SOME RESULTS GAINED FROM JAPE - AN OVERVIEW*[1]

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SUMMARY

During JAPE a variety of sound propagation experiments have been conducted, including long range measurements and investigations of the masking of sound by natural barriers. An overview of the measurements is given below. A comparison between measured SPL's and theoretical estimates is presented.

INTRODUCTION

The influence of meteorological conditions on outdoor sound propagation is of major interest, because the detectability of acoustic sources depends on the characteristics of the transmission channel. Since ATLAS ELEKTRONIK has limited access to met instrumentation, the JAPE offered a unique chance to conduct meteorological and acoustical measurements at one time.

Sensor Layout

ATLAS ELEKTRONIK operated a linear acoustic array during the experiments. During the first series of the measurements this array was located beyond the northern met-tower, heading in a south-to-north-direction. The sensor spacing was 100 m and eight microphones (type: Sennheiser MKH-110) were in use.

The mike close to the met-tower was collocated to the northernmost mike of the MIT sensor layout. Thus it was possible to link our results to those of the other teams having sensors displaced along the baseline of the sensor layout.

During the vehicle test additional geophones (type: Geospace GSC-300-3D, Sensor SM 6) and mikes were located close to the track.

The Terrain Masking trials finished the JAPE. For this purpose the sensors were deployed across the Elephant Hill, which was located south of the Dirt Site. Figure 1 is showing the sensor geometry as used during the trials.

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SELECTED RESULTS

Ambient Noise

Measurements of the ambient noise took place at least once a day. Figure 2 presents a spectral analysis of such a measurement. The variation of the spectral content of the background noise is shown over a period of two minutes. The frequency band displayed is ranging from DC to 200 Hz.

In order to enhance spectral lines the broadband contribution has been removed. The effect of this procedure can be seen from the comparison of both upper graphs. They are showing an averaged spectrum before (top) and after the normalization (below) has been applied.

In the spectrogram a set of stable spectral lines can be seen. They are generated by the mechanical noise of transformers, air conditioners, etc. In addition there are sources with varying frequency content. Mostly these kinds of signals could be identified as noise coming from passing vehicles.

Short Range Measurements

During the short range tests measurements including pure sinusoidal tones emitted by a loudspeaker and pulses from a propane cannon were conducted. Figure 3 shows the averaged lapse of the SPL vs range at three different frequencies, i.e. 80 Hz, 200 Hz and 500 Hz. These three frequencies were emitted simultaneously. The loudspeaker was mounted on top of the southern met tower (approx. 30 m AGL, 1000 m apart) and the integration time was 15 seconds.

At 80 Hz no major changes in the SPL can be seen within the presented range interval. Both other frequencies show a slight decrease at first, but beyond 1600 m even the energy at 500 Hz increases again. The met conditions showed a light upward refraction during these trials. The total velocity gradient close to the ground ($z \leq 100$ m) was about 0.28/sec. From this the shadow zone can be estimated to begin about 920 m off the source.

A spectral analysis of this measurement is presented in Figure 4. The frequency band shows ranges from 400 Hz to 600 Hz. The 500 Hz tone is the dominating spectral line in this band. The other narrowband contributions are due to nonlinearities of the loudspeaker.

The graph to the left is showing the total energy (left line) and the broadband energy (right line) in the given frequency band. The difference corresponds to the narrowband contributions. Since the 500 Hz line is by far the strongest line, it can be concluded that the variations in the difference is caused by fluctuations of this line. Indeed these variations are very strong though there have been only light winds ($\approx$ 3 m/s). The relative SPL varies between 24 dB and 48 dB and the strongest change occurred about 40 seconds after the measurement started: the relative SPL dropped about 20 dB within six seconds.

Long Range Measurements

A number of helicopter flights have been conducted starting about 20 km north of the test site, approaching with constant speed and altitude. Since there were good propagation conditions the helicopter could be detected over a large distance. This can be seen in Figure 5, which is showing the first minute after starting the run. The blade passing frequencies can be detected after about 15 seconds. Figure 6 shows the analysis while the helicopter was close to the CPA.

This trial has been chosen to compare the measured SPL as a function of range with the theory. In a first step the sound pressure power density at two discrete frequencies, i.e. 50 Hz and 200 Hz, and in the frequency band between 25 Hz to 225 Hz has been evaluated. The result is shown in Figure 7. All three levels behave in a similar way. In Figure 8 the measured level at 50 Hz is compared with three theoretical estimates. The dotted lines represent geometrical spreading plus absorption only. The full line shows the estimated level according to the CERL-FFP-model. All theoretical results have been fitted with the measurement at a distance of 10 km. It can be seen from Figure 8 that the result obtained with the CERL-FFP-algorithm fits best with the measurement. Especially at closer ranges there is a good correlation, whereas the model seems to predict higher levels at larger ranges than really have been measured.

Terrain Masking

The aim of these measurements was the investigation of the masking of sound by a natural barrier. For this purpose ATLAS deployed its microphones across a hillside as shown in Figure 1.

