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VII.3 Applicability of horizontal components for detection and phase discrimination

In the report 'On three component slowness analysis of secondary phases (Kværna and Doornbos, 1986), one conclusion was that the horizontal components may have some potential for detection of regional S_n. This statement was based on the fact that for several events recorded on NORESS, larger amplitudes were observed on the radial and transverse components than on the vertical. On the other hand, for Lg, the trend was that most energy was confined to the vertical and transverse components.

If the above mentioned assumpions on the distribution of energy are generally valid, the amplitude or energy ratio between the vertical and radial components should be a possible discriminator between S_n and Lg.

To test these hypotheses, 17 regional and and local events were subjected to a detailed detection and amplitude ratio analysis. The selected events represented 13 different source regions, and spanned a wide range of SNR.

Detection analysis

In the current online processing of NORESS data, the incoherent beamforming technique, (see Ringdal et al., 1975) is applied for detection of secondary phases. This method provides better detectability than coherent beamforming for such phases (Ringdal, 1985), so in this study we chose to follow this concept by forming incoherent beams applying different filters and array subconfigurations. The specific subconfigurations were:

1) AOZ, CRING and DRING
2) AOZ, BRING, CRING and DRING
3) All horizontal components

4) All north components
5) All east components
6) AOZ, CRING, DRING and all horizontal components
7) AOZ, BRING, CRING, DRING and all horizontal components.

For each subconfiguration the following bandpass filters were applied to the individual channels prior to incoherent beamforming:
1) 0.5 - 1.5 Hz
2) 1.0 - 2.0 Hz
3) 1.5 - 2.5 Hz
4) 2.0 - 3.0 Hz
5) 2.5 - 3.5 Hz
6) 3.0 - 4.0 Hz
7) 3.5 - 4.5 Hz
8) 4.0 - 5.0 Hz

The maximum STA/LTA values in the respective incoherent beams were computed for each phase, filter band and subconfiguration and stored for further analysis. For evaluation, it was in addition necessary to convert the observed SNR's to values that were directly comparable for detection purposes. For example, an SNR of 5.0 is more significant on an incoherent beam consisting of AOZ, BRING, CRING and DRING than on a beam formed from just the 8 horizontal components, because the noise variance is smaller in the first case and we can therefore operate at a lower threshold without increasing the false alarm rate.

A confidence measure D' of a given detection can be obtained by transforming the maximum observed SNR (SNR_{MAX}) as follows:

$$D' = \frac{SNR_{MAX} \cdot \overline{D}}{\sigma}$$

where D is mean STA/LTA (≈ 1) and σ is the noise standard deviation, i.e., the STA/LTA applied to representative noise samples.

The incoherent beam consisting of AOZ, CRING and DRING had the best detection characteristics when only taking the vertical channels into account. Including the ARING caused correlated noise to be added to the beam at most frequency bands, thereby increasing the noise standard deviation. Slight improvements were seen only at the highest frequencies.

We had earlier found that the correlation between the different components of 3-comp. sensors was low, so we expected to reduce the noise variance if we added the horizontal components to the already defined vertical subconfigurations. Also in that case, the ARING in subconfiguration number 7 reduced the detectability by introducing correlated noise in most frequency bands. The beams consisting of only NORTH or EAST horizontal components in some cases gave the best observed SNR, either as the radial component of Sn or as the transverse component of Lg. But we found the noise variance suppression obtained by those four instruments to be too small to match the performance of beams with more stations included.

Based on the argumentation above, we selected three different beam deployments for direct comparison: These were numbers 1), 3) and 6) in the list above, respectively. Configuration 1) was used as a reference. In the following figures, the filled squares mark the ratios between SNR for configurations 3 and 1, whereas the crosses refer to ratios between configurations 6 and 1.

From Fig. VII.3.1 it is obvious that the horizontal components in most cases will give higher SNR than only the verticals for the S_n phase. For example, if we had to choose between an equal number of horizontal or vertical stations for detection of S_n, it would be wise to choose the horizontals.

