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Seismic Noise at 2 Hz in Europe*

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Abstract. Seismic noise spectra at many sites in Europe exhibit a sharp peak between 2.0 and 2.1 Hz. Similar peaks have previously been reported from the United States. The spectral peak can be resolved into two monochromatic components, the slightly varying frequencies of which are, respectively, those of the Western and the Eastern European power networks, divided by 24 (this is 2.083 Hz on the average). The sources of both components apparently are heavy machines driven by synchronous electric motors with 125 rpm. One source of this type, a large piston compressor, has been identified. The observed noise level varies periodically as a result of interference of the two components, and these variations are essentially synchronous at KHC (Czechoslovakia), BUH (W. Germany), WLS (France) and others. It is not yet understood how the signal propagates over distances like that from Czechoslovakia to France (400 km).

Key words: Seismic 2 Hz Noise in Central Europe – Spectral Properties, sources, propagation.

Introduction

Extensive investigations of short-period seismic noise were carried out in many countries over the past ten years. One interesting result was the occurrence of a sharp peak with a stable frequency near 2 Hz in the noise spectra of mutually very distant stations, especially of stations with a low level of manmade noise. For instance, a spectral peak between 2.0 and 2.1 Hz was observed at WMO and CPO (U.S.), KHC (Czechoslovakia), BUH (W. Germany), WLS (France), and recently at NORSAR (Norway) – see Bogert, Menard and Walker, 1964; Kárník and Tobyáš, 1961; Plešinger and Wielandt, 1972; Hjortenberg, 1973.

High resolution spectrograms, whereever they could be performed, resolved the peak into one or more line components. Usually some other lines are also visible in the spectrograms which clearly are of local origin. Most of the lines including the 2 Hz lines in the U.S. have been observed to

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start and stop abruptly and were interpreted as industrial noise (Bogert *et al.*, 1964), but the European 2 Hz line was always present.

Various assumptions have been made to explain the microseismic anomaly at 2 Hz, including: widespread artificial sources (Kárník and Tobyáš, 1961; Frantti, 1963; Bogert *et al.*, 1964), an extremum in the group velocity at the recording site (Frantti, 1963), a filtering mechanism for surface waves (Douze, 1967), or a common subsurface source (Douze, 1967). Our own investigations reported in this paper show that the 2 Hz noise in Europe is manmade, but its widespread occurrence indicates that a not yet understood propagation mechanism may contribute to the 2 Hz anomaly.

Amplitude Observations

At many quiet sites in Czechoslovakia, e.g. the seismic station Kašperské Hory (KHC), the 2 Hz signal is the main contribution to the seismic noise besides the common 4 to 9 sec marine microseisms (Kárník and Tobyáš, 1961; Kulhánek, 1966; Holub, 1969). It can be seen on seismic records as a sinusoidal oscillation of slowly varying amplitude, superimposed on the slower 4 to 9 sec waves. The mean amplitude at KHC is 8 nm peak-to-peak. This has been observed for over 10 years but, in spite of considerable effort (Fučík, 1970), the source has not been found. Considering the widespread occurrence, the persistent amplitude variations (Plešinger, 1971), and the

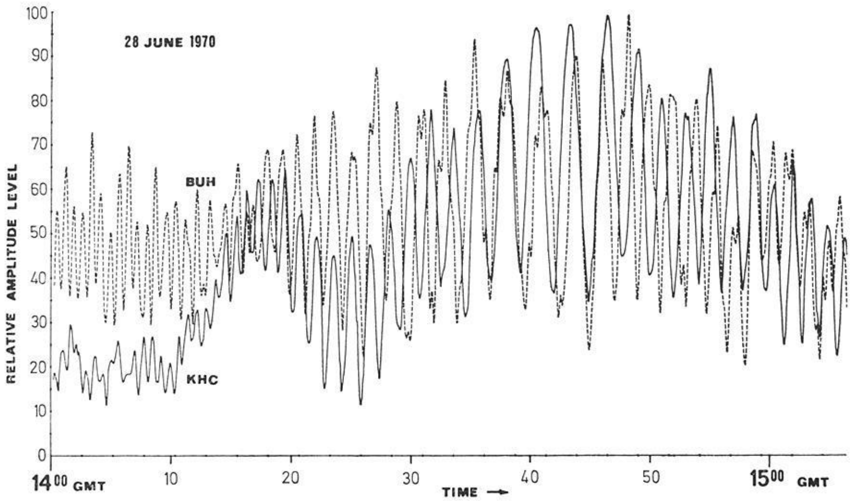

Fig. 1. Superimposed amplitude records of the 2.08 Hz microseismic signal at BUH (W. Germany) and KHC (Czechoslovakia). The period of the amplitude oscillations is the same at both stations, but there is no constant phase shift or propagation delay

fact that the signal was never switched off, the simple explanation as man-made noise was rejected at that time.