Both helicopters and high explosives were used during these trials. In the following only results obtained from helicopter measurements will be presented. The insertion loss of the barrier has been derived by calculating the spectral difference between the microphone in the shadow and the one on top of the hill. This one was used as a free field reference (labelled CH-3 in Figure 1). Figure 9 is showing the result of such a measurement. The helicopter was hovering 200 m south of the hill at an altitude of 65 ft above ground level (AGL). Since the height of the hill was approximately 100 ft, the helicopter was masked at all microphone positions beyond the hill (CH-7 to CH-12).

Two microphone outputs have been analyzed, i.e. CH-9 at the northern toe of the hill and CH-12 at the end of the sensor layout. The analysis has been restricted to the harmonics of the blade passing frequencies. Beyond 175 Hz the S/N was too poor to obtain reliable results. Both channels show a very similar lapse of the relative SPL. The calculated lapse follows a simple relation: insertion loss IL [db] ~ 0.1 * f [Hz]. At helicopter altitude of 330 ft AGL there are line-of-sight (LOS) conditions between the helicopter and the microphone at location CH-12. The microphone at the toe of the hill, however, is still masked by the hill. The result of the analysis is shown in Figure 10. The lapse of the IL for the microphone located at CH-9 is very similar to the previous results. The signal received at CH-12 seems to be almost unaffected by the barrier, as would be expected under LOS conditions.

SUMMARY

In this paper a short overview of the results obtained from the JAPE is given. The most important results gained up to now are:

Even under almost good met conditions strong changes of the SPL can occur. At 500 Hz variations of 20 dB and more have been measured over a transmission distance of 1000 m.

The level of the sound emitted by an approaching helicopter has been analyzed at ranges starting at 20 km. These results were compared with theoretical estimates and it was found that the CERL-FFP fits reasonably well with the measurements.

From the Terrain Masking experiment it turned out that within the investigated frequency range the insertion loss in decibels is almost linear related to frequency, i.e. IL [dB) ~ - 0.1 · f [Hz].

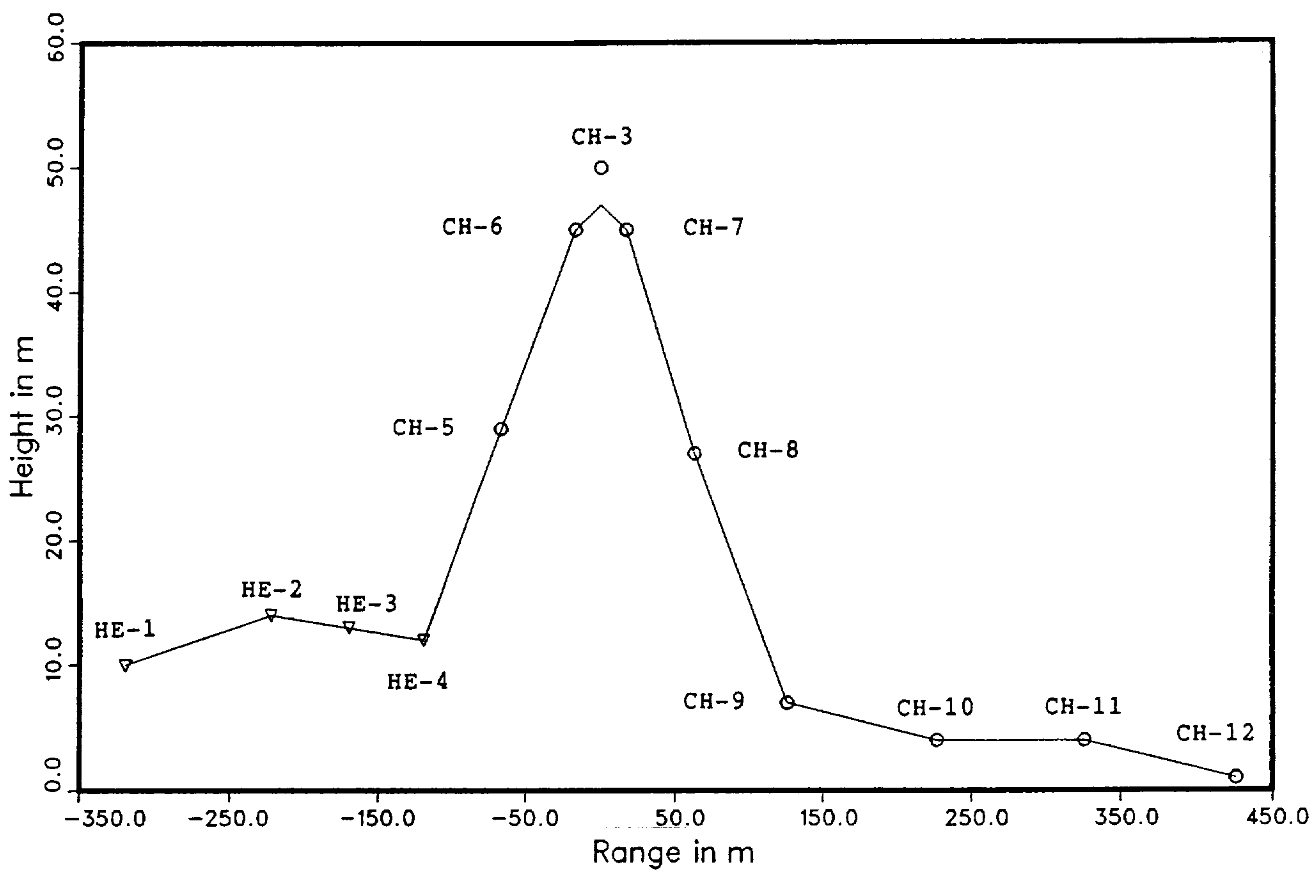

Figure 1: Topography and sensor layout during the Terrain Masking trials. Circles indicate the positions of the microphones; triangles indicate the positions of the high explosives.

