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A NEW METHOD FOR PREDICTION OF THE STATISTICAL ACOUSTICAL FOOTPRINT (SAF) USING A METEOROLOGICAL DATABASE

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1. INTRODUCTION

Noise attenuation contours for a point source, predicted on the basis of long term meteorological data for a chosen geographical location, are invaluable for planning purposes. Many prediction schemes for the determination of such contours have been devised the most noteworthy being the CONCAWE procedure [1] originally developed for petroleum plant noise. The CONCAWE method has subsequently been modified and reused for many different industrial and military problems. The main difficulty with the CONCAWE scheme, and all of its derivatives, is the inadequate treatment of long range sound propagation and in particular its dependence on meteorology.

In this paper a completely new procedure is described which was developed specifically for explosive noise propagation from sources on MoD test ranges [2], [3] (the methodology can easily be generalised for other sources). The novel features of the new procedure are its use of full field predictions over large ranges using our Crank-Nicholson Parabolic Equation (CN-PE) program and its method of incorporating wind directional data. The first procedure developed was based on a Pasquill Stability Frequency (PSF) database but our latest version employs the more accurate Scaling Parameter Frequency (SPF) database which can be more robustly linked to specific meteorological profiles and hence to the corresponding acoustic field predictions.

2. FOOTPRINT MODEL BASED ON THE PSF METEOROLOGICAL DATABASE

The model was originally written for determination of isoclines of distance within which the background level was exceeded for n% of the time (for example the full year) [2]. However for general use we wish to obtain attenuation contours referred to a distance r_0 from the source which have a known probability of occurrence for a given part of the day and a given part of the year [the initial study used 24 hours all year].

2.1 PSF Database

This is a table of data available from the Meteorological Office, calculated from 10 years (typically) of synoptic data, which gives percentage probability values for 5 wind speed classes (WSC) centred on wind speeds of 0.5 (calm), 2, 5, 8.5, 13.5, 20 knots for each of 5 Pasquill Stability Categories (PSC) taken for 12 wind directions in 30° intervals. The table gives monthly and all year values for any chosen part of a 24 hour day.

2.2 Profile Calculation

There are a number of available schemes for converting the PSC, WSC into a set of meteorological profiles for temperature, wind speed and wind direction as a function of height [4], [5]. These are all based on the established Monin Obhukov similarity theory. The procedure we would recommend is described in reference [5]. A set of 25 ($q = 1, 25$) profile sets, one for each PSC, WSC combination, were then calculated.

2.3 Attenuation Contour Calculation Using the Parabolic Equation

The surface wind direction for a profile set corresponding to one Pasquill case, index q, was aligned with East and acoustic attenuation plots for a source height of 5m and a receiver height 1.2m above ground were calculated on 24 azimuths in 15° intervals (index j, $j = 1, 24$) using our CN-PE algorithm [6], [7] over a 20 km range. Since our interest is primarily in explosive noise the predictions were obtained for frequencies around 30 Hz. However for other sources predictions could be obtained over the appropriate frequency range (at a number of frequencies) and an overall attenuation could be found. The PE predicted attenuations are stored at radial intervals of $\Delta r = 200$m ($i = 1, 100$), for a 20 km range. A set of attenuations for each q were obtained.

The attenuation plots obtained were realistic in downwind azimuths but exhibited shadows with much larger attenuations than expected in upwind azimuths. This occurred because no account had been taken of turbulent propagation effects which are significant in the upwind direction. Using our turbulent CN-PE model in place of the standard version rectified this problem [8].

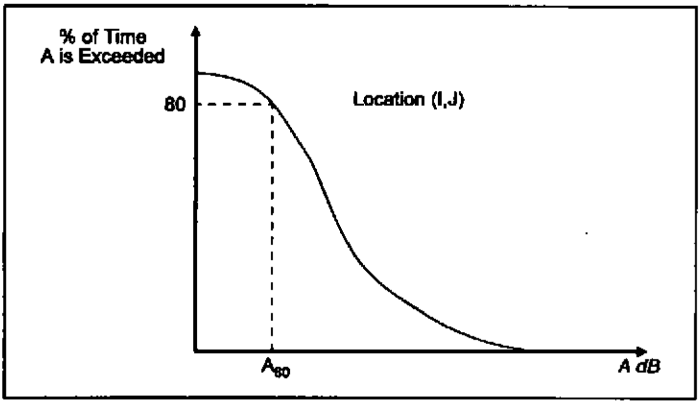
2.4 Collection of Attenuation Values at a Given Location Index (I, J)

We take the first acoustic attenuation plot stored as a set of attenuations A_q (i, j). The plot is aligned along the Easterly direction (rotation index $w = 1$). The attenuation value at point I, J

$$A_q^{w=1} = A_q\,(I, J)$$

is stored and the plot rotated 15° to rotation index w = 2 where the corresponding attenuation $A_q^{w=2}$ can be found. For each rotation index w, that is each wind direction angle, we can obtain a probability value p_q^w from the PSF table (which has been recomputed for 15° wind direction angle intervals by interpolating the original data).

The rotation of the plot index q produces 24 attenuation values at point (I, J) $A_q^{w=1,24}$. For the 25 q cases we have a set of 24 attenuation values and each has an associated probability P_q^w. We can then obtain a cumulative distribution of attenuation values.



We seek an attenuation A_n which is exceeded for say n = 80% of the total time. We find the A_{80} value at <u>all</u> points I, J so that we can then construct an isocline for this attenuation value using a radial contouring package. At all locations outside of the isocline we can expect <u>greater</u> attenuations. This is a particularly useful output since we will usually know the maximum permitted noise level at a given location $L_{Allowed}(I, J)$ and knowing the source level (say at r_0 = 100m) L_{Source} we have effectively specified an attenuation $A = L_{Source} - L_{Allowed}$.

3. MODEL BASED ON THE SPF METEOROLOGICAL DATABASE

The SPF database like the PSF database is derived from records of synoptic observations routinely taken over a long period by the meteorological station closest to the geographical location of interest. However the SPF database, unlike the PSF database, is defined directly in terms of the meteorological scaling parameters u_* and θ_* calculated from each synoptic observation. Extraction of the profiles in the PSF database model for cases q requires extraction of the surface scaling parameters for each q case. When using the PSF database these processes incorporate approximations and compromise the robustness of the whole procedure. When using the SPF database, on the other hand, the profiles can be obtained more directly because the database is formulated using the very surface scaling parameters required for the profiles calculation [3]. For each location of interest the SPF cases can be specified by 7 θ_* and 7 u_* classes, each u_*/θ_* combined class corresponding to a new profile set. These combined classes can be indexed with q = 1, 49. Generally only 25 of these cases need be considered. For the chosen geographical location a set of probability values each corresponding to one of the classes and subdivided for each of 12 (interpolated for 24) wind direction classes, P_q^w can be determined.

The same procedure, as defined in section 2 for determination of the attenuation isoclines A_n, can now be followed.

4. CONCLUDING REMARKS

Once the idealised meteorological profiles for each u_*/θ_* class and the corresponding PE attenuation field data have been obtained the new algorithm may be easily applied for any geographical location. The only input required is the SPF database which can be produced by the Meteorological Office. The methodology as described here has been developed for military noise sources, but could quite easily be extended for any industrial noise source or even multiple sources.

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