Mausam, (1995), 46, 2, 169-174

550.348.432

Spectra of seismic noise at selected Indian stations

V. P. KAMBLE, R. S. DATTATRAYAM*† and H. N. SRIVASTAVA**
India Meteorological Department, New Delhi
(*Received 24 May 1993, Modified 8 August 1994*)

सार — भारत मौसम विज्ञान विभाग द्वारा पिछले कुछ वर्षों से नई दिल्ली, शिलाँग, पुणे, कोडाईकनाल और धर्मशाला में पांच डिजिटल भूकंपलेखी प्रणालियों के प्रचालन का कार्य किया जा रहा है। प्रस्तुत शोध पत्र में उपकरण अभिलक्षणों से संबंधित विवरण और आंकड़ों को पुन: प्राप्त करने तथा उनके संसाधन के लिए साफ्टवेयर का उल्लेख किया गया है। पी० सी० आधारित एलगॉरिथम के माध्यम से, इन पांच केन्द्रों के लिए, नॉयज़ स्पैक्ट्रा का परिकलन और व्याख्या की गई है। पुणे, शिलाँग और कोडाईकनाल के लिए चरम शीर्ष लगभग 6 हर्ज पर दृष्टिगोचर हुआ, जबकि नई दिल्ली और धर्मशाला के लिए इसका मान लगभग 2 हर्ज ही पाया गया। एस० आर० ओ० प्रणाली से ज्ञात किया गया शिलाँग का स्पैक्ट्रल शीर्ष लगभग 1 हर्ज तक खिसक गया, जो कि गौरीबिदनौर भूकम्पीय एरे के इसी प्रकार के परिणाम के समतुल्य है।

ABSTRACT. India Meteorological Department (IMD) is operating five digital seismograph systems at New Delhi (NDI), Shillong (SHL), Pune (POO), Kodaikanal (KDK) and Dharmsala (DHM) since last few years. The details pertaining to instrumental characteristics and software for data retrieval and processing are presented in this paper. Through PC based algorithms, noise spectra are computed and interpreted for these five stations. It is found that the maximum peak occurs at about 6Hz for Pune, Shillong and Kodaikanal while at New Delhi and Dharmsala, it is noted at about 2 Hz. The spectral peak at Shillong as deduced from the SRO system shifts to about 1 Hz which is in agreement with a similar observation reported at Gauribidanur seismic array.

Key words — Microtremors, Noise spectra, Ground noise, Seismic noise, Digital seismograph systems.

1. Introduction

The surface of the earth, under the influence of various sources of ground motion, is subjected to continuous vibrations called "microtremors". In earthquake recording, these tremors constitute the noise and are superimposed on the earthquake signal. Therefore, study of this noise is considered essential both for selection of an appropriate instrumental response as well as to eliminate the effects of noise on the signal. The principal vibration sources of these tremors include movement of vehicles, cultural noise and wind. Sometimes such types of noise can also be of broadband in nature produced by sonic booms, strong wind gusts and trains. Waterfalls and waves in local bodies of water (called "Seiches") can also generate noise at one to a few Hertz (Hz) in addition to ocean-generated microseisms. The ground motion is generally attributed to fundamental mode of Rayleigh or Love waves or their higher modes.

Extensive measurements of microtremors in Japan have shown that the period distribution of microtremors shows a definite form for respective kinds of sub soils (Kanai and Tanaka 1961, Omote *et al.* 1972). The displacement amplitudes and the frequencies of these vibrations are less than several microns and 10 Hz respectively. The peak period of microtremors was found to be the most significant period for earthquakes. Application of microtremor measurements for understanding the local soil characteristics is relatively simple and inexpensive with regard to the design of earthquake resistant structures. The method has been extended in several countries to study the influence of deep sediments on seismic ground motion using electromagnetic seismometer with a 10 second period for observations of 1 to 5 second microtremors (Kagami *et al.* 1982). Detailed knowledge of noise level is critical for the development of recognition algorithms used in digital seismographs, particularly for weak teleseismic signals (Evans and Allen 1983).

The object of this paper is to study the noise spectra at five Indian stations, *viz.,* New Delhi, Dharmsala, Shillong, Pune and Kodaikanal where short period digital seismographs are in operation. The results are compared with similar estimates

* Department of Science and Technology, New Delhi.
** Meteorological Office, Pune.

