AN ENVIRONMENTAL NOISE IMPACT ASSESSMENT AND FORECASTING TOOL FOR MILITARY TRAINING ACTIVITIES

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1. INTRODUCTION

The Impulse Noise Propagation Model (INPM) was developed by JASCO Research Ltd for the Canadian Department of National Defence as an environmental impact assessment and forecasting tool for airborne noise from military training activities. Progressing beyond its defence environment roots the INPM is currently being expanded to encompass a wide range of industrial noise sources both impulsive and continuous. This paper describes some of the features and capabilities of the airborne noise modelling core software, focusing on its benchmarking, validation against measurements, and special handling of propagation conditions such as atmospheric turbulence.

2. ALGORITHMIC MODULES

2.1 Acoustic Source Levels Modelling or Retrieval

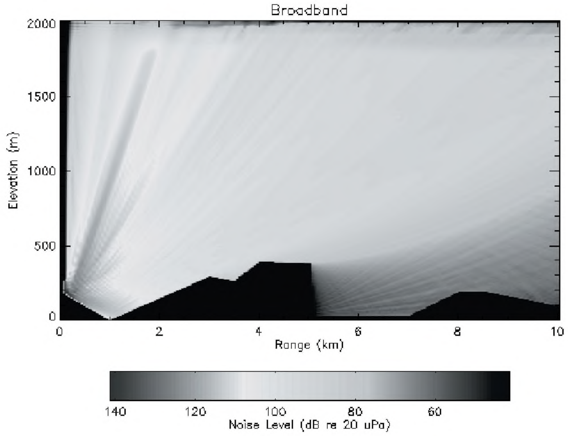
Sound propagation modelling requires as input the source levels in individual frequency bands, expressed in dB re $20\mu Pa^2$ at 1m distance. Depending on the modelling accuracy requirements, the range of spectral levels to be modelled is resolved into octave or one-third octave bands. Finer spectral resolution allows more accurate modelling of the frequency-specific sound propagation structure, which may have an impact on the spatial distribution of received noise even after the results are combined into broadband levels. The software incorporates two alternative approaches to the generation of spectral source levels: numerical estimation of the acoustic output for source types that are amenable to a modelled description (such as detonations of explosive), or retrieval and possibly interpolation of stored levels from a database compiled from measurement results.

2.2. Sound propagation modelling

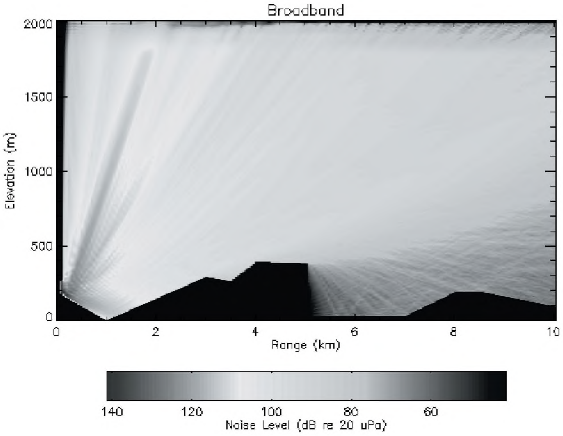
The computational core of the INPM is the sound propagation module, which is based on the widely adopted Parabolic Equation (PE) model. The software uses a two-dimensional implementation of the PE method that takes into account diffraction, air turbulence and sound interaction with the terrain; it also incorporates a faster Ray Tracing algorithm that can be automatically invoked in place of PE for higher frequencies at which ray methods approximate well the propagation of sound in air.

The PE modelling algorithm in the INPM is based on the split-step Padé method introduced by Collins (1993) of the US Naval Research Lab for use in underwater acoustic propagation problems. Collins' code, known as RAM, was extensively modified at JASCO Research to adapt it for atmospheric use. Substantial alterations to the existing routines and development of entirely new algorithms were required to include in the propagation model the effects of terrain cover (variable complex ground impedance) and atmospheric turbulence, among others. An example of a requirement specific to airborne propagation modelling is the need to introduce an artificial absorbing layer to extinguish the field before it reaches the upper edge of the computational grid, adjusted for each frequency so as not to affect those transmission paths that could potentially be refracted back towards the ground.