When turning to the instrument selection possible from the NORESS configuration, we have to take into account the fact that with more instruments included, the noise variance is reduced. In Fig. VII.3.2 we have displayed the corrected SNR values (D') for the atual configurations. The horizontal beam in two cases was considerably better than the reference beam, whereas the the beam with both horizontal and vertical components in most cases was the best.

As expected, the SNR contributions from the horizontals was less for the Lg than for the Sn phase, (Fig. VII.3.3), but some of the events still had the highest SNR on the horizontal beam. The corrected values in Fig. VII.3.4 show that the horizontal beam in only one case was the best, and the improvement by the mixed beam was marginal.

In conclusion, there is a gain to be achieved by incoherent beamforming using both horizontal and vertical components together, especially for S_n detection. This gain must be weighted against the increased computer requirements involved.

Amplitude ratio analysis

After rotation of the horizontal components of each three-component station to create the radial and transverse traces, all permutations of component ratios were calculated for each station in the different detection filter bands. Both max. amplitude and energy ratios, and mean ratios over all stations were computed.

In Fig. VII.3.5, we have displayed the Z/R ratios in the frequency band with highest SNR. The values are averaged over all four three-component stations, because the ratios may differ as much as 20 percent from station to station. Even though we have not obtained full separation between the phases, 25 out of 29 phases were correctly classified if we set the critical ratio to 1.0. We also found that the improvement of applying energy ratios instead of amplitude ratios was marginal, and that the ratios Z/T or R/T did not give any pattern as applicable for phase discrimination as Z/R.

Thus we conclude that the Z/R test applied together with other types of information like apparent velocity and frequency content, is likely to improve the possibility of correctly identifying S_n and Lg phases, and thereby increase the reliability of regional event location.

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References

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Ringdal. F., E.S. Husebye, and A. Dahle (1975): P-wave envelope representation in event detection using array data, in Exploitation of Seismograph Networks, K. G. Beauchamp, Editor, Nordhoff-Leiden, The Netherlands, 353-372.

