitude $2\pi fzg_oG_eR_o(f)/V_r$ cm on a recording instrument operating at a sensitivity of V_r volts/cm when the overall system responds only to the extent of $R_o(f)$ whose maximum value is 1.

For the system interfaced to a seismometer used in the present experiment, typical magnification curve generated from the above formulation is shown in Fig. 4 where the peak magnification of 1400K is obtained at a signal period of 0.10 sec.

DIGITAL DATA TRANSCRIPTION

For carrying out spectral analysis of noise samples, we took representative wide band (0.5 - 45 Hz) analog tape records of about five minutes duration from each of the three provinces (Kulgi, Idagundi and Kumbarwad) and converted them into digital records at 200/samples/sec/channel. The digital data were initially stored on a minifloppy diskette and then transcribed on a computer compatible tape for further processing.

To examine the behaviour of the off-line digitizer system in high frequency range upto the Nyquist frequency of the input waveform (100 Hz in the present case), we obtained digital records corresponding to known sine waves of different frequencies at constant amplitude. It is noticed that the sinusoidal waveform tends to become distorted at 35 Hz. This, therefore, sets an upper limit of signal frequency in the reproduction of digital seismograms and would imply that spectral analysis of such seismograms in this case gives reliable information only upto 35 Hz.

Typical noise samples reproduced for 40 sec from each of the three channels of wide band digital records are shown in Fig. 5. These representative noise data have been used by us in spectral analysis.

ANALYSIS OF NOISE DATA AND DISCUSSIONS

In each province, more than five hours of seismic monitoring on May 23-25, 1989, has been made at different sites to get a clear picture of the prevailing background noise there. The instrumental constants have been maintained unaltered during the whole exercise. Noise records in one province are found to differ from those in the other (Figs. 6 - 8) on account of the differences in geographical features and surface geology of the three provinces. A summary of overall noise levels in the region are given in Table I, which is based on band limited (upto 12 Hz) helicorder records. It shows that while oceanic microseisms around 1 sec period are comparable in amplitude (15-20 nanometers peak ground displacement) in all the three provinces, those in the higher frequency range upto 12 Hz are distinctly different. For example, Kumbarwad records give 25 nanometers peak ground displacement as compared to Kulgi records which do not give more than 3 nanometers in the high frequency range (Table I). Thus, on a preliminary estimate, Kulgi appears to be the least noisly of all three provinces.

Further details of noise characteristics at each site supported by spectral estimates are described below :

(a) Kumbarwad

As shown in the 12 Hz band limited specimen helicorder record (Fig. 6), the noise in Kumbarwad province is characterised by high frequency microseisms due mainly to wind generated by a large number of tall trees around. The high frequency components appear prominently in the form of transients or bursts repeating in quick succession over a long period of time. This picture is clearly revealed in the wide band digital transcript (Fig. 5 : Channel 3). The observed wind generated disturbances are also characteristic of the presence of a thick layer of unconsolidated material below the surface, which contributes reverberation noise substantially. These noises made it difficult to identify any seismic event in the records obtained at Kumbarwad. Probably, such surface noises may be reduced at the base of an excavation 8-10 meters deep where the material should be reasonably compact.

Spectral analysis of 1.4 minutes (2^{14} samples) of noise data using fast fourier transform (FFT) technique (see, for example, Cooley et al., 1967) shows relatively large energy in the frequency band extending from 6 Hz to 16 Hz (Fig. 9a). This features is better resolved in the plot of power spectral density (Fig. 10a) which also shows clearly the noise contribution at the lower frequency end on account of oceanic sources. In fact, the effect of oceanic noise at periods around 1 sec is practically the same in all the three provinces (Fig. 10) as we expected. Large spikes in the amplitude spectra in Fig. 9 are due to noise surges present in the raw data itself. These surges seem to be mainly the tape recording system noise.

The tunnel in the vicinity of Kumbarwad will be another source of relatively high frequency noise when water gushes through it during monsoon season. Since the tunnel was dry at the time of the present experiment, the water channel noise has remained unassessed.

(b) Idagundi

The sites surveyed in this province show continuous microseismic disturbances in a wide frequency range upto about 30 Hz owing mainly to the presence of tall trees, high dam and water reservoir in close proximity. The high frequency noise of small amplitude is superimposed on the relatively large amplitude oceanic microseismic background of period 0.8-1.5 sec (Fig. 7). There are, however, no bunches of high frequency noises unlike what we notice at sites in Kumbarwad. Nevertheless, the high frequency components appear in largely varying amplitudes. In such a kind of background, although detection of moderate seismic events may not pose serious problem (see in Fig. 7, for example, signals due to a local seismic event and a distant earthquake), it is difficult to detect a small event such as a microearthquake.

