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VII.6. NORESS noise spectral studies - beam suppression

We refer to section VII.5 for description of the NORESS noise spectral system.

The objective of the system is to collect, on a regular basis, data that are relevant to the detection algorithms. In this report we will draw some conclusions based upon 6 months of data, during which period we have recorded noise spectra for NORESS short period instruments and beams every hour. We will also go into some of the data in more detail to document the outcome of the huge amount of processing that has been done.

The production scheme listed in section VII.5 gives a far too large amount of plots to be documented in this summary, and will therefore be the subject of a separate report. Rather, we have chosen to show a few examples which illustrate our conclusions, based on 4-6 months of data.

We have chosen week 30, 1986, as reference for this report, due to good recording statistics that week.

Beam suppression spectrum S(f) is defined as the ratio between the beam power spectrum B(f) to the average SPZ power spectrum ('MEANZ'). This ratio is expected to reach the value $1/N$ for random uncorrelated noise, or $1/\sqrt{N}$ for noise amplitudes.

In this report we have plotted the function SUPP(f) defined by:

$$S(f) = B(f)/MEANZ(f), \quad SUPP(f) = 10\log(S) = 10\log(B) - 10\log(MEANZ)$$

For TELEV beam, SUPP(f) is expected to obtain the value -12.3 dB.

Figs. VII.6.1-2 display the observed TELEV beam suppression spectra for week 30. The number of spectra in the figure is 166, i.e., 7*24 minus 2 hours with no recording. The -10log(N) line is denoted $\sqrt{N}$ in all figures concerning beam suppression. In Fig. VII.6.2 we show the arithmetic mean of the beam suppression spectra together with plus/minus one standard deviation.

All average spectra that are displayed in this report have been corrected for outliers in the following way:

For each frequency the mean value and standard deviation is calculated. If an individual spectrum at one point is more than two standard deviations from the mean, then that spectrum is given one outlier score. If the value is among the 15% highest or lowest values it is also given one score. Then, if a spectrum obtains more than 250 scores (one spectrum is 512 points), that spectrum is excluded from the final estimate of average and standard deviation.

From Figs. VII.6.1 and VII.6.2 we observe that on an average the theoretical $\sqrt{N}$ noise suppression is obtained for all frequencies above 1.3 Hz using the TELEV configuration. Lower frequencies are not suppressed as much by this beam configuration, since noise for these lower frequencies becomes more coherent within the NORESS array. For frequencies above 4 Hz, the beam suppression spectrum follows the expected results for normally distributed stochastic processes. Between 1.3 and 4.0 Hz the TELEV beam configuration clearly demonstrates a better suppression than expected. At 2.13 Hz the average suppression is -17.5 dB, which corresponds to a theoretical number of instruments of 56.

Morever, this 'extra' suppression has been consistently observed during our recording period. As an illustration of this, Figs. VII.6.3 and VII.6.4 show the spectra for GMT hours 00 and 08 only. We may here conclude that the minima are the same for night-time and day-time, but the extra suppresion is narrower for day-time periods. This feature is to some extent observed throughout this reporting period.

Fig. VII.6.5 displays frequencies between 1.9 and 2.1 Hz plotted versus time during week 30. We see that the TELEV extra suppression is mostly independent of time-of-day and week-day. The variation is ± 1.5 dB. We are not able to see any characteristic features that correlate with time of observation.

There is a 'bump' in the spectrum at 7.3 Hz which is more pronounced on night-time observations during week 30. This effect, however, is not systematically observed for other time periods.

In Figs.VII.6.6 - 13 we have displayed the features of the other beam configurations, and only the average values with standard deviations are plotted.

Fig. VII.6.6 shows that the BRING configuration (A0Z - A3Z plus B1Z - B5Z, Fig. VII.6.6) approaches the theoretical suppression for frequencies above 5.3 Hz. Moreover, the suppression obtained is on an average more than expected.

Fig. VII.6.7 shows the CRING configuration (A0Z , B1Z - B5Z, C1Z - C7Z). This beam shows additional suppression for frequencies between 2.5 and 7.7 Hz, which is systematically observed. Again the minima are independent of time of observation, as seen in Fig. VII.6.8.

The HIFRQ configuration has no pronounced extra suppression, at least not of the same dimension as TELEV and CRING. Still, a very consistent pattern is however observed. These remarks also apply to the INTER and ALLV configurations.

The consistency of observations is shown in Figs. VII.6.12 - 13 where we have average beam suppression for CRING and TELEV. These are averages of observations made at 02 local time only, and over the period day 062 through day 187 (4 months). We see that there is not much variance in the observation of beam suppression. Single case studies may actually give a good measure of a beam suppression spectrum.

Conclusions for the configuration study are shown in Fig. VII.6.14. Comparing with the bold curve for ALLV configuration we see that the TELEV and the INTER configuration has better noise suppression charactersistics than using all the instruments in the array:

TELEV is 'best' up to 2.8 Hz.
INTER is 'best' from 2.8 Hz and up to 3.9 Hz.

The results based upon more than 5000 noise spectra for each array configuration can be summarized as follows:

Better than $\sqrt{N}$ suppression can be consistently achieved at selected frequencies and subconfigurations, and a subgeometry can outperform the full array.

ALLV - Full array geometry: A0, A, B, C, D rings, 25 instruments. Noise suppression of $\sqrt{N}$, 14 dB is consistently achieved in the band 3.0 - 20.0 Hz.

TELEV - Geometry: A0, C, D rings, 17 instruments. Noise suppression better than $\sqrt{N}$, 12.3 dB is consistently achieved in the band 1.3 - 4.0 Hz. This subgeometry is superior to the full array for all frequencies below 3 Hz.

CRING - Geometry: A0, B, C rings, 13 instruments.
Noise suppression better than $\sqrt{N}$, 11.1 dB is consistently achieved in the band 2.4 - 7.5 Hz.

BRING - Geometry: A0, A, B rings, 9 instruments.
Noise suppression better than $\sqrt{N}$, 9.5 dB is achieved in the band 5.3 - 20.0 Hz, however not as consistent as TELEV. The geometry responds with smaller noise suppression for spurious local noise extremums.

HIFRQ - Geometry: A0, A, B, C rings, 16 instruments.
Noise suppression of $\sqrt{N}$, 12.0 dB is achieved in the band 3.0 - 20.0 Hz. Better than $\sqrt{N}$ is observed, but inferior to TELEV.

INTER - Geometry: A0, B, C, D rings, 22 instruments.
Noise suppression of $\sqrt{N}$, 13.4 dB is achieved in the band 2.0 - 20.0 Hz.
This subgeometry is superior to the full array for all frequencies below 4 Hz.

