MEASUREMENT OF INSTANTANEOUS PEAK SOUND PRESSURE LEVEL

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INTRODUCTION

This paper describes work carried out to illustrate the problems involved in determining instantaneous unweighted sound pressure level. Assessment of this peak level will become necessary when UK regulations are enacted to meet the requirements of the CEC Directive on the protection of workers from the risks related to exposure to noise at work [1].

Article Four of the Council of European Communities Directive [1] requires that action should be taken for workers exposed to "unweighted instantaneous sound pressures likely to be greater than 200 Pa" (140 dB re 20μPa).

A previous study [2] has shown that 'peak' sound pressure level is preferable to 'impulse' sound pressure measurements. However the same study concluded that IEC 651: 1979 does not adequately test the 'peak' characteristic of sound level meters.

It was considered that differences in the 'peak' time constant specifications could cause similar meters to give different measurements when presented with the same impulsive sound input. Additionally variation of 'linear' frequency response might be expected to produce variability in results; particularly if the sound pressure changes contained significant low-frequency components. Two experiments were conducted to demonstrate these effects.

The first experiment was designed to highlight any variability in readings of maximum sound pressure levels, and to determine whether maximum 'A' weighted, or linear, rms measures might be used as a guide to the true peak sound pressure level. The second, was designed to show how the maximum peak level of a signal will change according to the lower limiting frequency of the measuring instrument.

COMPARISON OF MAXIMUM SOUND PRESSURE MEASUREMENTS

Method

A 16 bit digital recording/playback system with a frequency response from 5Hz to 22kHz was used to provide input signals for these tests. The six different impulsive sound recordings used for the tests were:

1. A cap gun fired in semi reverberant conditions
2. A cap gun fired in anechoic conditions
3. A starting pistol fired in anechoic conditions
4. An explosion of aspirin dust (at 25 meters)
5. A drop forge
6. A blanking press

The recordings were replayed into eight different sound level meters simultaneously using dummy microphones.

The eight sound level meters used were all type 1 according to IEC 651: 1979 and BS 5969: 1981, and had passed acceptance tests performed by the Noise and

Vibration Section to prove conformance with the type 1 specification. Details of the sound level meters are given in Table 1, along with a list of their manufacturer's specifications for unweighted frequency range and peak onset time constants.

For the six recordings of impulsive sound, measurements were made of:

1. peak unweighted SPL
2. peak A-weighted SPL
3. rms (fast) unweighted SPL
4. rms (fast) A-weighted SPL,

using, where possible, all eight sound level meters.

Measurements were also made of the maximum peak level using a Bruel & Kjaer type 2032 Dual Channel Analyser sampling every 15.3μs with no band-limiting filters applied.

Results

The results of the measurements of maximum sound pressure level are summarised in Table 2. This table shows, for each recording, the mean and spread of sound pressure levels measured by the various meters. Also shown in Table 2 is the difference of the mean sound level from the 'true peak' level as measured using the B&K 2032.

Observations

Inter-instrument agreement between indicated maximum sound levels is generally best for rms (fast) A-Weighted, and worst for peak unweighted measurements. This may be attributable to differences between meters in their specification for the unweighted frequency range and peak response times.

Some meters give maximum peak readings which differ significantly from the values obtained using the Dual Channel Analyser. It is emphasised that all meters used in the tests satisfy the requirements of IEC 651: 1979 [3] and BS 5969: 1981 [4].

Proposals have been made that maximum peak levels might be assessed using some other SPL measurement such as the A-weighted 'fast' SPL. The results presented in Table 2 clearly show that there is no simple relationship between 'peak linear', i.e. unweighted, SPL and any of the other sound pressure measurements.

THE EFFECT ON MEASURED PEAK LEVELS OF LOWER CUT-OFF FREQUENCY

Method

This exercise was carried out on a computer using digital filtering software. The filter simulated by the computer is a Butterworth 12dB per octave high-pass filter.

Two input signals were considered. The first, a computer acquisition of the sound from a coal dust explosion with a sample rate of 45000 samples per second and a 20kHz low-pass filter applied. This event has significant low-frequency energy content. The second input signal was a computer generated, 40000 samples per second, single cycle 1kHz sine wave pulse, preceded and followed by 0.0128 seconds of no signal.

