A METHOD TO CALCULATE THE NOISE LEVEL OF PASSING TRAINS AS FUNCTION OF TIME. APPLICATION TO THE T.G.V.

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1. INTRODUCTION

In order to evaluate the noise impact of the T.G.V. (the french high speed train), a method to calculate the level/time evolution of passing trains has been developed.

This method is based on two steps. First an acoustical impulse response between a point source moving at a velocity V on the track and a receiver is calculated using a ray tracing method. Then the convolution product of this function with the spatial sound power level distribution of a T.G.V. along the track gives the level/time evolution of a passing train.

The method has been implemented in MITHRA [1] : a software for the prediction of traffic noise adapted to most urban or peri-urban situations, including open built-up areas, typical urban streets and open areas with any topographical characteristics. It is composed of several modules which allow to define the topography and buildings, to enter traffic conditions, calculate the equivalent sound level, the level versus time evolution of passing train and display the main path or the main part of the line source contributing to the noise level. It is used in France for the prediction of the noise impact of the T.G.V. and for optimising noise barriers in order to control noise impact by high speed trains.

The results of this software are compared with measurements made outdoor along the french high speed train lines.

2. THE ALGORITHMS

2.1. Acoustic paths

The algorithm for constructing the acoustic propagation paths between sources and the receiver is based on three essential assumptions which are : in urban areas, most of the reflective surfaces (except the ground) are vertical ; in the absence of wind, the reciprocity principle is applicable, the noise sources can be represented as line elements (elements of circulation channels), acoustic power is defined by a length unit.

The first assumption initially allows the consideration of the problem of ray research in two dimensions. If the second assumption is verified, it is possible to launch the rays from the receiver. The third assumption solves one of the problems encountered with the use of ray methods because the target to reach is not a point but an element of a line.

Initially, N rays are launched from the receiver in all directions in the horizontal plane (figure 1). Each ray is the axis of an angular sector $d\theta$. The trajectory of the ray is defined by a succession of impacts. Each impact is the intersection of a ray with a segment defining the site. At this stage, the true propagation paths might not have been identified. It is therefore necessary to consider all the possibilities which are : the ray passes above some obstacles (with or without diffraction), i.e. the ray cuts the corresponding site segment ; the ray is reflected by a vertical wall, or the ray is specularly reflected by the segment. In this way, from a ray shot, a branching of possible paths can be generated each time the ray encounters a segment representing a vertical wall. The generation of the branching is stopped for the branches which reach the site limits or when the distance covered is greater than a limit fixed by the user.

The second stage allows the identification of the propagation paths in three dimensional space. For each trajectory in the horizontal plane, a vertical cut traversing the ground and the obstacles is defined by considering the altitude of the segments which have been impacted. Only the cuts corresponding to the physically possible paths are held and the rays which do not cut the source segments are abandoned. This research method is well adapted to computing. It is very fast because only the physically possible paths are calculated, the others have been eliminated by logical tests.

This method is well adapted to the calculation of the multiple reflection between the bodywork of the train and the screens. Taking into account these interactions is very important because they reduce the efficiency of the screen.

2.2. Acoustic calculation

The acoustic calculation is done for each ray issued from the receiver which cuts a line source . If the angular step is sufficiently small (some degrees), one supposes that the topography represented by segments intersected by the ray doesn't vary in the angular cone ; in other words that the propagation medium doesn't vary in the cone. In these conditions, the problem is restored to that of the calculation on a cross sectional cut between a punctual source and a receiver. For this, it is necessary to define the acoustic power associated to the cross section, the directivity of the source, the attenuation by the geometric divergence, absorption by the air, diffraction, ground effects, absorption by the vertical surfaces on which the ray has been reflected.