These studies indicate that there are considerable benefits to be obtained using narrow band filters and selecting array subconfigurations for optimum noise suppression. In addition, the signal beam loss must be studied to determine the best configuration for array beamforming signal-to-noise gain (see Section VII.4).

J. Fyen

86 WEEK 30 TIME 202: 0 208.23

Telev Beam Power - Average SPZ Power

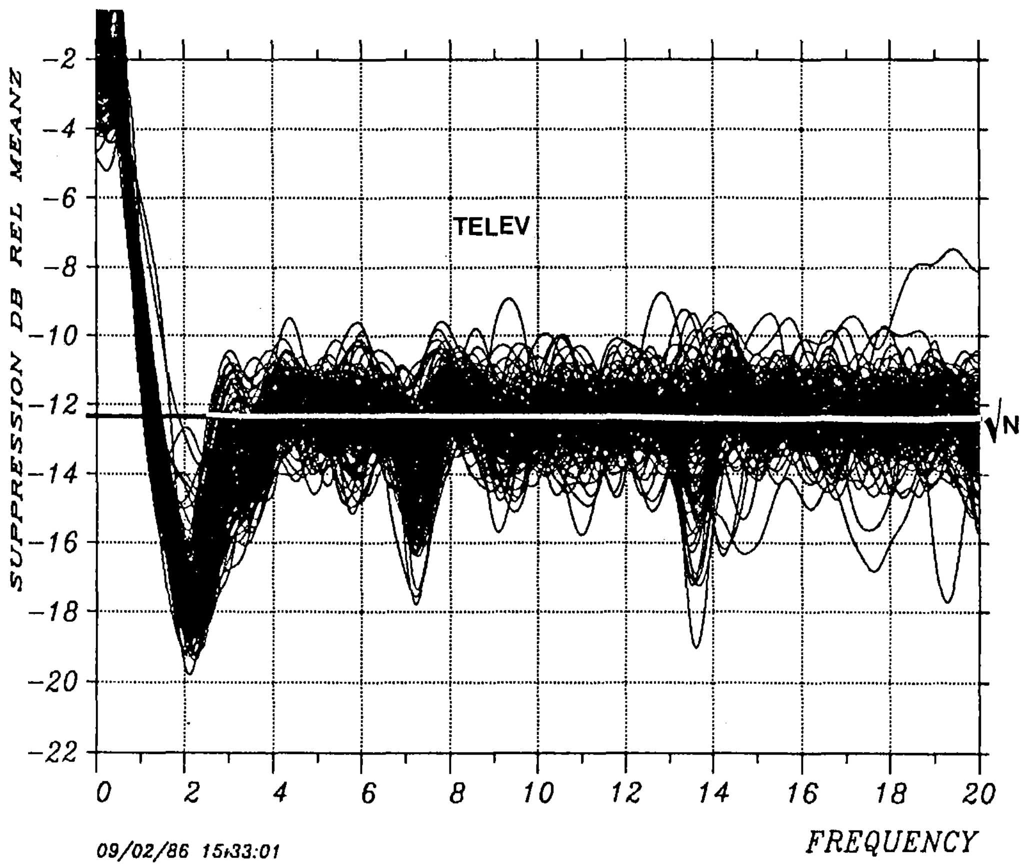

Fig. VII.6.1 Noise suppression for TELEV subgeometry week 30, 1986. The plot contains 166 curves, which are all hourly observed noise suppression spectra for TELEV during week 30.

86 WEEK 30 TIME 202: 0 208.23

TelevﾠBeam Power - Average SPZ Power

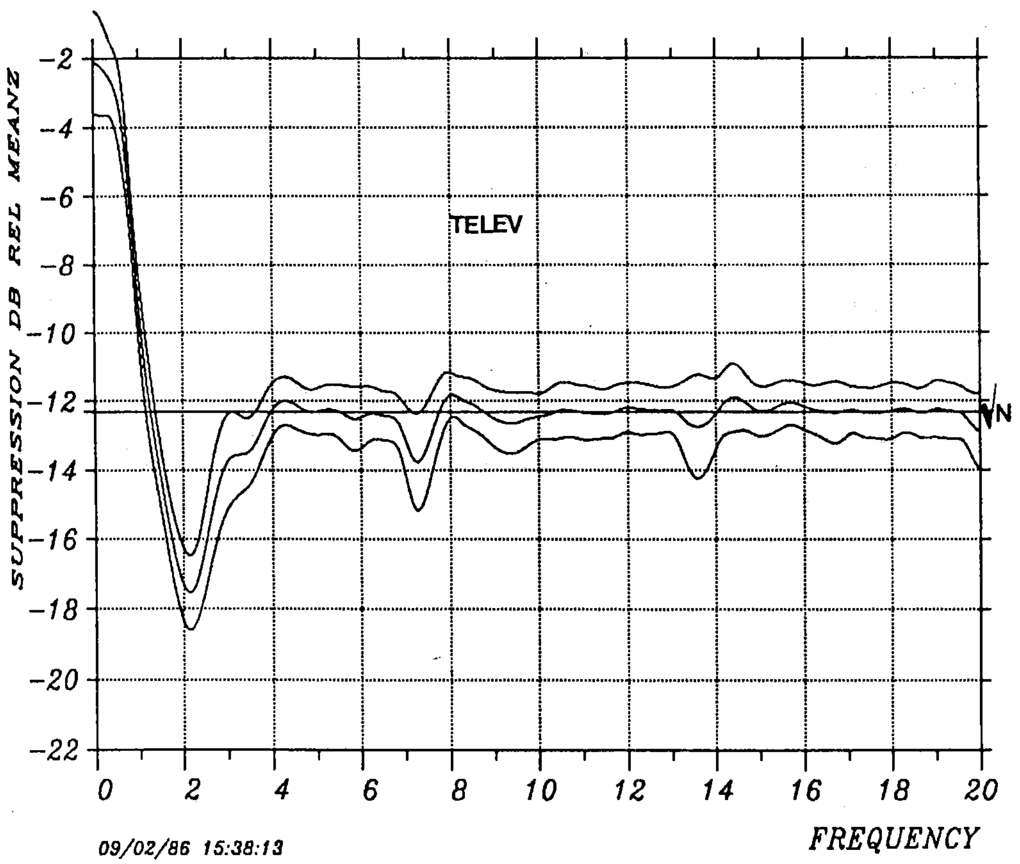

Fig. VII.6.2 Noise suppression for TELEV subgeometry week 30, 1986. The curves plotted are average noise suppression spectrum together with plus/minus one standard deviation.