The amplitude spectra of Idagundi noise samples (Fig. 9b) confirm the existence of strong oceanic microseisms of signal frequency above 2 Hz and a steadily decreasing high frequency noise that extends upto 33 Hz. A large spectral peak centered at 30 Hz is also seen in Fig. 9b. These two features are well brought out in the corresponding power spectral density plot (Fig. 10b) which shows large energy concentration in the lower frequency band (2 - 5 Hz) and practically little concentration of energy in the higher frequency band. The 30 Hz spectral peak is found to have small energy density compared to maximum in the whole range upto 35 Hz.

(c) Kulgi

As seen from the wide band sample data retrieved from the digital tape (Fig. 5 : Channel 1), the maximum peak-to-peak amplitude of noise at Kulgi is only about half of those in the two other provinces. The nearly 1 sec period background oceanic noise itself is marginally smaller (approximately 15 nm, Table II) than that at Kumbarwad and Idagundi sites. Moreover, the high frequency components are not discernible in the band limited record (Fig. 8).

The amplitude spectrum of the Kulgi noise samples shows some small high frequency energy in the band upto 11 Hz (Fig. 9c). This result is well corroborated by the power spectral) density plot in Fig. 10c. It clearly indicates that the Kulgi noise is practically free from high frequency ripples and that the overall noise in this area is constituted by mainly around 1 sec period microseisms of oceanic origin. This makes Kulgi province least noisy among the areas surveyed.

A suitable location for establishing a sensitive microearthquake monitoring station in Kulgi is found at Pansoli (15^{o} 09' 05" N, 74^{o} 36' 50" E) an elevation of 550 meters above mean sea level.

CONCLUSIONS

The following main conclusions can be drawn from the seismic noise monitoring experiment conducted recently in the Kaiga region, and spectral analysis of the noise data :

1. Among several sites in the three provinces, namely Kulgi, Idagundi and Kumbarwad, the overall background seismic noise is found to be lowest at Kulgi and highest at Kumbarwad.

2. The average noise amplitude of nearly 1 sec period due to microseisms of oceanic origin are comparable in all the three provinces, although it is marginally smaller in Kulgi.

3. Due mainly to the presence of large number of tall trees and thick layer of unconsolidated material near the surface, the wind generated high frequency noise in the range above 4 Hz, which seriously interferes in seismic event detection, is prominently large at Kumbarwad. At Idagundi, such noise is comparatively small,

diminishing gradually with increase in frequency until nearly 30 Hz where it appears to build up again and then tapers off. The Kulgi area overlying the relatively homogeneous hard country rock of extensive nature is found to be practically free from the contamination high frequency seismic noises.

ACKNOWLEDGEMENTS

This work was carried out as part of the programme of the Nuclear Power Corporation (NPC) to establish systematically a telemetered seismic network for continuously monitoring seismicity of the Kaiga region where a nuclear power station is under construction. It is envisaged to upgrade some of the independent seismographic stations run by the Karnataka Power Corporation Limited (KPCL) for monitoring microearthquake activity in the Kalinadi hydroelectric project (KHEP) area to be compatible with the elements of an integrated sensitive seismic network in this region.

We are thankful to NPC as well as KPCL organisations for extending all necessary logistical support during the noise survey. Thanks are also due to Mr. R. Bhargava (RASD, BARC) for rendering help in transcribing digital data in the ND computer compatible form.

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Table I : Average Background Seismic Noise Levels in the Three Provinces, Based on the Band Limited (1-12 Hz) Helicorder Recordings

Province Name	Ground Displacement in Nanometers estimated from :		
	Seismometer records		Geophone record
	Oceanic microseisms of around 1 sec period	High frequency noise in approximately 4-8 Hz band	High frequency noise in approximately 8-12 Hz band
Kulgi	15	5	3
Idagundi	20	17	13
Kumbarwad	20	- 12	25

