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THE INFLUENCE OF RECEIVER HEIGHT ON SOUND LEVELS FROM SOUND SOURCES IN LARGE DISTANCES

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1. INTRODUCTION

A reliable sound propagation model is the basis of any prediction for noise load and rating levels, respectively, to assess the annoyance of people. For high energy, low frequency blasts the influence of weather conditions, terrain, ground and vegetation on the propagation of sound over large distances are not yet fully understood. Therefore, a series of joint experiments focusing on blast propagation was conducted in Norway in order to establish a well-documented database. This database provides detailed test data to develop and to validate propagation models for blasts. A presentation of these joint experiments including the description of the test layout is presented elsewhere in these proceedings.

At the receiver sites of these trials the blasts were recorded simultaneously at different heights up to 30 m above ground level primarily to study the effect of vegetation on the propagation of sound. However, the results of these experiments are also useful to study in general the influence of receiver height on sound levels for far range propagation of blasts.

The superposition of direct and reflected sound normally explains that sound levels can vary with receiver height. For close range propagation (< 500 m), a simple physical model - including locally reacting boundaries and sound speed gradients - can predict these variations [1]. For large scale propagation of blasts the receiver is expected to collect contributions from sounds traveling on different paths from source to receiver. Some will propagate on so-called direct paths; Others will suffer one or more reflections at the ground. The ground is typically not flat and does not provide uniform boundary conditions: the signals are not coherent anymore. The fluctuation of weather conditions along the paths adds more reasons to the assumption that - for a series of events - these effects should average out all influences of receiver height on sound levels.

At first sight, the results obtained in Norway support this view so far single event levels are concerned. However, without any respect to source strength or range or weather condition, there seems to be a clear influence of receiver height on the third octave spectra of the measured sound pressure. This paper focuses on the analysis of this influence.

2. RESULTS

At the north and at the west mast the microphones line up parallel to the mast at heights of 0 m, 1 m, 2 m, 4 m, 8 m, 16 m and 30 m. Tab. 1 lists the average difference between the levels at these heights and the level measured at ground level for some frequently used weighted levels.

Tab.1 Average differences of single event levels between the levels at different receiver heights and 0 m for west and north mast

Level	ΔL_{Peak} in dB		ΔCSEL in dB		ΔASEL in dB	
Location	west	north	west	north	west	north
30 m - 0 m	0.52	-1.00	0.19	-0.94	0.98	---
16 m - 0 m	0.96	-2.30	0.29	-2.51	1.02	---
8 m - 0 m	0.70	-0.80	-0.18	-1.20	0.72	---
4 m - 0 m	0.90	-0.67	0.30	-0.90	0.53	---
2 m - 0 m	-1.77	-0.54	-1.09	-0.61	1.35	---
1 m - 0 m	-0.84	---	0.17	---	2.53	---

The average procedure includes all events without any respect to distance between source and receiver, to source location, to charge or to wind conditions. The only condition that the levels must meet is that they sufficiently exceed background level. Obviously, the results in tab. 1 indicate that the receiver height has no significant influence on these levels. The differences are sufficiently small to say that they may due to measurement equipment or calibration, respectively.

Fig. 1 shows the same average difference for the third octave spectra. Now, there is a clear change with receiver height. The general pattern at both measuring sites is the same: The low frequencies have higher levels close to the ground; the medium frequencies have higher levels in greater heights; the cross-over frequency between these regions decreases with receiver height; the shape of each spectrum is changing smoothly with frequency. These observations conclude to the assumption that this behavior is not accidental and - because no selection is made according to special sources or sound propagation conditions - this behavior should have a common explanation.