86 WEEK 30 TIME 202: 0 208.23 00 GMT

Televⅿ MEANZ

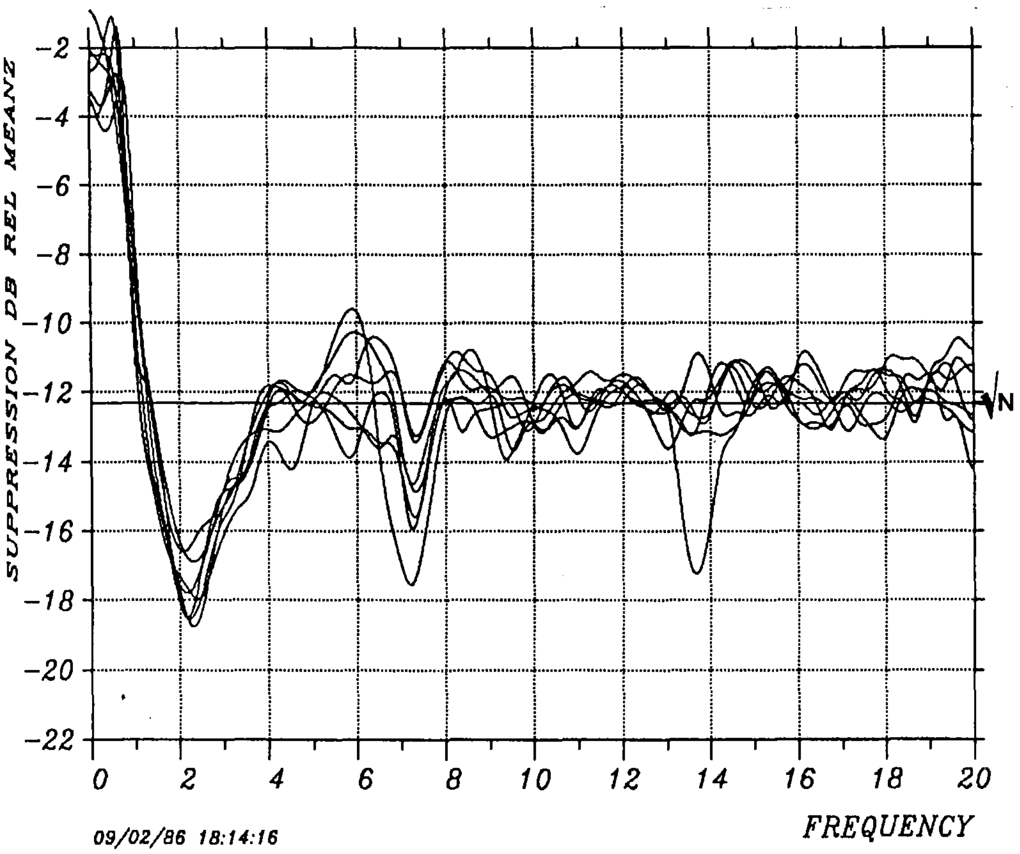

Fig. VII.6.3 Noise suppression for TELEV subgeometry week 30, 1986. The curves plotted are all noise suppression spectra observed at 00 GMT by the NORESS noise spectral system.

86 WEEK 30 TIME 202: 0 208.23 08 GMT

Telev MEANZ

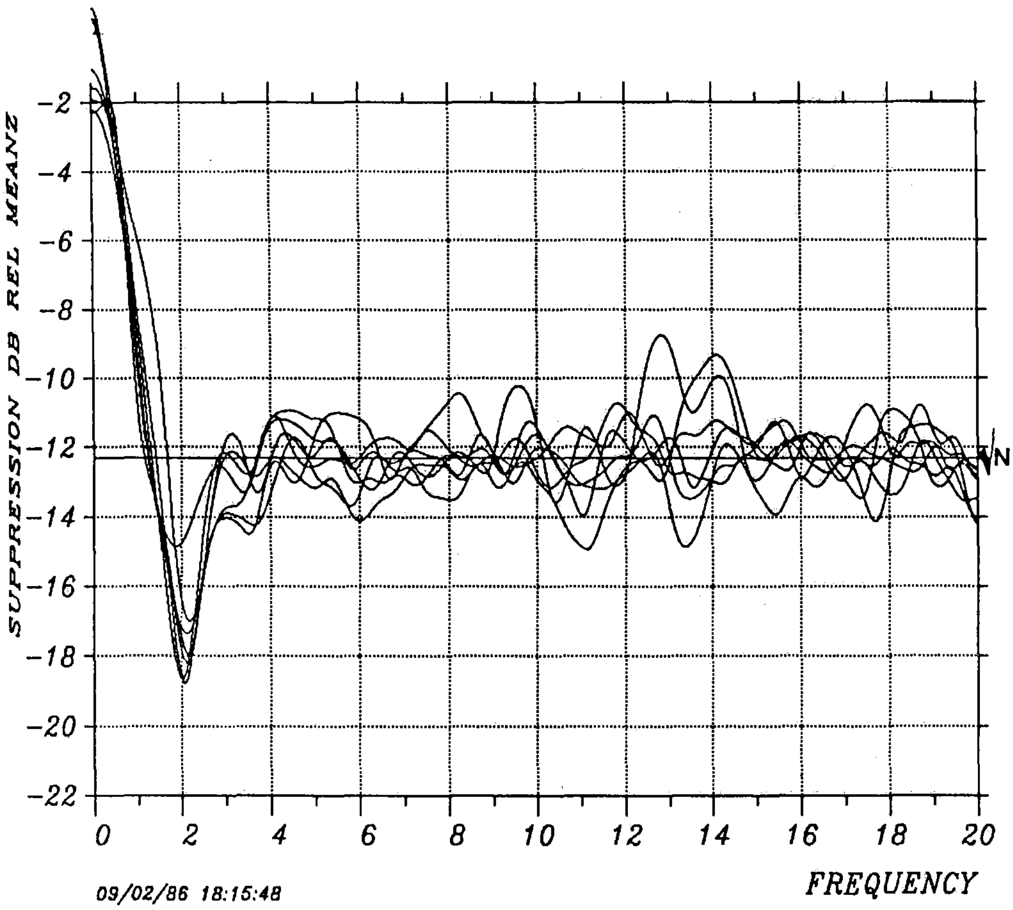

Fig. VII.6.4 Noise suppression for TELEV subgeometry week 30, 1986. The curves plotted are all noise suppression spectra observed at 08 GMT by the NORESS noise spectral system.