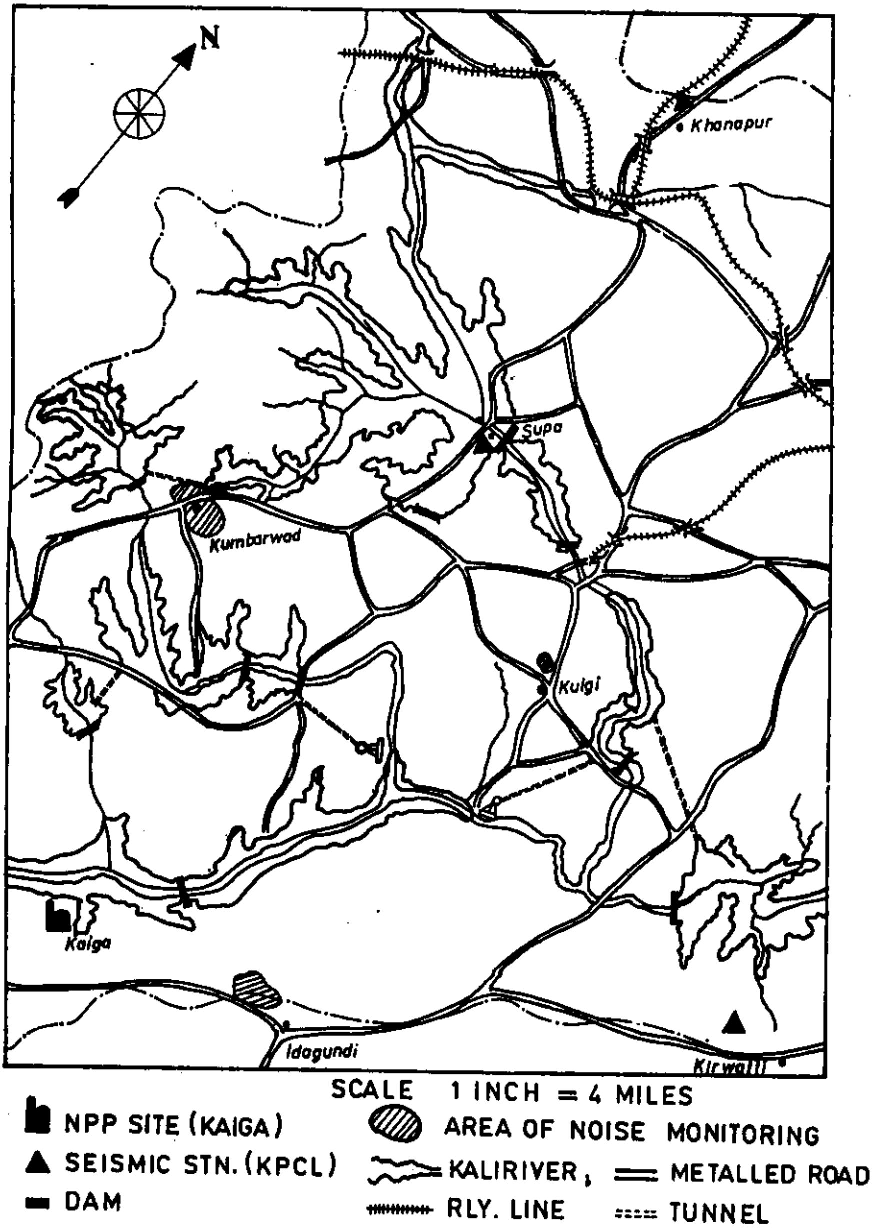

Fig. 1 Layout map of Kalinadi Hydroelectric Project scheme showing KPCL (Karnataka Power Corporation Limited) seismic stations (shaded triangles), Kaiga nuclear power plant (NPP) site and the three provinces (hatched areas) of Kulgi, Kumbarwad and Idagundi where seismic noise survey was carried out.

