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STATISTICAL AND REAL-TIME SPECTRAL ANALYSIS OF ENVIRONMENTAL NOISE: A COMPARISON OF PORTABLE SYSTEMS AND PERMANENT INSTALLATIONS.

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INTRODUCTION

Environmental noise is by nature time-varying. Were this not so, measurements made using a simple sound level meter would be sufficient for it characterization. As a result, a wide variety of descriptors are required to quantify environmental noise, the choice being a function of the application.

For land use planning, law enforcement and establishing a database against which to compare the results of noise abatement procedures, forms of time-averaged level such as Equivalent Continuous Level (Leq), Sound Exposure Level (SEL), Day-Night Average Level (Ldn), Community Noise Equivalent Level (CNEL) are useful. A-weighting is generally called for when measuring these parameters.

Time history information, tables or plots of dBA vs time, may also be useful. The parameter Noise Pollution Level (NPL) requires a knowledge of both the Leq and the standard deviation of the sound level over the measurement period.

For assessment of noise-induced annoyance, a measure of the extremes, such as the range of RMS levels (Lmin and Lmax) and the maximum instantaneous level (Lpeak) are important.

Focusing particularly on the annoyance phenomena, one can define a sound level threshold and deal with individual loud events which cause the sound level to exceed the threshold, thus generating Exceedance Events characterized by descriptors such as date, time and duration of the event, Leq, SEL, Lmax, Lpeak, etc.

SYSTEM CHARACTERISTICS

Instrumentation systems for environmental noise monitoring can usually be classified into the following three types:

1. Short term monitoring: characterized by easily portable hardware with minimal weather protection to be used over a 1-24 hour measurement period, as shown in Figure 1. Instruments will usually be tripod mounted and powered by internal batteries. Data will be stored internally and either downloaded to a computer or in some cases printed in report form directly from the instrument.

Figure 1: Short Term Monitoring System

2. Medium term monitoring: typically used over periods of 1-30 days. The measuring instrument and an external battery for extended operating life will be mounted within a weatherproof case, as shown in Figure 2. The microphone will be mounted on an external structure or tripod with inexpensive weather protection. In some cases simultaneous acquisition of weather data (wind speed, wind direction, temperature and humidity) will be required. Data is generally transferred to a laptop computer on-site for subsequent report generation.

Figure 2: Medium Term Monitoring System

3. Permanent monitoring. Based on a permanently installed pole supporting an outdoor microphone unit with windscreen, heater, dehumidifier and electrostatic actuator for automatic calibration, as shown in Figure 3. Instrumentation is located within a heavy duty pole-mounted enclosure. The system is mains powered, with battery backup. In remote locations, solar power generated from pole-mounted panels may be used. Simultaneous acquisition of weather data is frequently included. Digital transmission of data to a central computer is via modems and telephone lines or cellular telephones. For large systems with many remote monitoring stations, such as airports, the computer will usually be a workstation.

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Figure 3: Permanent Monitoring System

Systems applicable to each of these monitoring applications can be configured around handheld, battery-powered broadband noise analyzers. Because environmental noise is characterized by extremely large fluctuations of noise level, particularly in cases involving the passage of aircraft or loud vehicles through a suburban or rural environment, two prerequisites for a satisfactory noise measuring instrument are a low noise floor and a dynamic range on the order of 110 DBA. With modern technology, both of these can be obtained with small, battery-operated instruments with sufficient accuracy to meet ANSI and IEC specifications for Type 1.