86 WEEK 30 TIME 202: 0 208.23

Telev Beam Power - Average SPZ Power 1.9 - 2.1 Hz

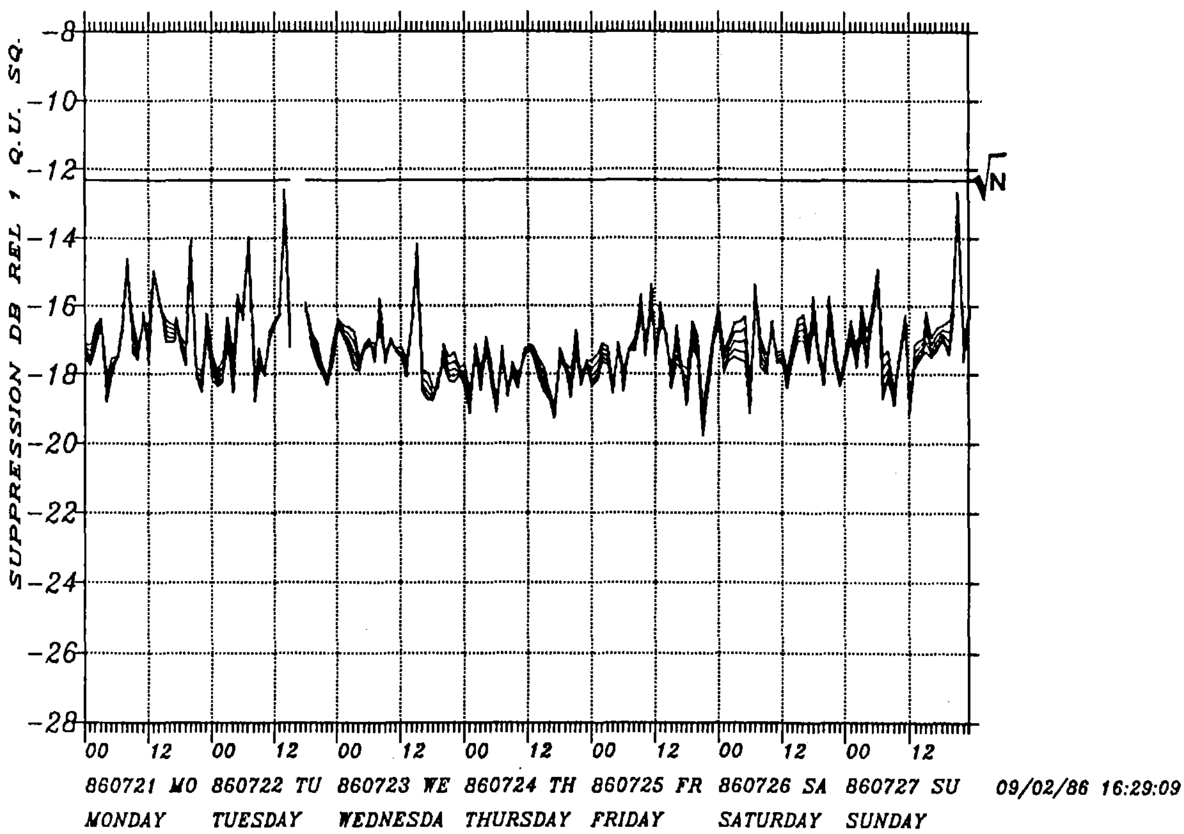

Fig. VII.6.5 Noise suppression for TELEV subgeometry week 30, 1986. The curves plotted are the hourly observed noise suppression values for frequencies between 1.9 and 2.1 Hz.

86 WEEK 30 TIME 202: 0 208.23

BRING Beam Power - Average SPZ Power

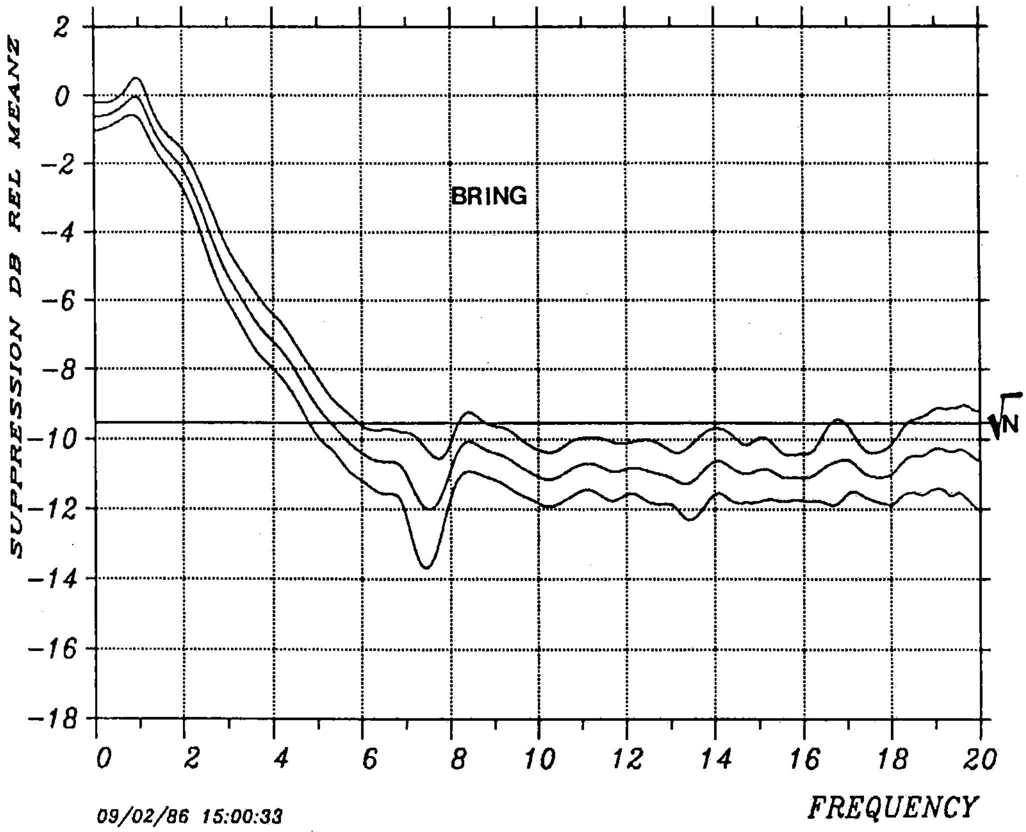

Fig. VII.6.6 Noise suppression for BRING subgeometry week 30, 1986. The curves plotted are average noise suppression spectrum together with plus/minus one standard deviation.

