ERROR BOUNDS, UNCERTAINTIES AND CONFIDENCE LIMITS OF OUTDOOR SOUND PROPAGATION

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1. INTRODUCTION

The evaluation of noise levels from sources in the atmosphere has been wrought with difficulties. Embleton in a tutorial paper highlights the complex nature of outdoor sound propagation [1]. The noise prediction models have varied from complex procedures as shown by Schmoer and White [2] to a very simple engineering method being adopted by an International Standard [3].

Part 2 of ISO 9613 [Reference 3] specifies a method for calculating the attenuation of outdoor sound propagation. While the standard discusses the accuracy and limitations of the method, it only provides a general uncertainty in the final sound level calculation. The uncertainty provided is based solely on the source-receiver height and distance separation. However, other environmental factors play important roles during sound level calculations. For instance, the normal range of temperatures varies from -5ºC to +40ºC for outdoor sound measurements. The standard does not provide adequate error analysis to account for such varying outdoor factors.

The present investigation focuses on the determination of uncertainties of the predicted noise levels associated with the standard environmental variables encountered while taking measurements such as temperature, wind speeds, and relative humidity. Measurements will be compared to the predicted sound level calculated via the ISO 9613 standards, using the software program CADNA/A [4], and an associated error for the changing variables will be developed. Preliminary results of the measurement program will be presented, with the intention of quantifying the uncertainties at a later date.

2. ISO 9613-2

ISO 9613-2 specifies an engineering method for calculating the attenuation of sound outdoors in order to predict the downwind sound pressure level from a variety of noise sources. The attenuation from specific physical effects include geometric divergence (A_{div}), atmospheric absorption (A_{atm}), ground effect (A_{gr}), barriers (A_{bar}) and effects of foliage, industry, houses etc. (A_{misc}). The primary factor in attenuation is A_{div}, with A_{atm} and A_{gr} also playing a part. For the purposes of this paper, A_{bar} and A_{misc} were not included in the testing.

A_{atm}, the attenuation due to atmospheric absorption, is dependent on environmental factors. Note #8 and #9 of ISO 9613-2 does address the dependence of atmospheric attenuation on the environmental variables and the need to use "average" values, however it does not address the range.

The method also includes a correction factor to calculate the long-term average A-weighted sound level, where the long-term implies months or years. However, local regulatory agencies require measurements over a 48-hour period [5]. The variation in environmental conditions can be severe over such short periods and the regulatory authorities usually require that the evaluations is conducted under calm weather conditions.

The variability in measured and/or predicted noise levels with variation in environmental conditions is a parameter of utmost importance and is the aim of the current investigation.

3. CADNA A

CadnaA for Windows is a program for noise and air pollution prediction and efficient for expert purposes [4]. It is capable of calculation noise attenuation according to the ISO 9613-2 methods.

Cadna/A allows the user to enter meteorological information for the Pasquill-Gifford stability class, wind speed and direction. This information is taken into account when calculating the noise attenuation.

4. METHOD

The investigation included both predictions of far-field noise levels from known sources of sound as well as measurements of noise levels.

The sound power of the source was determined from near-field sound intensity measurements. The sound power levels were then used in CadnaA in order to predict sound level as per ISO 9613 part 2. A statistical comparison of the actual measurements vs. the predicted levels was carried out, taking into account the recorded environmental variables.

Testing was done in a large, open, flat, grassy field, away from any major noise sources (roads, airplanes etc.) The ambient noise at the field did not exceed 40 dBA at any time. The loud speaker was set-up at a height of 2.0 meters above the ground. A continuous "pink-noise" source was fed to the speaker to generate a sound, with an L_p of 100 dBA at 1 meter.

The far-field microphone was set-up at distances of 100 and 300 meters from the speaker, at a height of 1.5 meters above the ground. The sound level meter was set-up to record the L_{eq} 1/1-octave spectrum from 31.5Hz to 8 KHz in dB. Measurements were repeated upwind and downwind of the propagation path.

A control microphone was set-up in front of the loud speaker, at a distance of 1 meter from the speaker face. The noise was recorded for the duration of the test to ensure any changes in the noise output were taken into account.

