A WIDE AREA NOISE MONITORING SYSTEM FOR THE VALIDATION AND OPTIMISATION OF NOISE MAPS

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1 INTRODUCTION

This paper describes the architecture and realisation of a new noise monitoring system, and its application to the validation and optimization of noise maps.

The practicalities of monitoring noise over a wide area with any degree of accuracy have always been dominated by issues such as capital cost, running cost, complexity, communications and data management. Continuous developments in both measurement and information technology now permit large-scale collection of data on a cost-effective basis, offering a powerful tool for both noise management and public communication.

Several pilot schemes have been installed, and organic growth of these systems provides invaluable practical experience for further development, both in systems capability as well as future applications such as source identification and automatic control.

2 BACKGROUND

For several years now, noise has been identified as one of the dominant factors in environmental pollution. European Directive 2002/49/EC addresses the harmonisation of regulations on environmental noise in Member States. It addresses primarily the following issues:-

1. Provision of an overview of the current noise exposure by development of strategic noise maps
2. Provision of information to the public regarding its exposure to noise (transparency regarding population
3. Development of action plans to improve the noise environment over time

It deals with noise exposure from road, rail, airborne and industrial sources and its impact on the population in a complete range of environments, from public parks to built-up areas. It also emphasizes the need for extended noise monitoring for the purposes of noise control and preservation of quality of life.

In the UK, city-wide modeling and mapping of noise exposure is well under way, the pioneering work of Birmingham City Council predating even the EC Directive, and with the publication of noise maps for London on the internet(1), unprecedented public access to predicted noise exposure has been achieved.

The accuracy, or otherwise, of such noise maps not within the scope of this paper, but the issue of their validation and continuous updating will come to the fore as more city noise maps reach completion. As the importance of noise maps becomes more apparent to the public, as the information is disseminated, the implications of, for example, ‘noise blight’ on property prices will require careful handling.

The concept of wide-area noise monitoring is one that is fraught with problems, not least one of cost, but by analysing the requirements for the measurement as well as the back-end data management, existing technologies can be used to optimise a practical system configuration.

Traditionally, the validation of predicted data has taken the form of intermittent short-to-medium term installations, based on sound level meters, with either manual data gathering on-site or using remote dial-up, both being expensive in terms of manpower and instrumentation cost. This has meant that only infrequent sampling both in time and location has been possible, with consequent reduction in data confidence.

This is certainly not a feasible basis for optimisation of noise maps (real-time or otherwise), so an alternative solution is required.

3 SYSTEM REQUIREMENTS

The requirements of a wide-area noise monitoring system can broadly be classified into two technologies:-

1 Measurement technology, concerned with acquisition of the noise data, accuracy, dynamic range, calibration, weather protection, stability, etc and
2 Information technology, concerned with gathering measurement results, storage, management, analysis and publication

In both cases, recent advances have brought about efficiencies, making a true multi-point system practically feasible.

3.1 Measurement technology

The following issues need to be addressed before any system can be used for long-term noise monitoring:-

1 Dynamic (measurement) range and linearity
2 Frequency range
3 Calibration
4 Weather protection (stability)
5 Ancillary data

3.1.1 Dynamic range and linearity

The well-known standard IEC61672-1:2002 lays down the requirements for the performance of sound level meters, and in general, most users and manufacturers aspire to Class 1 accuracy. Most modern instrumentation is realised digitally, and the raw signal from a high quality microphone and amplifier is fed to a 24bit A/D converter, from which data, all the acoustic parameters are calculated.

This means that, in many cases, the dynamic range and linearity is defined by the performance of the microphone/amplifier combination. For example, some manufacturers offer their instruments in either Class 1 or Class 2 accuracies, the only difference being the quality of the microphone itself. This allows economies of scale in the manufacturing of the electronics, as well as being able to offer a choice of instruments to the end-user.

A Class 1 instrument will typically offer one measurement range from 20-137dB, whereas, when fitted with an ‘inferior’ microphone for the Class 2 market, a range of 30-137dB will be offered, the higher noise floor being caused by lower sensitivity and higher inherent noise.

