Meteorological effects on long-range propagation: evaluation of the long-term sound level using statistical analysis.

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Introduction

The influence of temperature and wind gradients on long-range sound propagation has been known for years. However, today it is very difficult to estimate a reliable long-term sound level value from one level measured over a period smaller than one year.

The first part of this paper presents the method used to obtain a series over several years of theoretical hourly sound attenuations between a point source and a receiver. Typical results given by a statistical analysis of this series are also presented. The second part presents an application of this method for estimating the long-term sound level value from one level measured over a short period.

The Long-term reconstitution method

Basis of the method

The long-term reconstitution method [1] is based on the coupling of a micrometeorological model with a model of sound propagation. The micrometeorological model [2] provides the hourly gradients of wind speed and air temperature, from standard climatic data either given by a local meteorological office or by a long-term monitoring experimental site (see [3] for ex.) and also from the acoustical and geometrical characteristics of the ground and source/receiver position. These gradients are combined with wind direction to obtain a series of hourly vertical gradients of sound celerity which is then introduced in a numerical propagation model. This model is based on the resolution of the Helmholtz equation by parabolic equation [4]. Finally we obtain a series of hourly sound attenuations, or $L_{eq(A)}$, over a period which is too long to be observed in practice (typ. several years).

Assumptions

The results presented here relate to a monopolar source with a typical road-noise spectrum. The source and the receiver are respectively located at 0.05 m and 1.2 m above the ground. The ground is assumed to be flat and is modelled with the Delany-Bazley model with σ=300 kNms^{-4} (grass). The meteorological data were measured near Angers, France, from Jan. 1, 1962 to Dec. 31, 1990.

Typical results

The spectral analysis represented fig. 1 shows that a series of $L_{eq(1h)(A)}$ over 29 years has no higher periodicity than one year. This is in agreement with the results given in [1] that mention that the $L_{eq(1\ year)(A)}$ is a good estimation of the long-term value [1].

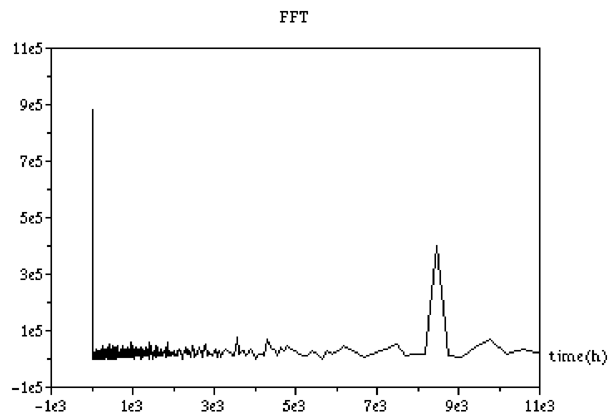

Figure 1: Spectral analysis of a 29 years series of $L_{eq(1h)(A)}$

When using ephemerides the series of $L_{eq(1h)(A)}$ over 29 years can be merged into diurnal and nocturnal sound levels. The figure 2 gives the typical distribution of the diurnal series of $L_{eq(1\ month)(A)}$. Important amplitudes in attenuation variations clearly appear with the seasons.

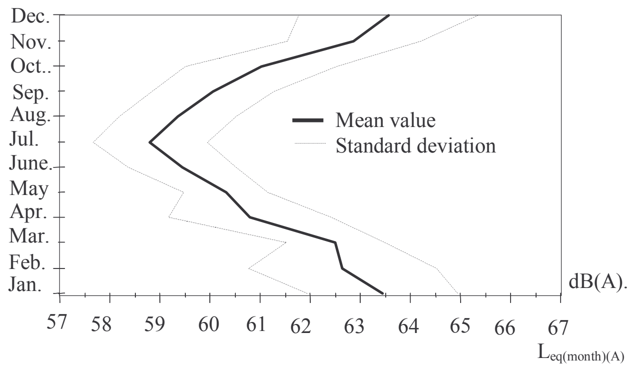

Figure 2: Typical distribution of $L_{eq(1\ month)(A)}$ (arbitrary reference).

Application : measurements and long-term estimation

Introduction

Even if a measurement over one year can provide a good estimation of the long-term sound level, it is rarely possible to perform such a measurement in practice. This part describes a procedure for correcting the acoustic measurements in order to estimate the long-term sound level from a short period of measurement.