86 WEEK 30   TIME 202:   0 208.23

CRING Beam Power - Average SPZ Power

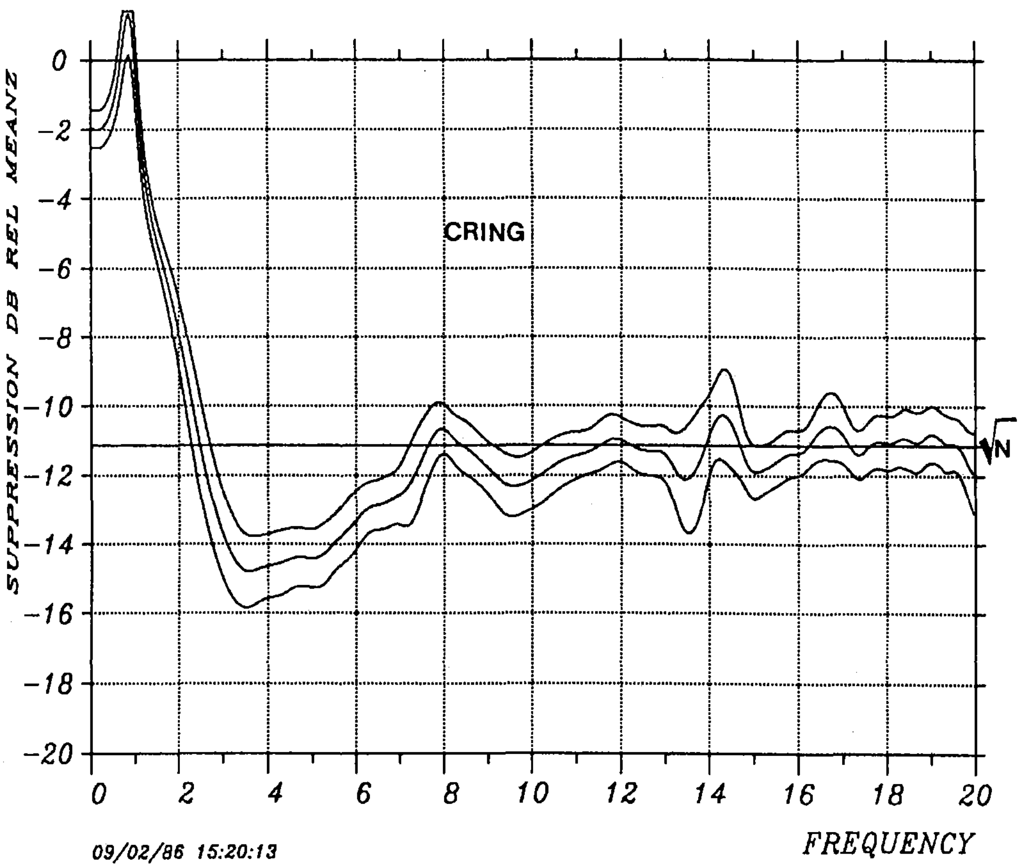

Fig. VII.6.7 Noise suppression for CRING subgeometry week 30, 1986. The curves plotted are average noise suppression spectrum together with plus/minus one standard deviation.

86 WEEK 30 TIME 202: 0 208 .23

CRING Beam Power - Average SPZ Power 3.4 - 3.7 Hz

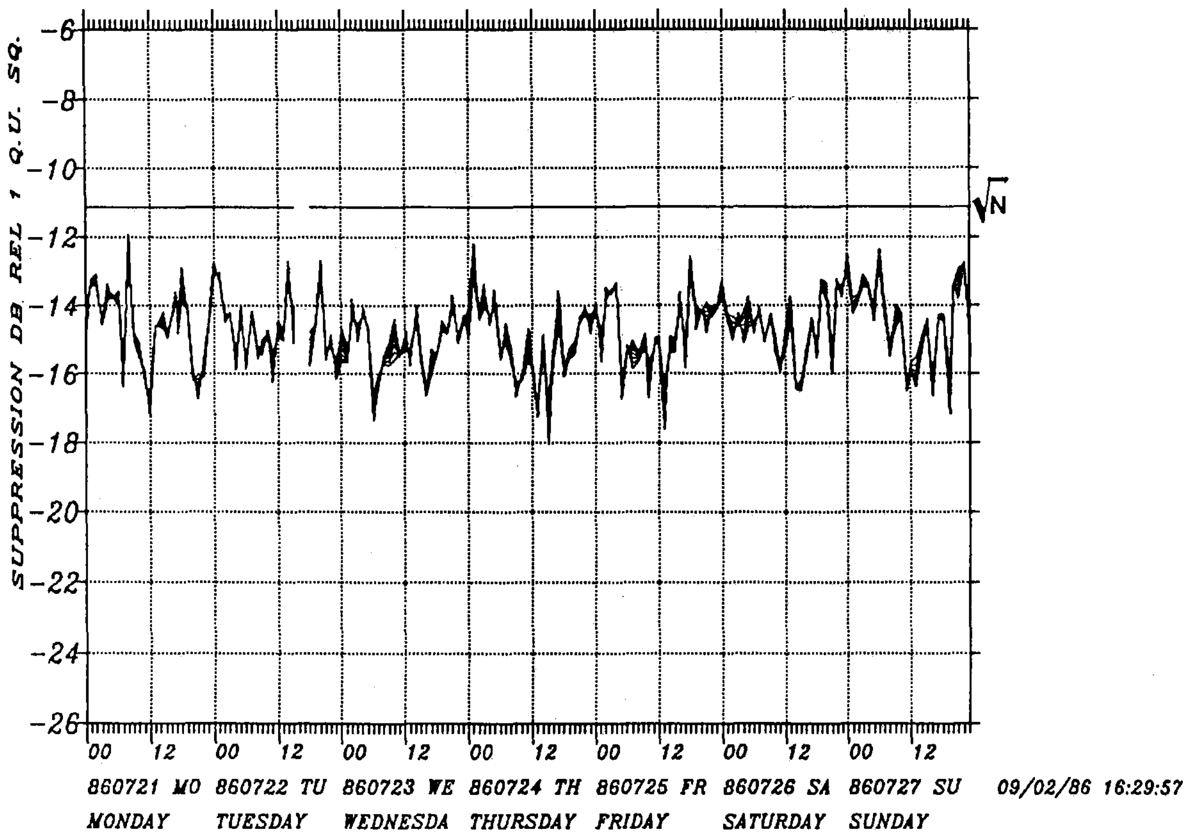

Fig. VII.6.8 Noise suppression for CRING subgeometry week 30, 1986. The curves plotted are the hourly observed noise suppression values for frequencies between 3.4 and 3.7 Hz.