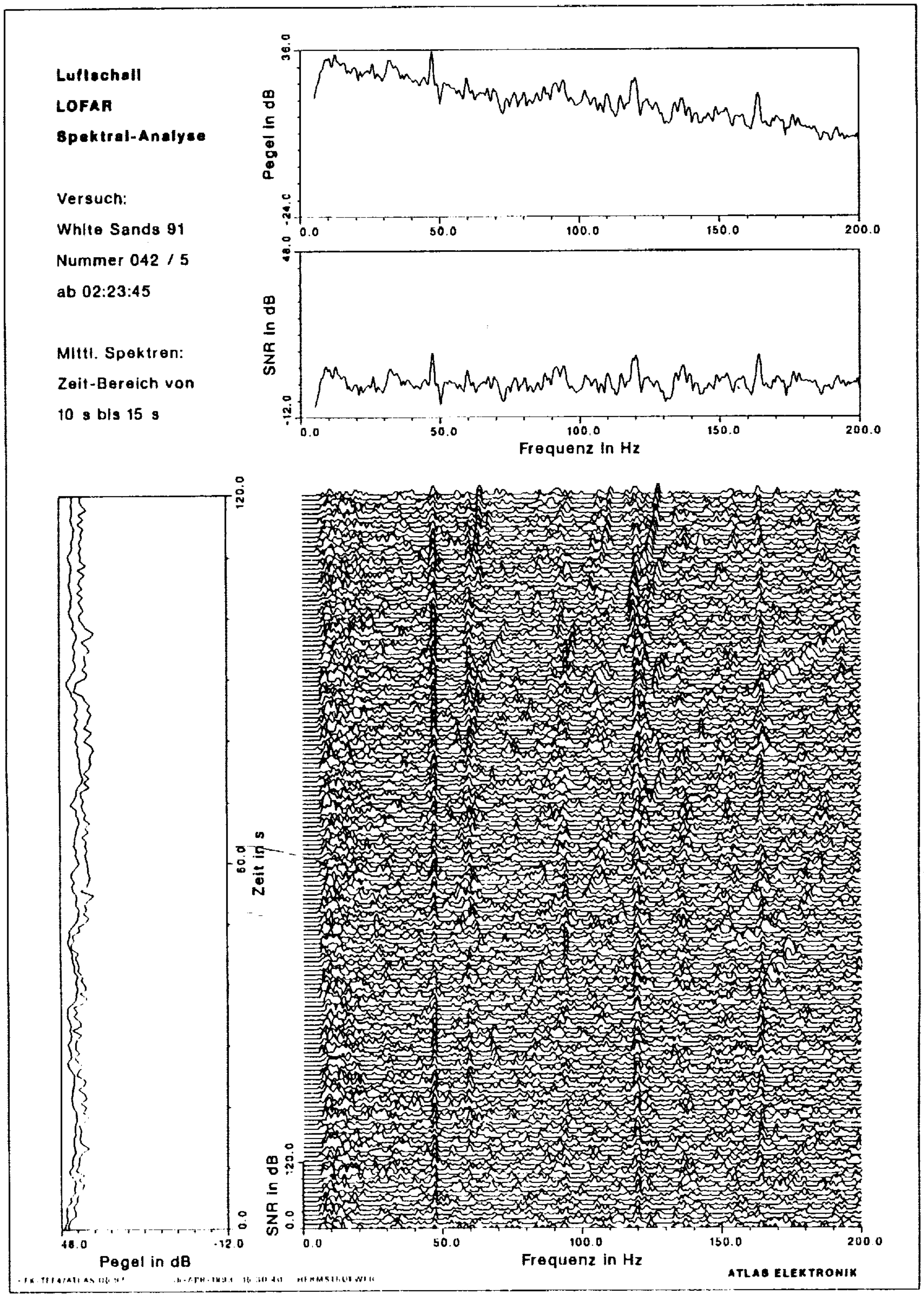

Figure 2: Ambient noise measurement. Top: averaged reference spectrum before and after (below) the broadband contributions are removed. Right: spectrogram of the ambient noise. Left: energy in the shown frequency band (left) and broadband contribution in the same band (right).