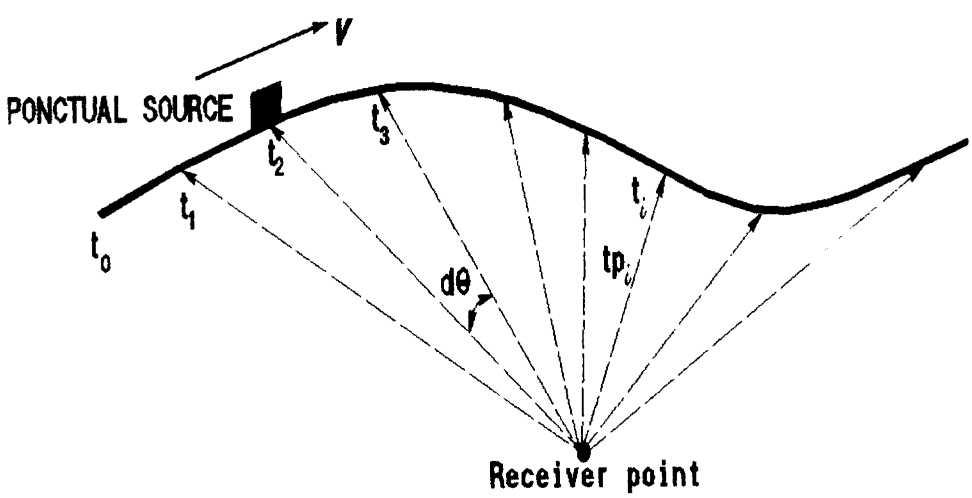

Fig. 1 : Rays launched from the receiver

2.3. The level/time evolution of a passing train

The rays launched from the receiver with a constant angular step cut the line source either in a direct way or after multiple reflection and/or diffraction (figure 1).

The position of the point where the ray intercepts the line source allows the calculation of the travel time t_i, referred to an origin of time (or space), of a punctual source running at a velocity V on this line. Moreover, if tp_i is the sound propagation time between the source and the receiver, the arrival of the acoustical signal referred to the origin of time is :

$$T_i = t_i + tp_i$$

Let Lp_i the sound level at receiver R caused by the ray i arriving at T_i,
ΔT, the sample step of the impulse response.

The impulse response Lp(t) of a punctual source running with a velocity V is obtained by considering in each time step ΔT the summation of the acoustical level Lp_i of the rays arriving in this interval.

The level/time evolution of a passing train is then the result of the convolution product of the impulse response Lp(t) of the mobile punctual source and the time sound power level function distribution of a train Lw(t).

Figure 2 summarises the principle of the method.

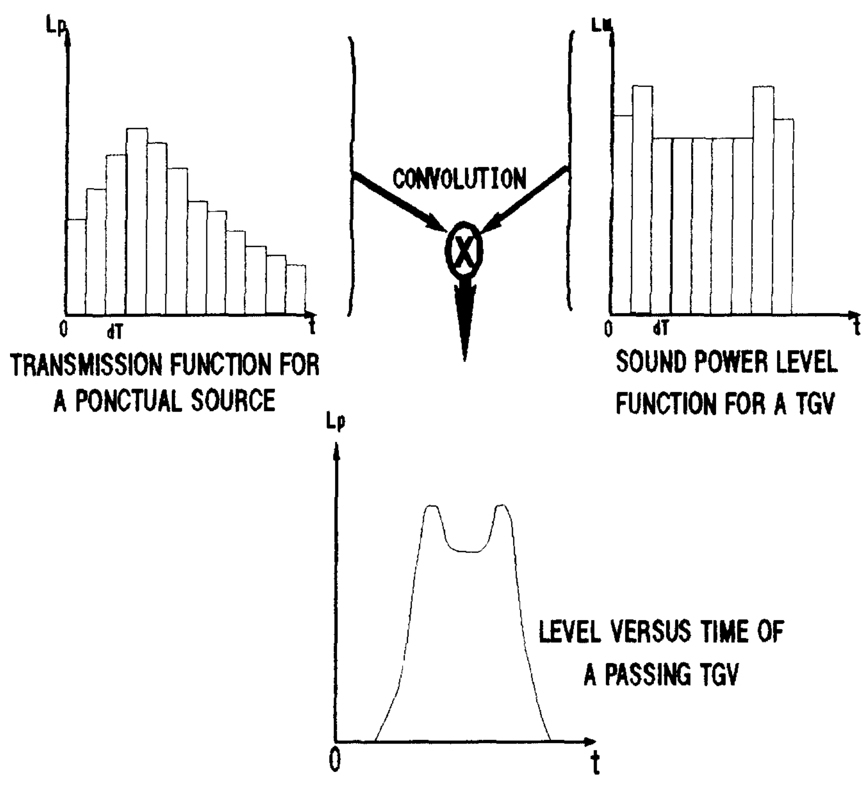

Fig. 2 : Principle of the method to calculate the noise level/time evolution of a passing train.

The sound power level function distribution of a train is calculated from a measured level/time evolution of a passing train at a reference distance (typically 25 m from the rail). Knowing the velocity of the train and the spatial distribution of the bogies, it is possible to deconvoluate the global level/time evolution to obtain the sound power level of each bogie and then spatial sound power level distribution.

