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The role of short-term L_{Aeq} in problem areas of environmental noise measurement

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1. INTRODUCTION

The use of the equivalent continuous A-weighted sound pressure level, L_{Aeq}, as a general descriptor of environmental noise is now widespread and is embodied in international standards such as ISO 1996 (1), and in various national standards sush as British Standard 4142 (2). Such standards use the concept of a reference time-interval to which an equivalent continuous level is referred. Generally such reference time-intervals are of the order of an hour which can give a rather broad picture of a given situation. At the other extreme we can record the whole noise signal for subsequent analysis but this can be inefficient in the use of data storage. In the last decade, the advent of cheaper computer disc storage has made feasible a method of storing data called "short - L_{eq}", which compresses the data using integration times as low as 125 ms, but ensures its integrity and provides a true statistical representation of the original noise. At Inter - Noise 87, Wallis and Luquet (3) described an instrument which uses this concept and allows a full realisation of IEC Standard 804 (4).However there are situations when integration times of 125 ms can be too long and even more detail is needed. An integrating sound level meter has been modified to take the short term or elemental period down to 5 ms and this paper describes the application of this technology to three "problem" areas,

(i) impulsive noise, where special rating methods have been developed.

(ii) low-altitude military aircraft noise, where measurement of the onset rate of the noise level is important, and

(iii) airport noise monitoring, where it is necessary to analyse time-histories to eliminate non-aircraft events.

2. SHORT - TERM L_{Aeq}

Equivalent continuous A-weighted sound pressure level, $L_{Aeq,T}$, is the A-weighted sound pressure level of a continuous steady sound that within a specified time-interval, T, has the same mean square sound pressure as a sound that varies with time.

It is given by the equation:

$$L_{Aeq,T} = 10 \log [1/T \int_{t_1}^{t_2} (p_A^2(t)/ p_o^2) dt] \text{ dB}$$

where p_o is the reference sound pressure (20 μPa)
$p_A(t)$ is the instantaneous A-weighted sound pressure (Pa)
$T = t_2 - t_1$

One can consider the value of $L_{Aeq,T}$ as a measure of the energy of the signal $p_A(t)$ between t_1 and t_2. We can choose small values of T such as one-second or less without giving any statistical significance to these values of $L_{Aeq,T}$ with respect to the $p_A(t)$ process. This integration over successive periods leads to a time-series with each value being totally independent of previous and succeeding values, and this time-series can be analysed for itself.

To implement the technique in practice, a Cirrus 2.36 Data Acquisition Integrating Sound Level Meter was specially modified to take the short-term period down to 5 ms. The basic instrument described by Wallis and Luquet (3), is a very large capacity data logger. After acquisition the stored values are copied across to a hard disk file in a microcomputer, where the time-series can be displayed and other calculations made. The modifications to the standard unit required that the whole system be speeded up to perform the integration to a high accuracy in the period available. In the conventional unit, the internal microprocessor checks the keyboard every 125 ms, reads the analogue integrators via an A to D converter and calculates the current value of the short-L_{Aeq}. It then "goes to sleep" for about 120 ms as this whole task takes about 5 ms. With the shorter elemental period, the unit operates 200 times per second, which means the microprocessor operates almost all the time, with corresponding demands on the battery power supply. 5 ms was chosen to allow all the longer elemental periods such as 125 ms to be synthesised by simple concatenation. Furthermore the recombination accuracy for computing the I time-weighting, where required, can be to IEC 651 Type 1. The sole disadvantage of the modified instrument is that the total dynamic span has had to be reduced from 120 dB to 108 dB due to the finite size of the digital stores in the L_{Aeq} computation.

3. ASSESSMENT OF IMPULSIVE NOISE

For compatibility with earlier studies (5), carried out using a computer based data acquisition system, a short-term period of 10 ms was used for this work. Software was written to analyse the time-series of $L_{Aeq,10\ ms}$ to produce a number of "impulsivity descriptors".

Three descriptors were evaluated - standard deviation, salience and increment. Standard deviation is obtained by taking each of the 100 values of $L_{Aeq,10\ ms}$ in any one-second interval and calculating according to the common formula,

$$(\text{standard deviation})^2 = 1/100 \sum_{i=1}^{100} (L_{Aeq(i)} - \bar{L}_{Aeq(i)})^2$$

Salience is calculated from the difference between the maximum value of $L_{Aeq,10\ ms}$ in a one-second interval and the overall value of $L_{Aeq,1\ s}$ for that interval. Increment is found by taking differences between successive values of $L_{Aeq,10\ ms}$ and noting the maximum positive difference. The concepts of salience and increment are illustrated graphically below for a one-second segment of pile driver noise.

