NORSAR

ROYAL NORWEGIAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

Scientific Report No. 1-79/80

SEMIANNUAL TECHNICAL SUMMARY 1 April—30 September 1979

By
H. Gjøystdal (ed.)

Kjeller, 15 November 1979

VI.4 An Experimental Small Subarray within the NORSAR Array

One of the principles governing the design of the NORSAR array was that distances between instruments should be so that ordinary beamforming should give near to optimum gain in SNR for teleseismic events, which means that the distances should be large enough to give a low noise coherency (at around 1 Hz) and small enough to maintain a high signal coherency. This resulted in distances within each subarray of about 3 km, and it was soon discovered that this gave very low signal coherencies for regional and local events. An interesting consequence of this is that the 'incoherent' or envelope beamforming principle, which has been developed and implemented in the NORSAR online processing system as a means to overcome the incoherency between subarrays (Ringdal et al, 1974), might be applied with favorable results also within subarrays.

With the recent increased interest for regional and local events in a discrimination context, it was decided to implement, for experimental purposes and for a limited time period, a test subarray with very small station distances. The subarray became operational on 12 October 1979, and it consists of 6 seismometers as shown in Fig. VI.4.1, with station distances from 125 to 2051 meters. A change from 5 to 8 Hz lowpass filters was implemented on 23 October 1979.

Using these new data, we have started an analyzing program both on noise and signal characteristics. In Table VI.4.1 we give noise coherency values for four frequencies at one octave difference (0.5, 1.0, 2.0 and 4.0 Hz), and in order of increasing station distances. The results for the two middle frequencies are also plotted in Fig. VI.4.2, and coherency and phase vs. frequency for one particular combination is shown in Fig. VI.4.3. The block-averaging method of direct spectral estimation has been used, with 20 blocks each of 512 samples of 20 Hz data, amounting to a total of 8.53 minutes. With that much data the bias is relatively small, so that we expect 90% of the uncorrelated values (observed coherence for true zero coherence) to fall in the range 0.05 to 0.35 (Amos & Koopmans, 1963). Moreover, a frequency smoothing has also been applied, by averaging the output values into three estimates per octave.

The noise results show that the coherency (note that we use the so-called 'root coherence') for 0.5 Hz is maintained above the random level out to distances of about 2.3 km, for 1.0 Hz to 1.3 km, for 2.0 Hz to 0.7 km and for 4.0 Hz to about 0.4 km. Those values follow quite closely the regression

$$\log \Delta = 0.11 - 0.83 \log f$$

where Δ is distance in km and f is frequency in Hz. Of course, it is not known to which extent this formula will apply for frequencies outside the range 0.5-4.0 Hz, but it is known that the derived coefficients will not necessarily be valid at other times. The latter point is an effect of the large time variations expected in the level, propagating characteristics, and coherency of the seismic noise (cf. Bungum et al, 1971). A preliminary frequency-wavenumber analysis of our new data indicates that there is a significant amount of propagating noise at frequencies at least up to 1.0 Hz, with phase velocities in the order of 4-5 km/s.

We have also started investigations of signal characteristics across the new subarray, and Fig. VI.4.4 shows the Lg waves from an event about 200 km away (17 October 1979, 09.58 GMT, 60.3^{o}N, 7.5^{o}E). While signal coherencies for Lg waves previously have been very low for the distances in the ordinary NORSAR geometry, we see now that the signal similarities in the first few cycles are quite high, and especially so for the two closest channels, 2 and 6. For the Lg coda the coherence seems to be maintained at a reasonably high level only out to distances of about 400-600 m. The signal frequency is around 3 Hz, and at this frequency the noise coherency is close to random also at 500 m, which indicates that this may be a critical distance for 'coherent' processing of Lg waves. Computed coherencies for the waves in Fig. VI.4.4 are shown in Fig. VI.4.5, where the average coherence between all channel combinations is plotted. With the present large variation of distances (cf. Table VI.4.1) the standard deviation is also quite large, and it is only in the frequency range from about 1.5 to 3.0 Hz that the coherency is kept well above the random level, which in this case is much higher than for the noise analysis.

