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FOUR DIMENSION ENVIRONMENTAL NOISE ANALYSIS (4-DENA)

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1. INTRODUCTION

The spreading use of the energy average of sound levels ($L_{Aeq\ T}$) to quantify the impact noise, in spite of its poor correlation with population reactions, is justified by the simplicity of the method. Looking to environmental noise research around the world, we see that this limitation is somehow by-passed by specifying the kind of source which controls every specific $L_{Aeq\ T}$. The work we present here should be considered as a tentative suggestion to improve the quality of noise monitoring - with the ability to recognise from the monitoring results not only the noise levels themselves but the nature of the sources controlling them. To be able to reach such a target, we first developed the concept of acoustic semieotics based on the possibility to recognise energy-significant events through the analysis of $L_{A\ F}$ profiles and relationships between Interval $L_{A\ eq\ T}$s and percentile levels. The method has the limitation of being sensitive to low level sources only when they are of stationary or semi-stationary and continuous nature. To overcome this limitation, we try to introduce into the monitoring procedures the Interval Third Octave Statistical Analysis.

2. MATERIALS AND METHODS

To perform the experimental part of the work, we use a Larson Davis 2800 Third-Octave Portable Real-Time Frequency Analyser, which automatically performs the distribution analysis in each of the Third-Octave Bands. The system is able to save 24 hours' of 10 minute Interval third-octave data in less than 100kbytes of its memory capacity. To analyse the outcome, we use the Noise Work software from Spectra srl. In a previous phase, we collected the characteristic $L_{A\ F}$ profile and Third-Octave spectra of the most common sources - such as trains, jet and propeller aircraft, cars, trucks, birds, rain, wind, crickets, etc. In a second phase, we use this data to interpret the outcome of 10 minute Third-Octave Interval measurements. The system allows us to choose any time interval. Generally speaking, the more narrow the time interval selected, the higher the likelihood of recognising the nature of the noise sources.

3. THE THREE DIMENSIONAL ANALYSIS

In Fig. 1 we show a typical result from one week, three dimensions, noise monitoring of urban traffic. The dimensions are Time, $L_{A\,eq\,1hr}$, $L_{A\,F\,1hr}$ distribution. We feel justified in handling $L_{A\,eq}$ and $L_{A\,F}$ as two separate dimensions since the first, being an energy average of L_A shows a very poor correlation with loudness while the correlation of L_{AF} and its statistical distribution with loudness is not bad. In Fig.1, the $L_{A\,F\,min\,1hr}$ day time Interval history, ranging 48-50dBA, shows us the kind of noise-fog we are always in with traffic noise - though we can state this from direct experience, we can't demonstrate it from the results of this measurement. We would need the spectrum structure of one-hour L(1/3 bands)F min.

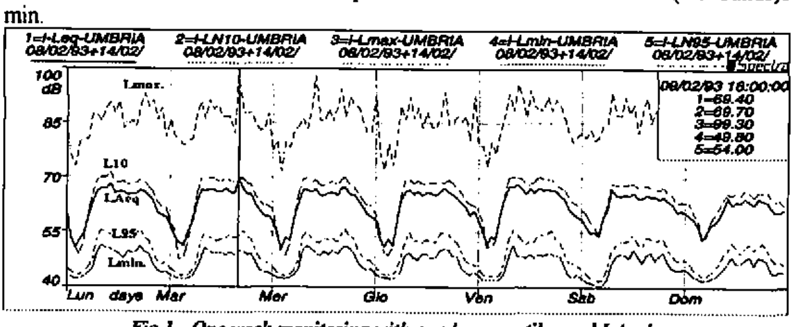


Fig.1.- One week monitoring with one hour centiles and LAeq's.

When the value of $L_{A\,eq\,1hr}$ crosses the $L_{A\,F\,10\,1h}$ value, we know that an energy-significant event altered the dependance of $L_{A\,eq\,1hr}$ from traffic noise. We can see the $L_{A\,F\,max}$ value of this event from the $L_{A\,F\,max\,1hr}$ interval history, but we can't tell the nature of the source itself. To do this, we need at least the $L_{A\,F}$ time history of the event. In Fig. 2 we see for such a case the profile of a siren, causing a $L_{A\,F\,max}$ value of 100dBA.

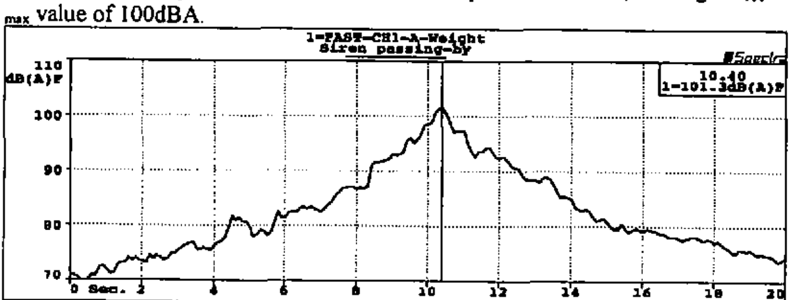


Fig.2.- The LAF time history of a passing-by siren.

4. THE FOUR DIMENSIONAL ANALYSIS

Introducing into the monitoring procedure the statistical cumulative distribution of third-octave levels with 1/8 second exponential time averaging, we add a fourth dimension to provide the dimensions:

1. Absolute time (t) and Interval Time (T), for which the recorded data are valid.
2. Energy Average of sound levels ($L_{A\,eq\,T}$) - which we can correlate with energy but not with loudness.
3. Distribution of sound levels ($L_{A\,F\,N\,T}$) - which we can correlate with loudness distribution.
4. L_{eq} and cumulative distribution of each third-octave sound pressure levels ($L_{1/3oct\ 1/8sec\ N\ T}$) - which we can correlate with the timbre and temporal characteristic of every specific source.