When selecting a microphone front end for long-term monitoring, the user must first have an idea about the expected levels of noise in the environment, as well as the use to which the results will be put. For example, if measurements are to be made in the heart of a busy city, where the hourly noise levels may vary over a limited range (typically 45-65dB $L_{A,eq}$), is it necessary to have a more expensive microphone which can measure down to 20dB(A)? Also, if the results are to be used to validate a noise map, where the calculated tolerance of accuracy might be +/- 1.5dB(A), how accurate does the measuring system need to be?

3.1.2 Frequency range

Similar arguments apply when considering the frequency range of the measuring device. Again, a Class 1 instrument will have a demonstrable frequency range from 20Hz to 20kHz, on the axis of the microphone capsule. This is clearly important if the user is trying to measure high or low frequency phenomena, or perhaps perform frequency analysis over a wide range.

However, this level of performance is often compromised by practical considerations, such as microphone mounting, weather protection and microphone orientation. For example, the practice of using free-field microphones mounted vertically with weather protection of undocumented performance is still widespread.

Additionally, if the target data to be validated is A-weighted, how important is high or indeed low frequency response?

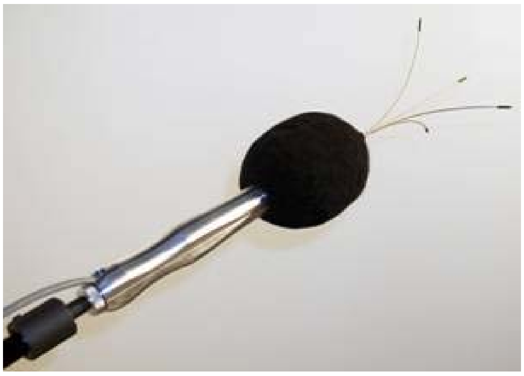
3.1.3 Calibration

A long-term noise monitoring system will need to be regularly calibrated to ensure integrity of results. This is to ensure (apart from correct operation of the system) that measured levels are not subject to drift over time as a result of environmental changes to the microphone/system.

Site visits should only be required if traceability through a sound level calibrator is required, normally infrequently, so a non-invasive system check is advisable. Several methods are available, such as SysCheck where a signal is injected into the microphone chain, to establish sensitivity and any other changes. For more stable calibration, electrostatic actuators can be used and these are built-in to permanent installations, with consequent higher cost.

3.1.4 Weather protection

For any system used long-term in the British weather, a good degree of weather protection is required. For the microphone system, this is normally achieved by adding a rain cover to an existing microphone capsule, as well as a windshield topped off with anti-bird spikes. Where large variations of temperature and humidity are expected, the preamplifier can be protected by desiccant, or preferably by heating the electronics, so the temperature of the microphone is always slightly above ambient. A typical microphone system is shown in Figure 1.



Dedicated, but expensive, outdoor microphone units are also available, but their cost is likely to preclude their use for many monitoring points.

As far as the monitoring electronics is concerned, where the system needs to be installed outside, a minimum of IP65 protection will be needed.

3.1.5 Ancillary data

As well as the primary function of collecting noise data, it may be necessary to acquire other results, such as weather data, in order to validate the measurements. This is particularly important when wind noise can affect the microphone, or temperature inversions occur, which might influence the measured results. In general, global measurements can be taken at one point on behalf of several, or it might be considered more practical to use published data from other sources. Either way, noise results will need to have weather data appended in some form.

Other data could include images, captured from a camera (still or video) as a function of some trigger (timed or threshold) in the event of unusual noise events which may influence the long-term result. Similarly, audio data could be stored for source identification.

3.2 Information technology

Once the data has been captured and pre-processed (for example, broad-band A-weighted values, 1/3 octave spectra, etc), the main function of the monitoring unit is to store or transfer the results to a central operator, for analysis and presentation. In particular, the system needs to:-

1. Be easy to set up and configure remotely
2. Provide protection against data loss (uninterruptible power supply, local data storage)
3. Be synchronised with all other measurement points
4. Automatic transfer of data to a central database
5. Flexible publication of data through a variety of media (websites etc)

Fortunately, all of these technologies are widespread and have no bearing on the acoustics market, which gives a great amount of flexibility in implementation at low cost.