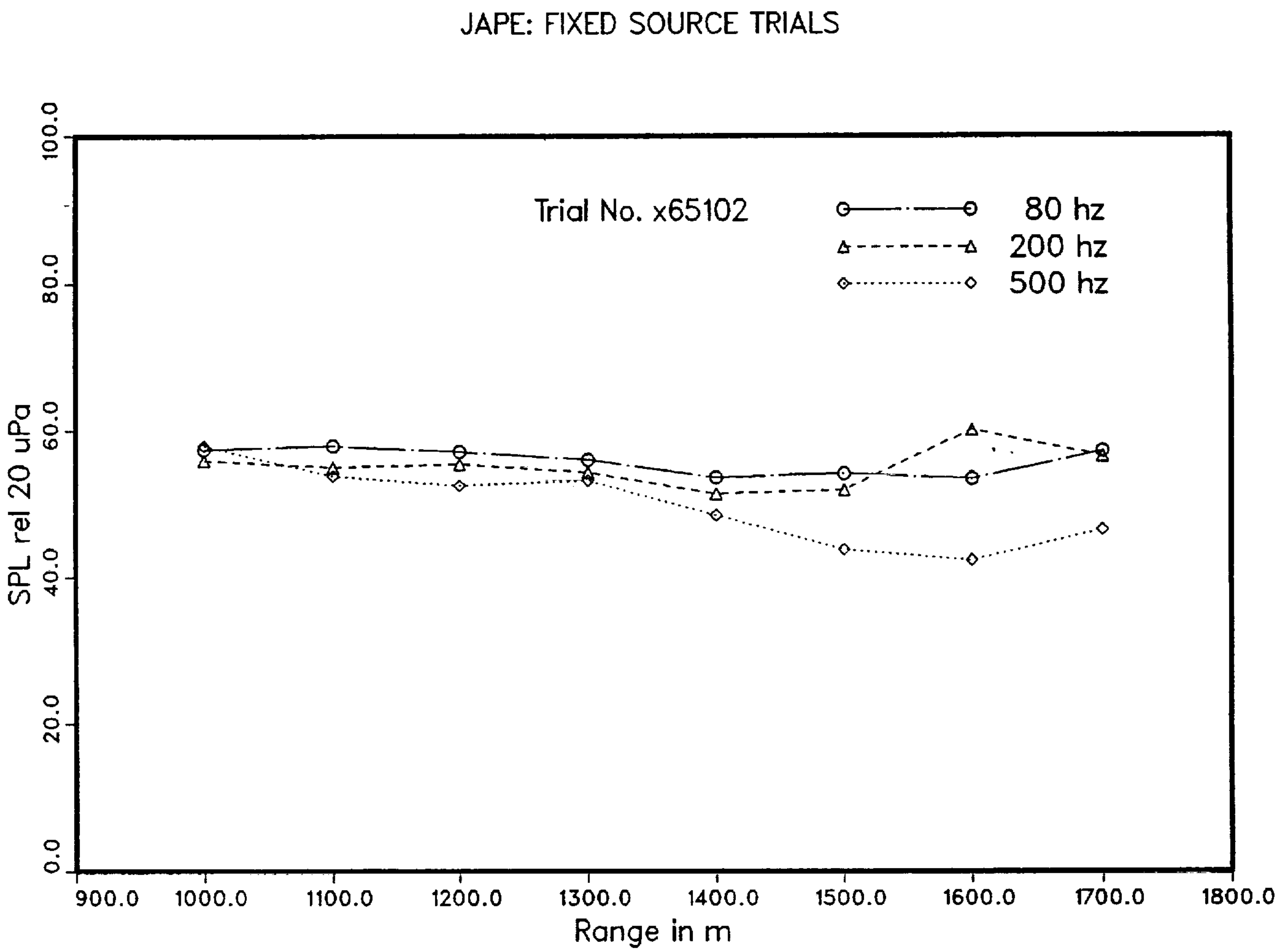

Figure 3: Averaged SPL as a function of range at three different frequencies. The loudspeaker was mounted on top of the southern met tower.