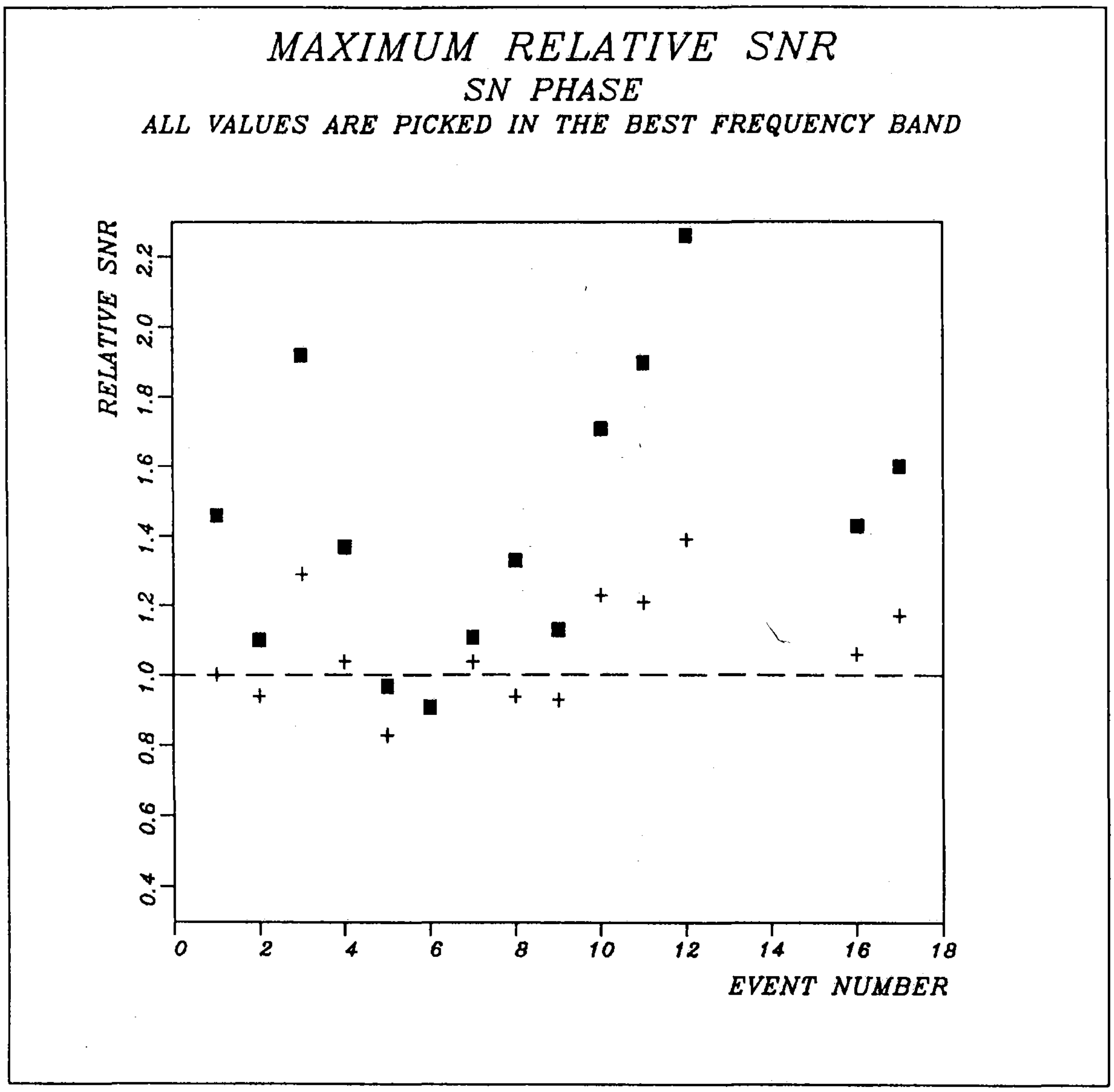

Fig. VII.3.1 Maximum SNR relative to the maximum of the AOZ, CRING and DRING configuration. The filled squares represent the beam of eight horizontal components. The crosses show the relative values of the beam with AOZ, CRING, DRING and the horizontal components, whereas the AOZ, CRING and DRING values are indicated by the dashed line at the 1.0 level.