The signals were passed through the high-pass Butterworth filter set to a series of different cut-off frequencies. At each cut-off frequency, values were obtained for the resulting maximum positive and negative peaks. These peak level values (in volts) were then converted to levels in dB.

Results

Figure 1 shows, for selected cut-off frequencies, the results of filtering on the coal dust explosion signal. The original signal is gradually reduced as the cut-off frequency is increased. Figure 2 shows how the maximum positive and negative peak levels change as a function of the cut-off frequency.

Figure 3 shows how the single cycle sine wave is modified by the application of high-pass filters at selected frequencies. Figure 4 shows how the maximum positive and negative peak values of the computer generated signal change as a function of the cut-off frequency. As the filter cut-off frequency rises above 1kHz the apparent peak level falls rapidly.

Observations

It can be seen in Figure 3 that filtering may produce features in the signal which are not real. At cut-off frequencies of 500Hz and 1kHz the maximum negative peak of the single cycle 1kHz tone burst is actually a second negative peak created by the resonance of the filter.

It is clear that, depending on the frequency content of the input sound and the measurement frequency range, a wide range of apparently correct values for the measured sound pressure level might be obtained.

DISCUSSION

Article Four of the Council of European Communities Directive [1] requires that action should be taken for workers exposed to "unweighted instantaneous sound pressures likely to be greater than 200 Pa" (140 dB re 20 µPa). For measurement of the instantaneous sound pressure level the Directive requires an instrument with "an onset time constant not exceeding 100µs".

The International Electrotechnical Commission standard IEC 651: 1979 [3] and the British Standard BS 5969: 1981 [4] on sound level meters specify that the averaging time constant for 'fast' response should be 125ms and that in 'peak' mode the onset time of the detector should be specified by the manufacturer, but that a single pulse of 100µs (50µs for type 0) duration produces a deflection of no more than 2dB below that produced by a pulse having a duration of 10ms and of equal amplitude. For unweighted (or linear) frequency response the manufacturer is required to specify the frequency range and the tolerance; the tolerances being no greater than those for the A, B, C or D frequency weighting characteristics.

It is clear that measurements of unweighted peak are likely to be influenced by the manufacturer's choice of peak response time and frequency range. The tolerances required of the weighting networks are, for type 1 meters, +3dB and minus infinity for frequencies lower than 16Hz or higher than 16kHz. With such wide limits applied to a linear frequency weighting it is inevitable that there will be discrepancies in results from different sound level meters.

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CONCLUSIONS

It has been shown that a range of, equally valid, maximum sound pressure levels may be obtained from apparently equivalent meters presented with the same input signals. These differences in SPL readings may be due to variations in manufacturer's specifications allowed by the sound level meter standards.

Although the rms 'fast' A-weighted measurements give the most consistent results over all meters, the values obtained do not relate easily to the true peak levels, being dependent on the frequency content of the sound impulse as well as the magnitude. Therefore such measurements cannot be used reliably as a guide to true peak levels. It should also be noted that measurements of this sort do not conform to the EEC directive requirements for peak level measurement since the 125ms averaging time constant of the rms fast response is much greater than the required onset time constant of 100µs or less.

Clearly, for consistent assessment of peak exposure level the definition of unweighted instantaneous sound pressure level must be made less ambiguous. Both IEC and British Standards on sound level meters (IEC 651: 1979 and BS 5969: 1981, [3,4]) need to tighten their requirements for peak response time, unweighted frequency range and tolerances on unweighted frequency response filters. It should be noted that the standards for integrating-averaging sound level meters (Leq meters), IEC 804: 1985 [5] and BS 6698: 1986 [6], call on IEC 651: 1979 and BS 5969: 1981 for response time and frequency weighting characteristics.