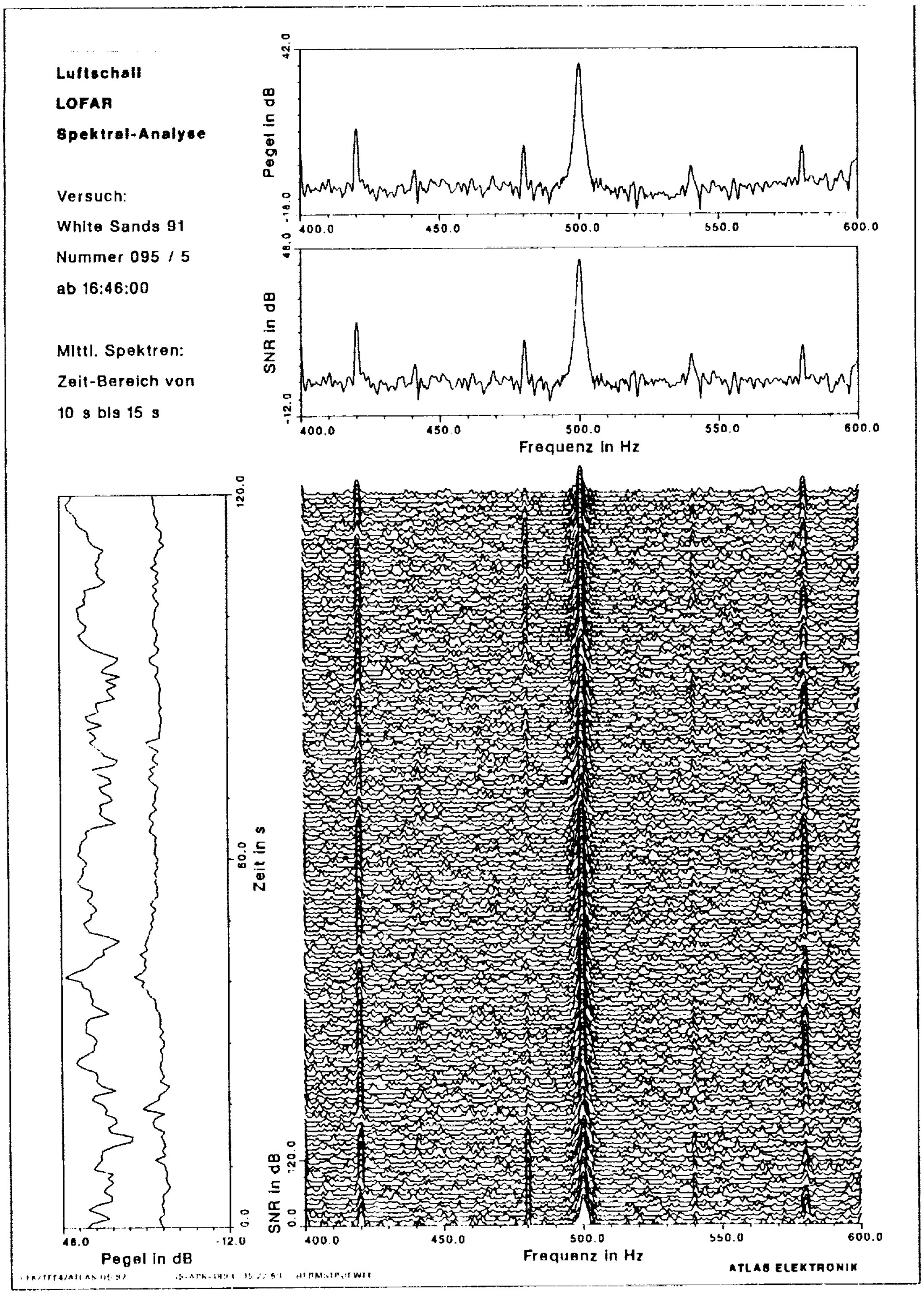

Figure 4: Spectrogram of a pure tone (500 Hz). The SPL shows strong variations due to changing propagation conditions.