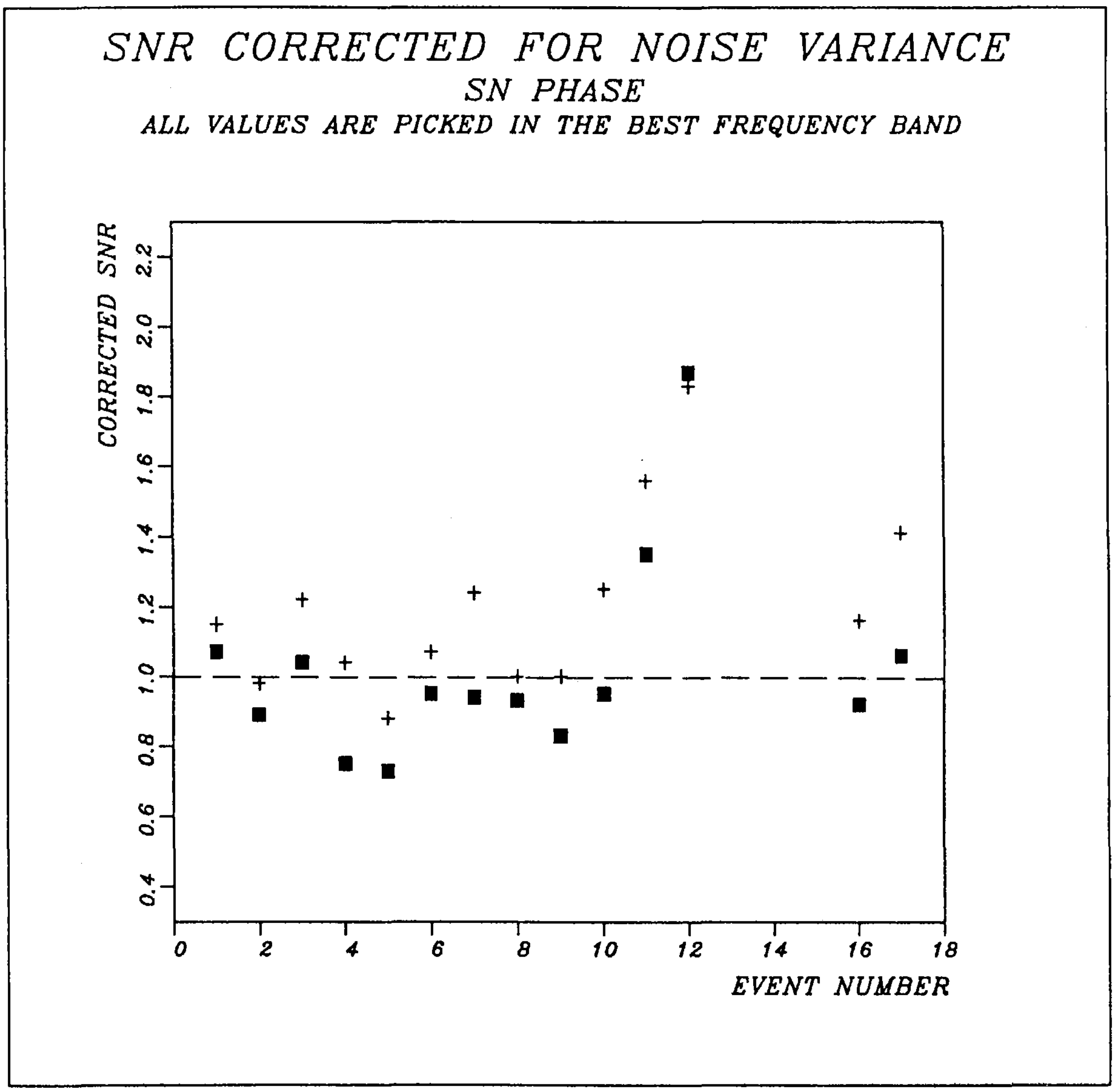

Fig. VII.3.2 Maximum corrected SNR relative to the corrected maximum of the AOZ, CRING and DRING configuration. The filled squares represent the beam of eight horizontal components. The crosses show the relative values of the beam with AOZ, CRING, DRING and the horizontal components, whereas the AOZ, CRING and DRING values are indicated by the dashed line at the 1.0 level.