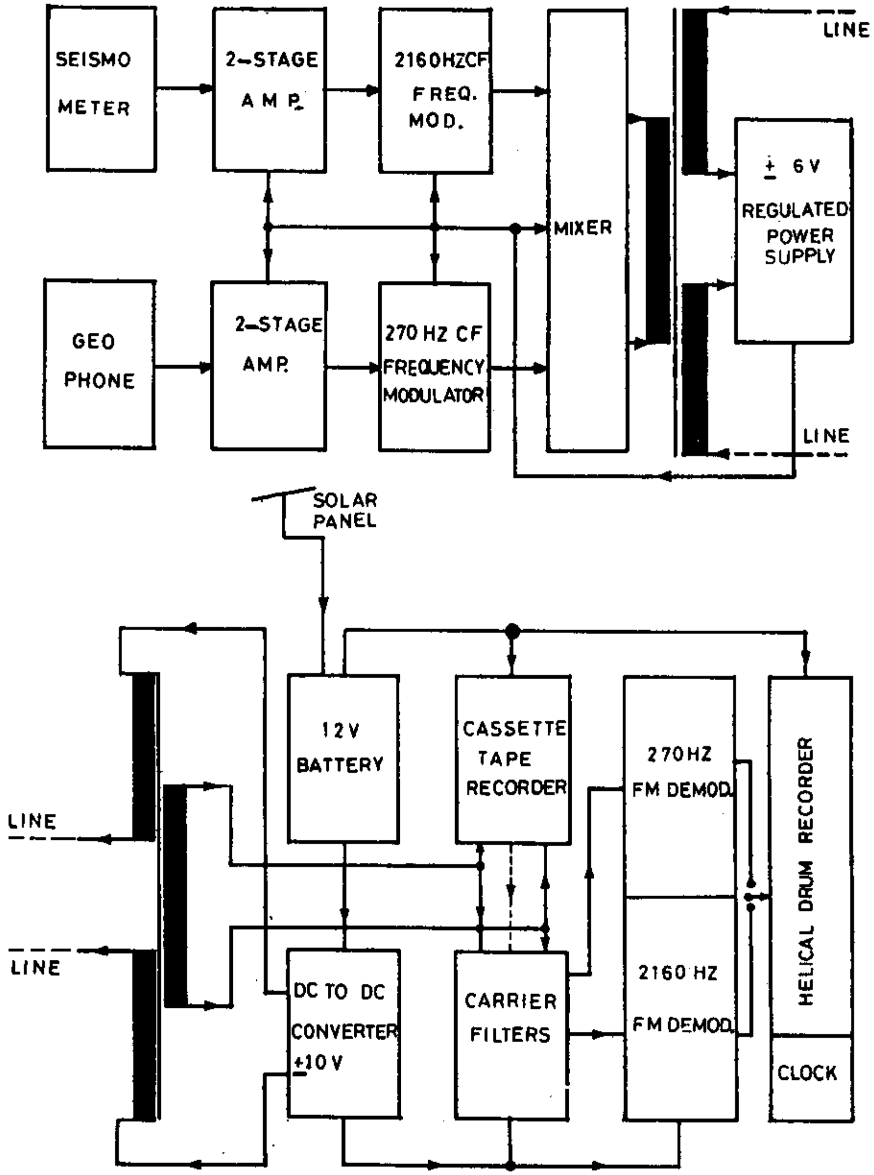

Fig. 2 Schematic block diagram of the system used for monitoring microseismic noise.

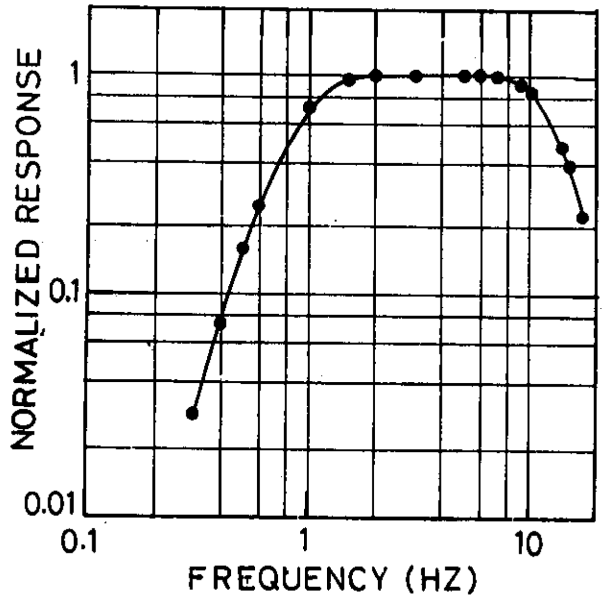

Fig. 3 Frequency response of the overall (visual) monitoring system.

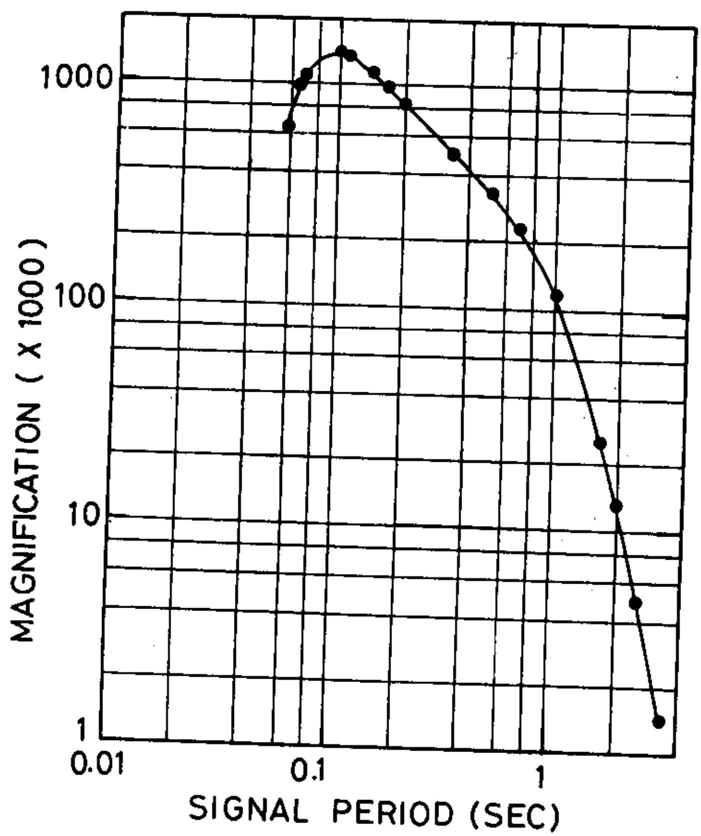

Fig. 4 Dynamic magnification of the overall seismic system.