Description of the procedure

We consider here a receiver and a set of monopolar sources S_j which acoustic power are $L_{w,j}$. The "true" long-term sound level L_{LT} is assumed to be the energetic average value over 29 years. The difference between this value and the sound level L_{mes} measured over a smaller period can be written

$$\Delta L = L_{LT} - L_{mes} = 10\log\left(\sum_j 10^{\frac{L_{LT,j}}{10}} / \sum_j 10^{\frac{L_{mes,j}}{10}}\right) \quad (1)$$

where $L_{LT,j}$ and $L_{mes,j}$ are respectively the long-term and the measured sound level contributions of the source S_j to the total sound levels L_{LT} and L_{mes}:

$$L_{LT,j} = L_{w,j} - A_j \quad (2)$$

$$L_{mes,j} = L_{w,j} + 10\log\left(p_{d,j}10^{\frac{-A_{d,j}}{10}} + p_{h,j}10^{\frac{-A_{h,j}}{10}} + (1 - p_{d,j} - p_{h,j})10^{\frac{-A_{u,j}}{10}}\right) \quad (3)$$

$A_{d,j}$, $A_{h,j}$ and $A_{u,j}$ are the acoustic attenuations between the source S_j and the receiver, for respectively downward, homogeneous and upward refraction conditions that occur at the respective probabilities $p_{d,j}$, $p_{h,j}$ and $1 - p_{d,j} - p_{h,j}$. A_j is the long-term total attenuation between the source S_j and the receiver.

The values of the various probabilities are provided by micrometeorological measurements (temperature and wind data) during the acoustic measurements period. The attenuations are provided by computation by using the long-term reconstitution method described in the first part.

Application to a road source

The road is classically split into a set of source segments distributed along its axis. When considering a far field model, each source segment can be modelled by an equivalent acoustic monopole S_j located in the corresponding segment. The acoustic power of each source S_j depends on the length l_j of each segment (equiangular distribution from the receiver).

Eq. (1) to (3) finally lead to the following estimation of the long-term value of the sound level at the receiver:

$$L_{LT} = \Delta L + L_{mes} \quad (4)$$

with

$$\Delta L = 10\log\left(\sum_j l_j 10^{\frac{-A_j}{10}}\right) - 10\log\left(\sum_j l_j\left(p_{d,j}10^{\frac{-A_{d,j}}{10}} + p_{h,j}10^{\frac{-A_{h,j}}{10}} + (1 - p_{d,j} - p_{h,j})10^{\frac{-A_{u,j}}{10}}\right)\right) \quad (5)$$

where ΔL is to the long-term correction.

The figure 3 gives an example of application: the road is split into 4 sources located respectively at the distances 300m, 173m, 150m and 173m from the receiver, at the angles 220°, 200°, 180° and 160° from the North.

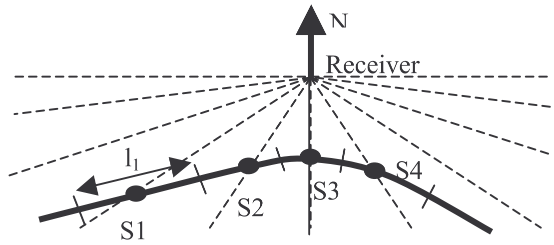

Figure 3: example of sources/receiver locations

The measurements and the long-term method provide the data given in table 1: for this example, eq. (5) leads to a long-term correction equals to -1.2 dB(A).

Sj	l_j (m)	Probabilities		Long-term attenuations (dB(A))			
		$p_{d,j}$	$p_{h,j}$	$A_{d,j}$	$A_{h,j}$	$A_{u,j}$	A_j
S1	200	0.5	0.02	66.3	74.1	82.6	70.5
S2	100	0.45	0.02	59.3	68.8	75.5	63.6
S3	70	0.4	0.02	44.9	53.5	58.5	49.3
S4	100	0.35	0.02	59.9	68.8	75.2	65

Table 1: measured and long-term data

Conclusion

The method described in this paper is a much interesting tool for estimating the long-term sound level from a short period of measurement. It is valid for a flat ground with no important change of its characteristics during the measurements. A campaign of measurements is currently in progress in order to validate this theoretical method.

References

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