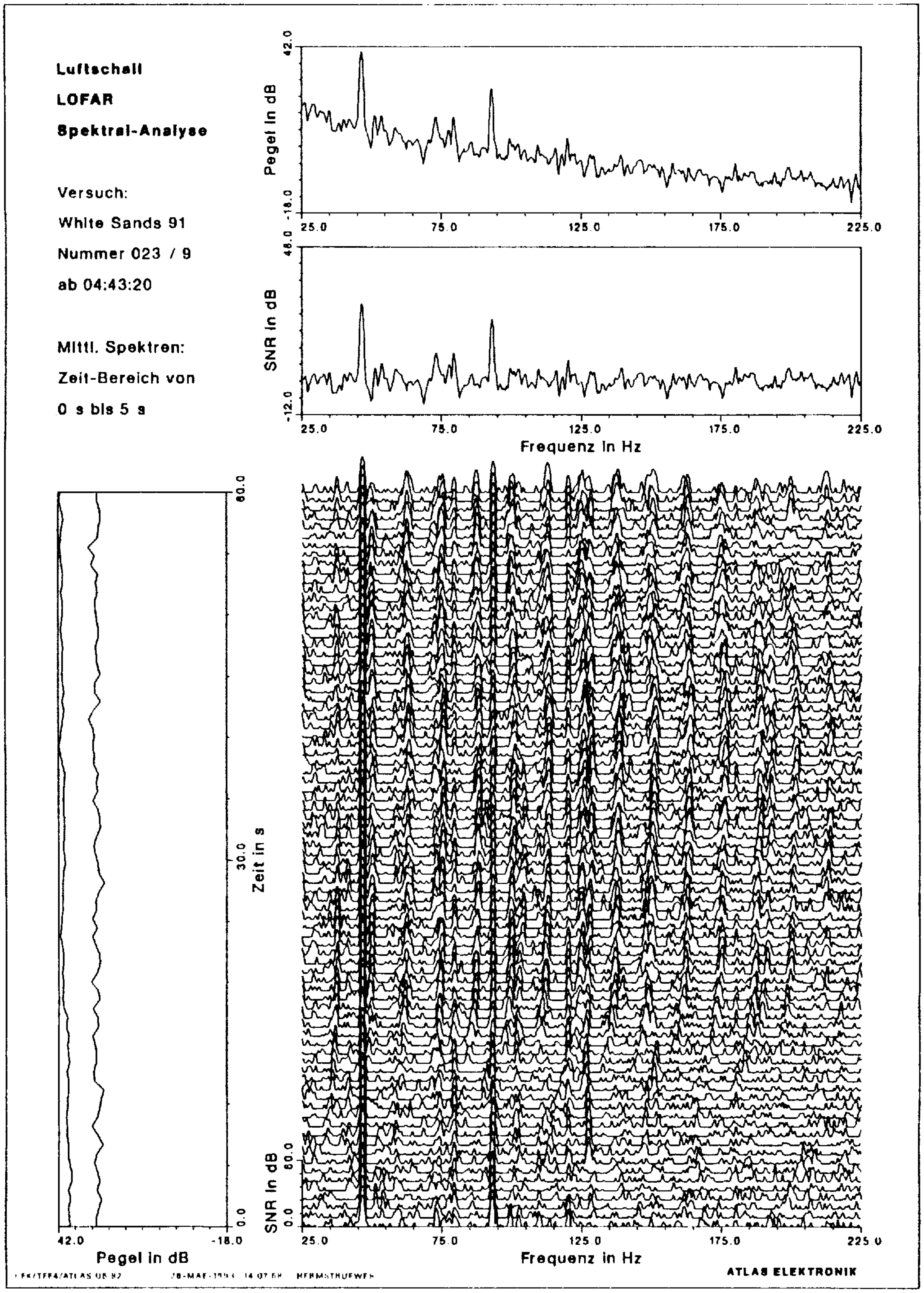

Figure 5: Spectrogram of an approaching helicopter. Beginning of the run.

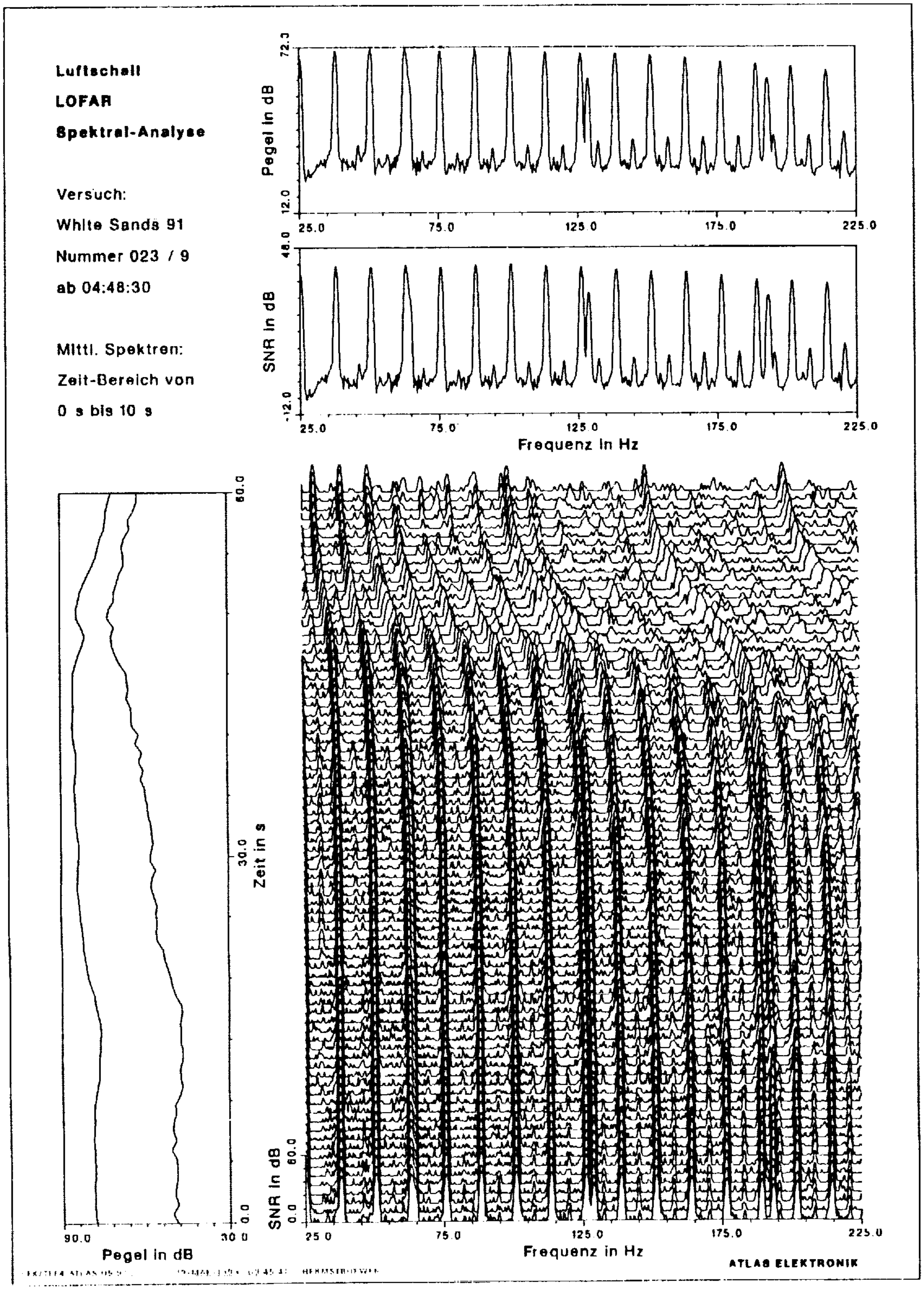

Figure 6: Spectrogram of an approaching helicopter close to the CPA.