† Views expressed in this paper are of the author only and in no way reflect those of the organisation he is working for.

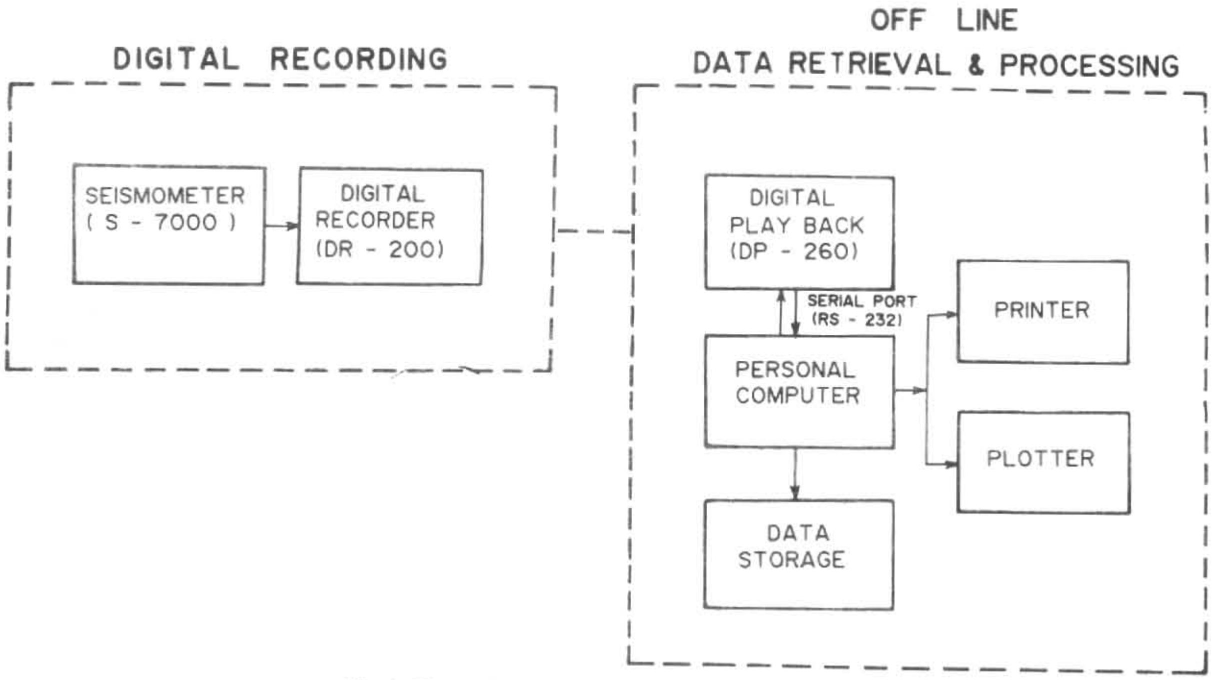


Fig. 1. Block diagram of digital seismograph system

obtained through a seismic array at Gauribidanur (GBA) and Seismic Research Observatory (SRO), Shillong equipped with a borehole seismograph at a depth of 100 m (Srivastava 1989). It may be clarified that noise shows some variation with time of the day and season. However, day-time recordings are considered in the present study, as the man-made noise is more predominant during this period. No attempt has, however, been made to study the variations in the noise spectra with time of the day or season.

2. Local geology of the sites

The local geology of the observatory sites, where digital seismographs have been installed, is detailed below:

Delhi—The observatory at Delhi is situated on the northeastern margin of the Aravalli ranges in the Indo-Gangetic plains. The site at the observatory consists of massive quartzite.

Dharmsala—Dharmsala observatory is situated in a complex system of rocks. To the southwest the area is bounded by sandstone, shale and conglomerate. Towards northwest, it is characterised by granite, grano-diorite and pegmatite. Towards north and northeast, it is bounded by slate and quartzite. Thus, the site is predominantly composed of quartzite and granite with overburden of sandstone and shale.

Shillong—The observatory at Shillong is situated at a height of 1600 m above mean sea level, over quartzite sandstone. Shillong massif is bounded by alluvial deposits of Brahmaputra valley in the north, the Dauki fault in the south and NS trending Dhubri fault on the western margin.

