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LOW FREQUENCY NOISE EMITTED BY COMPUTER DISK DRIVES-EFFECT OF MULTIPLE DISK DRIVE INSTALLATIONS

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ABSTRACT
This paper explains why low frequency noise from computer disk drives has become a relevant issue in the computer industry and describes the effect of multiple drive installations on noise emission declaration procedures. Results are presented demonstrating the effect of a fluctuating low frequency tone at the disk drive fundamental rotational frequency due to the beating effect between drives. This can result in a fluctuating A weighted sound power level which makes it essential that the sound power level be measured in accordance with procedure given in ECMA -74 C.9.4 and that the standard deviation of repeatability be included in the calculation of declared noise emission levels. Although, in some instances, the A weighted fluctuation may be masked by other noise sources, the drive frequency tone still fluctuates, leading to difficulties in assessing the presence of a prominant discrete tone.

1 - INTRODUCTION
Disk drive technology has changed rapidly over the past few years and high performance 3.5 inch form factor drives with rotational speeds of 7200 and 10000 rpm are in common use The fundamental drive frequency has increased from 87 Hz to 120 and 167 Hz respectively and is now within the frequency range of interest defined in ECMA-74 [ref. 1] which was not the case with previous lower speed drives. This, combined with the use of multiple drive arrays in one box, has raised a number of problems in noise measurement and product noise declaration since the low frequency tone emitted by a box containing an array of disk drives fluctuates with time at the drive rpm frequency. In addition the perceived 'sound quality' of the product suffers since fluctuating low frequency tones are more annoying than steady state noise

Measurement anomalies, such as the operating noise emission level being lower than the idling noise emission level, can also occur when the sound pressure level in the one third octave, containing the drive fundamental frequency, is so high compared to the levels in the other bands, that the A weighted sound pressure level also varies with time. This can only be eliminated by using a time averaged sound power measurement as described in ECMA -74 and also a standard deviation of repeatability. In ECMA 109 [ref. 2] only the standard deviations of production and reproducibility are used when calculating the total standard deviation which is used in calculating the declared noise emission level. The standard deviation of repeatability is defined but is not normally included in the calculation.

This paper reports measurements made on multiple disk array products made in accordance with ECMA-74 C.9.4 and also describes how the standard deviation of repeatability can be used to calculate the declared noise emission level and demonstrates the difference it makes to the declared noise emission value, its accuracy being essential in controlling product sound quality.

2 - MEASUREMENT PROCEDURE
Sound power measurements were made using the rotating boom techniques specified in ISO 3744 [3] for free field measurements over a reflecting plane. By running the boom continuously a series of measurements with time can be made to include several beat cycles. This is slightly different from the ECMA-74

procedure in that a number of discrete measurements are made which allows both the time average sound power and the standard deviation of repeatability to be calculated from the measurements.

3 - RESULTS

Fig. 1 shows the variation in the 125 one-third octave band sound power level and the A weighted sound power level with time, in idle mode, on a product containing 16 3.5 inch form factor drives with a drive rotational speed of 7200 rpm, i.e. a fundamental drive frequency of 120 Hz. Also included in Fig 1 is the arithmetic average and standard deviation of the measurements over a 1 hour period. The results demonstrate the large variation in the 125 one-third octave band with time with a variation 9.0 dB between maximum and minimum measurements and a standard deviation of 2.50 dB. The corresponding figures for the A weighted measurements are 2.5 dB and 0.73 dB.

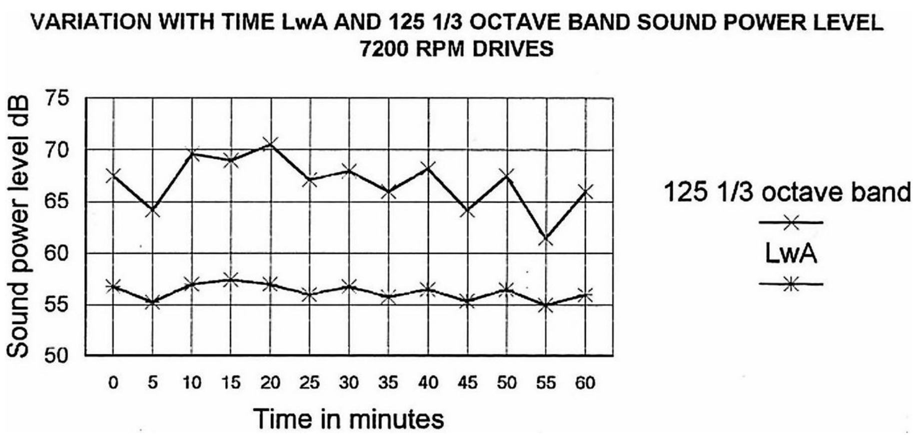

Figure 1: LwA average 56.3 dB, STD 0.73 dB, maximum difference 2.50 dB; 1/3 octave, average 66.9 dV, STD 2.4 dB, maximum difference 9.00 dB.

Fig. 2 gives similar results for a 10 drive product with a drive rotational speed of 10000 rpm.