86 WEEK 30 TIME 202: 0 208.23

HIFRQ Beam Power - Average SPZ Power

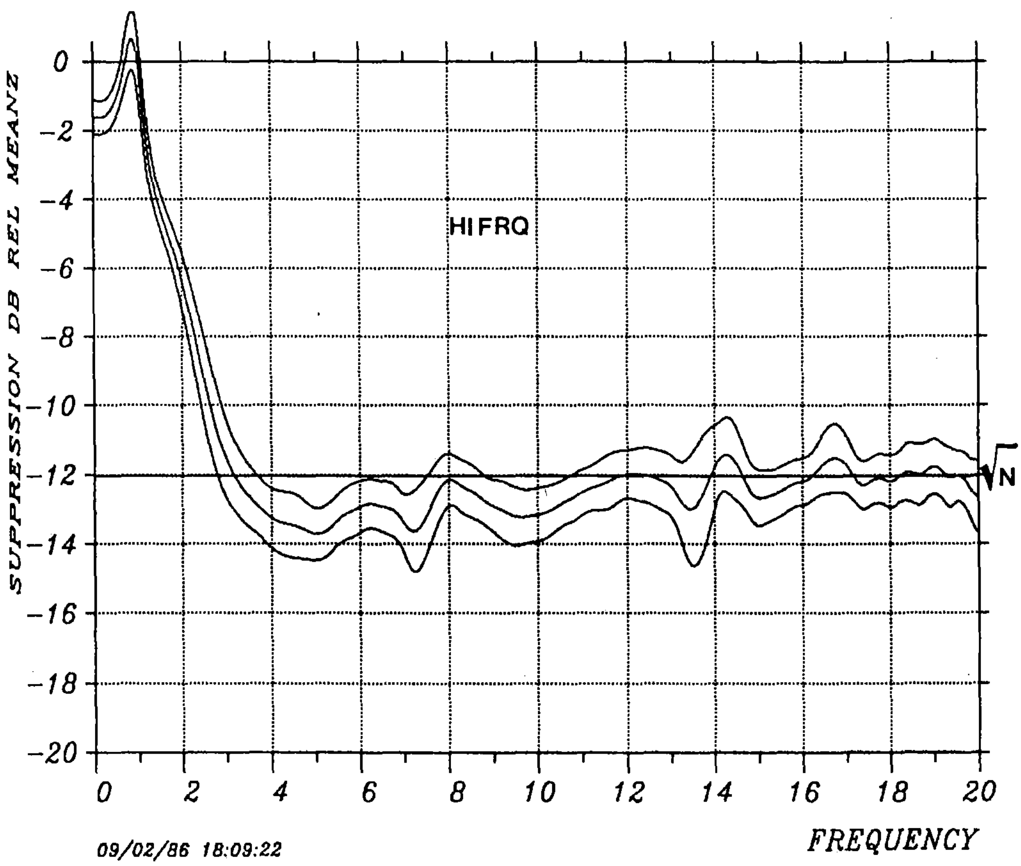

Fig. VII.6.9 Noise suppression for HIFRQ subgeometry week 30, 1986. The curves plotted are average noise suppression spectrum together with plus/minus one standard deviation.

86 WEEK 30 TIME 202: 0 208.23

INTER Beam Power - Average SPZ Power

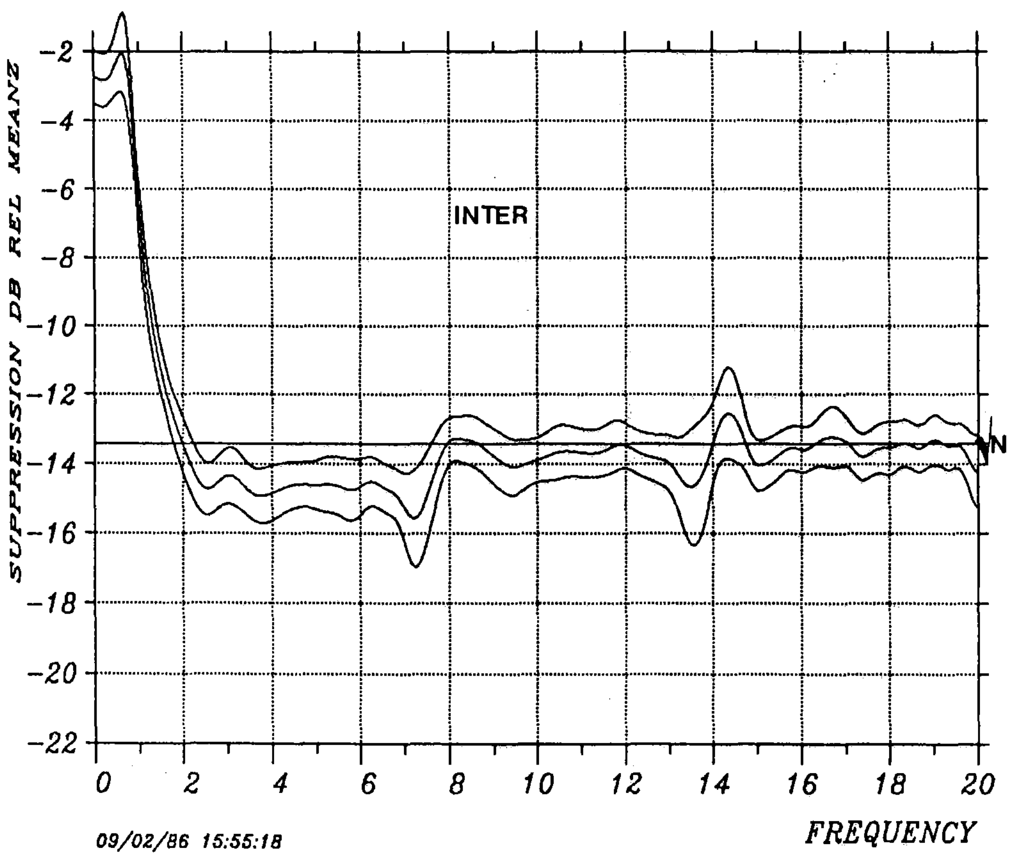

Fig. VII.6.10 Noise suppression for INTER subgeometry week 30, 1986. The curves plotted are average noise suppression spectrum together with plus/minus one standard deviation.