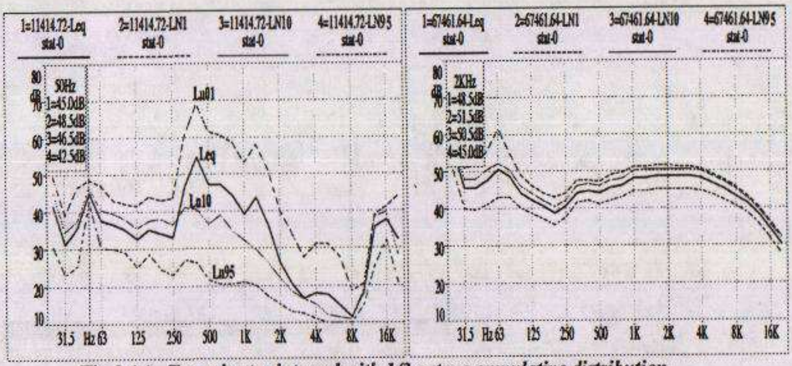


Fig.3 / 4.- Ten minutes interval with 1/3 octave cumulative distribution.

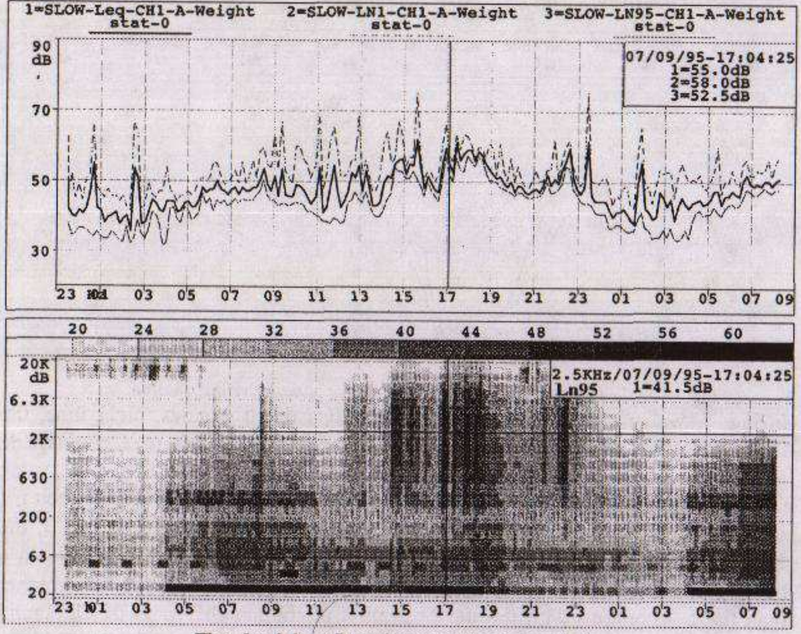
In Fig. 3, we can see for a specific time interval of 10 minutes, night time, the $L_{1/3oct\ 1/8sec}$. The monitoring reported in the next figures refers to a countryside sound climate. We feel it to be of special importance to show the the $L_{1/3oct\ eq}$ value together with the $L_{1/3oct\ N}$ values since, to our experience, L_{eq} values higher then L_{10} values shows the presence of sounds which are impulsive in nature. In Fig. 3, the L_{01} values between 250 and 2000Hz show a spectrum typically attributable to a barking dog; the L_{eq} value that in the same frequency range shows values higher than the L_{10} confirm, with the demonstration of the impulsiveness of the sound controlling this spectrum, that the $L_{A\,eq\,T}$ in the same time interval is controlled by a barking dog.

In the 50Hz band, we see that the percentiles and L_{eq}s group in a small level range, demonstrating the presence of a stationary, almost continuous, sound with tonal characteristics - possibly the exhaust noise of a car parked with engine running.

In the 14kHz and 16kHz bands, we find again that the percentiles and L_{eq}s group together, and this is a rather more difficult source to identify - it is an *occanthus pellucens* (a particularly small species of cricket) which emits their "cri-cri" at this high frequency.

In Fig. 4 we can see results from the same day's monitoring which show an interval dominated by rain - the L_{eq} and percentiles groups in the 200Hz to 6.3kHz range show a pink noise spectrum.

If we now plot in absolute time the contents of the intervals, we can obtain something like a common 3-D analysis, as in Fig. 5a. But if we also plot at the same times a definite percentile, such as $L_{1/3oct\ 1/8sec\ 95}$, as in Fig. 5b, we can see the structure of the background noise and with it, in this special case; how long and when there was strong rainfall (frequency range 200Hz to 6.3kHz, from 14:30 to 19:30 and from 22:30 to 22:50); how long, and when the *occanthus pellucens* played their instrument (frequency range 14kHz to 16kHz, from 23:30 to 05:00); and in the frequency band 25Hz it is possible to see a strong tonal component controlled by a far-away foundry, which starts up at 04:00 in the morning and ceases at 19:00.



Figs. 5 a & b.- 4-D environmental noise analysis.

5. CONCLUSIONS

The authors of this paper feel strongly that there is an importance to obtain better understanding of how to make noise monitoring results which correlate with the reaction of people to noise. Although it is a difficult task to obtain good results in this respect, in that we cannot easily correlate sound climate sound levels with the nature of the source, we believe that by adding a fourth dimension to the sound monitoring, as we illustrate in this paper, we can considerably improve our chances of success.