This work will now proceed with more detailed and thorough investigations of both signal and noise characteristics. It is possible that the array will be extended from 6 to 11 seismometers, all within the old subarray 06C.

H. Bungum
S. Mykkeltveit
O.A. Sandvin

References

Amos, D.E., and L.H. Koopmans, 1963: Tables of the distribution of the coefficient of coherence for stationary bivariate gaussian processes, Sandia Corporation Monograph SCR-483.

Bungum, H., E. Rygg and L. Bruland, 1971: Short-period seismic noise structure at the Norwegian Seismic Array, Bull. Seism. Soc. Amer., 61, 357-373.

Ringdal, F., E.S. Husebye and A. Dahle, 1974: P-wave envelope representation in event detection using array data, in: Exploitation of Seismograph Networks (ed. K.G. Beauchamp), Nordhoff-Leiden, 353-372.

Pair	Distance (m)	Noise Coherency 0.5 Hz	1.0 Hz	2.0 Hz	4.0 Hz
2-6	125	1.00	.99	.96	.86
1-2	303	.98	.96	.72	.54
1-6	408	.95	.91	.54	.41
3-4	603	.88	.86	.32	.26
1-4	724	.92	.77	.35	.25
2-3	750	.88	.74	.38	.32
3-6	809	.89	.71	.34	.30
2-4	827	.90	.70	.25	.27
1-3	875	.80	.71	.30	.25
4-6	945	.87	.64	.27	.30
1-5	1180	.79	.41	.29	.32
2-5	1400	.68	.36	.29	.25
5-6	1432	.64	.35	.29	.27
4-5	1730	.59	.25	.27	.23
3-5	2051	.36	.25	.27	.24

Table VI.4.1

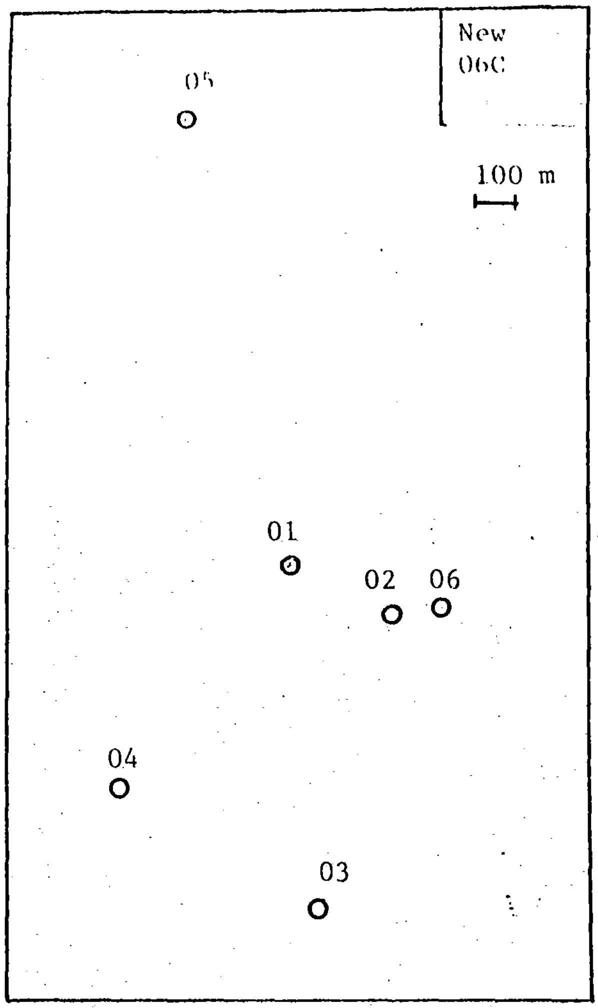

Fig. VI.4.1 Geometry of the new experimental small subarray inside the old subarray 06C. The data are transmitted over the old lines from 06C, with station 2 being unchanged. The old stations 1, 3, 4, 5 and 6 are for the time being not giving data.