Pune—Aerial photographs and Landsat imageries supported by field observations have shown that the zone of fracturing along the west coast and inland extends upto Pune and neighbourhood. It also appears to favour the intrusion of basic dykes. The basaltic flows south of Pune have southwesterly dips of 1 in 100 to 1 in 300. The observatory is located at a height of 560 m above mean sea level (msl) over the Deccan traps.

Kodaikanal—The Kodaikanal observatory is situated at a height of 2347 m above msl in the peninsular India. The region is characterised by high grade granulites of south Indian shield and is in close proximity to the shear zones near Idduki and Idamalyar dams in Kerala.

3. Instrumental set-up

Fig. 1 is a block diagram showing the instrumental set-up for digital recording and off-line data processing. It essentially consists of a seismometer (S-7000), digital recorder (DR-200), digital playback (DP-260) manufactured by Sprengnether Ins., Inc. USA and a personal computer (PC/AT-80286) with

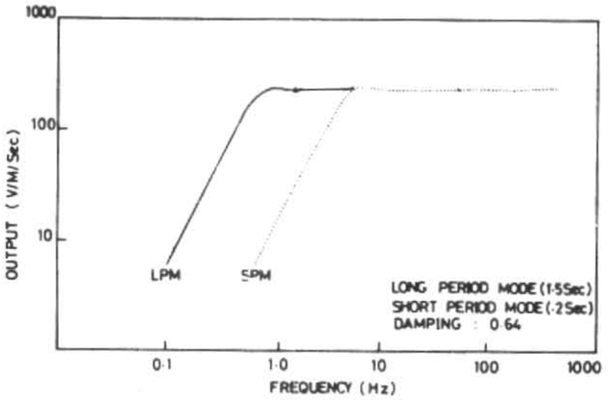


Fig. 2. Response characteristics of seismometer (S-7000)

peripherals for processing and reproduction of data. A brief description of these units is given below:

(a) Seismometer (S-7000)

The S-7000 seismometer is a suspended coil, fixed magnet, velocity transducer which has a variable natural period ranging between 0.2 to 1.5 sec, in two operating ranges of 0.2-0.5 sec and 0.5-1.5 sec. It can be operated either in horizontal or vertical mode in the same period range. Sensitivity of the seismometer is 230/V/m/sec with stability over a wide range of frequencies. The response curve is shown in Fig. 2. In all the recordings presented in this paper, the seismometer was operated in vertical mode with a free period of 1.0 sec.

(b) Digital event recorder (DR-200)

The DR-200 series event recorders using CMOS technology accept single or multiple (four) inputs to record either low level signals from a seismometer or high level signals from an accelerometer. The high dynamic range (108 dB) permits on scale recording of larger events with reasonably good resolution. Variable sampling rate (1 to 800 sps) allows applications ranging from high frequency microearthquake investigations to long period teleseismic studies and facilitates minimising the aliasing noise. For the purpose of recording near as well as distant shocks distinctly, the short term average (STA) and the long term average (LTA) durations were selected as 1.6 sec and 102 sec respectively at all the stations. In the ratio trigger mode the STA/LTA ratio was fixed at 9 dB at each station. The seven pole (42 dB/octave) anti-alias low-pass filter frequency was chosen as 12.5 Hz and accordingly the sampling rate was fixed (four times) at 50 sps at all the recording stations. The pre-event and post-event durations were taken as 4 and 100 sec respectively at all the stations. The instruments at Delhi, Pune and Kodaikanal were operated at a maximum gain of 1K, whereas those at Shillong and Dharmsala were operated at a low magnification of 0.1K because of spurious triggering due to line interference. The recorder has a built-in internal TCXO controlled clock.