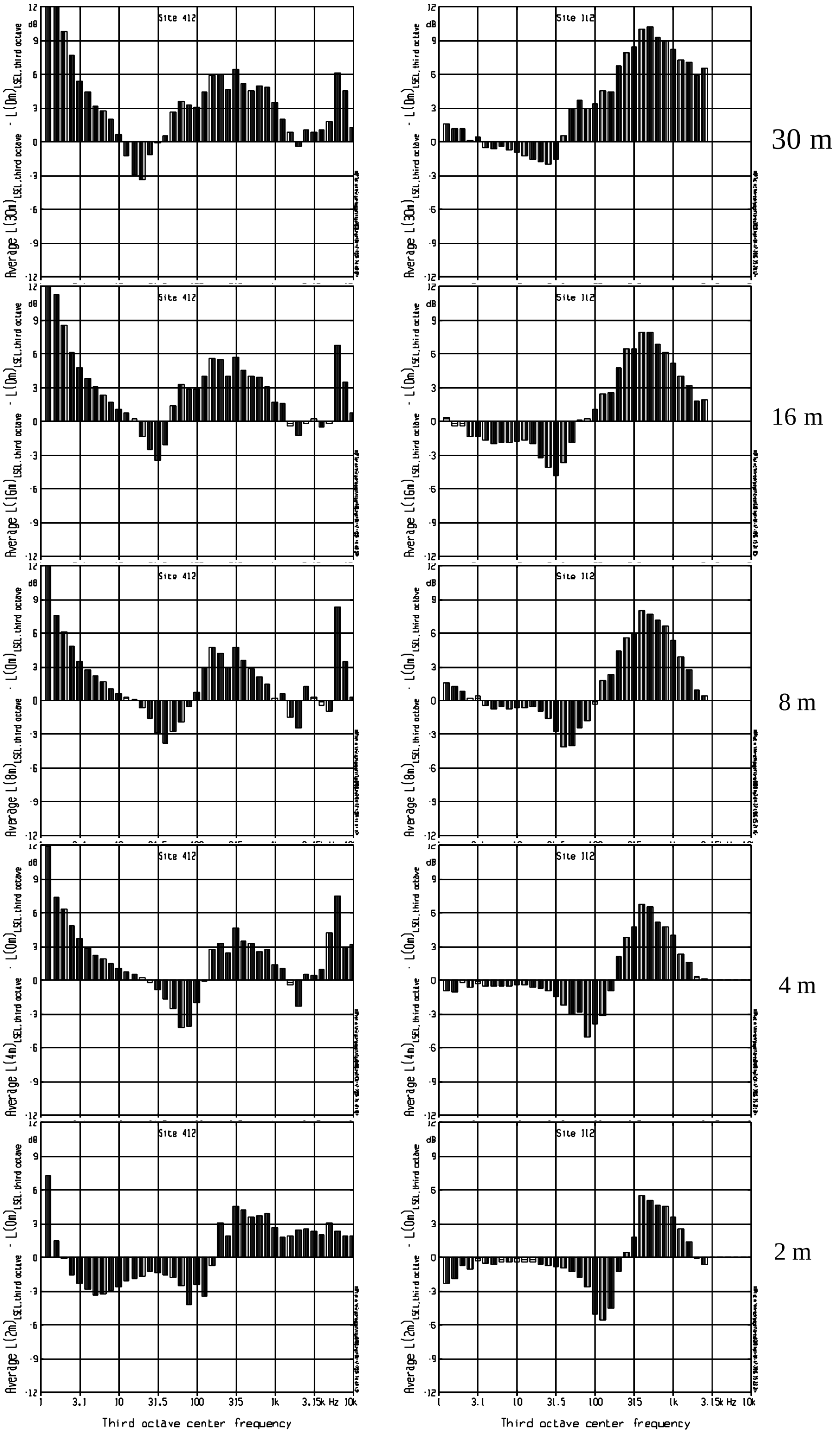

Fig. 1 Spectral level difference for different receiver heights and 0 m height at the west mast (left column, 412) and at the north mast (right column, 112) (At the west mast the microphone at 0 m has a cutoff frequency at 2.6 Hz, so, the third octaves lower than 3.1 Hz are not reliable).

The results in fig. 1 are looking very clear. However, we need to know whether a series of events grouped by the same condition - for example, having the same wind direction or charge weight - dominates this average. Therefore, fig. 2 representatively shows a more detailed analysis for the difference between the 30 m levels and the 0 m levels measured at the west mast for some representative third octaves. Fig. 2 compares the average for all measurements to the average for the group of all 1 kg charges, of all 8 kg charges, of all 64 kg charges, of all charges fired on the north-south leg, of all charges fired on the west-east leg, of all events propagating under downwind conditions and of all events propagating under upwind conditions.

In fig. 2, the symbols indicate the mean values, the bars indicate the standard deviation for each selection and third octave. The standard deviation is about 3 dB in the low frequency part of the spectrum and