The question was raised again when obviously the same signal was observed at BUH (Black Forest, W. Germany) with a mean amplitude of 1 nm peak-to-peak. It was extracted from the general noise by narrow band-pass filters and recorded for several months. The amplitude variations turned out to be coherent with those at KHC. By visual inspection of the original records the coherence is good over hours and even days, but the mathematical correlation coefficient is rather low for samples longer than 20 min, mainly due to a frequency-dependent phase shift. Fig. 1 shows superimposed amplitude records from the two stations more than 300 km apart.

It has not been possible to determine uniquely a propagation delay from the amplitude records, nor to find a permanent direction of ground motion or of propagation for the seismic signal itself. The latter is not coherent over distances greater than 0.5 km.

High Resolution Spectrograms

The amplitude variations of the 2.1 Hz signal look very much like the interference of two continuous waves of slowly varying frequency, and an effort was made to resolve these. A frequency resolution of 0.001 Hz was necessary to separate the two hypothetical signals giving beat periods up to 1000 sec. To achieve this, a "Sonagraph" (Kay Electric Co.) was equipped with an auxiliary motor which revolved the drum once in 30 hours and thus produced the desired resolution in the frequency range 0.00—0.12 Hz. The telemetered seismic signal from BUH was prefiltered, mixed down into this range by chopping it with 2 Hz from a quartz clock, and recorded 24 hours for a playback. The result is shown in Fig. 2. The

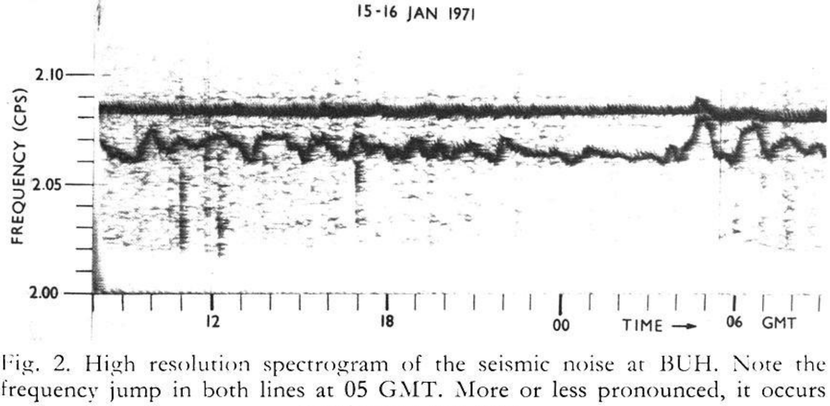

Fig. 2. High resolution spectrogram of the seismic noise at BUH. Note the frequency jump in both lines at 05 GMT. More or less pronounced, it occurs regularly at that time

two components of the signal are clearly visible, one being rather stable at 2.083 Hz, the other less stable and somewhat lower in frequency. The frequency difference between the two lines as recorded at BUH is exactly the frequency of the above-mentioned amplitude oscillations both at BUH and at KHC. Later it became clear that the irregular frequency shifts of both lines were statistically correlated with daytime. It was further noticed that they were in suspicious coincidence with those of the Western and the Eastern European synchronized electric power networks, and that the seismic frequency of 2.083 Hz was just the ac frequency, 50 Hz, divided by 24. For the "western" component, this has finally been established by recording the seismic and the divided electric signals at the same time. The "eastern" component, recorded at BUH and WLS, has been compared with the "eastern" ac frequency recorded directly at Prague. Fig. 3 demonstrates that the frequency shifts are identical.