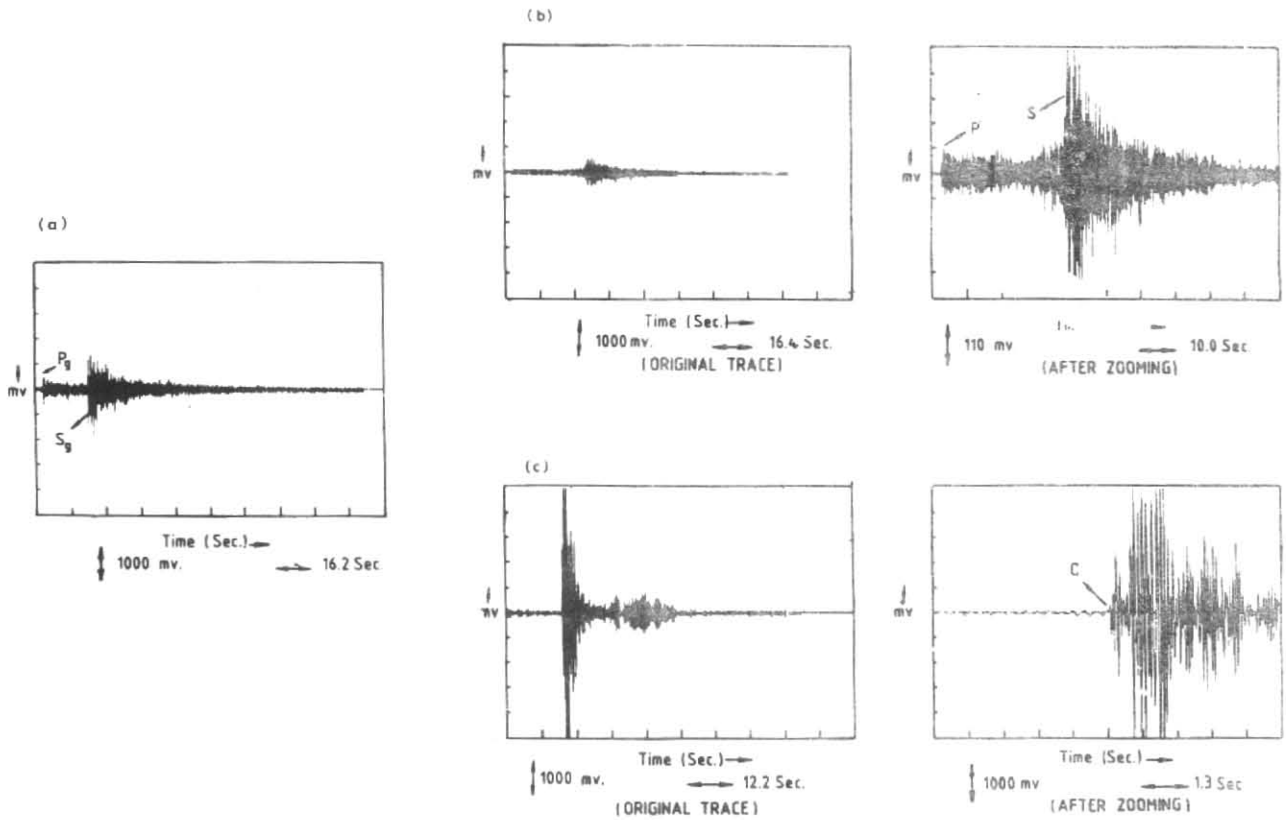
(c) Digital playback (DP-260)

The digital playback (DP-260) is designed around the RCA microbus microcomputer. The unit provides for an analog or digital playback of the data recorded in the cassettes. The analog output is through a built-in single channel strip chart recorder or four optional analog reproduce channels. The system operation is command-oriented through a front panel terminal or a host computer system in remote mode operation for direct data transfer *via* a standard RS-232 serial port.

4. Data retrieval and processing

The data recorded on cassette tapes consists of event header information of 122 bytes (maximum) written in ASCII followed by data blocks of 4096 bytes each written in hexadecimal ASCII. In case of multichannel recording, the data words are multiplexed. The 16 bit data word structure is divided into 1 time bit, 1 bit for channel indication, 2 bits for gain and 12 bits for sample. The data is recorded in a 4-track single sided (side-A only) non-serpentine format. On completion of one track, the tape automatically rewinds and selects the next track till the end of tape is reached.