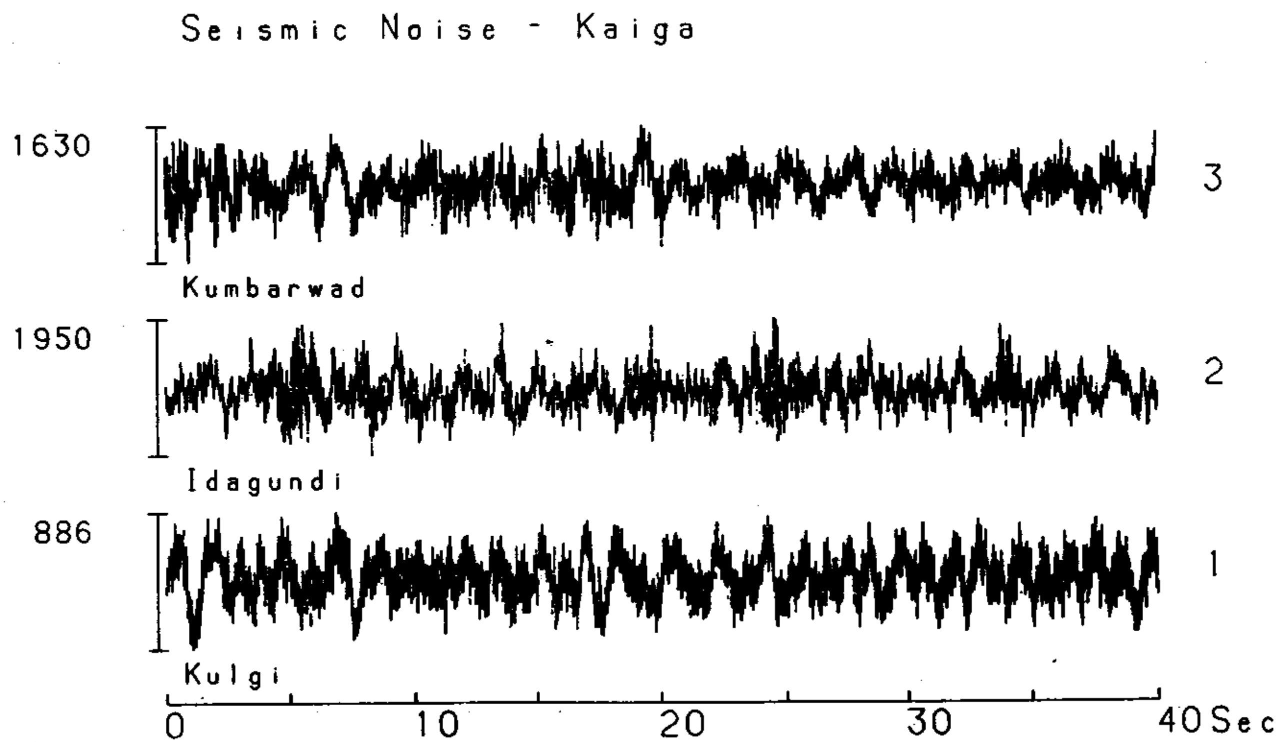

Fig. 5 Typical digital waveform of seismic noise sample reproduced for 40 sec from wide band tape records of (1) Kulgi, (2) Idagundi and (3) Kumbarwad channels. Vertical bars and the corresponding numbers for each record represent maximum relative signal amplitude in digital counts.