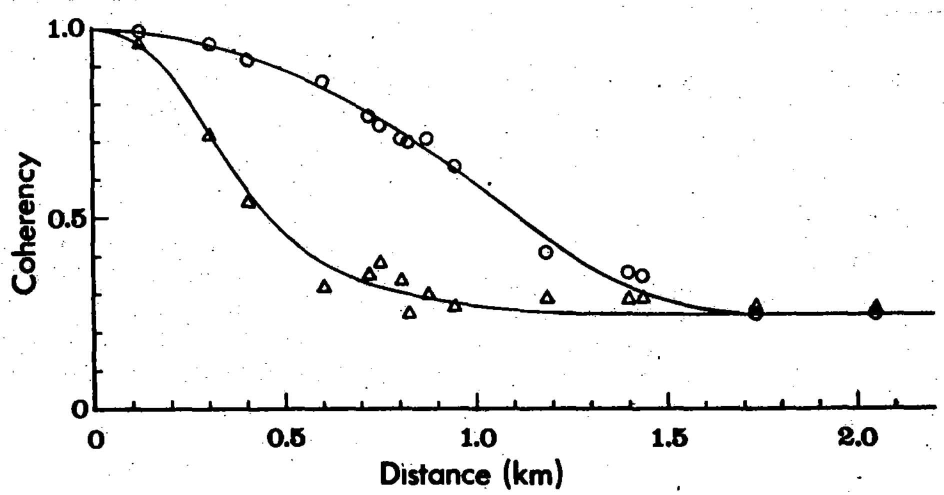

Fig. VI.4.2 Noise coherency vs distance for 1.0 Hz (circles) and 2.0 Hz (triangles). The estimates are obtained from 8.5 minutes of 20 Hz data, with 40 degrees of freedom, and an additional frequency smoothing has been applied by averaging over a frequency band of ± 0.17 octaves.