TYPICAL NON-STATISTICAL DATA MEASURED AND STORED:

These meters will measure and store most of the parameters mentioned in the first section of this paper, as indicated in the following:

Interval Data:	Leq, Lmax, Lmin, SEL, Lpeak, Lpeak (unweighted) for each equal time interval, user-selected.
Standard Time History Data:	Leq and Peak as fast as 32/second

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Exceedance Data:	Based on exceedance of threshold (RMS or Peak). Date and Time, Duration, Leq, Lmax, Lpeak, Lpeak (unweighted) and SEL and Exceedance Time History similar to Standard Time History.
Daily Reports:	Leq, Ldn, CNEL

BROADBAND STATISTICAL DATA

A useful parameter for characterizing environmental noise is Ln, which is the A-weighted broadband level which is exceeded n percent of the time, determined from noise level samples level taken over a time interval sufficiently long to be statistically meaningful. The ninety-percentile exceeded sound level, L90, often is taken as a measure of the residual noise level, little influenced by nearby discrete events. The L1, and to a lesser extent the L10 sound levels are heavily influenced by the noisier discrete events that may occur [1].

The meters described above calculate the statistical distribution of sound level with 0.1 dB accuracy over the total measurement period, permitting calculation of any Ln (integer values of n) between L1 and L99.

Six different values of Ln, user-specified for integer values of n, can be calculated and stored for each interval. The full statistics table is not stored, as this would make excessive demands on the instruments internal memory.

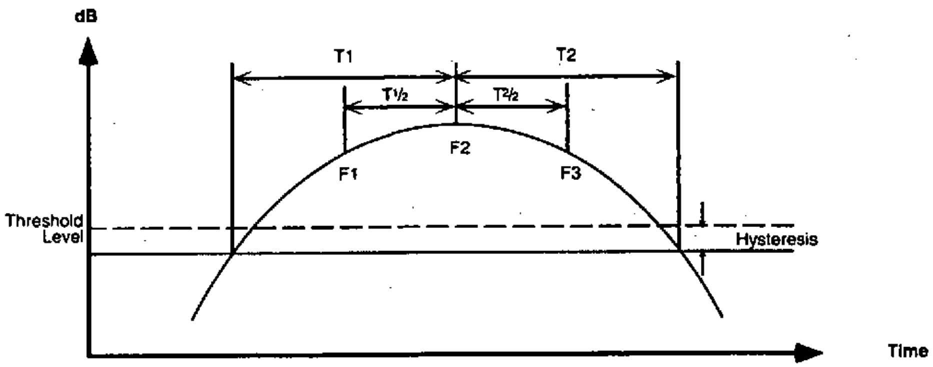
ACQUISITION AND UTILIZATION OF SPECTRAL DATA

For noise source identification, frequency spectra associated with exceedance events are extremely valuable. In an airport noise monitoring system, these data can be used to differentiate between aircraft and non-aircraft events, between airplane and helicopter events, to identify instances where the noise level is wind generated, and with some experience and a spectral database of different aircraft, to assist in identifying the aircraft type.

To add such a frequency analysis capability to the monitoring system, another instrument containing a real-time 1/3 octave digital filter is added to the basic sound level meter/environmental analyzer in a "piggy-back" configuration as shown in Figure 1. Communication between the two instruments is via a second RS 232 interface, which is independent of the RS 232 interface for digital communication.

During each exceedance event, a series of 1/3 octave spectra are stored to memory at a rate set by the user, which may be as fast as 32 spectra/second depending on the digital filter averaging mode selected by the user.

The complete series of spectra is available for analysis, but in most applications several spectra are sufficient for purposes of source identification. For airport noise monitoring systems, we have selected to store three spectra for each exceedance event, which we describe as the inbound spectrum (F1), the maximum spectrum (F2) and the outbound spectrum (F3), as shown in Figure 4. Note that the initiation of the exceedance event corresponds to the instant the level exceeds the threshold level, while the conclusion is based on the time the level drops below the threshold level by an amount equal to the hysteresis, a user-defined parameter. The maximum spectrum is the spectrum corresponding to the time of the maximum broadband sound level. T1 identifies the time interval between the beginning of the exceedance event and the time of the maximum level and T2 the time interval between the time of the maximum level and the end of the exceedance event. The inbound spectrum corresponds to the time mid-way between the beginning of the event and the occurrence of the maximum level and the outbound spectrum corresponds to the time mid-way between the occurrence of the maximum spectrum and the end of the exceedance event.