The environmental recording equipment (thermometer, vane anemometer, hygrometer) were all set up next to the far-field microphone. The air temperature and humidity was recorded ever 1 minute. The wind speed was measured once every 5 minutes, with the data captured being the average speed of the preceding 30 seconds.

5. RESULTS

Figure 1 shows the comparison of the predicted noise level from Cadna/A vs. the measured noise at 1 meter, in dBA.

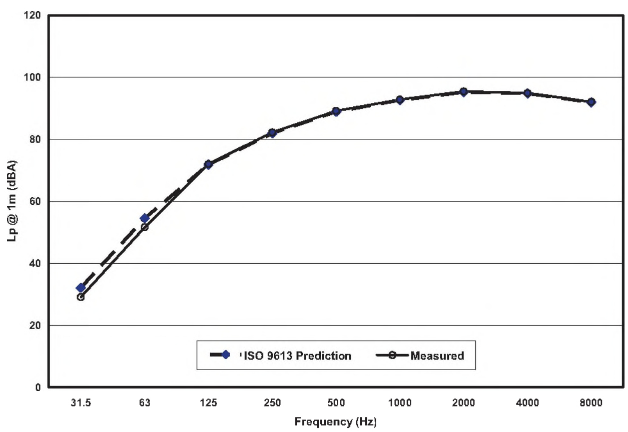

Fig. 1. Pink Noise generated from Speaker, measured at 1 m.

Results from the testing show a good correlation when the distance is 100 meters as shown in figure 2 below. For the purpose of this paper, any measured levels below the ambient background levels were not reported.

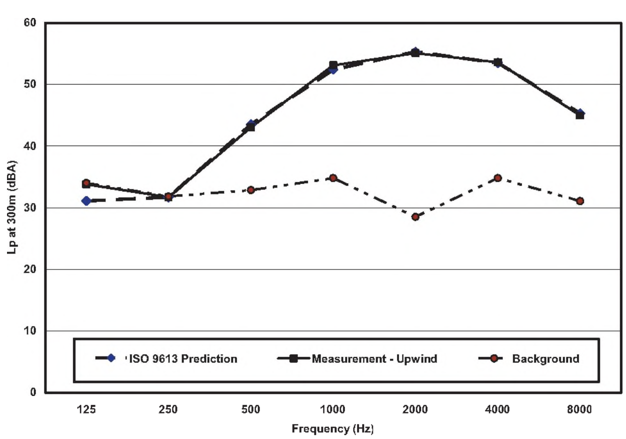

Fig. 2. Predicted vs. Measured values – Pink Noise at 100 m.

For a distance of 300 meters, there are discrepancies different environment variables with the measured values and the predicted values. Figure 3 shows a comparison of the measured and predicted values at a distance of 300 meters.

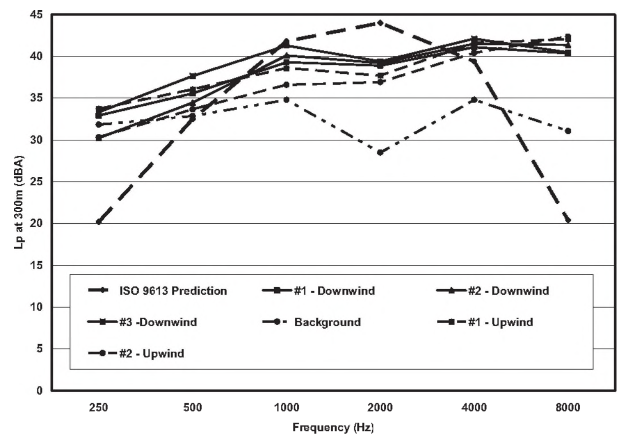

Fig. 3. Predicted vs. Measured values – Pink Noise at 300 m.

6. DISCUSSION

It is clear from the data that the ISO 9613-2 calculations show a high degree of accuracy in predictions of attenuation for shorter distances. At greater distances, there are deviations between the predicted and the measured data.

A detailed explanation of the types of waves that propagate outdoors has not been given, and neither has the detailed factors affecting outdoor noise propagation; however it is clear that one needs to carefully consider them when predicting noise attenuation over large distances.

It is the intention to carry out tests at larger distances (>1km) as well as for different environmental conditions in order to further understand the limits of the current ISO 9613-2 calculation methods.

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