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VII.2 Initial results from the NORESS High Frequency Seismic Element (HFSE)

The HFSE is an advanced seismic recording system, specially designed to record high frequency energy with high resolution and large dynamic range. The system, which is a self-contained, modular hardware package, has been designed and constructed by Sandia National Laboratories.

The HFSE provides for both single axis and three axis field selectable implementations. The single axis (vertical) configuration has the widest bandwidth and permits studying frequencies to above 100 Hz. The three axis (Z,N,E) configuration permits the studying of vertical-horizontal relational characteristics of frequencies to above 50 Hz. In the initial implementation, the three axis configuration has been chosen.

The digitizer is a Gould Inc. Enhanced Delta Modulation Encoder (EDME). The EDME provides 21 bits of dynamic range (120 dB) in a 24-bit format. The vertical axis EDME is configured as a dual sample rate device; both 125 and 250 Hz sampled data are provided to the system processor. The two horizontal EDMEs are configured as 125 Hz sample rate devices. The 250 Hz sample rate EDME incorporates a digital filter to obtain a usable bandwidth of 3-112 Hz. The 125 Hz sample rate EDME channels have a usable bandwidth of 3-56 Hz. The input voltage ranges are ±10 volts full scale for all channels.

The HFSE has been installed at the center site of the NORESS array, i.e., at 60.735 N, 11.541 E, at an elevation of 247 m above sea level. Data input is from a three-component short period seismometer of type Geotech S-3. The seismometer is emplaced in a 60 m borehole.

We note that the same seismometer is currently being used as one of the three-component sensors in the NORESS array (code FO). Thus, we have a possibility to verify the HFSE response in the frequency band where the two systems overlap (0-20 Hz).

The HFSE installation was conducted during October/November 1985, in cooperation between Sandia and NORSAR personnel. Data have been available at the NORSAR Data Center since late November 1985, and are currently being stored permanently on magnetic tapes.

We are currently conducting a systematic study of the spectral characteristics of HFSE-recorded seismic phases, and in this section we present a few representative examples, together with brief comments summarizing the most important features. For further detail, reference is made to Ringdal (1986).

The noise spectra shown in the following represent the noise prior to the P phase of each event, and have been estimated using the indirect covariance method. We first estimate the correlation function by splitting a long data record into many windows, calculating a sample correlation function for each window, then averaging the sample correlation functions. Typically, we use 20 windows, each of which is 5 seconds long. Because the earth noise has such a large dynamic range, we prewhiten it prior to estimating the correlation function with a low-order prediction-error filter. The spectrum is then estimated by windowing the correlation function with a 3-second Hamming window, then computing the Fourier transform. The spectral estimate obtained this way is compensated then for the effects of prewhitening and normalized to a 1-second window length.

Signal spectra have been estimated using the same technique, but with 4 overlapping windows, each of 7 seconds length. Start times of these windows are 3, 2, 1 and 0 seconds before signal onset, respectively. Thus we achieve a smoothing of the signal spectra while retaining compatibility with the noise spectra.

Fig. VII.2.1 shows, as an example, uncorrected P-wave spectra for 4 regional P-phases, together with spectra of the preceding noise. A noteworthy feature is distinct noise peaks at selected frequencies. The strong peak around 30 Hz apparently reflects noise interferences caused by mechanical equipment installed in the NORESS hub (fans, etc.), and is not thought to represent any malfunctioning of the HFSE, nor actual earth noise. The peaks occasionally seen at 6 and 12 Hz are typical of daytime hours, and seem to be generated by a sawmill located about 15 km from the site. With regard to the signal spectra shown, the most noteworthy feature is the considerable high frequency P-energy, across the entire HFSE bandwidth, for the two closest events.

Fig. VII.2.2 shows, schematically, a suite of smoothed P-wave spectra representing typical regional events, at various distances, recorded at the HFSE. The figure has been compiled on the basis of about 100 regional events, and represent average spectra over all azimuths, scaled to magnitude $M_L = 3.0$.