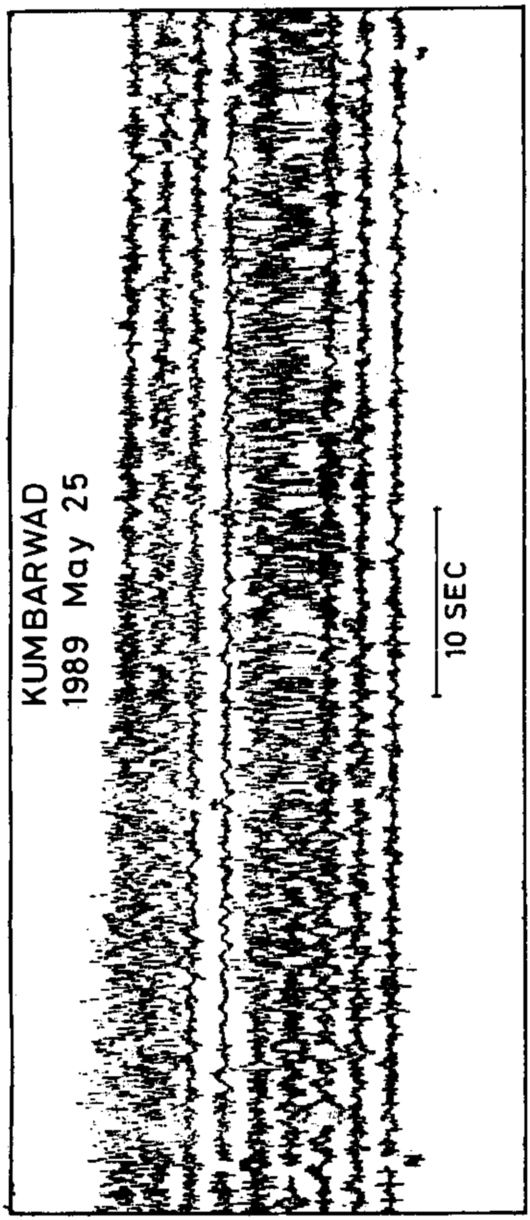

Fig. 6 Band limited specimen noise record obtain on helicorder at Kumbarwad on May 25,1989.

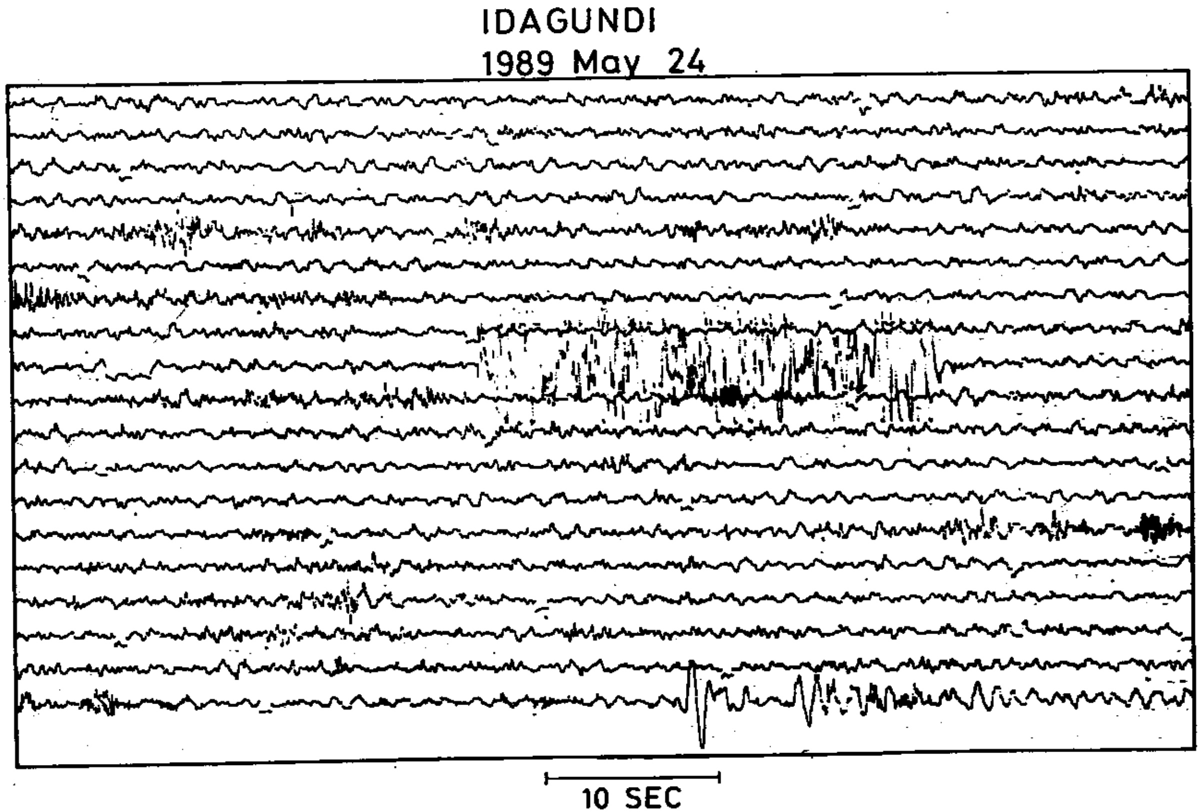

Fig. 7 Band limited specimen noise record obtained on helicorder at Idagundi on May 24,1989. Along the bottom trace of the record, P wave signals and coda from the Sulawesi (Celebes) region earthquake can be seen.