3.2.1 Setup and configuration

A permanent monitoring system must be able to be configured remotely, without a site visit. Therefore all functions (measurement parameters, time intervals, calibration, ancillary data, etc) should be accessible via whatever communication is chosen.

3.2.2 Data protection

A permanent system will normally be mains powered, but in the event of power loss, the system must be able to restart without intervention, and any data stored up to that point should be protected. Battery backup will allow a safe shutdown of the system for extended periods of power outage. This also applies in the event of communication failure, for example, if a GSM cell is unavailable, data can be buffered until communication is restored.

3.2.3 Synchronisation

In a multipoint system, all the points must be synchronised, so any resulting presentation media, such as maps, relate to synchronous data. This can be achieved by reference to a global clock, normally achieved through a Global Positioning System (GPS). Regular clock maintenance, and use of Universal Timing Convention (UTC) covers any geographical or summer/winter variations.

3.2.4 Data transfer

In many systems, modem (either PSTN or GSM) communication is used to transfer data on demand. This normally requires a large amount of local data storage, as well as some intervention by the user, e.g. to dial up periodically and download the data.

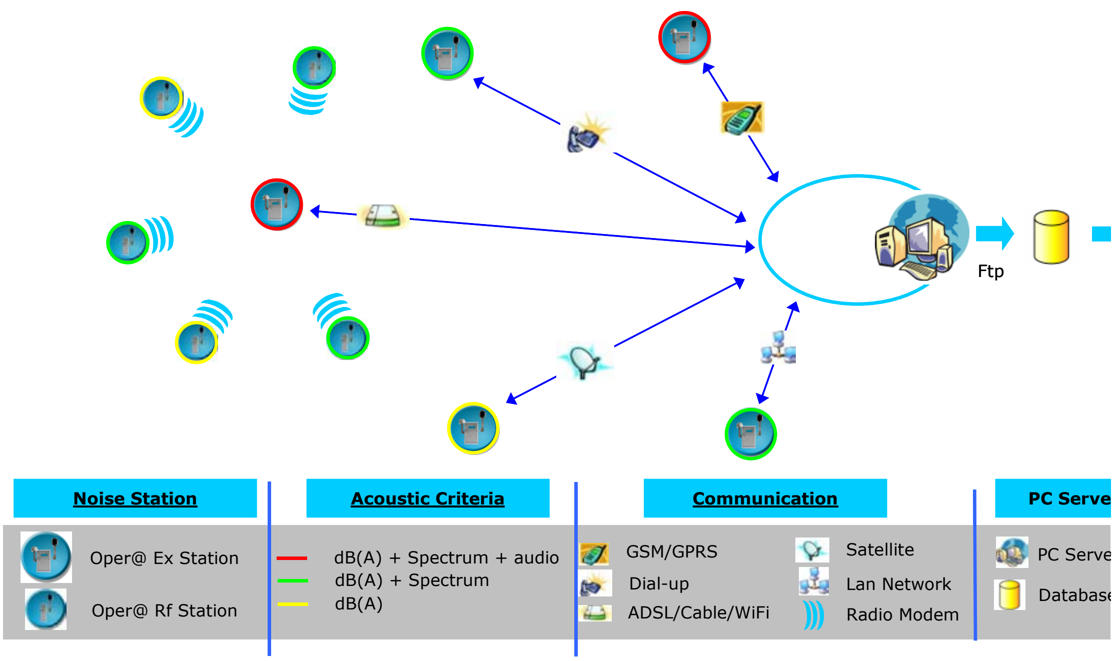
By making use of ‘push’ technology, where the data is ‘published’ regularly, any medium or protocol can be used for permanent transfer of data. Many technologies are available such as Ethernet (TCP/IP), WiFi, GSM, GPRS and DSL depending on the location of the system. In practice, in an urban environment, ‘always on’ technologies are commonplace, and even bus stops are equipped with real-time data channels, often using ISM networks, which can be used for noise data transmission.

3.2.5 Publication of data

By using these methods of communication, data is published continuously to a central database, automatically, allowing the use of the results in real-time for further data-mining. This could include detailed analysis of the noise climates, including audio analysis, periodic collation of results, or real-time presentation of results to a public access website, as part of the community communication policy.