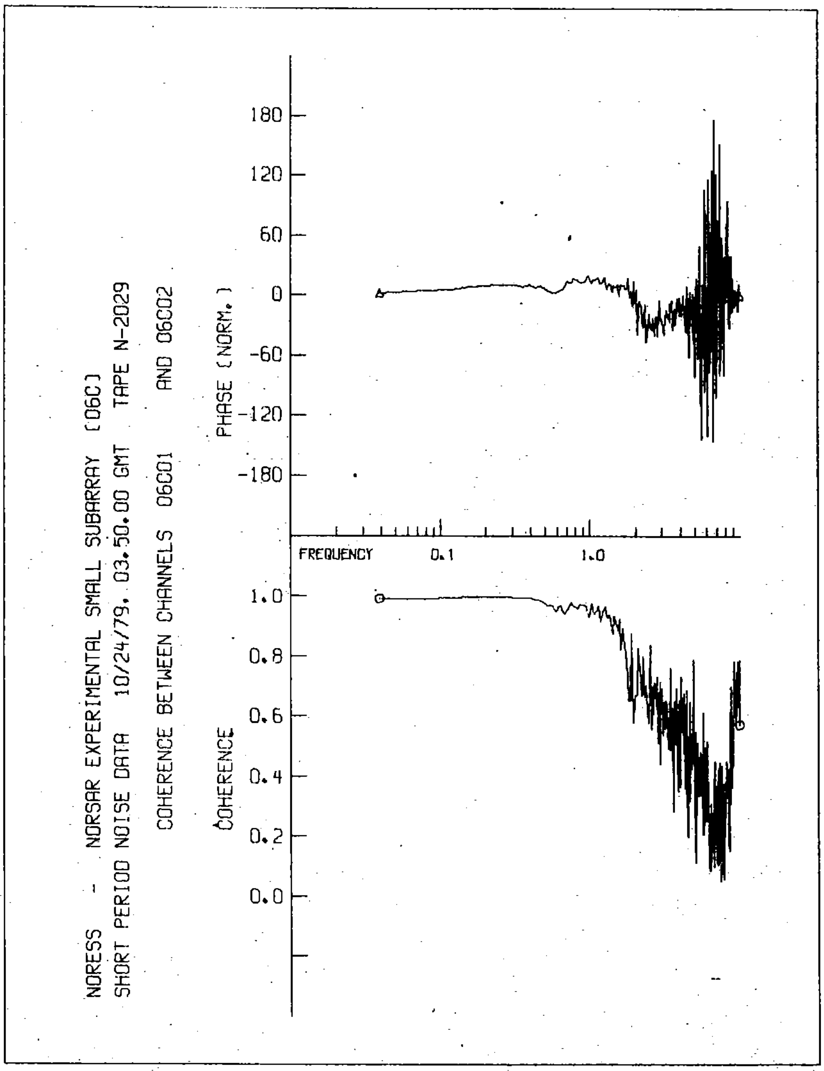

Fig. VI.4.3 Noise coherencies and phase lags vs frequency for channel combinations 1-2, with 303 m separation. The results in Table VI.4.1 and in Fig. VI.4.2 are taken from such calculations for all possible channel combinations, only with an extra frequency smoothing.

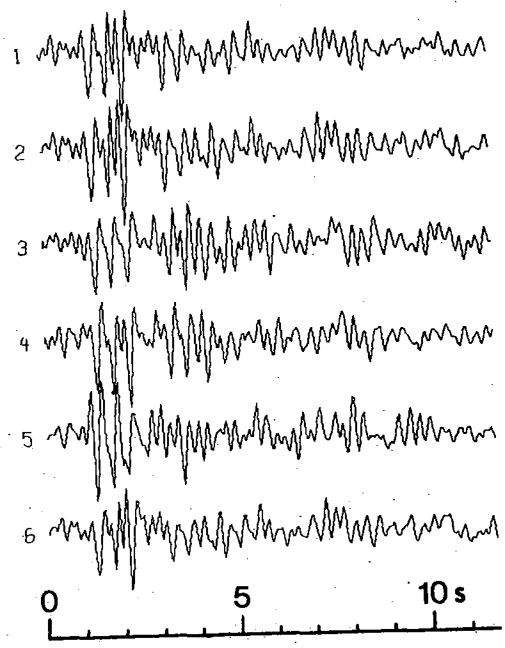

Fig. VI.4.4 Lg waves from a local event 200 km away (see main text).

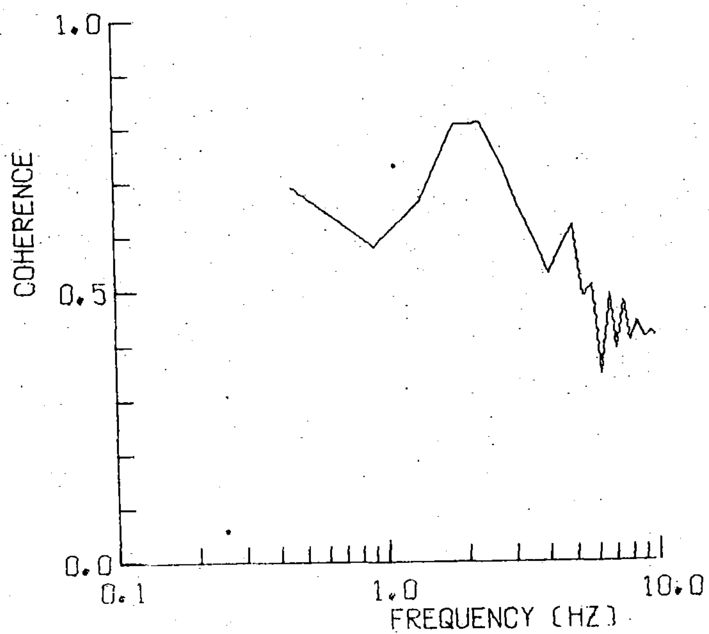

Fig. VI.4.5 Signal coherency for the data in Fig. VI.4.4. The length of the time window was 10 sec and the maximum lag in cross-correlation 15%, corresponding to about 6 degrees of freedom.