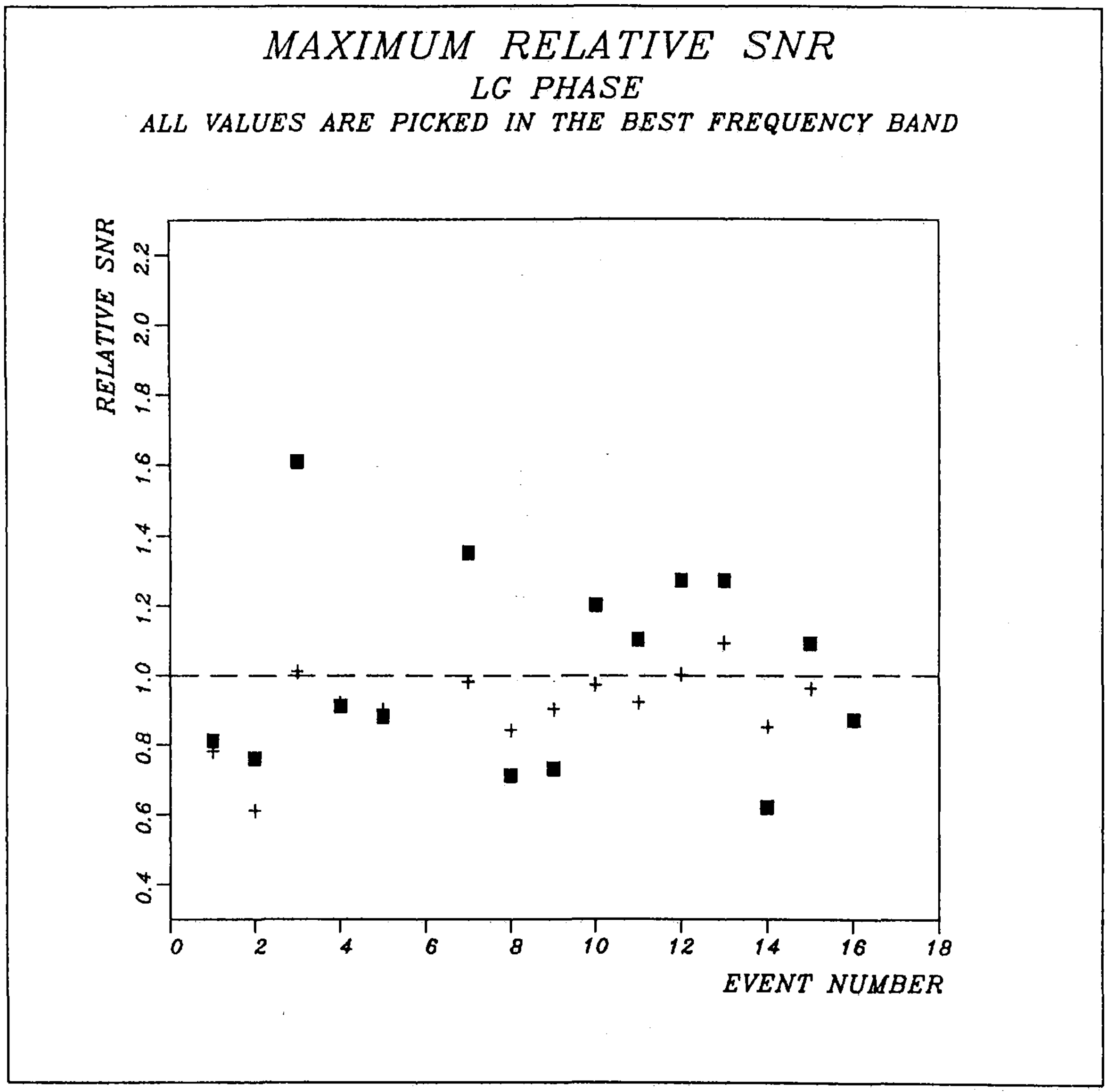

Fig. VII.3.3 Maximum SNR relative to the maximum of the AOZ, CRING and DRING configuration. The filled squares represent the beam of eight horizontal components. The crosses show the relative values of the beam with AOZ, CRING, DRING and the horizontal components, whereas the AOZ, CRING and DRING values are indicated by the dashed line at the 1.0 level.