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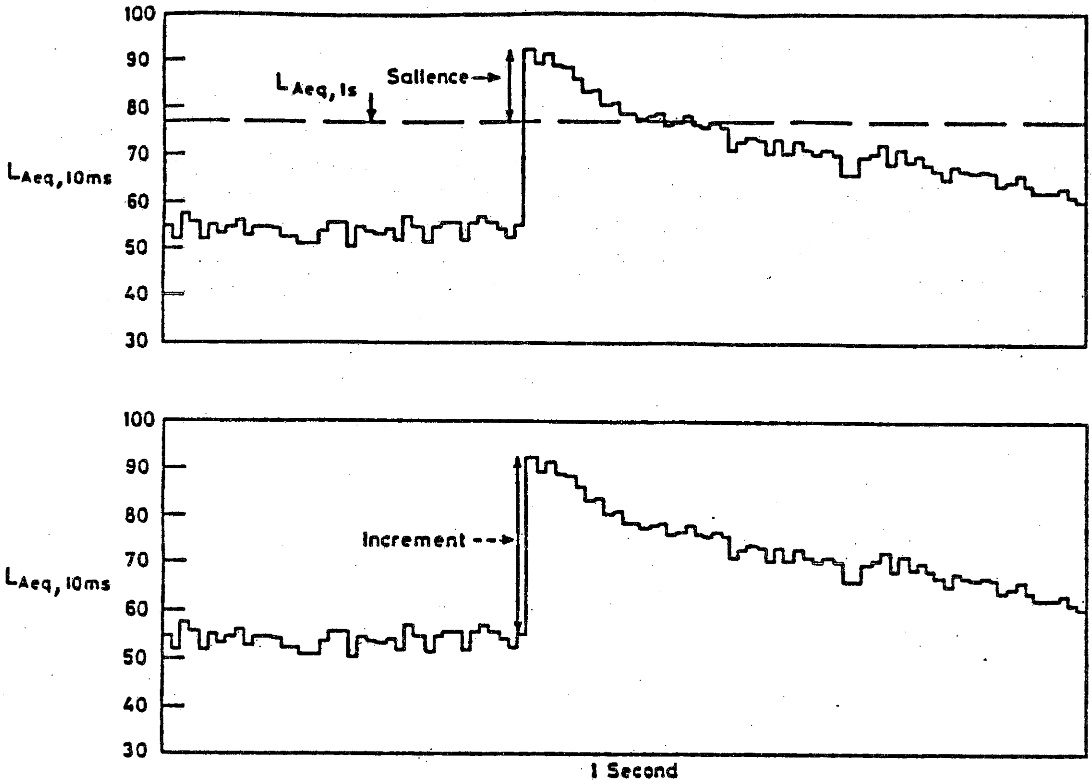

Figure 1. Salience and increment descriptors.

The individual values making up the time-series are evident in this "zoomed-in" view of the time-history provided by the standard software.
Noises used in the CEC Joint Project on Impulse Noise (6) were analysed using these descriptors, together with others such as crest factor and L_{AI} - L_{AS}. The results indicate that increment performs best in terms of correlation with subjective data (7).

4. LOW-ALTITUDE MILITARY AIRCRAFT NOISE

In the UK as in other NATO countries, there is growing public concern about noise from high-speed low-altitude operations of military jets. The problem of measuring, predicting and rating this type of noise has been studied in depth in recent years in the USA (8), and the role of the onset rate of the noise has been emphasised to the extent that a special descriptor termed " onset rate adjusted sound exposure level" has been proposed (9).

To obtain data on a number of aircraft types, a special noise trial was conducted at RAE West Freugh in Scotland in which a number of aircraft were flown straight and level at altitudes down to 100 feet at various speeds and engine power settings over an array of microphones. The recordings have been analysed by various methods and the detailed results published (10). In the absence of a standard specification for the measurement of onset rate the opportunity was taken to assess the effect of integration time.