A software package (called 'DPX') was used to retrieve the header information and sample output in millivolts for all the recorded events. The DPX first reads and transfers the raw data from DP-260 to the computer and then converts into binary event files. The processed data can then be stored as an event file in ASCII for future use. The DPX also enables remote control of DP-260 for rewinding the tape, selection of track, skipping of any desired number of events and reading the header/event data of the recorded shocks. The digital output can be displayed on the monitor as a seismogram with time (or corresponding sample number) and amplitude in millivolts of any identified phase. The software also features a facility to enable zooming/enlarging of any time window of the displayed seismogram for quick and accurate identification of the earthquake phases. Figs. 3 (a-c) shows typical seismograms retrieved through DPX for two earthquakes and a



Figs. 3 (a-c). Seismograms of selected events (a) Koyna event recorded at Pune on 8 July 1990 (01 H 56 M 07 S), (b) Earthquake near Burma (Lat. 24.6°N Long. 95.1°E; Magnitude 4.6; Focal Depth 120 kms) recorded at Shillong Observatory on 27 July 1991, (c) Deep Seismic Sounding explosion (Charge capacity of 225 kg) recorded near Burdwan, West Bengal on 7 March 1990 (18 H 31 M)

Deep Seismic Sounding (DSS) explosion in West Bengal, providing confidence in the software used.

5. Results and discussion

The spectra of seismic noise, presented in this study, mainly aim at estimating the predominant frequency characteristics of the ground at each site. For this purpose, it is necessary to consider a waveform consisting of purely the ambient ground noise only. The digital recording systems offer a trigger mechanism to initiate/cease recording the ground motion above/below a pre-determined threshold value, which is normally selected on the basis of the level of the ambient ground noise. The pre-event memory and post-event duration recordings, thus, provide a unique opportunity for studying the ground noise characteristics. The pre-event memory recording is relatively more free from signal and is, therefore, considered in the present study to compute the noise spectra. To start with, the time series is tapered by applying a Hamming window to reduce the effect of unwanted frequency components in the spectra arising due to sharp discontinuities. The time series is then subjected to Fast Fourier Transform and spectra obtained over a frequency range of 1-12 Hz. Day time recordings of one event each from all the five stations are considered to obtain the noise spectra presented in Fig. 4. However, no attempt has been made in this paper to study the variations in noise spectra with time of the day or season.

It may be seen from the spectrum for Delhi that the predominant frequencies occur near 1.6 and 5.0 Hz. Another small peak is also noted near 8 Hz. The spectrum for Dharmsala shows almost a similar pattern. Both these sites are characterised by relatively quiet locations away from main roads and could, therefore, be considered as representative of the basement hard rock with almost negligible surficial cover, similar to that considered as kind I in the building code of Japan.