The figure illustrates the strong distance-dependence of high frequency signal energy. Of particular interest is the observation that the signal and noise spectra are approximately parallel across the entire frequency band for distances out to about 500 km. Thus, within this distance range, the possibility of utilizing high frequencies for event characterization are excellent even at very low magnitudes. At further distances, the signal spectra start to merge with the noise (the crossover point being dependent on distance as well as magnitude). E.g., at 900-1000 km, there seems to be significant SNR at M_L = 3 for frequencies up to about 25 Hz.

It must be noted that we have observed considerable spectral variability with source type and location, even within limited distance ranges. Thus Fig. VII.2.2 must be interpreted accordingly. We are currently in the process of studying further these spectral variations, and the results reported here are of preliminary nature.

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Reference

Ringdal, F. (1986): Quarterly Technical Report, High Frequency Signal Propagation Studies, NORSAR, Kjeller, Norway.

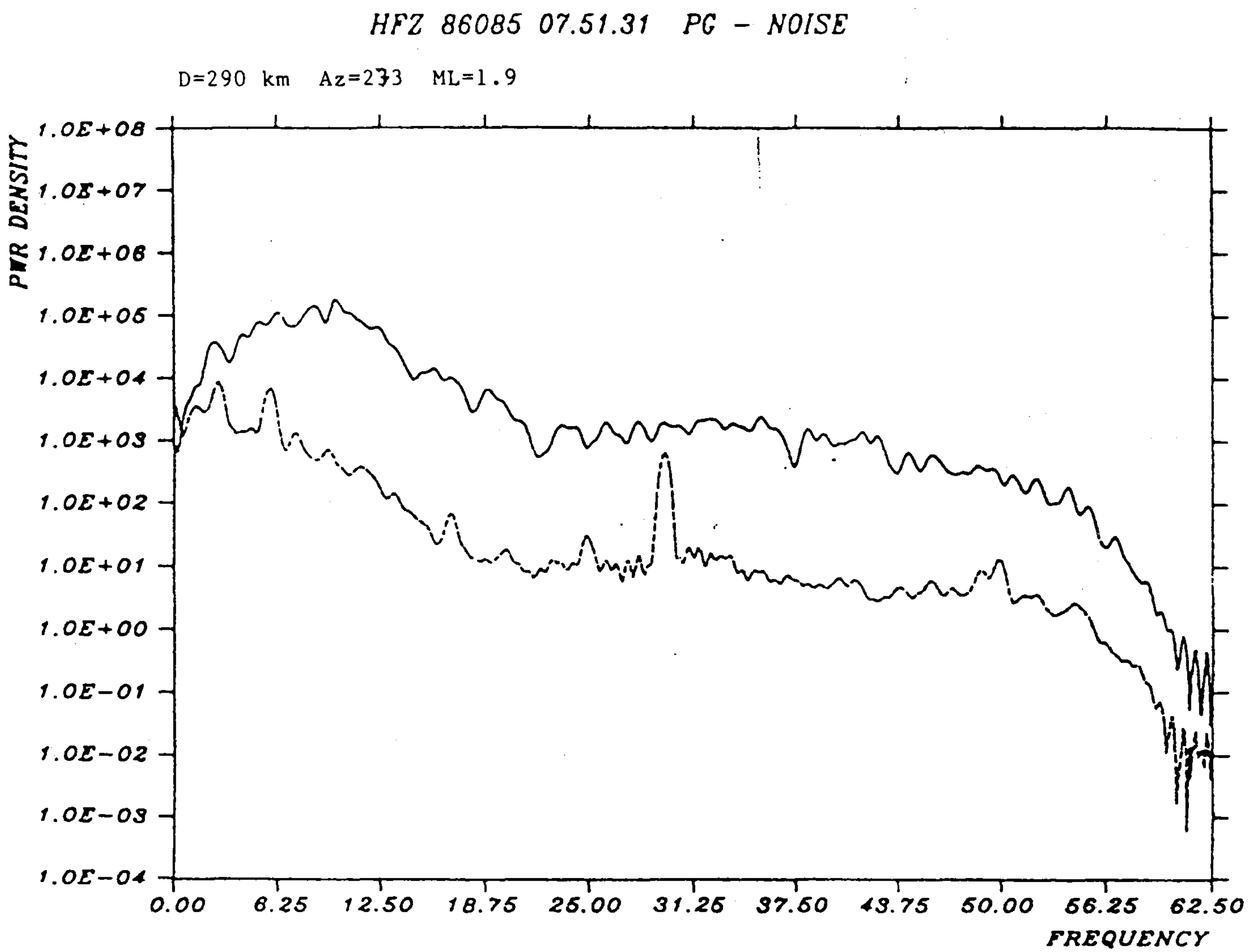

Fig. VII.2.1a-d HFSE uncorrected P-wave and noise spectra (SPZ component) for four regional events. Event parameters (data date, time, distance, azimuth, M_L, source type, if known) are given in each case. Note the gradual decline of high frequency signal energy with increasing distance.