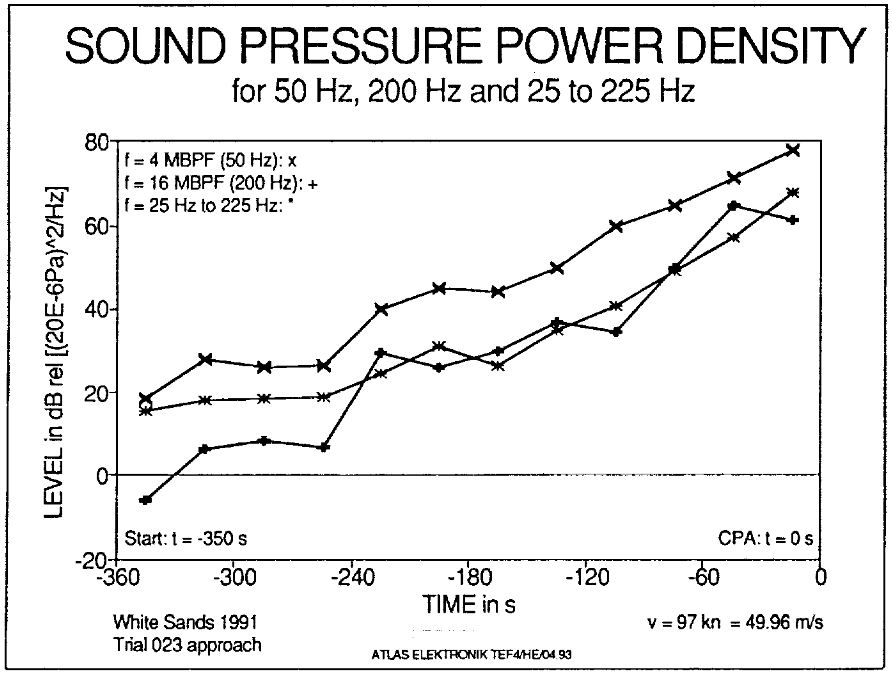

Figure 7: Measured sound pressure power density as a function of time. Same trial as in Figs. 5 and 6.

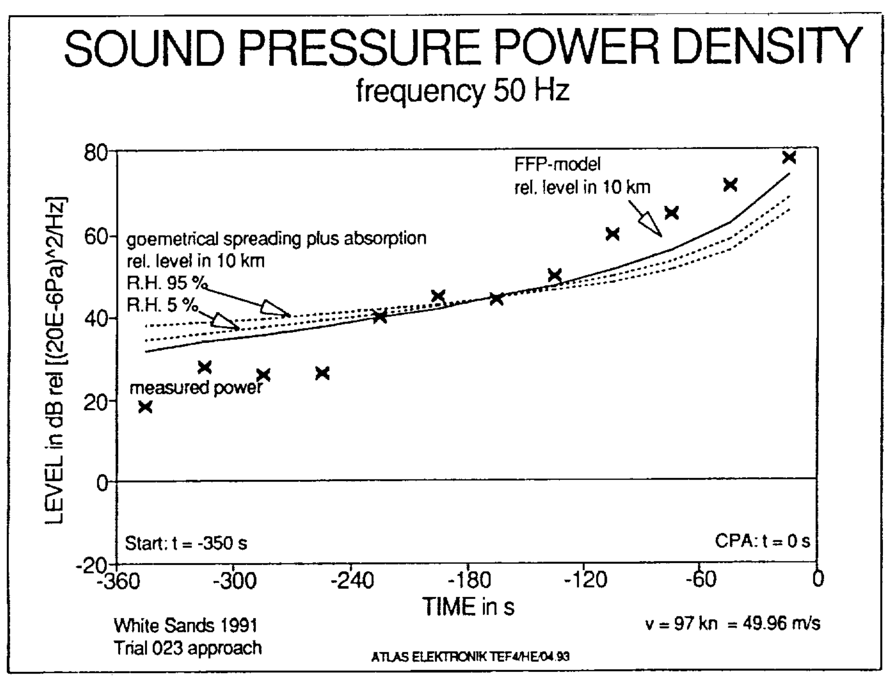

Figure 8: Comparison of the measured lapse of the SPL with theoretical models.