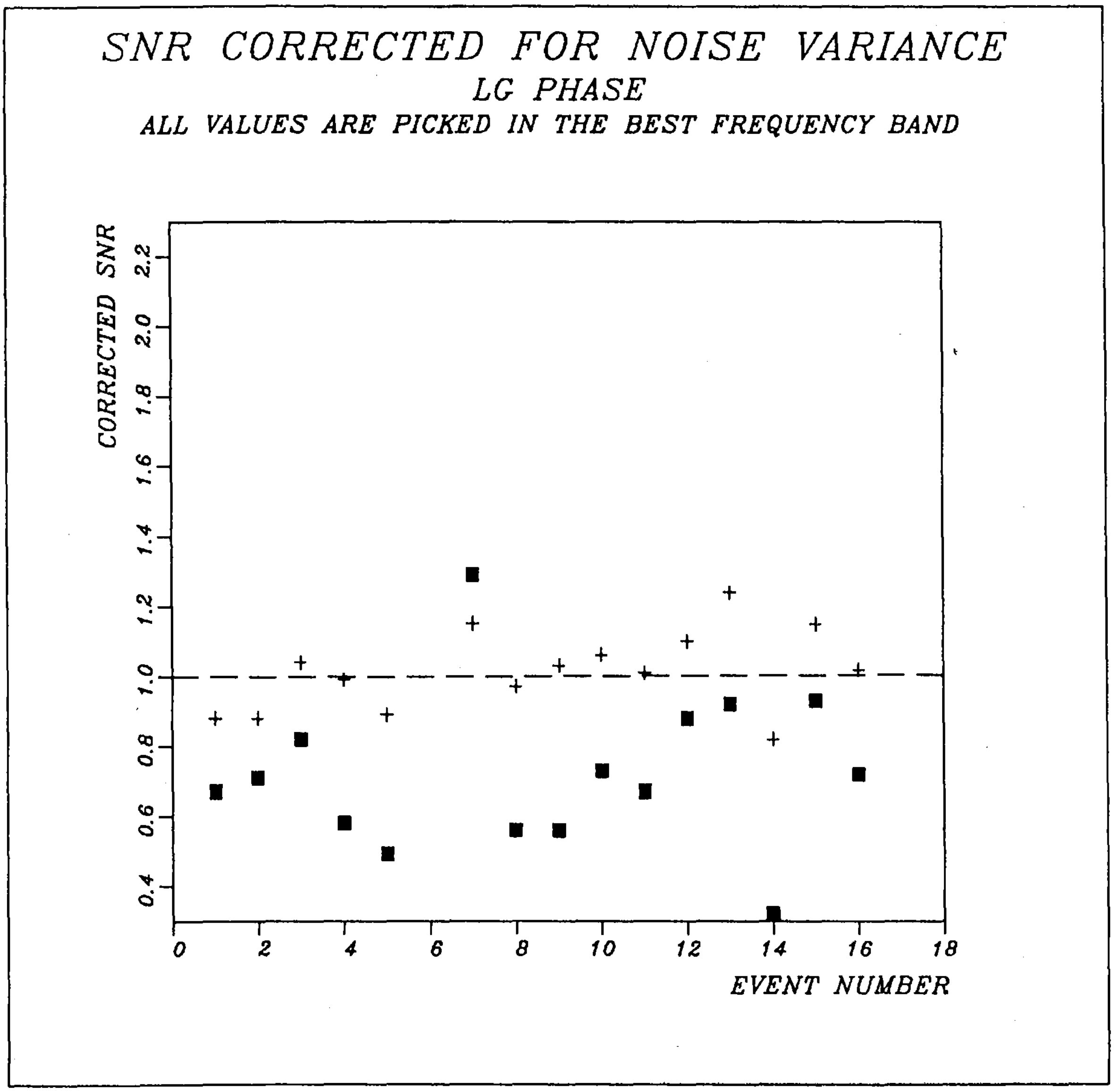

Fig. VII.3.4 Maximum corrected SNR relative to the corrected maximum of the AOZ, CRING and DRING configuration. The filled squares represent the beam of eight horizontal components. The crosses show the relative values of the beam with AOZ, CRING, DRING and the horizontal components, whereas the AOZ, CRING and DRING values are indicated by the dashed line at the 1.0 level.