HFZ 86091 09.58.08 PC - NOISE

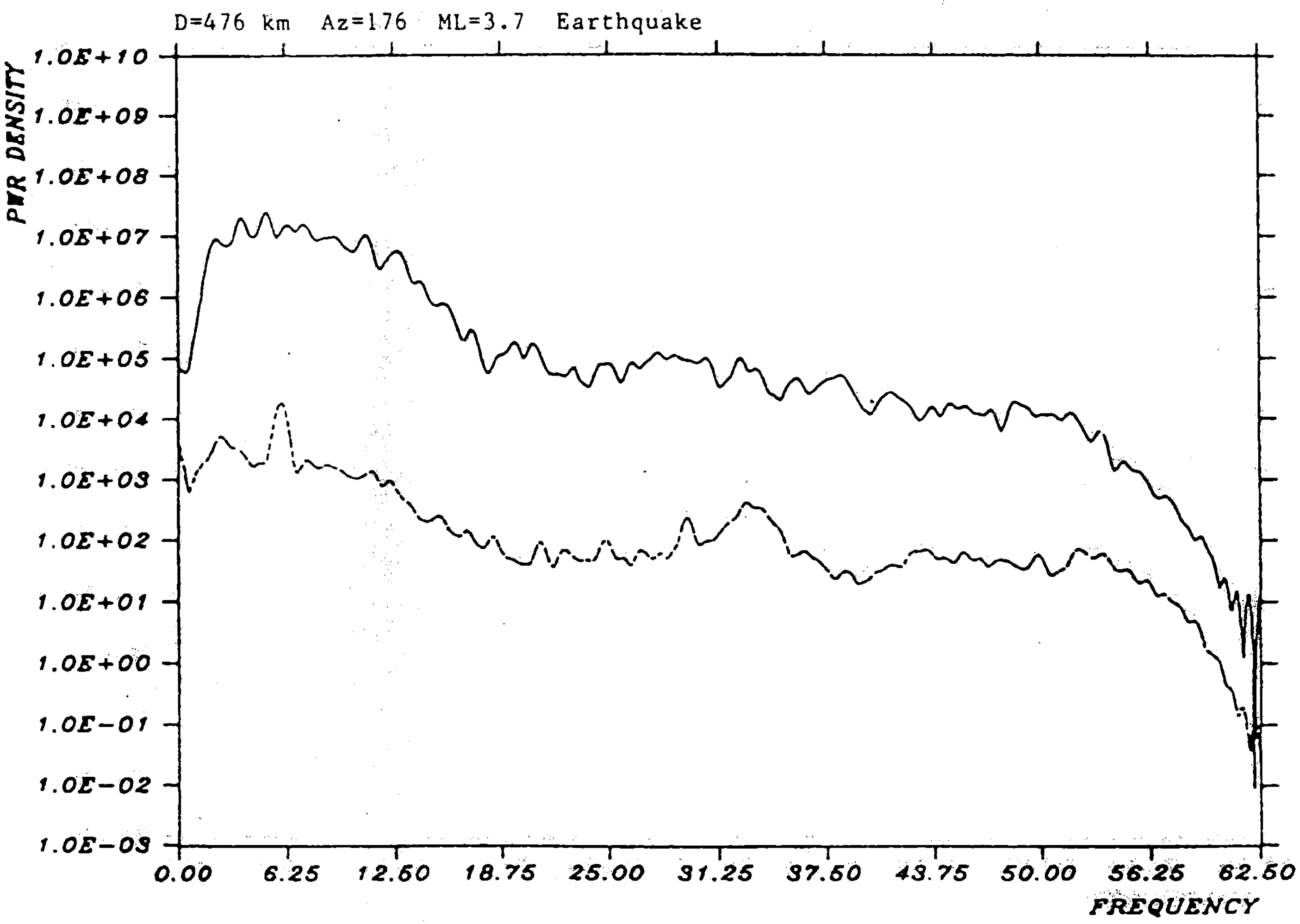

Fig. VII.2.1b

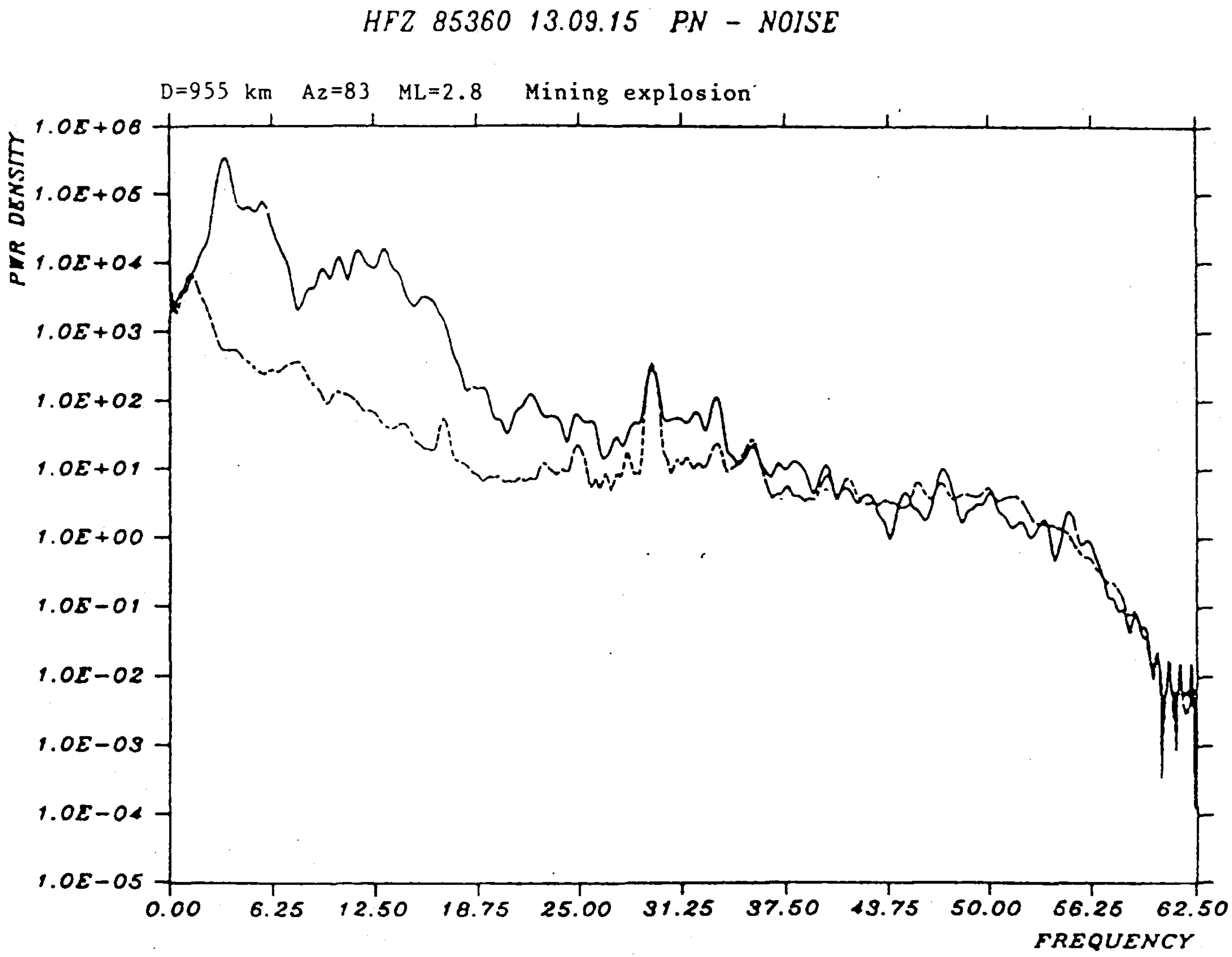
HFZ 85360 13.09.15 PN - NOISE
D=955 km Az=83 ML=2.8 Mining explosion
PWR DENSITY
1.0E+08
1.0E+06
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
1.0E-05
0.00
6.25
12.50
18.75
25.00
31.25
37.50
43.75
50.00
56.25
62.50
FREQUENCY

