# THE USE OF MEASUREMENTS & GPS FOR NOISE MAPPING

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# 1. INTRODUCTION

The following gives an overview of how sound level measurements can be used in noise mapping and how GPS can help in determining measurement position.

There are two types of noise maps using input of measured noise levels:

- Short- or long-term measurement-based, where no account is taken of the XYZ-position of the sources
- Calculated maps based on an acoustic model where reverse engineering is used to determine source levels based on measurements. The reverse engineering process can be simple, with no restrictions placed on the possible source noise levels, or can be more advanced including more complex estimations of the possible source noise levels

The EU Environmental Noise Directive 2002/49/EC [1] (END) requires strategic noise maps (these are based on long-term noise emission levels with normalized (average long-term) acoustic propagation. In addition, action plans (for environmental noise management) are required. It recommends the following measurement methods (or their national equivalents):

- ISO 1996 Environmental Noise Assessment
- ISO 8297 Sound power levels of multisource industrial plants for evaluating environmental sound pressure levels
- EN ISO 3744 Sound power levels (sound pressure – free field)
- EN ISO 3746 Sound power levels (sound pressure – enveloping measurement surface)

Other useful methods include:

- ISO 9614 Sound Power (Sound Intensity): useful for determining source emission on industrial sites where several sources are active
- ISO 3891 Aircraft Noise Monitoring: a standard from the 1970s(!), however under revision
- Reverse engineering (inverse modelling)

The AEN Good Practice Guide for Strategic Noise Mapping [2]:

- encourages computation methods for the first round of strategic noise mapping for the END
- recognises that some noise measurement is essential to the development and validation of computation methods
- points out that measurement also has a role to play in:
  - verification of noise mapping results
  - development of the local elements of action plans
  - assessment of the effectiveness of implemented action plans

Measurements can be used in strategic noise maps in the following ways

- Source data determination (creation of source emission databases, determination of individual sources)
- Receiver point data (validation & verification of levels, source calibration). The DEFRA Birmingham noise map pilot study [3], included nearly 30 sets of measurements, several over 1 month and 6 of 1 week's duration.

## 1.1. Why Validate Strategic Noise Maps?

For a 100,000 inhabitant agglomeration, there are typically >30,000 dwellings/households and the cost of noise mapping may be ca. 100,000 €. The additional cost of noise map calibration is estimated at <20,000 €.
WG-HSEA has estimated the cost-benefit as 25 €/dB[1]*/dwelling/year [4]. Thus, for the agglomeration, 1 dB is worth 750,000 €/year. As the strategic noise map is valid over 5 years, a 1 dB average error in noise contours costs 3.75 M€. Assuming that 5% of this is invested in action plans for every dB exceedance, and that calibration can improve the overall quality of the noise map by 2 dB, the economic benefits of calibrated maps

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may be 375 k€ for this 100,000 inhabitant agglomeration due to savings in unnecessary noise control activities due to noise map calibration.

### 1.2. Possible Errors In Noise Contours

Errors can be:

- **Bias:** This global error results in too big or too small noise contours. The following action planning will be fair and efficient as the hot spots are correctly identified. However, there may be too much or too little investment. This can be reduced through noise map calibration (see below).
- **Error:** This results in wrong placement of the noise contours at certain positions. The following action plan will be inefficient as hot spots may be incorrectly identified. This can be reduced through local calibration (see below)

### 1.3. Calibrating Noise Maps with Measurements

Noise maps can be calibrated by comparing similar measured & calculated noise levels. This process is like calibrating a sound level meter during an assessment routine. There are 2 approaches:

- **Global correction of noise levels:** Adjust the map "en-masse". Optimise the difference between calculated & measured values (e.g. by minimising the mean-squares of the differences between the calculated and measured values)
- **Local correction of noise levels:** Measure close to sources to estimate the source levels by an iterative technique. This helps determine unknown source parameters and should be used as such[1]. The technique is particularly useful when estimating emissions of several "non-separable" sources (e.g. railways). As it is iterative, the source-measurement relation need not be 1:1. Although, there is no exact fit with multiple sources/receivers in practice, experience shows acceptable results, and large deviations indicate need for further work (more site investigation and model detail). This is the recommended calibration method

To locally correct noise levels, first create the model for the whole ambient condition in the modeling software. Include sources with roughly estimated emissions. Define receiver positions and import measured levels into them. The Brüel & Kjær Lima 7812 calculation software uses an iterative technique to best fit emissions to the measured data. Other effects should be considered (e.g. other sources, reflections, diffraction, meteorology). Link sources to maintain relationships between emissions.