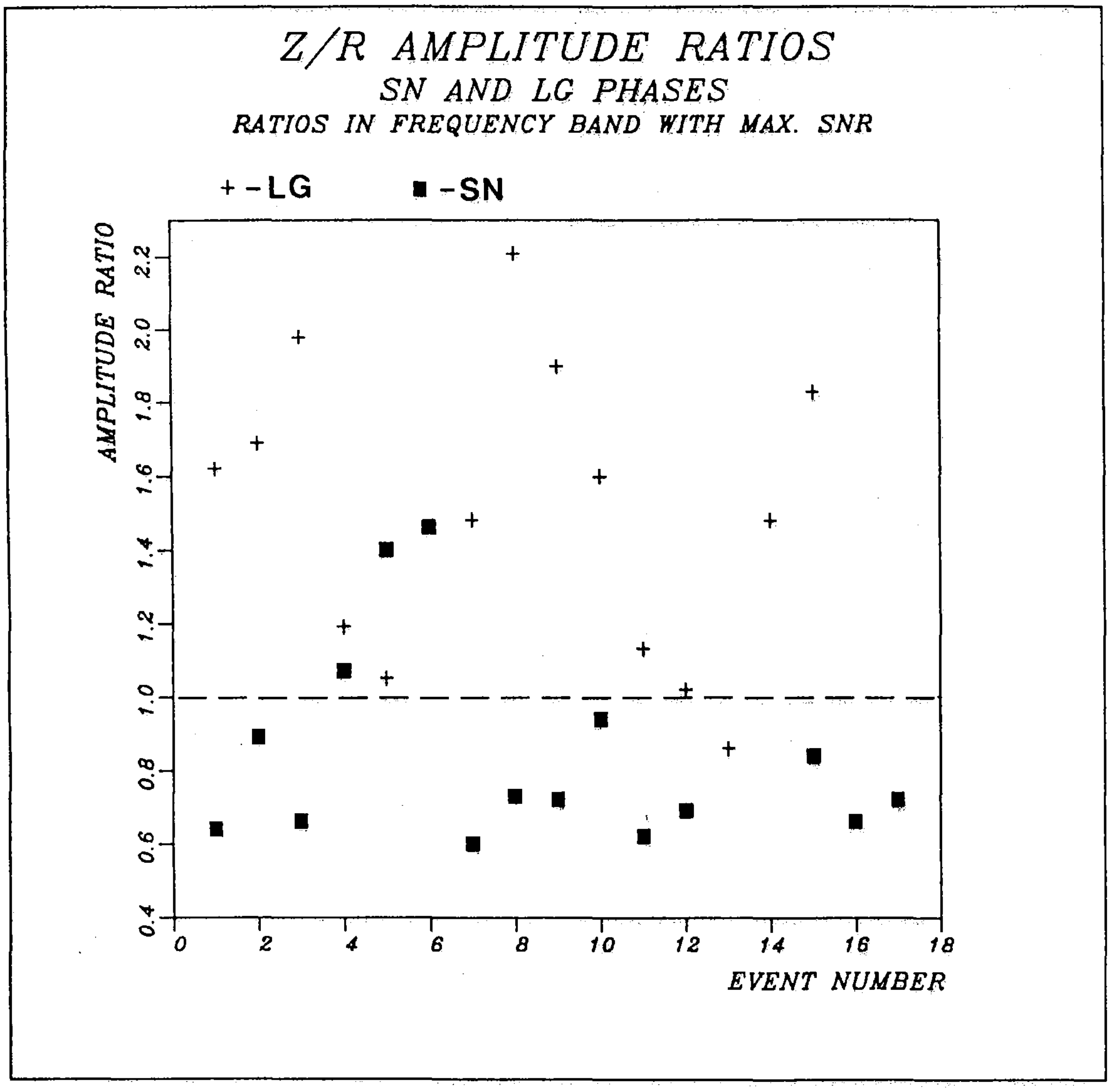

Fig. VII.3.5 Mean vertical / radial amplitude ratios for S_n and Lg phases. Only values corresponding to actually detected phases are plotted.