The results can also be used to update existing noise maps.

4 A NEW WIDE-AREA NOISE MONITORING CONCEPT



The Oper@ concept from 01dB-Metravib(2) is a new noise monitoring system, optimised specifically for wide-area multi-point use, developed in response to requirements raised in the EC Directive. It allows continuous noise measurements to be taken over many points simultaneously, using commonly available internet technologies. A smaller satellite system also reduces the cost of providing many measurement points.

A schematic of the total concept is shown in Figure 2.

4.1 Main processing unit

The main terminal in the architecture is the EX terminal. This consists of a single or dual channel front-end supporting Class 1 or 2 microphones, or even permanent outdoor microphones. Powering and conditioning is provided, including preamplifier heating, and built-in calibration via SysCheck or electrostatic actuator.

Many parameters can be measured and logged including any weighted broadband parameter, as well as real-time 1/3 octave spectra with audio recording. Options allow powerful triggering of spectrum or audio collection dependent on event parameters.

Data is buffered and published continuously to whatever communication interface is chosen. This can include GSM/GPRS modem, ISDN, ethernet (DSL, ADSL, WiFi) depending on the infrastructure in the environment. A typical multi-station environment will use some form of ethernet. This allows the possibility of setting up a virtual private network (VPN) over the internet for secure transfer of data and remote setup of the terminal.

All data is transferred without user intervention, and stored to a central database, which can then be queried for whatever purpose using SQL.

Software is provided for expert analysis of results including replay of audio, as well as querying the database for publishing of results to a website or noise map.

An EX terminal is shown in Figure 3, installed with a typical microphone system

4.2 Satellite unit

To equip a multi-point system with EX units can unnecessarily increase the cost of the project, even allowing for the fact that up to two channels are supported. Therefore, to make the system more efficient, a satellite unit, the Oper@ RF has been developed, which is designed to augment the capability of the EX.

Up to ten RF units can be associated with one EX unit, and they provide weighted broad-band data to the EX, which are then combined into the data stream published to the database.

Data is communicated via a dedicated radio frequency link, using radio modems on the IMS radio spectrum, commonly used by other data collection devices such as meter reading equipment. A TDMA protocol is used to ensure data integrity.

As with the EX, Class 1 or 2 microphones can be used, depending on the application of the data, including periodic calibration checks. An RF unit is shown in Figure 4:-

In theory, such a radio link provides a range in free field of up to 5km, but in urban environments, i.e. for city noise mapping, this range will be very much reduced, so a site survey will be necessary to establish the best locations for the terminals.

All noise-monitoring points are synchronised using GPS. A sophisticated protocol is used to monitor the data integrity, and it is made easy to assign a 'dataloss' coefficient to the results in the event of poor reception. In practice, the effects are minimal.

4.3 Software

Four software modules are used:-

1 System management and setup
2 Data mining
3 Advanced manual and automatic analysis
4 Data publication

4.3.1 System management

The management software dB@dmin allows the user to install, configure and manage all the monitoring terminals in the system. Complete control is given over:-

1 Measurement parameters
2 Communications parameters (e.g. IP address)
3 Event settings
4 Calibration
5 Firmware upgrades

All features can be set remotely, without site visits, and all stations in the system are available on one graphical screen as in Figure 5.

4.3.2 Data mining

The heart of the system is the central database, which receives data from all the terminals, typically via File Transfer Protocol (FTP). The raw 'production' database uses SQL and associates the data to a physical location. Results can then be processed to store other parameters such as L_{den} which can then be used as the basis for live noise mapping.

New measurements are appended to the database continuously using standard software mechanisms and the interfaces are open to allow other software to access the data in real-time. This allows further applications to be developed, and these ‘hooks’ can be used by ‘live’ noise map updates.

4.3.3 Advanced analysis

The acoustic expert will always want to have the raw data available for all normal standardised analysed, such as periodic tables, statistics, level time histories, audio recordings and frequency spectra. Data can be analysed using the dBTrait software, more commonly used with sound level meters and PC-based analysis systems.

