NORSAR

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N. SIGNAL-NOISE CLASSIFICATION

When an event has triggered the NORSAR automatic event detector, the analyst is faced with the problem of deciding whether this is earthquake- or explosion-generated seismic signals or just correlated noise. His data are the seismograms from the 22 subarrays, filtered and time-shifted according to the estimated epicenter, and the array beam, the phased sum of the sensors, which has a signal-to-noise ratio about 13 dB better than the individual subarrays. Together with this he uses his experience about the signal shape, the subarray amplitude distribution, detectability and seismicity in the actual area. In most cases the signal-to-noise ratios on the subarray level are high enough to see the incoming P-wave on all or some of the subarrays, and the decision is easily made. But when the signal-to-noise ratio is so low that only the beam and maybe a few subarrays have a visual signal, then the analyst must use other information as a basis for a decision.
As an aid to the analyst, three different statistical tests were implemented in the Event Processor in December 1974 to test the hypothesis whether the triggering wavelet is correlated noise or a real seismic signal. The test statistics are calculated for events with signal-to-noise ratios in an interval just above the (time-varying) prethreshold. One test statistic considered is the Sign-bit Semblance test which checks on the signal similarity between subarrays. Another is a Binomial test which checks on the sign distribution of least square amplitude weights calculated for the subarray beam traces. The third test statistic is a Student's t-test which checks on the distribution and size of subarray beam amplitude weights.

The amplitude weights are an estimate of the amplitude factor, γ_j, in the model $Y_j = \gamma_j S+n_j$, where Y_j is the recorded data on the j-th sensor, S a signal part and n_j a noise part (Fyen et al, 1975). For noise wavelets, the amplitude weights will be random in sign and size, while for P-waves the $\hat{\gamma}_j$-weights are expected to match the amplitude pattern in the region in question. However, for events with a signal-to-noise ratio as small as 3.6-4.0 units, the $\hat{\gamma}$-weights contain reliable amplitude information for the "best" subarrays only, and the correspondence between the observed $\hat{\gamma}_j$-weights and the known amplitude pattern for larger earthquakes is small, a problem which will be investigated further. Also for some extreme cases, noise has the same characteristics as an earthquake signal, as seen in Fig. N.1 where the test statistics accepted the event, but these cases may be eliminated by the anlyst due to his experience of earthquake occurrence and signal shape.

Another type of events which give test statistics results high above the thresholds are events with magnitudes below 4.0 located on the west coast of America and mid-Atlantic Ridge, where NORSAR normally only detects earthquakes above magnitude 4.6. These events are correctly classified by the analyst as being correlated noise and represent most of the statistical false alarms. For events having their origin to the east of NORSAR, we did a case study of weak Japan events. A list of events located in the Japan area, including both cases classified as noise and cases classified as earthquakes, was sent to Japan Meteorological Agency (JMA). Out of 36 events listed, 20 NORSAR-reported earthquakes were confirmed by JMA-stations, and 5 of these earthquakes were classified as noise by the test statistics (missed detections). Out of the remaining 16 events, 11 were not reported in the NORSAR bulletin, nor reported by any JMA-station, and 4 of these were classified as signals by test statistics (false alarms). The 5 other events were out of range for the JMA-stations. After 5 months of processing experience there has been no significant increase in the number of earthquakes