REFERENCES

[1] The Council of European Communities "Council Directive of 12 May 1986 on the protection of workers from the risks related to exposure to noise at work" 86/188/EEC (May 1986)

[2] I R Price and E J Walles "Measurement of impulsive industrial noise exposure" Proceedings of The Institute of Acoustics Vol 7 Part 2 (1985)

[3] International Electrochemical Commission "Sound level meters" IEC 651 (1979)

[4] British Standards Institution "Specification for sound Level meters" BS 5969 (1981)

[5] International Electrochemical Commission "Integrating-averaging sound level meters" IEC 804 (1984)

[6] British Standards Institution "Specification for integrating-averaging sound level meters" BS 6698 (1986)

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Table 1. Specifications of the sound level meters used in the tests

Manufacturer and type	Unweighted Frequency range (Hz)	Standard Microphone: type	frequency range (Hz)	Peak onset time (µs)
Computer Engineering Ltd:				
CEL 193(IS)	2 - 30000	186/2F	<20 - 20000	50
CEL 193	2 - 30000	186/2F	<20 - 20000	50
CEL 393	5 - 25000	182/2F	<20 - 20000	100
CEL 493	5 - 25000	MK221	<20 - 18000	50
Bruel & Kjaer:				
B&K 2209	2 - 70000	4144	2.6 - 8000	<20
		4134	4 - 20000	
B&K 2221	20 - 20000	4176	6.5 - 12500	<30
B&K 2230	10 - 50000*	4155	4 - 16000	<50
	20 - 20000**			
B&K 2231	2 - 70000*	4155	4 - 16000	<50
	10 - 20000**			

* all-pass linear
** limited pass linear

Table 2 Summary of results

Meter response	Frequency weighting		Cap gun reverb.	Cap gun Anechoic	Starting pistol	Aspirin dust	Drop forge	Blanking press
Peak	Linear	Mean (L)	130.7	134.7	141.8	148.5	151.8	151.4
		L-true pk	-0.2	-0.3	-1.7	1.0	-0.5	-0.9
		max-min	7.3	10.3	5.6	3.6	5.4	4.2
	A	Mean (L)	129.0	133.4	141.7	142.8	149.6	149.1
		L-true pk	-1.9	-1.5	-1.8	-4.7	-2.7	-3.2
		max-min	7.7	10.0	9.5	1.7	3.1	2.7
rms	Linear	Mean (L)	106.5	106.5	125.4	138.6	135.6	138.7
		L-true pk	-24.6	-29.8	-20.4	-9.5	-16.8	-13.7
		max-min	0.7	7.2	7.8	4.0	0.9	0.9
	A	Mean (L)	106.0	101.7	112.3	119.4	133.3	137.2
		L-true pk	-25.9	-33.2	-31.2	-28.1	-19.0	-15.1
		max-min	1.1	2.8	4.9	0.8	0.8	1.1

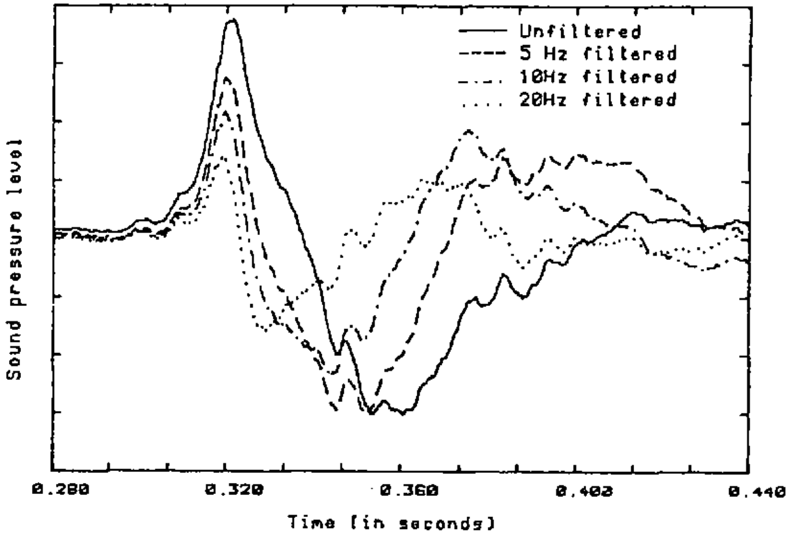

Figure 1 Dust explosion time signal high-pass filtered at 0, 5, 10 and 20Hz.