Fig. VII.2.1c

HFZ 86054 06.16.57 PN - NOISE

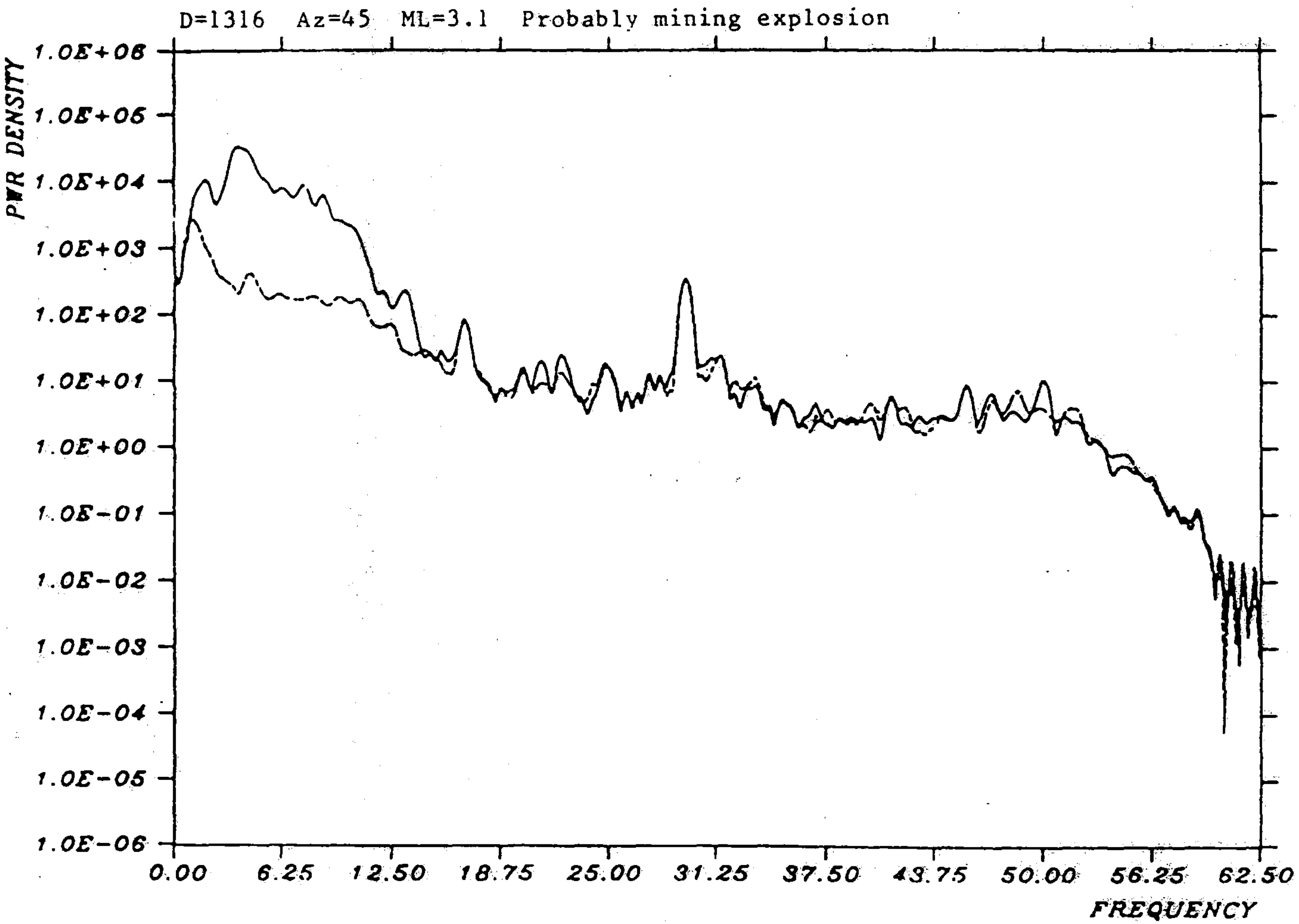

Fig. VII.2.1d

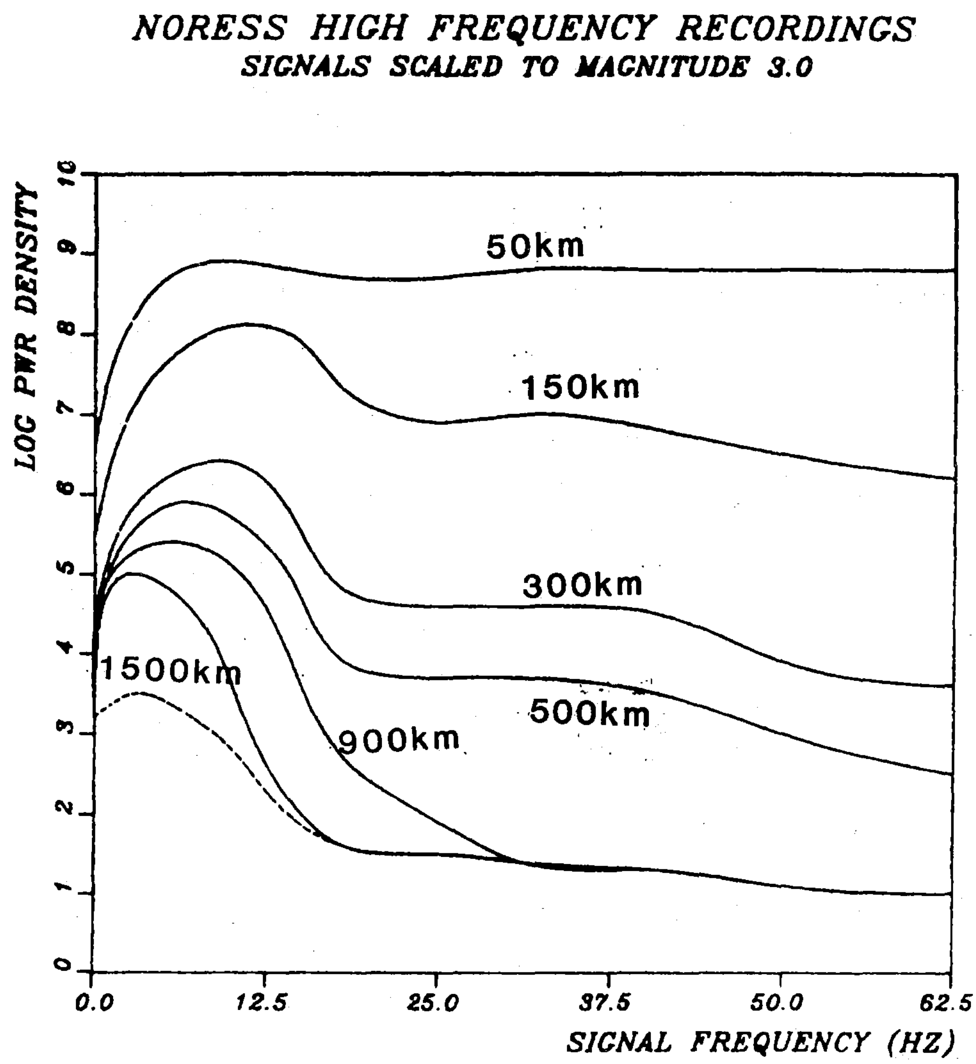

Fig. VII.2.2 Schematic illustration of high frequency P-wave spectra recorded at the HFSE, at various regional distances. The figure represents average features of about 100 regional events at various distances and azimuths, all scaled to M_L = 3.0. A typical noise spectrum is shown as a dotted line. Note that a considerable smoothing has been applied to the spectra, and that there are significant variations between individual events, even within limited epicentral areas.