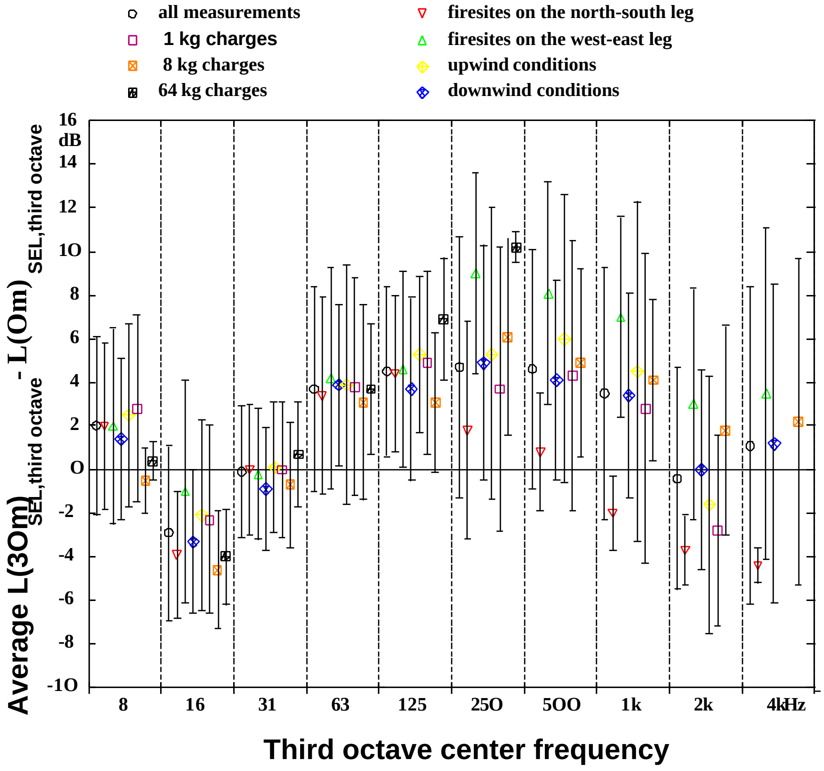

Fig. 2 Spectral level difference between 30 m and 0 m height at the west mast
Different symbols indicate different selections for source or propagation conditions.
The bars indicate the standard deviation for each center frequency and selection.

increases to about 5 dB for higher third octaves. For some selections there are missing values in the 2 kHz and 4 kHz third octave due to too low levels in either the 30 m level or the 0 m level or both compared to the background noise. The results for every selection support individually the shape pattern of the overall spectrum. This strongly holds true for the low frequency part up to 125 Hz. There seems to be no influence of the selections under consideration. However, beginning with the 250 Hz third octave, the results for the fire site selection diverge. Sounds produced by firing on the north-south leg yield approximately 7 dB higher levels than those fired on the west-east leg in 30 m height. This selection is sensitive to the direction of incidence of the blast wave and may indicate the influence of terrain either in the vicinity of the mast or over the whole path of the blast wave. However, the terrain cross-sections for all these sound paths are looking very similar. If shielding is responsible for this clear result, it is remarkable to note that the selection of wind direction does not yield such a difference in behavior.

3. DISCUSSION

Overall, the result of this analysis for large scale propagation is very similar to those validated theoretical results obtained for blast propagation close to the source [1]. In this case the superposition of the direct and the reflected wave from the ground can yield ‘dips’ and ‘peaks’ in the spectrum of the sound pressure signal. The center frequency and the depth of these dips strongly depend on the angle of incidence determined by source and receiver heights, on variations of ground impedance and on additional phase shifts between direct and reflected wave due to slight changes in wind speed and temperature profiles.

It is an interesting hypothesis to use the same explanation for the level differences in the results under consideration. In the introduction we stated that blast sound will lose coherence if it travels on different paths to the receiver (There is no doubt that such a multiple path propagation takes place because the receiver signal lasts a very long time compared to the original blast signal.) Without coherence we cannot explain dips and peaks in the spectra by superposition. So, it is important and sufficient to assume that we have again coherent signals at every receiver location. Only reflections in the vicinity of the receiver, normally from the ground, can cause this coherence. If the ground providing a complex, frequency dependent impedance is the reflector we could explain the frequency dependent phase shifts that will cause the dips and peaks in the spectra. However, in order to get reflections from the ground, we must assume that the sound and every contributing part of the sound, respectively, has a typical angle of incidence.

If this hypothesis holds true the impedance of the ground in the vicinity of the receiver is the key to understand the measured pressure signals. And, the sound pressure levels are not the direct key to understand the sound propagation over far distances in general. The reason for the second statement is that the so-called energy equivalent sound levels like SEL or the third octave spectrum built on sound pressure measurements do not measure the acoustical energy in this case. With respect to sound propagation models, this conclusion means that we should not aim on the prediction of pressure levels but on the prediction of true energy-equivalent levels - true in the sense of acoustical energy -, because pressure signals are locally produced and are sensitive to the ground impedance.

However, we need further tests to validate or falsify this hypothesis. This study does not yet include the so-called winter trials: another set of data collected in the same manner at the same sites at low temperatures and with a typical snow cover. Considering these results should help to understand the presented influence of receiver height on measured sound levels. It will be interesting to see whether a snow cover changes the results and whether the impedance measurements conducted parallel to the tests will help to understand the sound pressure signals in different heights.

4. CONCLUSIONS

The paper shows that the sound pressure signal strongly depends on receiver height and that this dependency needs not to yield differences in single event levels. The second statement includes the warning that there will be important differences also in the weighted single event levels if certain frequency components dominate the signals.

The hypothesis that the superposition of direct and locally reflected waves at the ground can explain this dependency. However, more test data are needed to validate this hypothesis.

ACKNOWLEDGMENTS

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REFERENCES

[1] K.-W. Hirsch, ‘A Simple Model For Explosions In Air’, to be published.

[2] Papers on the general description of the joint experiments on blast propagation in Norway printed elsewhere in these proceedings.