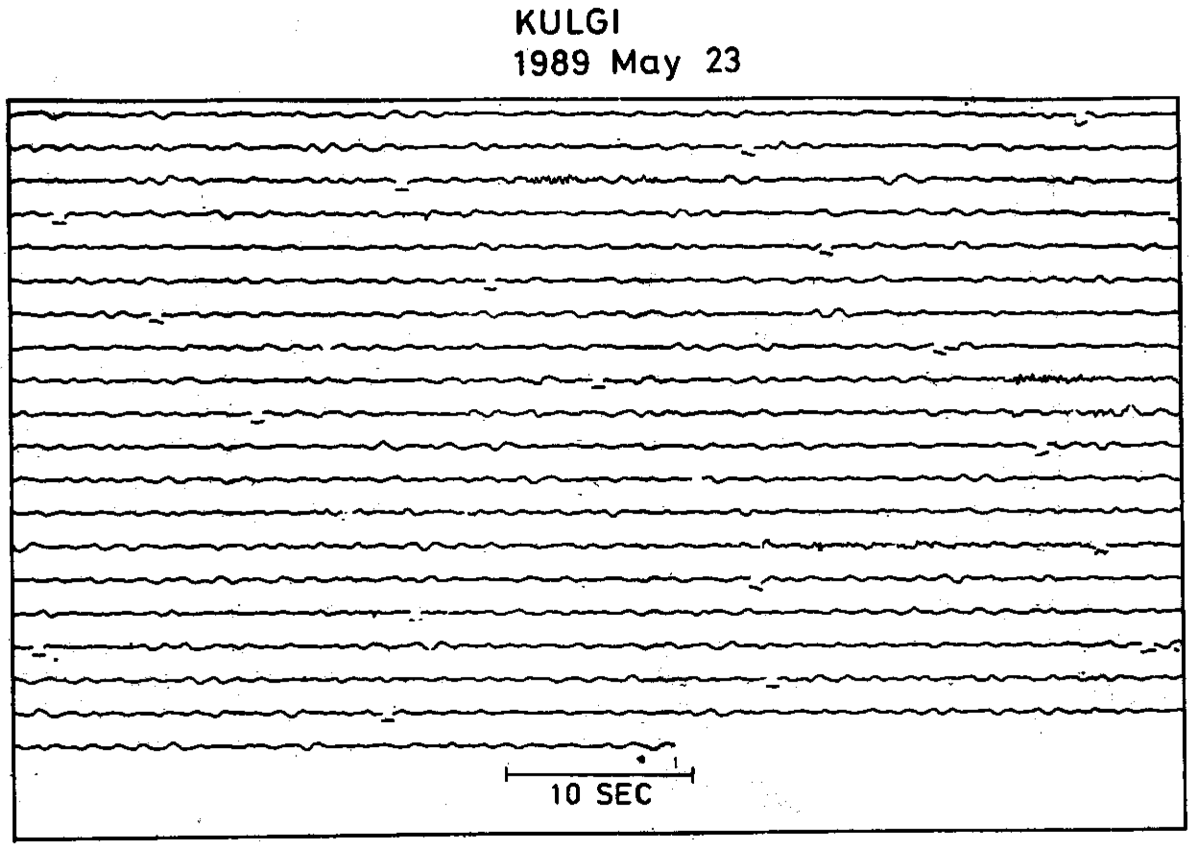

Fig. 8 Band limited specimen noise record obtained on helicorder at Kulgi on May 23, 1989.