3. COMPARISON WITH MEASUREMENTS

Measurement campaigns have been undertaken by the French Railways Company S.N.C.F., in order to validate the presented method. These comparisons cover most of the topographical configurations encountered on the french high speed train lines and a wide data base has been collected. Here are some typical experimental results compared with the theoretical results.

On figures 3 and 4, the level versus time evolution during the passage of a T.G.V.-A (the second generation of T.G.V.) with a velocity 300 km/h is plotted. Figure 3 gives the experimental result (—) and the theoretical result (---) at a distance of 25 m from the nearest rail and 3,5 m above the running plane. Figure 4 gives the same results but for a distance of 300 m. The result of figure 3 shows clearly the particular evolution of the level of the T.G.V.-A with two hills corresponding to the engine-bogies at each end of the train.

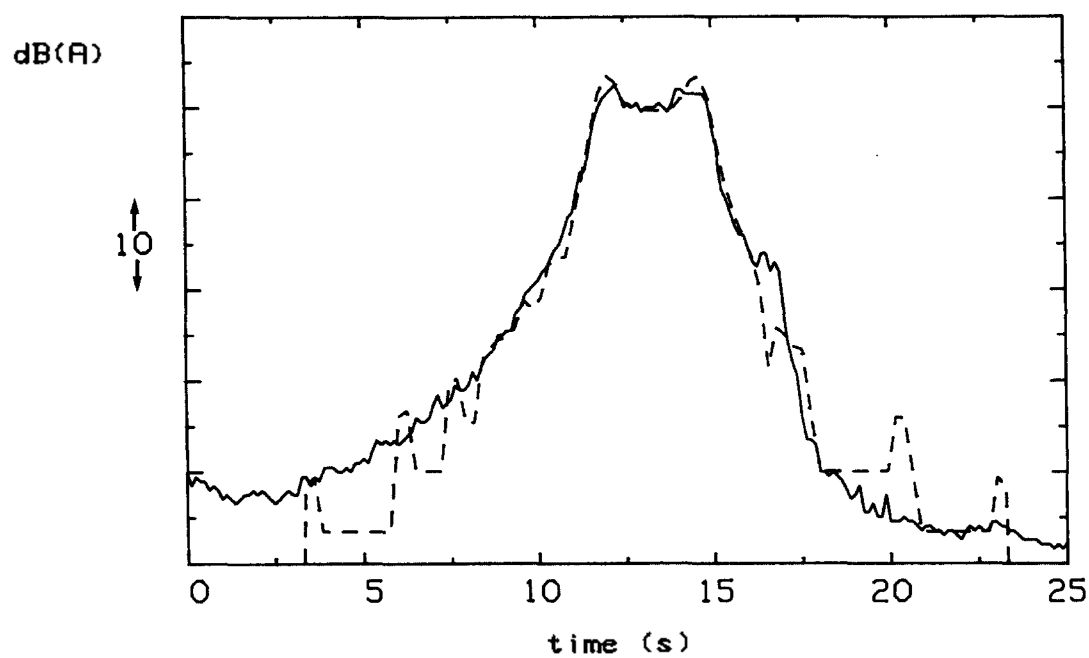

Fig. 3 : Level versus time of a passing T.G.V.-A at a velocity of 300 km/h
and a distance of 25 m from the nearest rail
(—) experimental (---) theoretical