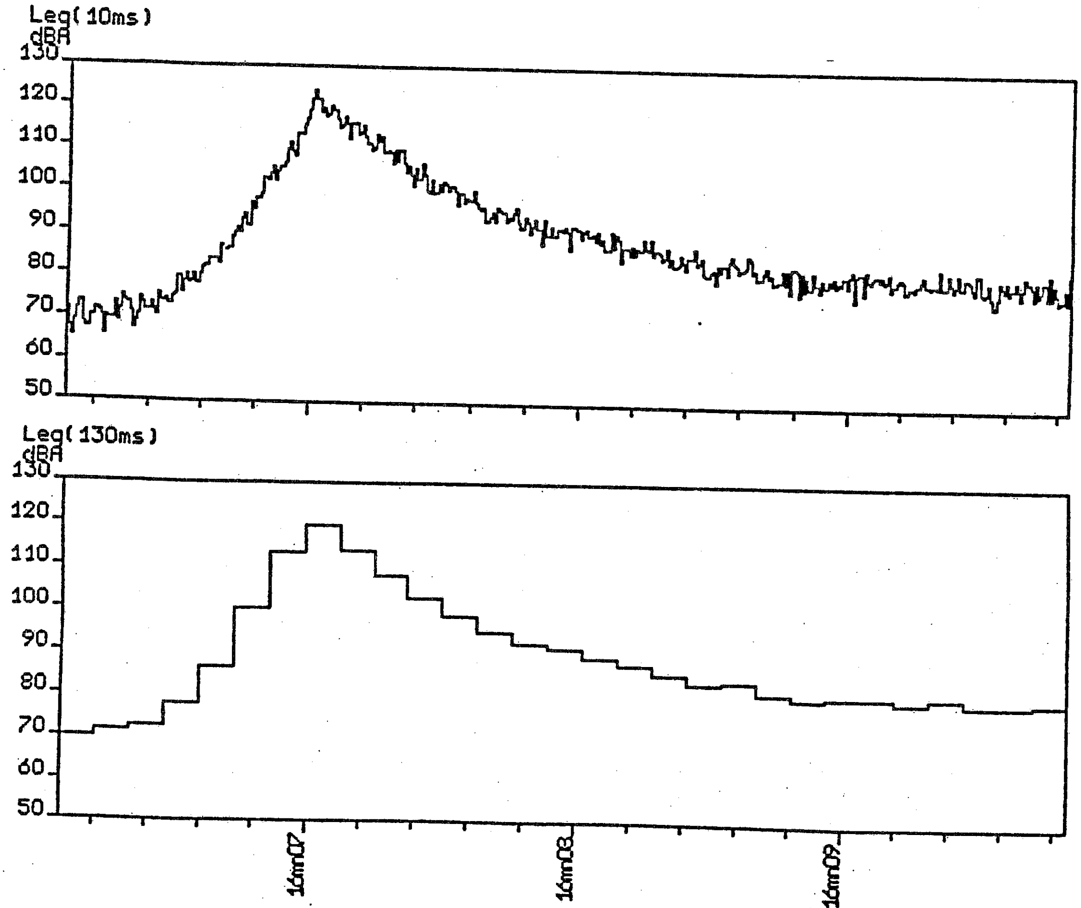

Figure 2. Effect of integration time: military aircraft noise.

Figure 2 shows a 4-second period of a typical time-history obtained with the modified Cirrus meter set to 10 ms, compared to the time-history obtained when the 10 ms periods are concatenated to approximate the Fast time-weighting. The shorter elemental period gives a clearer picture of the rapid onset, the level rising 50 dB in the half-second before the maximum. Because of the "smoothing" and the consequent reduction in the maximum level, the use of the Fast time-weighting tends to underestimate the calculated value of the onset rate.

5. AIRPORT NOISE MONITORING

One of the major problems in airport noise monitoring is that of discrimination between aircraft and other noise. A typical aircraft event may last for about a minute with a fairly fast onset and a somewhat slower decay. The particular onset and decay times will depend on the flight profile of the aircraft as well as the aircraft type. The use of short-term L_{Aeq} as the basis of acquisition allows the data to be used as a template comparator, where the computer attempts to fit the acquired data to shapes stored in memory. The high resolution provided by the use of an elemental period of 10 ms makes this task simpler as the computer can try sliding fits, where the data is incremented in steps of 10 ms until the best fit is obtained. When this is done the short term values allow the conventional values of L_{AFmax} and the percentile values L_n to be computed without sampling error.The alternative method of producing the values of L_{AFmax} and L_{ASmax} is by sampling the output of an exponential integrator. Such a sampling method has associated errors unless the sampling rate is far higher than current systems permit, as, with long periods between samples, the sample time is unlikely to coincide with the actual maximum of the rectified signal. Conversely with the very short elemental periods, the energy in each 5 ms element allows accurate recombination to give the true maximum values. After acquisition, the use of very short elements allows the final short-L_{Aeq} values, which are required to be stored for record purposes, to be any value in multiples of the elemental period, typically one-second.

A further advantage of these very short periods is that the data from different monitors can be compared for time correlation. For example, several monitors "hear" an event at roughly similar times. When interrogated, the units can attempt to quantify the time differences, which can give spatial resolution down to about

3 metres. Because of wind, reflections and other acoustic factors, this cannot be used to give exact positional information about the aircraft and cannot provide the accuracy that the spatial resolution suggests, but it does provide a reasonable check on the approximate position of the aircraft. When correlated with radar information, it provides an additional check on the aircraft track.

6. CONCLUSIONS

An integrating-averaging sound level meter has been developed capable of calculating and storing values of $L_{Aeq,T}$ where T can be as short as 5 ms. Methods for rating impulsive noise based on calculations on the time-series of $L_{Aeq,T}$ have been implemented and tested against subjective data. The instrument has advantages over conventional techniques in the measurement of the noise of low-altitude military aircraft, where information is needed on the onset rate of the noise level. Use of such short-term L_{Aeq} techniques has enabled the development of airport noise monitors which can discriminate between aircraft noise and other noise using template comparison.

7. REFERENCES

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Note

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