LONG RANGE OUTDOOR SOUND PROPAGATION MODEL

Alex Boudreau[1], André L'Espérance[1], Jean Nicolas[1] and Gilles Daigle[2]
1) Faculty of Applied Sciences, Université de Sherbrooke, Sherbrooke (Qué) Canada, J1K 2R1
2) Institute of Microstructural Sciences, National Research Council of Canada, Ottawa Canada, K1A 0R6

Introduction

In the case of medium and long ranges outdoor sound propagation, refraction due to temperature and wind gradients may increase (or decrease) the sound pressure due to a point source[1,2]. To fulfill the needs of practical outdoor sound propagation studies, it appears to be necessary to develop practical and reliable software for engineering purposes to predict outdoor sound propagation under general meteorological conditions. This paper present the software *LORAP* developed to reach that goal.

1.0 Theoretical background

This software included an acoustical propagation model and a meteorological model. Those theoretical model are based on the research done in the past 10 years on the effect of ground and of the atmospheric conditions on outdoor sound propagation.

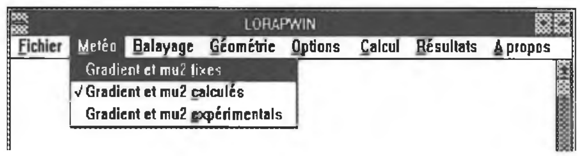
The acoustical model is based on an extension of the classical ray-theory[3]. This heuristic model assume a linear sound speed gradient '*a*' .) to consider the effect of the atmospheric refraction. This hypothesis allows an analytical determination of the curved ray path parameters (travel time, angle of reflection on ground, path length etc.). The effect of the atmospheric turbulence can also be included by considering the lost of coherence between rays. Various comparisons with other acoustical models and with experimental results done in the recent years have shown the efficiency of this model[3-4].

The meteorological model estimates the sound speed profile (SSP) between a source and a receiver and the fluctuating index of refraction according to input meteorological data. This (SSP) is calculated using the temperature and wind profiles. The exact determination of the wind and temperature profiles from general meteorological conditions is done using the surface-layer similarity scaling theory[5]. The data needed to estimated these SSP will be mentionned in the following section.

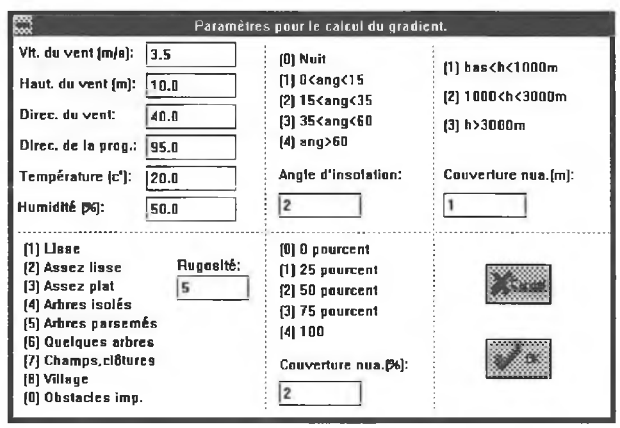
Using this SSP, the algorithm then calculated the linear sound speed gradient a necessary to the acoustical model to evaluate the effect of the atmospheric refraction. The linear sound speed gradient a used in the acoustical model is determined based on a method used in radio communications[5]. This method assumed that between a source and a receiver, the zone of space concerned with the propagation process is mostly defined by the first Fresnel ellipsoïd. The equivalent linear sound speed gradient is obtained by considering the mean of the real sound speed profile in the first Fresnel zone. Because the wide of the Fresnel ellipsoid is function of the distance and of the frequency, the linear sound speed gradient *a* depends not only on the heights of the source and receiver, but also on the frequency and on the heights of the source and of the receiver.

2.0 Data input

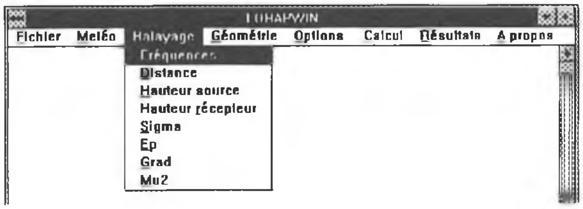
The software has been developed with the window standards and the main panel has 6 menus: *Fichier, Météo, Balayage, Géometrie, Options, Calcul and Résultats.*



The *Fichier* (*File*) menu is used to input old data files or store new data file and results. The option Météo is used to set the values of the sound speed gradient *a* and the index of turbulence$<\mu^2.>$. These values can be either fixed, calculated from meteorological conditions, or be experimental values. If the user want to calculated *a* from the meteorological conditions (the second choice), then a sub-menu asking for the wind speed and direction, the temperature, cloud cover, azimuth of the sun, and roughness of the ground will be presented, in which the user can change any parameters.