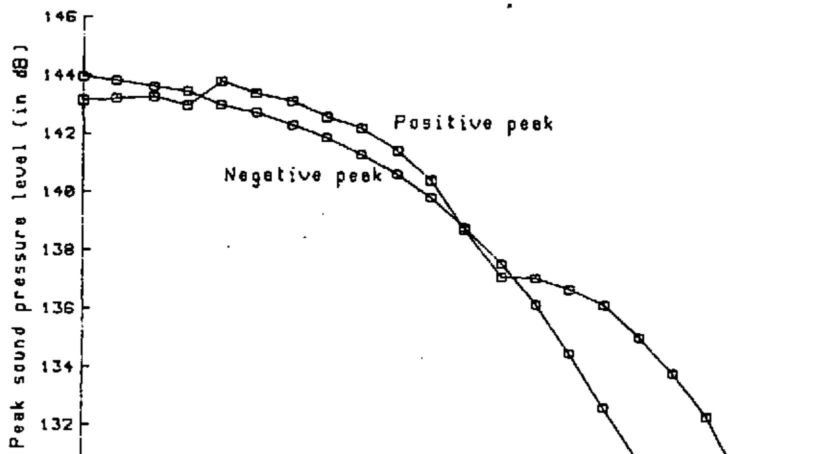

Figure 2 The effect of the lower cut-off frequency on the maximum peak levels of a dust explosion.

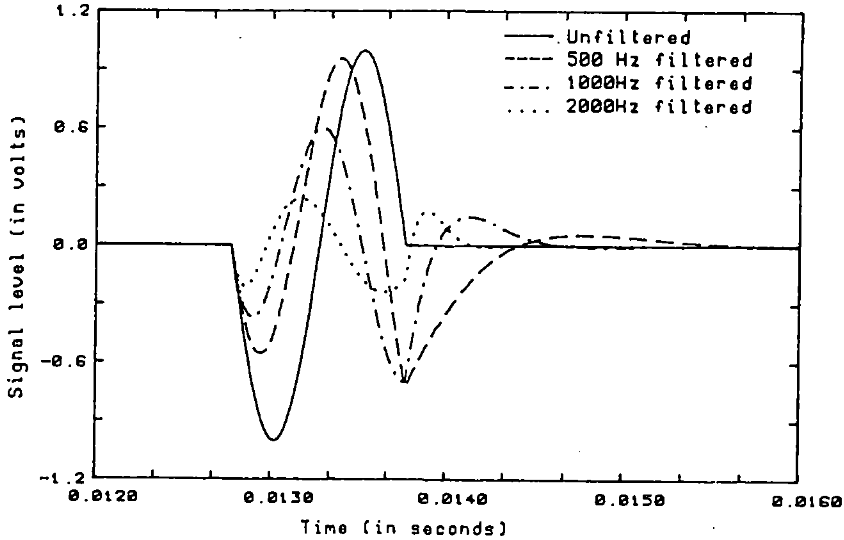

Figure 3 A single cycle 1kHz tone burst filtered at 0, 500, 1000 and 2000Hz.

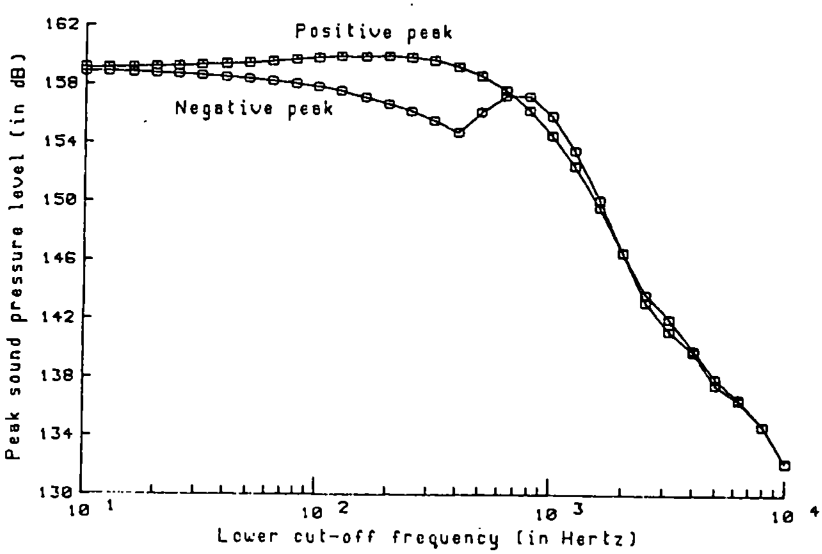

Figure 4 The effect of the lower cut-off frequency on the maximum peak levels of the single cycle 1kHz tone burst.