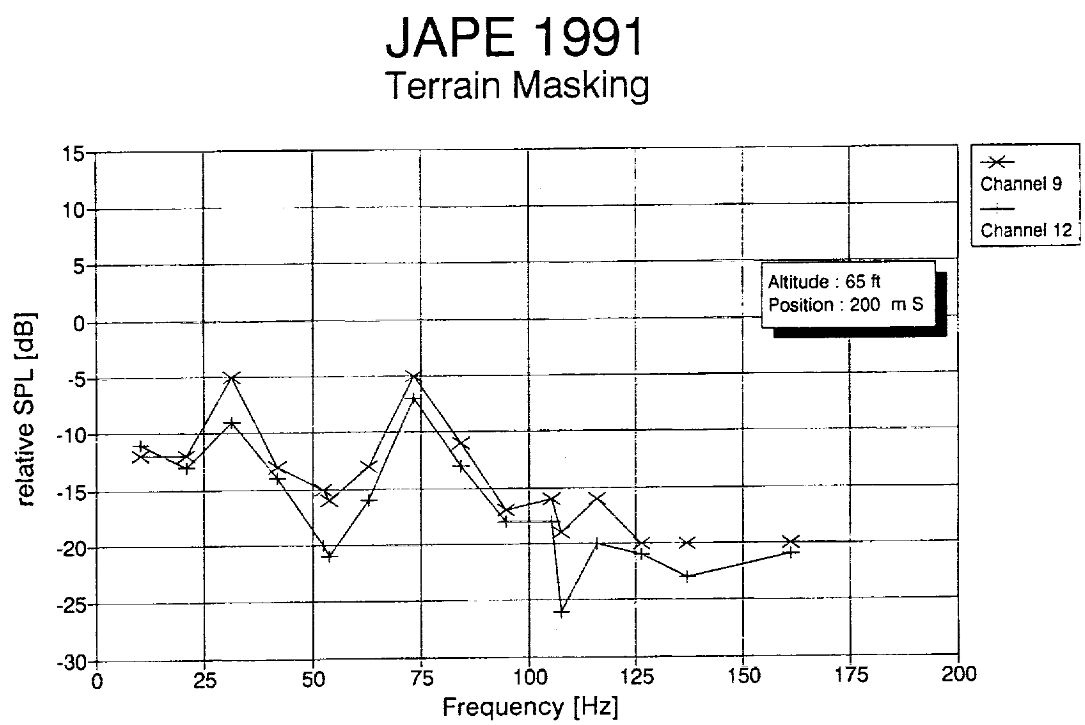

Figure 9: Frequency dependence of the insertion loss of a natural barrier for two microphone positions (see Fig. 1 for comparison). The helicopter is totally masked.

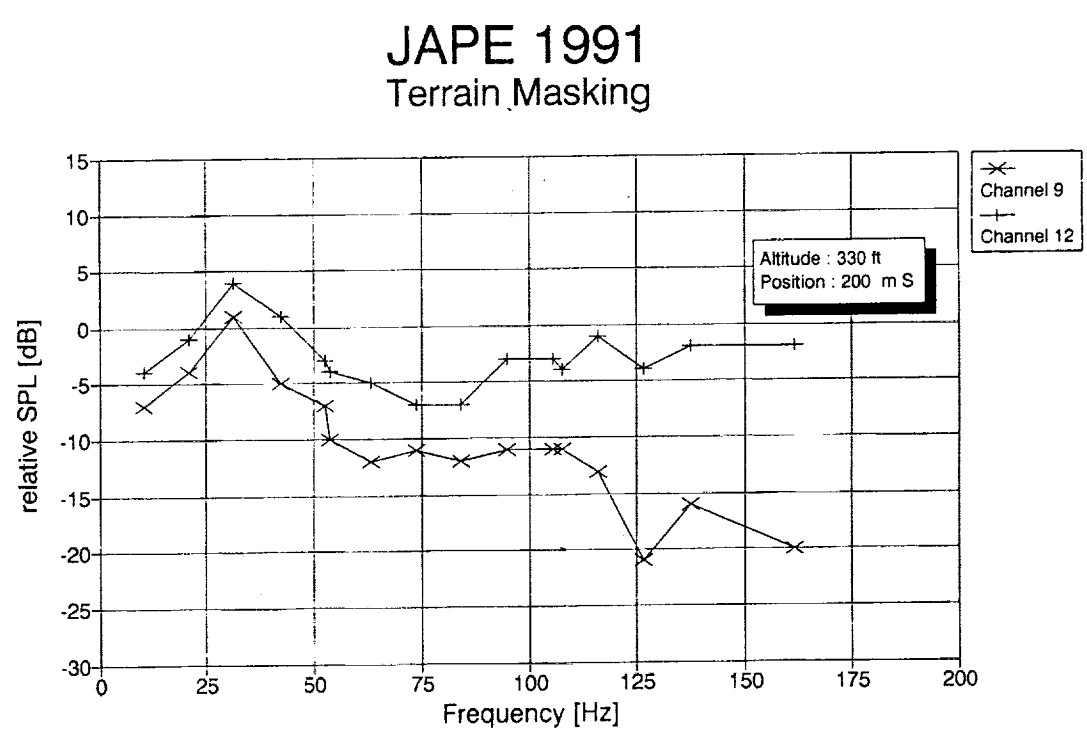

Figure 10: Frequency dependence of the insertion loss of a natural barrier for two microphone positions (see Fig. 1 for comparison). There are line-of-sight conditions between the helicopter and microphone CH-12.