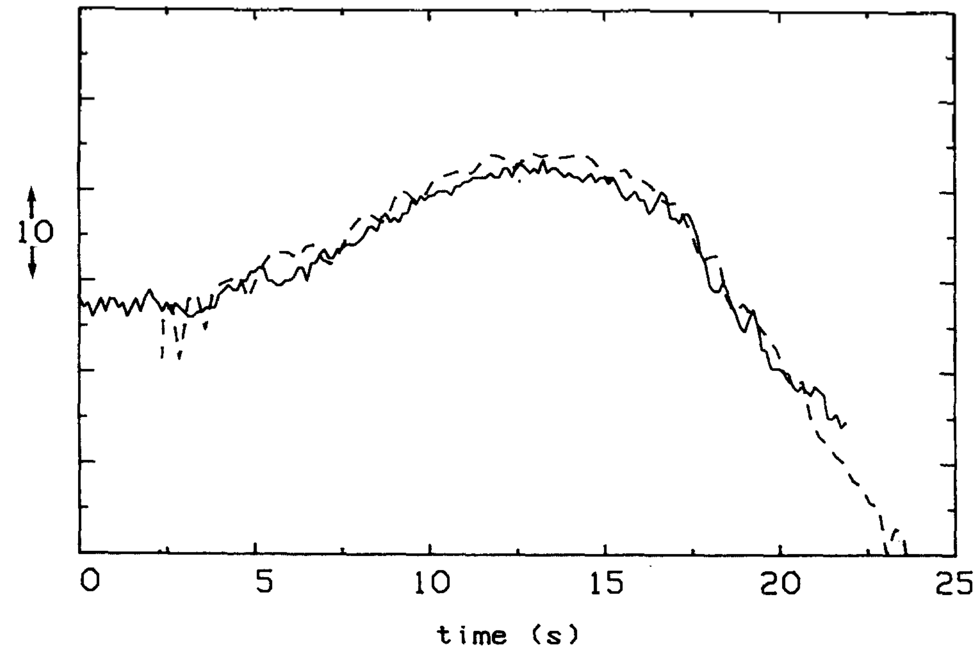

Fig. 4 : Level versus time of a passing T.G.V.-A at a velocity of 300 km/h
and a distance of 300 m from the nearest rail
(—) experimental (---) theoretical

Rather than comparing the predicted and measured time evolution of a passing train, it is easier to compare the predicted and measured $Leqt_p$. The $Leqt_p$ is the Leq value during the period when the T.G.V. is passing just in front of the measurement point. The time of passage t_p is given by :

$t_p = 3{,}6\ L/V$

where L is the length of the train in meter, V is the velocity of the train in km/h.

In table I, the measured and predicted results behind a screen of 2,3 m high versus the rolling plane and 4,5 m from the nearest rail are given. In the case of the absorbing screen, a layer of porous concrete of 60 cm height has been added at the top of the screen.

	Hard screen	Absorbing screen
Receiver*	Predicted-Measured $Leqt_p$ dB(A)	Predicted-Measured $Leqt_p$ dB(A)
15/2	0.3	0.4
15/4	1	1.4
15/8	0.5	1.8
25/3.5	1.6	0.6

*receiver 15/2 design a receiver placed 15 m from the nearest rail and 2 m above the rolling plan.

Table I : Comparison between the predicted and measured $Leqt_p$ behind a screen

The measured gain of 2 dB(A) obtained with the absorbent has been well predicted by the method.

In order to validate the program for the prediction of the T.G.V. noise impact in mountain zone, a measurement campaign has been carried out in a valley where a classical track exists. Table II gives the results obtained at 4 receiver points for a T.G.V.-SE (the first generation of T.G.V.) with a velocity of 130 km p.h..

Distance/height versus rail	Predicted-Measured $Leqt_p$ dB(A)
25/3.5	0.9
150/12	1.8
300/200	-1.9
400/100	-0.4

Table II : Comparison between the predicted and measured $Leqt_p$ in a mountain zone

In the same configuration, a comparison between measured and predicted SEL shows a difference lower than 1 dB(A).

The final comparison concerns the validation of the method for the calculation of the equivalent noise level during a day : Leq (8 h - 20 h). During this period of time, the railway traffic was composed of : 32 T.G.V.-SE, 32 double T.G.V.-SE, 22 T.G.V.-A, 8 double T.G.V.-A, with the velocity of trains varying between 240 and 270 km/h.

For a receiver 150 m from the track and 3,70 m above the rolling plane, the difference between the predicted and measured Leq (8 h - 20 h) is lower than 1 dB(A). The agreement between the measured and predicted values is typical of results obtained in a lot of various situations.

4. CONCLUSION

The MITHRA software is a powerfull and versatile program for computing both the noise impact of trains (including high speed train) and traffic noise. It includes multiple effects like reflection between bodywork of trains and screens, reflection on buildings, ground effect and diffraction by barriers and terrain in any kind of topography.

The calculation of the noise level versus time evolution of passing trains allows the determination of indicators like Leq, SEL, Lmax, $Leqt_p$ i.e. the Leq value during the time of passage, and any indicator requiring the level versus time evolution. It gives more accuracy in the optimisation of noise barriers for noise impact control of high speed trains.

The comparison of program results with in situ measurements shows a good agreement in a lot of various situations.

In order to improve the results at larger distances (> 600 m), a new version of this program, including the wind and temperature gradient effect has been developed [2] and its validation is in progress.

REFERENCES

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