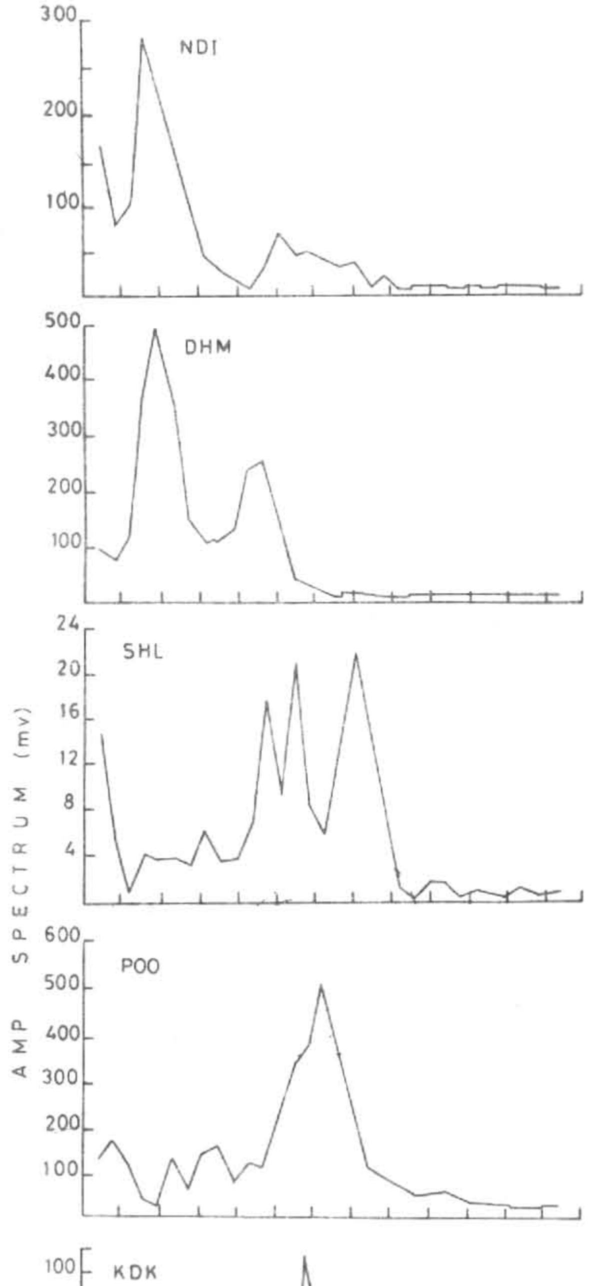


Fig. 4. Spectra of seismic noise

The spectrum for Shillong shows peaks around 3.0, 4.5, 5.5 and 7.0 Hz. The underground vault of the Shillong Observatory is situated almost at the same height as that of a road passing closeby (about 100 m) enabling the traffic noise to be effectively transmitted to the seismometer. Srivastava (1989) has studied the spectra of seismic noise from SRO at Shillong and also reported a peak around 5 Hz associated with the traffic disturbance. However, the results indicated some peaks between 0.75 and 1.2 sec (correspond to 1.3 and 0.8 Hz respectively) which was attributed to the rapid decrease of high frequency noise with depth. The spectral peak at 1.3 Hz could, therefore, be considered as characteristic of the site implying rocky conditions with a thin surficial layer which has amplified the observed high frequency noise. It may be mentioned that Herrin (1982) has found that the SRO system is limited by system noise above 4 Hz even at the quietest sites. The spectra found by Srivastava (1989) also showed a small peak between 4.2 and 4.6 sec which may be attributed to the microseisms generated from the oceanic areas. This is almost the same range of periods reported by Mathura Singh and Bhattacharya (1983) corresponding to the secondary microseisms associated with cyclonic storms over the Indian seas.

Tne spectrum at Pune shows a maximum peak around 6 Hz which may be attributed to the combined influence of the traffic vibrations and the effects of wind on the trees in the close proximity to the site. Smaller peaks are noted at 0.8, 2.3 and 3.5 Hz which could be characteristic of the underlying basaltic structure overlain by the traps. Since the distance of railway line at Pune is less than half a kilometre from the observatory, a question arises as to whether the noise spectrum is also influenced by passing trains. Sanford *et al.* (1968) have reported peaks in the power spectra ranging from 1.80 to 4.75 Hz depending upon the distance of the railway line, when the stations were located on consolidated tertiary or quaternary alluvium, but direct observations on traps are not available. On the other hand, vertical spring mass accelerations of road trucks, farm tractors, military transport, vehicles *etc* have power spectra showing peaks around 1.5 to 6 Hz with additional vibration on tire modes and axle bounce often extending from approximately 3 to 10 Hz. However, at Gauribidanur seismic array located on the Deccan shield over Archaean rocks with unweathered gneiss of 2 m upto the ground surface, the spectral peak has been found to be at 1 Hz with 2 nanometers as the median value corresponding to all time, *i.e.,* day and night spectrum (S. K. Arora, personal communication). It almost compares with that for Shillong site obtained through the borehole SRO system. In USA, an anomalous peak in the seismic noise spectrum near 2 to 3 Hz has been found to occur at many locations (Frantti

1963, Walker *et. al.* 1964, Robertson, 1965). Frantti *et al.* (1962) found that high noise stations, as a group, were those sites where recording was on alluvium, while low noise was characteristic of non-coastal stations in western and northwestern United States. However, the cause of anomalous phenomenon near 2 Hz could not be identified.

In the Indian region, spectral peak is observed at 2 Hz over Delhi and Dharmsala only, while it occurs near 6 Hz over Pune, Kodaikanal and Shillong, suggesting greater influence of cultural noise at the latter sites. Bache *et al.* (1986) studied high frequency seismic noise characteristics at the United Kingdom (UK) type medium aperture arrays, namely Eskdalemuir (Scotland), Warramunga (Australia), Yelloknife (Canada) and Gauribidanur (India) where digital recording is in operation since March 1979. It was found that in general, at all the arrays, the characteristic noise spectrum follows a linear trend above 2 Hz, with displacement amplitude slope varying from $f^{-1.7}$ to $f^{-2.5}$. However, GBA spectrum features flattening above 4 Hz, which is apparently due to locally generated high frequency noise, trapped near the surface. It was surmised that wind generated vibrations of large pylons and perhaps small trees in the vicinity could result in high frequency noise. Bungum *et al.* (1985) have reported that the quiet noise level above 2 to 3 Hz is nearly the same at various sites in southeastern Norway and Finland. This is not borne out from the results reported in this study for the Indian region.