86 WEEK 30 TIME 202: 0 208.23

ALLV Beam Power - Average SPZ Power

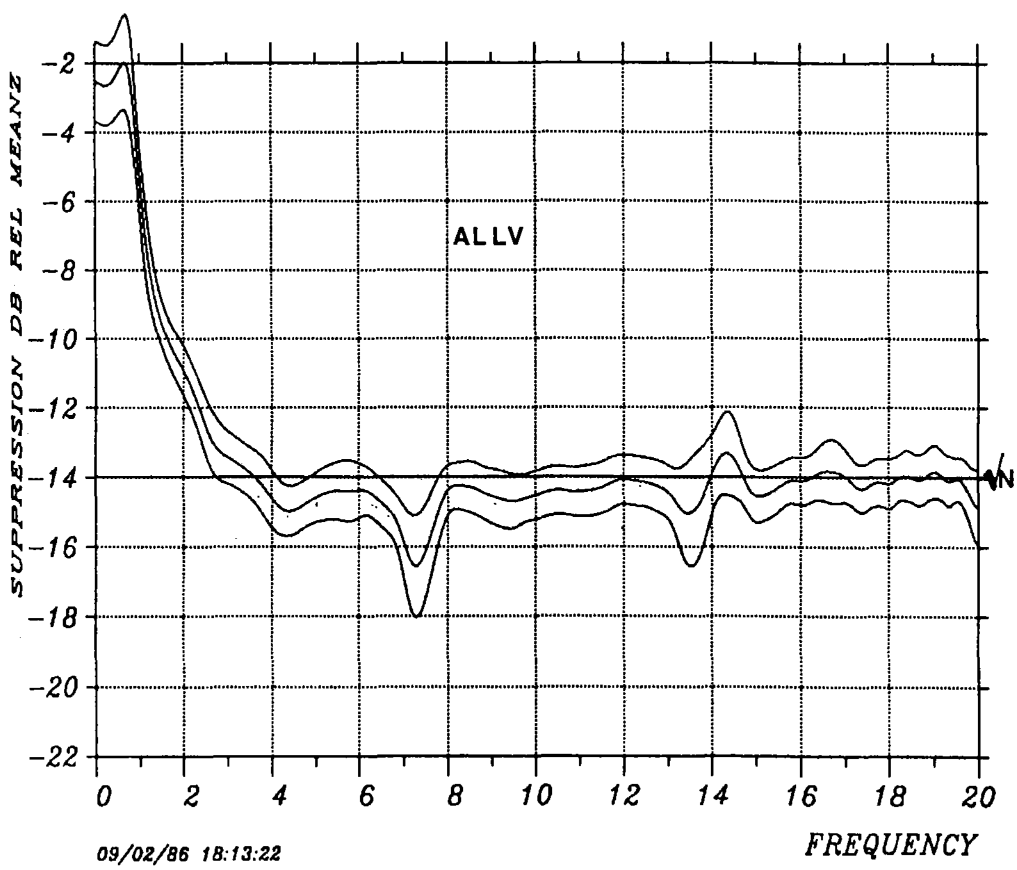

Fig. VII.6.11 Noise suppression for full array geometry week 30, 1986. The curves plotted are average noise suppression spectrum together with plus/minus one standard deviation.

86 TIME 062:00 187:23 (02 LOCAL)

7 CRING Beam Power - Average SPZ Power

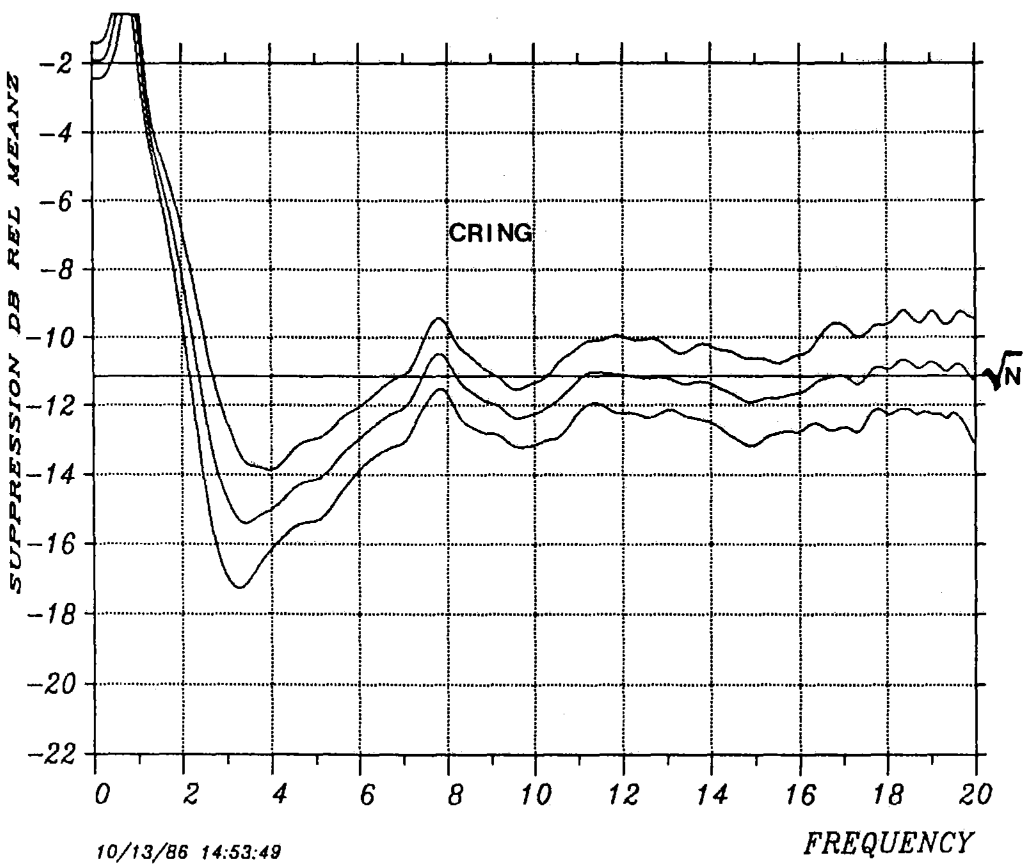

Fig. VII.6.12 Noise suppression for CRING subgeometry observed during the period day 062 through 187 for local times 02 only. The curves plotted are average noise suppression spectrum together with plus/minus one standard deviation.