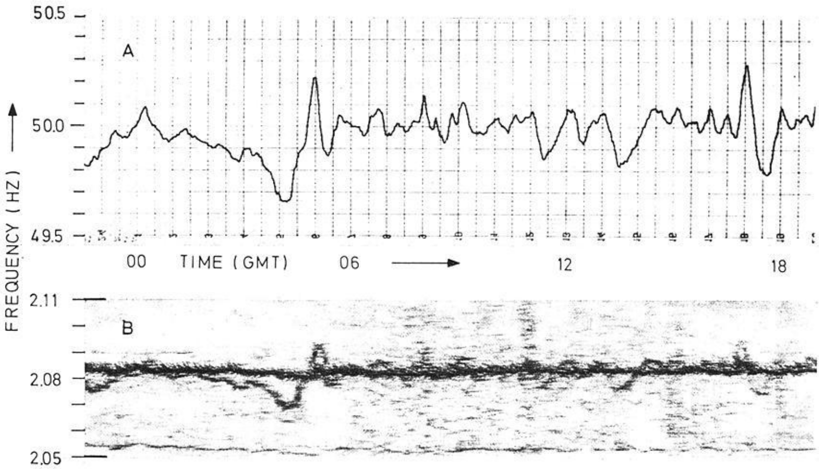

Fig. 3. (A) Frequency of the Eastern European electric power network, recorded at Prague on March 20, 1973. (B) Spectrogram of the seismic noise at BUH (W. Germany). Unfortunately, those noise spectrograms for which records of the eastern ac line frequency are available are not the clearest ones, but they leave no doubt that the less stable component of the 2 Hz noise in Southwestern Germany originates from machines powered by the Eastern European network

Sources of the 2 Hz Noise

At a new seismic station near Ludwigshafen, W. Germany, the stable 2 Hz component was found to be predominant, and there the seismic signal showed a constant phase relation to the ac line. A large piston compressor at Ludwigshafen, driven by a synchronous motor and generating intense 2.083 Hz vibrations, was identified as the major source of the stable component. A source of the less stable, "eastern" component has not yet been identified, but it is known that in Czechoslovakia several synchronous 3 to 5 megawatt motors with 125 rpm are in continuous duty.

We have also considered the possibility that the signal could be radiated synchronously from some or all electric power plants, but no evidence has been found for this. A spectral peak near 2.1 Hz is observed in the seismic noise near some power plants in Czechoslovakia, but when one comes really close to the generator block it disappears in a more continuous noise spectrum. Certainly power stations themselves cannot be a main source of the 2 Hz noise.

Propagation

It is surprising that industrial noise at 2 Hz can be observed over 400 km. Partly this may be explained by electric instead of seismic propagation, but in any case the "eastern" noise has to propagate seismically over 400 km into France. It is not yet clear whether this is "normal" — i.e. can be explained by simple P,S or surface waves —, or whether a special propagation mode has to be assumed. Earthquake records do not indicate a propagation anomaly near 2 Hz, but in the background noise there clearly is this anomaly, both in Europe and in the U.S. The simplest explanation would be that there exists a widespread type of machines with 125 rpm (120 rpm in the U.S.) which are especially effective as seismic sources, whereas at other frequencies no such machines exist. But of course locally strong industrial noise is generated at other frequencies as well, and the question arises why that noise does not propagate over hundreds of kilometers. So it seems worthwile to investigate the alternative explanation that frequencies near 2 Hz can propagate over the distances considered here with lower attenuation than others. This does not necessarily imply the existence of a "channel" or waveguide for 2 Hz which in fact has no place in our present conception of crust and upper mantle, but could involve irregular scattering as well. All that can be said for now is that surface propagation is very unlikely for different reasons, one of which is the observation of Douze (1967) that the 2 Hz noise, unlike other short-period microseisms, was present with its full surface amplitude at a depth of 3048 m.

Final Remarks

If industrial seismic noise can propagate over 400 km with an amplitude large enough to be detected by simple bandpass filtering, we can see no reason why this noise could not be extracted at much more distant places, by digital processing, as a peak in an otherwise continuous spectrum of natural noise. At least, this explanation should be checked before claiming extraterrestrial sources. On the other hand, the 2 Hz anomaly is not really worldwide. In Southern Portugal, a region with an extremely low level of short-period microseisms, where we hoped to determine the phase velocity of the 2 Hz noise, it was not present at all, nor was there any other anomaly in the short-period noise. Again, this could be caused simply by the distribution of sources, but it could also depend on geologic or tectonic structures and thus present a tool to investigate these when the propagation mechanism will be understood.

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