Care should be taken when comparing measured and calculated results so that one compares like with like:

- **Time issues:** Strategic noise maps determine long-term normalized levels. Although long-term source emission levels may be determined through measurements as described below under Data Gathering, the effects of long-term average propagation and their interaction with time-variant emission need special attentation, and may be difficult to assess. Research is needed in this field.
- **Parametric issues:** Calculated levels are often free-field (incident) levels that exclude the effects of reflection from the last façade. Measured levels may need correction to free-field (incident) levels to remove any influence of this reflection

### 1.4. Temporal and Spatial Sampling

Temporal & spatial sampling is necessary for determining the quality of strategic noise maps. Basically, the more measurements, the smaller the uncertainty. ISO/DIS 1996-2 (2003) [5] states that >5 samples determines uncertainty. This can be for temporal and/or spatial sampling under representative conditions. It states that the standard deviation, X, depends on the number of pass-bys, n and can be calculated:

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[1] The author does not advocate changing the source data but simply corrects the emission level to take account of uncertainties and unknown factors (any changes must be documented).

$$X \approx \frac{10}{\sqrt{n}} dB \qquad (1)$$

The measurement time needed for a fixed standard deviation varies with traffic flow/mix. For X≈1 dB for constant traffic conditions, you need to measure for:

- 10 min: major arterial road (5000 vehicles/hour with 12% heavy vehicles)
- 20 min: major road (3000 vehicles/hour with 10% heavy vehicles)
- 20 hours: minor road (125 vehicles/hour with 4% heavy vehicles)

Note: traffic flow varies over a day. Provided that you have a good knowledge of the annual variation in source operation, its interaction with weather conditions (e.g. roads may well have well-defined and repeatable daily and weekly cycles that are basically invariant over a year), then short temporal samples can be taken. By classifying receiver points into different groups, then a spatial sampling strategy can be developed.

## 2. GLOBAL POSITIONING SYSTEM (GPS)

### *2.1.1. What is GPS*

Global Positioning System (GPS) has been used by sailors for many years and is now in widespread use. It is an all-weather, continuous satellite navigation system that automatically identifies position and time. Connecting GPS to any transportable measurement unit can automatically identify position, date and time for speedier reporting, modelling, calculation and mapping, and accurate position data makes it easier to repeat noise measurements at the same position. Since Spring 2000, GPS has ~10 m accuracy worst case but altitude accuracy is only 30-50 m (normally not a problem as height can be accurately measured in other ways).

"Visible" NAVSTAR satellites contribute to GPS positional information. Appearance or disappearance of a satellite changes GPS unit's input information. The more active satellites there are, the more stable and accurate the position. Contact with a satellite is prevented by trees, buildings and heavy clouds (although there is no apparent effect from light cloud cover, e.g. when overcast). In addition, multipath-ghosting, where satellite signals are reflected locally causing longer signal delays, may occur in built-up areas or hilly terrain.

Differential Global Positioning System (DGPS) is more accurate and more expensive. It uses a local reference signal from a local beacon, FM-radio service or on a mobile phone network. Typically, 3 m accuracy is achieved (1m with some providers) but with no improvement in vertical accuracy. High-end systems can show position with cm accuracy.