The INPM acoustic propagation module can output the complete sound level field in range and height along a radial from the source. This can be rendered as a grey scale image plot as in the figure below, which presents an example of noise propagation in a slightly upwind condition (noise tends to bend upward in this case) in non-turbulent air.



The case just shown provides a baseline against which the handling of atmospheric turbulence by the model can be demonstrated. It is easy to see that in the region beyond the cliff side at 5km range very little sound energy can be found since in an upwind propagation regime the terrain drop creates an effective shadow. If turbulence is introduced, on the other hand, the sound field shown below results. Now higher noise levels can be found in the zone beyond the cliff side as sound is scattered into this zone.

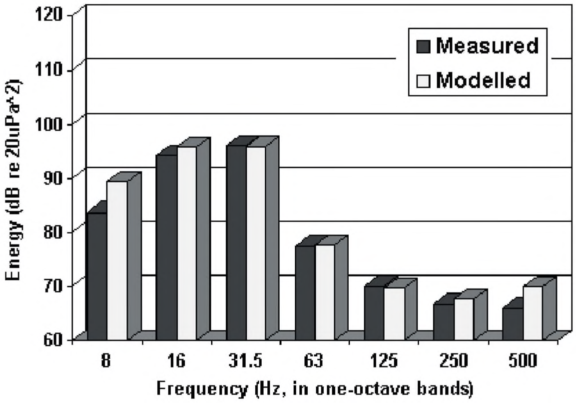


Turbulence in the INPM was implemented using a method developed by Gilbert et al. (1990) in which a 2-dimensional perturbation function is applied to the normal refractive index. The zero-mean perturbation function is characterized by maxima and minima that are semi-randomly separated according to a specified coherence length. Desktop validation of the PE model was carried out using benchmark results from Attenborough et al. (1995). Validation of the turbulence component was performed by comparing noise level predictions under turbulent conditions with data from an experiment by Wiener and Keast (1959).

3. EXPERIMENTAL VALIDATION

The model has been subjected to a thorough experimental verification. Noise from military detonations was accurately measured to provide data for validating the source level modelling and propagation components of the INPM. Measurements were performed at distances from the source ranging from about 100m to 3.5km along radials that spanned dry grassy fields, forested areas, vegetated hills as well as a stretch of water across an inlet. These experimental results were then used in the validation of the model. The acoustic recordings were resolved into one-octave band levels that could be directly compared to the output from the INPM. The only inputs provided to the model were the properties of the explosive charge and the propagation parameters along the source-receiver traverse: elevation, acoustic impedance for different types of ground cover, and air column profiles (temperature, humidity, wind speed and direction) from meteorological probe launches.

The bar graph below shows the result of the comparison between measured and modelled noise levels in individual octave bands for a detonation of C4 high explosive in a 30cm deep ground pit, at a range of 1.6km from the source. It can be seen from this example, which is typical of many others, that the propagation model in the INPM is able to replicate quite closely the transmission loss at all modelled frequencies (both model and measurement, for example, show a marked attenuation starting at the 63Hz band) and that the source model provides realistic starting levels.



4. THE INPM IN PRACTICAL USE

The INPM is an effective noise forecasting tool because of its integrated architecture. A comprehensive run manager module coordinates a range of tasks that include:

- Extraction from geographic grid files of the terrain elevation and ground cover data along an automatically-defined set of modelling segments;
- Importing of atmospheric data, usually in the form of encoded forecasts from meteorological agencies, for the period of applicability of a model run;
- Repeated execution of the sound propagation model to generate noise levels along the modelling segments for each frequency band;
- Additive merging of output sound level data over all computed frequency bands and multiple sources to generate either noise contour maps or time-location noise level reports.

The INPM has significant potential to make a contribution to the lowering of noise impact on the environment by enabling more informed planning and decision making.

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