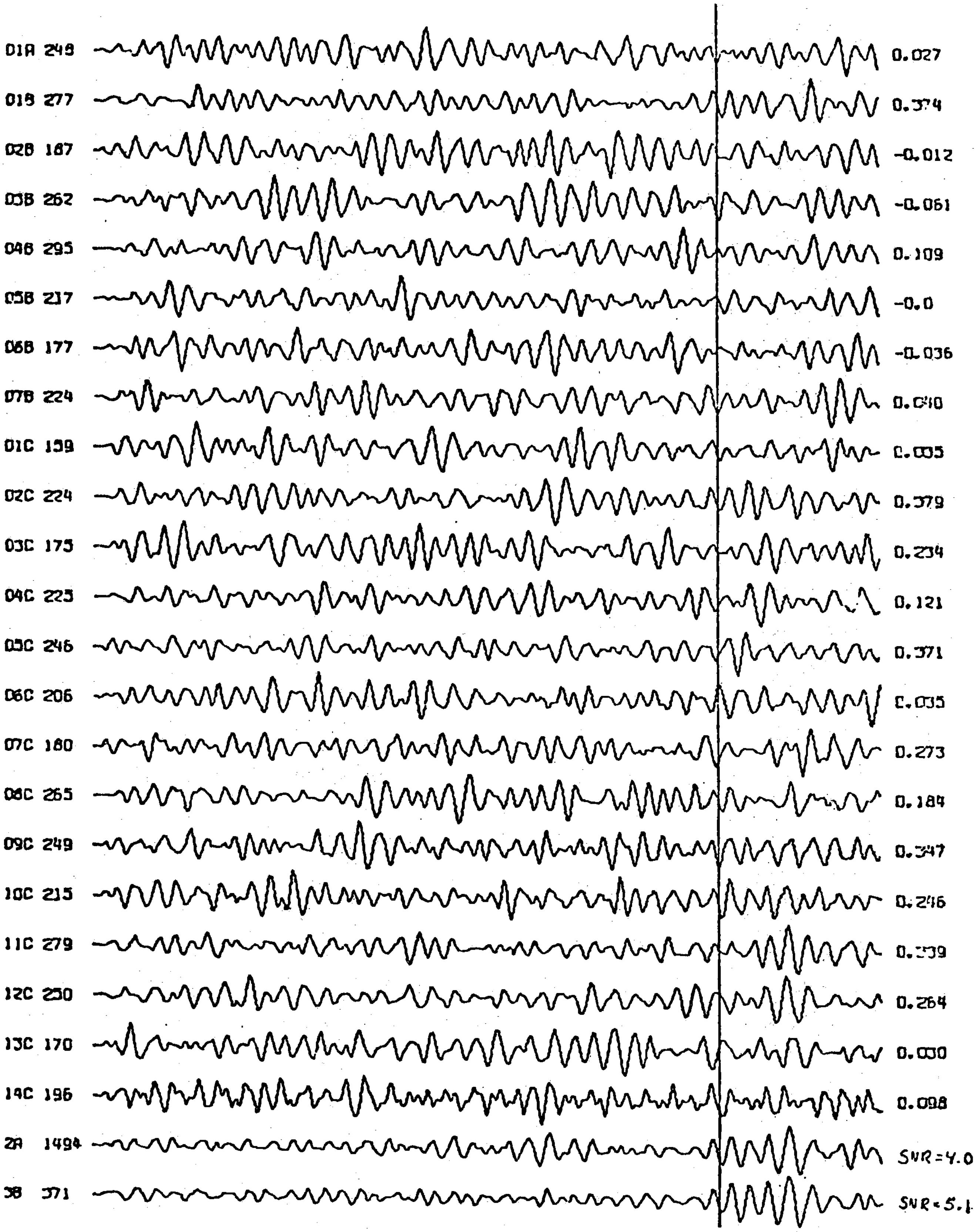

Fig. N.1 Example of extreme noise wavelets. The column to the right gives the $\hat{\gamma}_j$-weights. 2A and 3B denote array and weighted array beam respectively, pointing south of Honshu, Japan. The test results give high signal similarity and non-random sign and size of the amplitude weights, but a check with the amplitude pattern rejects this event as being an earthquake in Japan area.

reported by the analyst due to the test statistics. However, the tests are still considered as a good aid for the marginal cases, and also help the analyst to check whether the line-up of the subarray traces is good, i.e., giving correct time-delays for epicenter determination.

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REFERENCES

Fyen, J. E.S. Husebye and A. Christoffersson (1975): Statistical classification of weak seismic signals and noise at the NORSAR array, Geophys. J.R. Astr. Soc., 42, in press.