This means that permanent data can also be combined with results which have been sampled periodically – for example, if a sound level meter is deployed to a local ‘hot spot’, this stored data can be combined into the database and used to ‘hone’ the resulting noise map or analysis with localised data.

4.3.4 Data publication

In line with the requirements of the EC Directive, the end result of this technology should be to make data available to the public and downstream authorities, for the development of action plans.

A software module is available to mine the database and link to a localhost website, in real-time if necessary, using standard SQL and internet protocols. Noise level information such as L_{den}, L_{Aeq} and $L_{A,max}$ can be displayed on a graphical map and compared to existing predicted data.

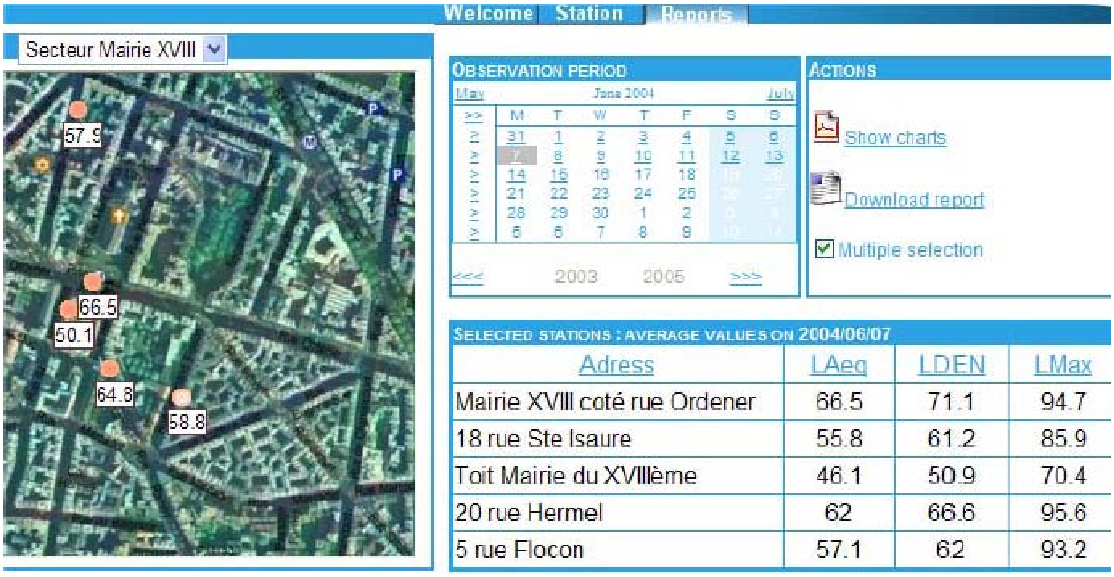
In principle, if adequate permissions were given, it would be possible for the public to view live data associated with a location, although in practice, some sort of time delay would be desirable. A similar approach has been used at airports to display live flight track data on the internet[(3)].

5 EXAMPLE OF INSTALLATION

Several sites have been installed in mainland Europe, for the validation of predicted noise maps.

One site in France uses two selected urban areas, to which are assigned one EX unit. Seven satellite RF units provide coverage of each area, and data is transferred to the database via ADSL across the internet, using a VPN.

The measured data is stored permanently in the database, for in-depth analysis by specialists, but overall information is published to a website, for consumption by the general public. A typical website layout is shown in Figure 6.



The user can select each measurement point graphically for a selected day or time period, and average values for each location are shown. Limited reports can be downloaded as required. The site developer has complete freedom over the layout, as the data can be queried using normal protocols, so data can be combined with other parameters such as air quality data from other sources.

It is only a short step to link this data to a GIS database, so noise data can be correlated with complaints management and noise predictions. Again, as the software interfaces are standard and open, validation of noise maps with real data is entirely possible. Several developments are currently underway to bring this to reality.

6 CONCLUSION

The rationale behind a wide area noise monitoring system has been discussed, and the implementation of a new system presented.

By using state of the art internet technologies, it is possible to provide real-time multi-point data over the internet for updating public websites, and updating/validating predicted noise maps

7 REFERENCES

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3. Passur website www.passur.com/sites