### *2.1.2. Using GPS*

In late 2000, the author investigated positional accuracy for noise measurements with a Brüel & Kjær 2260 Investigator with Sound Analysis Software BZ 7202 and a Garmin 12XL GPS unit [6]. The GPS unit continually supplies GPS data to 2260 Investigator via a serial interface cable. The 2260 Investigator automatically detects GPS unit and the user decides when to download GPS data. The loaded GPS data is then automatically stored with results and set-up. Predictor 7810/Lima 7812 convert GPS data to XYZ coordinates and maps positions. Practical accuracies of 1.5m to 2m were common but values more frequently were in the range of 3-20 m, with 5 m accuracy around buildings, and 18 m accuracy very close to large buildings.

Figure 1. *Using a GPS unit with a sound level meter.*

The Brüel & Kjær 2260 Investigator can also automatically identify source positions using GPS during intensity-based sound power level measurements in a similar manner. Recently, Brüel & Kjær also implemented a GPS interface for its mobile Noise Monitoring Terminal Type 3637 when used with Noise Monitoring Software Type 7802. However, the technique for GPS location used here is different. Here, the GPS position is logged and stored. Then, for every hour of measurement data, statistics are made of the logged GPS position. From these, it is identified if the terminal has moved (if a maximum change in position limit has been exceeded). If not, the extreme positions are removed and the average position of the terminal calculated. This is more accurate than the method described above. When the measurement results from the terminal are downloaded to the central server software, the position is automatically plotted on a map of the site and changes in position of the unit are also automatically identified.

| NMT NUMBER | LOC NUMBER | PERI NAME | START DATE | START TIME | END DATE | END TIME | ACTIVITY | TOTAL LEQ |
|---|---|---|---|---|---|---|---|---|
| 1 | 105 | 1-Hour Reports | 20040401 | 00:00:00 | 20040401 | 00:59:59 | 100.00 | 34.3 |
| 2 | 58 | 1-Hour Reports | 20040401 | 00:00:00 | 20040401 | 00:59:59 | 100.00 | 34.2 |
| 3 | 164 | 1-Hour Reports | 20040401 | 00:00:00 | 20040401 | 00:59:59 | 100.00 | 34.5 |
| 1 | 105 | 1-Hour Reports | 20040401 | 01:00:00 | 20040401 | 01:59:59 | 100.00 | 31.4 |
| 2 | 58 | 1-Hour Reports | 20040401 | 01:00:00 | 20040401 | 01:59:59 | 100.00 | 31.5 |
| 3 | 164 | 1-Hour Reports | 20040401 | 01:00:00 | 20040401 | 01:59:59 | 100.00 | 31.9 |
| 1 | 105 | 1-Hour Reports | 20040401 | 02:00:00 | 20040401 | 02:59:59 | 100.00 | 30.5 |

Figure 2. *Automatic identification of position of noise monitoring terminal achieved by GPS logging.*

## 3. CONCLUSIONS

The paper has given an overview of how sound level measurements can be used in noise mapping and how GPS can help in determining measurement position. It described the various ways that measurements can be used in strategic noise maps, and why and how to validate strategic noise maps and the issues regarding the comparison of measured and calculated results to be aware and take care of. The concept and issues of temporal & spatial sampling were also introduced. The use of GPS with measurement systems in various implementations has been shown.

## 4. REFERENCES


[1] "*DIRECTIVE 2002/49/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 June 2002 relating to the assessment and management of environmental noise*", Official Journal of the European Communities, 2002

[2] European Commission Working Group Assessment of Exposure to Noise (WG-AEN) Position Paper "*Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure*" Version 1, 2003

[3] Department for Environment, Food & Rural Affairs (UK) "*A Report on the Production of Noise Maps of the City of Birmingham*", 2000

[4] Position Paper of the Working Group on Health and Socio-Ecomic Aspects "*Valuation of Noise*" 2003

[5] Draft International Standard ISO/DIS 1996-2 "*Acoustics — Description, assessment and measurement of environmental noise — Part 2: Determination of environmental noise levels*", 2003

[6] "*Environmental Noise Measurement - Documenting Measurement Positions With GPS*", Proceedings of IOA Industrial Noise Conference, 2000