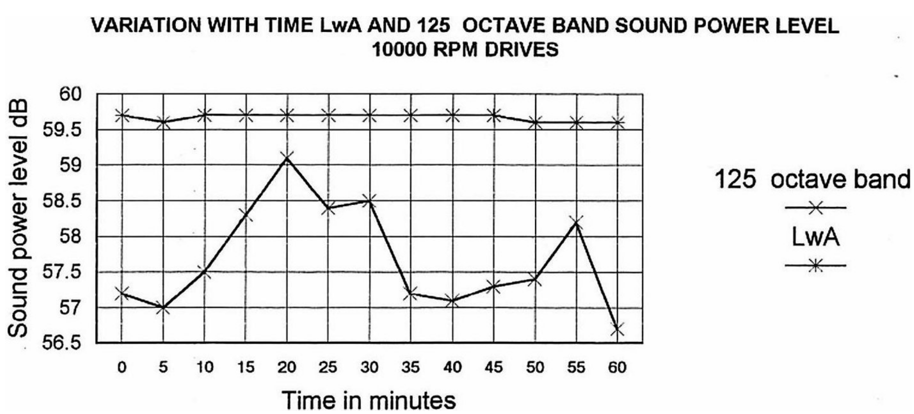

Figure 2: LwA average 59.7 dB STD 0.046 dB, maximum difference 0.1 dB; 1/3 octave average 57.7 dB STD 0.7 dB, maximum difference 2.4 dB.

In this case, since the fundamental frequency is 167 Hz, the 125 Octave band measurements have been plotted which show a maximum variation of 2.4 dB with the corresponding A weighted measurements showing a variation of 0.1 dB. The reason for this reduction in fluctuation with time, in the A weighted measurements, is that the product cooling fans' noise is dominant in the 250 Hz octave band and masks the variation in the drive noise. This is evident from the narrow band sound pressure measurements shown in Fig. 3 which illustrates the variation of the 167 tone with time which has a difference of 12.0 dB between minimum and maximum and a standard deviation of 3.5 dB.

4 - DISCUSSION

The results demonstrate the anomaly which can occur when either determining the noise emission level to be declared or when checking against a specified number based on a single measurement. A possible 2.5

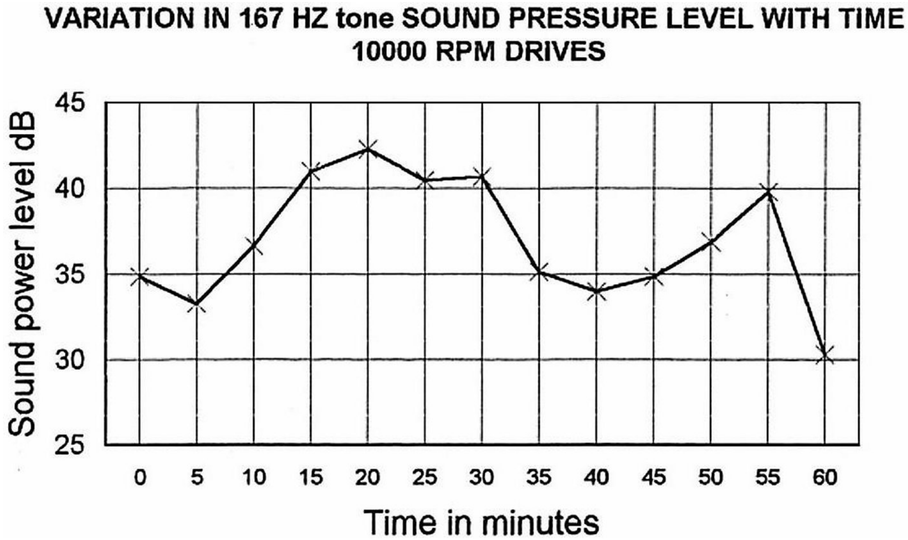

Figure 3: Lp average 36.9 STD 3.5, maximum difference 12.00 dB.

dB variation in the A weighted level for the 7200 rpm drives and the possibility of missing a prominent discrete tone with the 10000 rpm drives. A single measurement could be made with the tone at its lowest level which may not incur a tone penalty

Noise declaration – The procedure for establishing the declared noise level is defined in ECMA- 109 which use the arithmetic mean value of LwA obtained from measurements on a number of machines, the standard deviation of the measurements and the standard deviation of reproducibility (i.e. different labs and operators). ECMA -109 includes, by definition, a standard deviation of repeatability which can be used for fluctuating noise source but this is not included in the total standard deviation used to calculate the declared level.

If this was included in the case of the 7200 drives using a standard deviation of production of 0.7 dB bels (from past experience), a standard deviation of reproducibility of 1.5 dB and, from Fig 1, a standard deviation of repeatability of 0.73 dB the total standard deviation would be 1.81 compared with 1.65 ignoring time fluctuations. This in turn leads to the following comparison using the procedure given in ECMA -109 Appendix A 1.

- Declared level with time fluctuations taken into account: LwAd = 5.91 bels
- Declared level without time fluctuations; maximum level: LwAd = 6.02 bels
- Declared level without time fluctuations; minimum level: LwAd = 5.77 bels

A variation of 2.5 bels in the declared level is clearly unacceptable since this is greater than the difference between idling and operating on disk drive products. This confirms that the procedure in ECMA – 74 C 9.4 should be used to measure the sound power level and in addition the standard deviation of repeatability should be included in the declared noise emission calculation

5 - CONCLUSIONS

1. The A weighted sound power level of products containing multiple disk drives can vary considerably with time leading to a potential wide discrepancy in the declared noise emission value. This can be as great as 0.25 bels when using 7200 rpm drives which is greater than the 0.2 bels difference between operating and idling for typical disk drive applications. This problem can be resolved by using a time averaged value of the A weighted sound power as described in ECMA-74 C 9.4 plus the standard deviation of repeatability.

2. The A weighted sound power level as a function of time can be measured by using a rotating microphone array. By making a series discrete measurements both the time average sound power and the standard deviation of repeatability can be calculated.

3. The effect of the fluctuating drive frequency on the A weighted sound power for the 10000 rpm drives was minimal due to the masking from the cooling fans', although the variation in 167 Hz tone was still present This can affect the noise emission declaration due to the difference in discrete tone predominance assessed at the minimum and maximum tone levels.

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