It may be mentioned that Arora *et al.* (1992) carried out a noise survey during May 20-25, 1989 at Kaiga Atomic Power Project, 35 km off Karwar coast in Karnataka at four sites. They found that high frequency noise that interferes in signal detection is practically absent in Kulgi area, moderate at Idagundi and comparatively larger in Kumbarward province. These authors, have associated 1 sec period noise with oceanic microseisms, while the high frequency noise in the band of 4 to 8 Hz was attributed to the wind.

6. Conclusions

Noise spectra have been computed for five selected Indian stations where short period digital seismograph systems are in operation. The results have brought out marked similarity between Delhi and Dharmsala with spectral peak around 2 Hz and Pune, Kodaikanal and Shillong near 6 Hz exhibiting greater complexity in the underlying structure and larger influence of cultural noise. The noise spectra deduced from the SRO system at Shillong shifts to lower frequency (around 1 Hz) in agreement with a similar observation reported at GBA seismic array.

References

Arora, S. K., Bhat, M. K., Kulkarni, A. G., Basu, T. K. and Subbaramu, K. R., 1992, "Seismic noise measurement in the region around Kaiga atomic power project", *Bull. Ind. Soc. Earth. Tech.*, **29**, 1, pp. 17-33.

Bache, T. C., Marshall, P. D. and Young, B. J., 1986, "High frequency seismic noise characteristics at the four United Kingdom-Type arrays", *Bull. Seism. Soc. Am.*, **76**, 3, pp. 601-616.

Bungum, H. S., Mukkeltveit and Kvaerna, T., 1985, "Seismic noise in Fennoscandia with emphasis on high frequencies", *Bull. Seism. Soc. Am.*, **75**, pp. 1489-1513.

Evans, J. R. and Allen, S. S., 1983, "A teleseism specific detection algorithm for single short period traces", *Bull. Seism. Soc. Am.*, **73**, 4, pp. 1173-1186.

Frantti, G., Wills, D. E. and Wilson, J. T., 1962, "The spectrum of seismic noise", *Bull. Seism. Soc. Am.*, **52**, pp. 113-121.

Frantti, G., 1963, "The nature of high frequency earth noise spectra", *Geophysics*, **28**, pp. 547-562.

Herrin, E., 1982, "The resolution of seismic instruments used in treaty verification research", *Bull. Seism. Soc. Am.*, **72B**, S-61—S-67.

Kagami, H., Duke, C. M., Laiang, G. C. and Ohta, Y., 1982, "Observation of 1 to 5 seconds microtremors and their application to earthquake engineering, Part II. Evaluation of site effect upon seismic wave amplification due to extremely deep soil deposits", *Bull. Seism. Soc. Am.*, **72**, pp. 987-998.

Kanai, K., and Tanaka, T., 1961, "On microtremors VIII", *Bull. Earth Res. Insti.*, **39**, pp. 97-114.

Mathura Singh and Bhattacharya, S. N., 1983, "Amplitude spectra of microseisms generated by cyclonic storms", *Mausam*, **37**, 3, pp. 391-396.

Omote, S., Srivastava, H. N., Drakopoulos, J. and Tokumitsu, T., 1972, "Investigation of microtemors in the Akita plain in Japan", *Pure and Appl. Geophy.*, **99**, VII, pp. 85-93.

Robertson, H., 1965, "Physical and topographic factors as related to short-period wind noise", *Bull. Seism. Soc. Am.*, **55**, pp. 863-877.

Sanford, A. R., Carapetian, A. G. and Long, L. T., 1968, "High frequency microseisms from a known source", *Bull. Seism. Soc. Am.*, **58**, pp. 325-338.

Srivastava, H. N., 1989, "Performance characteristics of indigenously designed and imported seismographs", *Physics of the Earth and Planetary Interior*, **58**, pp. 19-27.

Walker, R., Menard, J. and Bogert, B., 1964, "Real time high resolution spectroscopy of seismic background noise", *Bull. Seism. Soc. Am.*, **54**, pp. 501-509.