The menu *Balayage* (sweeping) allows to the user to calculated the sound pressure as a function of the frequency, or the distance, or the height of the source, of the receiver etc. In each case, the minimum and the maximum values and the step could be choose by the users.



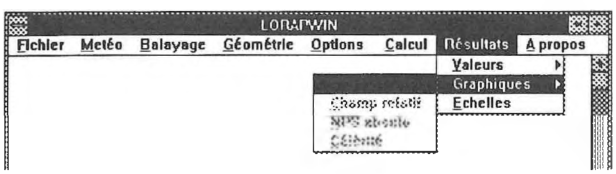
The data related to the geometrical configuration to study (height of the source and of the receiver, distance source to receiver, type of ground and sound power spectra of the source), are input using the geometry menu.

The *Options* menu allows to the user to modify some aspects of the theoretical calculation. For example, the maximum number of rays between a source and a receiver can limited. This option thus allows to the user to see the effects of additional rays in presence of a positive sound speed profiles. The effect of the atmospheric absorption can also be considered or not. The maximum height that a ray can reach can also be limited to a certain value, which can be usefull to simulate, for exemple the effects of a double linear sound speed gradient etc.

The *Calcul* menu start the calculation. For standard cases, the calculation time is couple seconds, even at high frequencies and long distances. When the sound speed gradient is important and/or when the number of calculation points increases (which depend on the value of the *step* choose in the *Balayage* menu), the computation time will increase, but in general it will be lower then a minute. It should be mentioned at this point that the heuristic acoustical model used in this software required very low computation time compared to other method like PE[6] or FFP[7] methods that could required hours of computation at long distances and high frequencies.

3.0 Results

After the calculation, numerical value or graphics of the results could be obtained with the *Resultats* menu.



Numerical values or graphics of the results can be obtained on the screen, and/or transfer on a Excel file. The results available are the excess attenuation (attenuation compared to the level at 1m), the relative sound pressure level (attenuation compared to the level in free field without atmospheric effects), and the absolute sound pressure level (which depend on the sound power of the source input in the *Geometrical* menu). Figure 1 give as an example the results of the benchmark case published in a recent paper[4]. Note that the sound speed profile calculated according to the meteorological data can also be visualized by choosing the *celerité* sub-option.

Figure 1 Excess attenuation at 100 Hz in the case of a linear gradient of 0.00295 m^{-1} source height 5 m, receiver height:1 m.

4.0 Conclusions

A practical software to predict outdoor sound propagation under general meteorological conditions have been developed. This software, presented on a friendly window environment, included a meteorological model and an acoustical propagation model. The results obtained are the absolute sound pressure level, the sound pressure level relative to free field and/or the excess attenuation. A second version of this software is now under development in order to calculate a mapping of the overall sound pressure level created by a different number of sources over a surface.

References

1. P.H. Parkin et al., "The horizontal propagation of sound from a jet engine close to the ground at hatfield", J. Sound Vib. 2, 4, pp. 353-374 (1965).
2. L'Esperance A. et al., Sound propagation in the atmospheric surface layer: comparison of experiment with FFP predictions", Applied Acoustics, (40) p. 325-346, 1993
3. L'Espérance A. et al.. "Heuristic model for outdoor sound propagation based on an extension of the geometrical ray theory in the case of a linear sound speed profile" Applied Acoustics, 37 p.111-139 (1992)
4. K. Attenborough,..., A. L'Espérance and others, "Benchmark cases for outdoor sound propagtion models", J. Acoust. Soc. Am., (97), 1, p.173-191 (1995)..
5. a. L'Espérance, G. Daigle « Effect meteorological conditions on outdoor sound propagation: modelisation and analysis of practical cases »,NATO-CCMS Symposium on Aircraft Noise Receiver Technology », Baltimore, Maryland, 16-20 May 1994.
6. K.E. Gilbert and X. Di " A fast Green's function method for one-way sound propagation in the atmosphere", J.Acoust. Soc. Am. 94 pp. 2343-2352 (1993).
7. S.W. Lee et al., "Impedance formulation of the Fast-Field program for acoustic wave propagation in the atmosphere", J. Acoust. Soc. of Am., **79** pp. 628-634 (1986).