86 TIME 062:00 187:23 (02 LOCAL)

9 TELEV Beam Power - Average SPZ Power

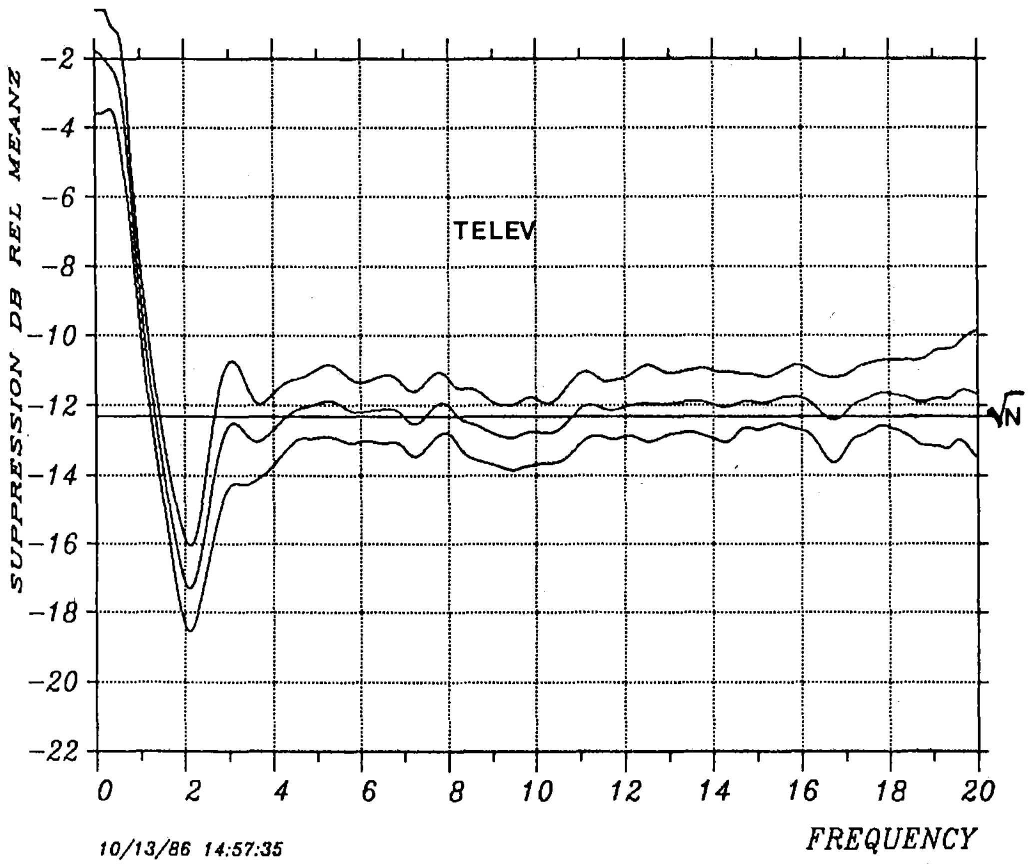

Fig. VII.6.13 Noise suppression for TELEV subgeometry observed during the period day 062 through 187 for local times 02 only. The curves plotted are average noise suppression spectrum together with plus/minus one standard deviation.

WEEK 30, 1986, AVERAGE NOISE SUPPRESSION

BRING CRING TELEV INTER HIFRQ ALLV

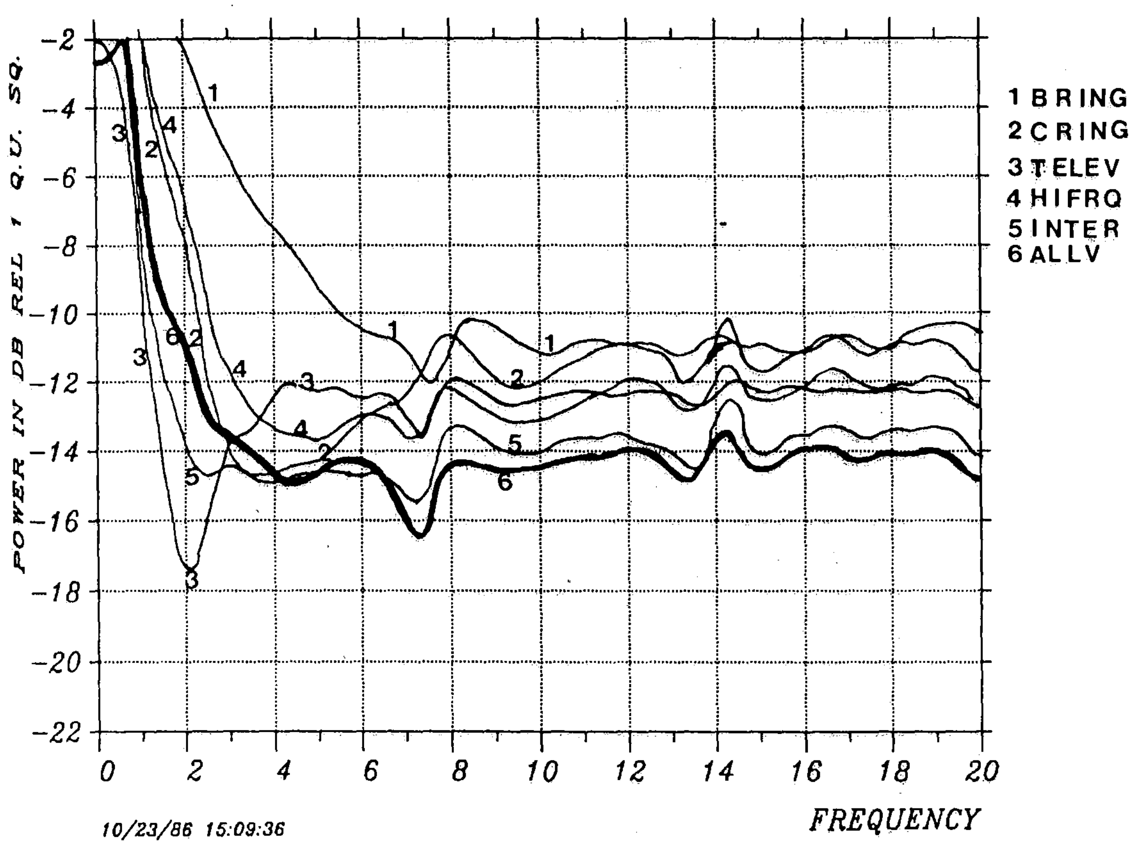

Fig. VII.6.14 Noise suppression for 6 different NORESS array geometries based on week 30, 1986. The curves plotted are average noise suppression spectrum for each geometry. The bold line is the full array, ALLV.