Definition of Inbound, Maximum and Outbound Spectra in Time-Domain

Figure 4

In the case of jet aircraft, there is a significant difference in spectral characteristics between the sound radiated from the engine inlet (predominant compressor tones) and that from the exhaust (strong combustion and jet shear noise); these three spectra will convey both these characteristics. Also, the inbound and outbound spectra can be used to estimate speed based on the doppler shift of the dominant pure tone components.

MEASUREMENT OF STATISTICS IN THE FREQUENCY DOMAIN

More information on the nature of environmental noise sources can be obtained by evaluation of the sound level statistics (Ln values) as a function of frequency. These data are useful when specifying noise attenuating devices for a proposed noise generating entity, such as a factory or power plant. One desires the facility to have a minimal noise impact on an existing environment without incurring excessive costs for noise control treatments. With frequency domain statistics of the existing environment, one could design the plant to produce a sound spectrum which does not exceed the L90 level in each frequency band, thus taking advantage of the masking effect of other noise sources already existent.

Octave and 1/3 octave bands are generally used for these measurements. Due to the space/time variations of environmental noise, and its typically non-periodic nature, there would be little additional information gained from using a narrower bandwidth than that. In the case of a pure tone source, however, special care must be taken. The existence of such a tone can be clearly seen from the frequency domain statistics, since all the Ln values converge to approximately the same value at the pure tone frequency.

The instrument configuration described in the preceding section could be used to obtain such data by generating an amplitude histogram table for each frequency band. At the present time, this capability has not been incorporated into the system firmware.

Using the same technique, however, a portable battery-powered real-time 1/3 octave frequency analyzer, such as shown in Figure 5, can be used to obtain the frequency domain statistics. An example of the display of this data is shown in Figure 6. For extreme cases, the 80 dB dynamic range of such a frequency analyzer may be insufficient to handle the range of noise levels actually occurring. In that case, the analyzer can be operated in an autoranging mode to cover a measurement range of 120 dB. With autoranging there is always the possibility of missing a low probability event during an autoranging operation, but at least the statistics will be consistent across the frequency range because with either system the spectral data are being acquired in real-time.

Figure 5: Model 2800 Real-time Frequency Analyzer

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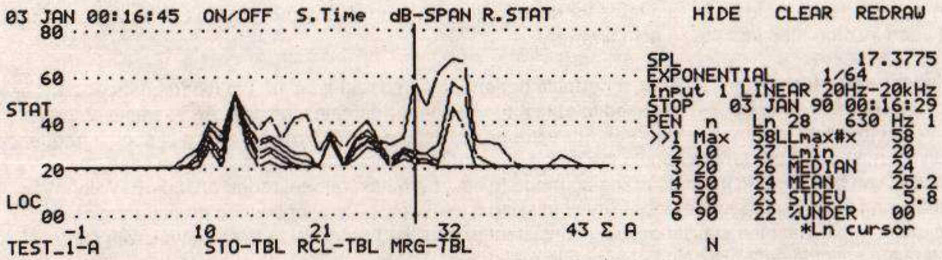

Figure 6: Example of Frequency Domain Statistics Display

CONCLUSION

In addition to the established use of time-averaged noise levels, both broadband and frequency domain statistics provide valuable information for characterizing environmental noise and the noise sources associated with it. Real-time spectral data are particularly valuable, since they permit essentially on-line identification of the noise sources responsible for specific Exceedance Events as they are detected by a noise monitoring system.

Modern instrument technology now permits the implementation of all these techniques in both highly portable and permanently installed noise monitoring systems.

REFERENCES

[1] C.M. HARRIS, Handbook of Acoustical Measurements and Noise Control, Third Edition (1992); Chapter 50, Community Noise Measurements, contributed by D.E. Bishop and P.D. Shomer