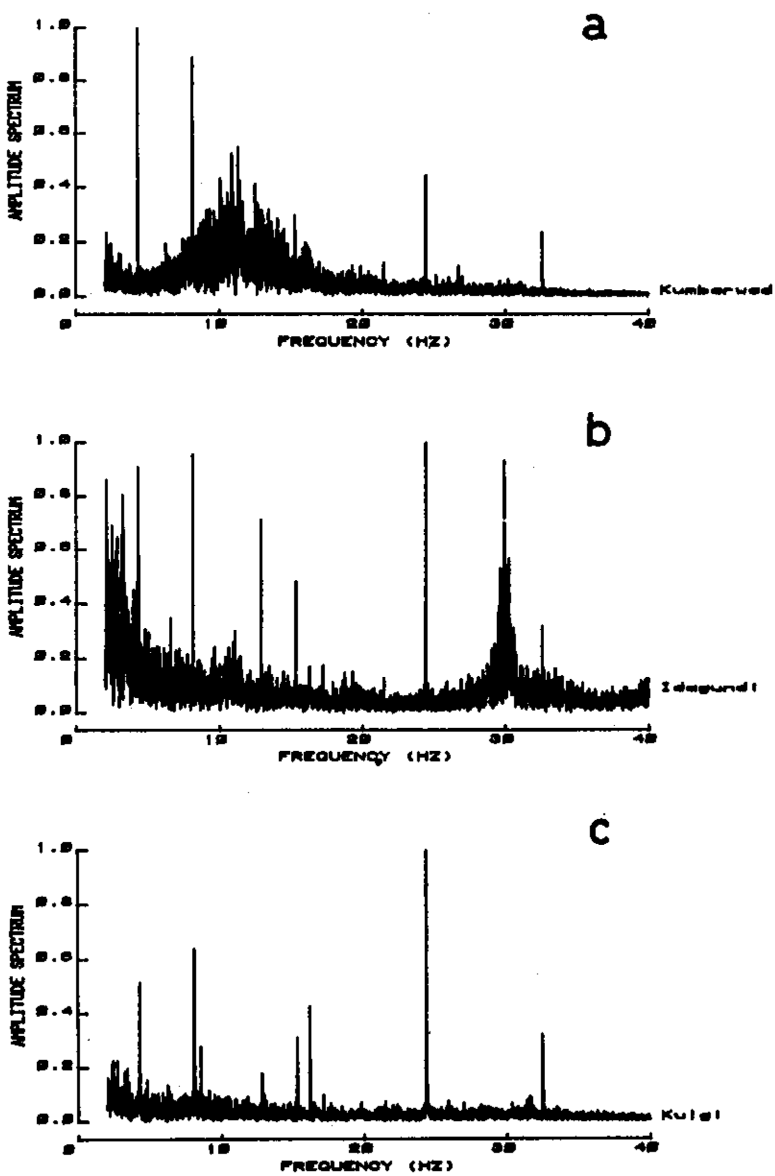

Fig. 9 Amplitude spectra of noise data from (a) Kumbarwad (b) Idagundi, and (c) Kulgi sites.

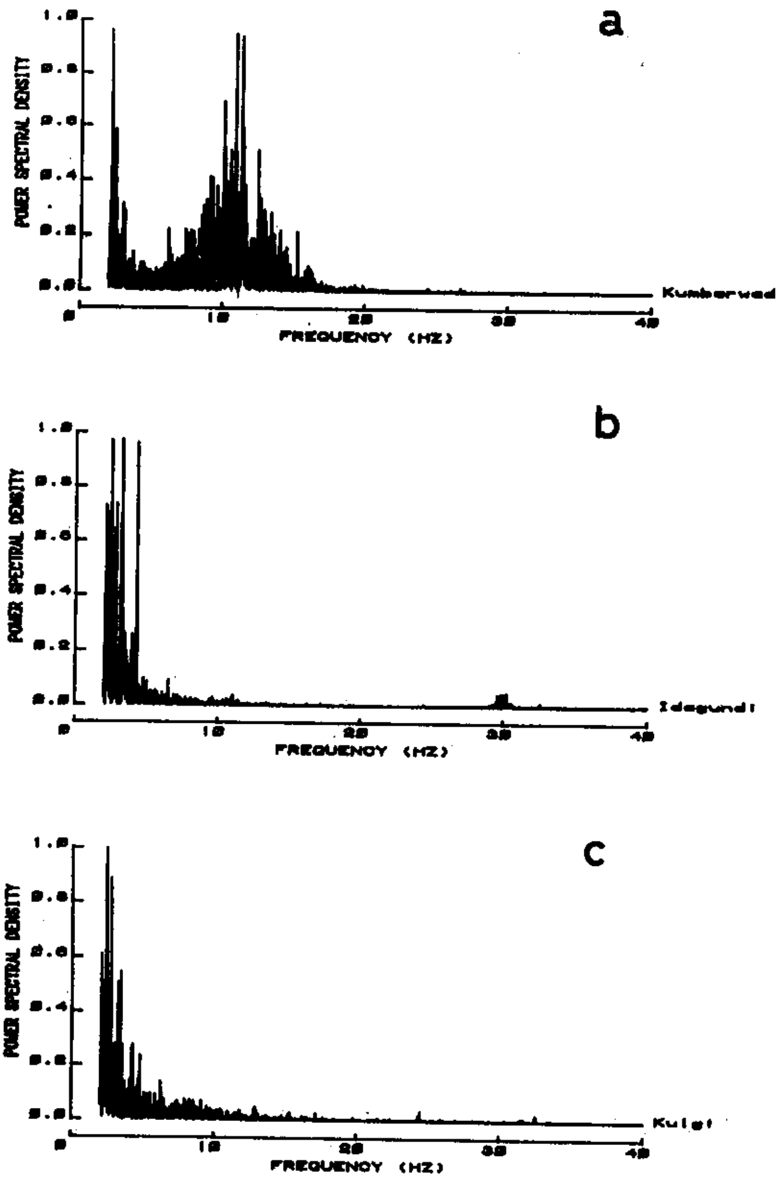

Fig. 10 Power spectral density as a function of signal frequency estimated from noise data of (a) Kumbarwad, (b) Idagundi, and (c) Kulgi sites.