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ON ACOUSTIC TESTS OF THE MOSQUITO HIGH FREQUENCY SOUND DETERRENT DEVICE

Abstract: *The Mosquito device is a small speaker that produces a high frequency sound which can be heard by young people 13 to 25 years old. The high frequency sound emitted from the device, which cannot be heard by older people, has been designed to deter small crowds of anti social young people from unwanted gatherings of youths and teenagers in shopping malls, around shops, discotheques, cafe bars and anywhere else they are causing problems. The results of acoustic tests of the Mosquito device will be given in this paper. On the basis of these results will be assessed whether the emitted sounds can cause damage to the hearing of the teenagers or people who live near to where on of these devices is sited and whether the device fulfil the hearing damage risk criteria adopted by governmental bodies and international organizations.*

Key words: Mosquito device, hearing damage, risk criteria, noise

INTRODUCTION

The Mosquito or Mosquito alarm (marketed as the Beethoven in France, the Swiss-Mosquito in Switzerland and SonicScreen in the US and Canada) is a wall-mounted electronic device, used to deter loitering by young people, which emits a sound with a very high frequency. The Mosquito is a small speaker that produces a high frequency sound much like the buzzing of the insect it's named after. The recommendation it that the device be mounted at least 3m above ground level to reduce the risk of the vandalism. The Mosquito device automatically shuts down after 20 minutes and cannot be reactivated for at least a further 20 minutes.

The Mosquito works on the principle that the audible range of the human ear generally ranges between 20 Hz and 20 kHz, with the higher end of the audible spectrum being the first to deteriorate naturally due to age related deafness called "presbycusis". Presbycusis is the loss of hearing that gradually occurs in most individuals as they grow older. Hearing loss is a common disorder associated with aging. About 30-35 percent of adults between the ages of 65 and 75 years have a hearing loss. It is estimated that 40-50 percent of people 75 and older have a hearing loss. Younger people can hear sounds up to about 20 kHz.

The loss associated with presbycusis is usually greater for high frequency sounds. For example, it may be difficult for someone to hear the nearby chirping of a bird or the ringing of a telephone. However, the same person may be able to hear clearly the low frequency sound of a truck rumbling down the street.

Based on this natural phenomenon, the Mosquito emits high frequency sound, which can generally only be heard by people up to 20-25years of age.

The high frequency sound emitted from the device, which cannot be heard by older people, has been designed to deter small crowds of anti social young people from unwanted gatherings of youths and teenagers in shopping malls, around shops discotheques, cafe bars and anywhere else they are causing problems. If played loud enough it can cause unpleasant symptoms of nausea and tinnitus.

The newest version of the device from 2008 [1] has two frequency settings, one of approximately 17.4 kHz that can generally be heard only by young people, and another at 8 kHz that can be heard by most people.

Figure 1. *The Mosquito device type MK-4* [1]

The new Mosquito MK4 Multi-Age has additional function of dispersing people of any age from areas where loitering can be an issue such as subway terminals, car parks or any areas where people feel insecure at night due to other people loitering in the shadows etc.

Field trials have confirmed that juveniles and young people who have regularly congregated at known meeting places moved away to other areas after a few minutes exposure to the Mosquito. In addition, it is understood that there have been no reported incidents of noise complaints from residents living in close proximity to the Mosquito during its operation.

The aim of this paper was to present the results of acoustic tests of the Mosquito and the assessment of compliance emitted noise levels with current acoustic legislation.

DAMAGE TO HEARING BY SOUND OF VERY HIGH FREQUENCY

Most environmental sounds are made up of a complex mix of many different frequencies. The frequencies that the normal human ear can detect (up to age 25 years) range from 20 Hz to 20 kHz, although individuals can very greatly in terms of their sensitivity. Below 20Hz lies the range of infrasound and above 20 kHz the ultrasound range. The range above 8 kHz is very high frequency range.

The human hearing system is not equally sensitive to all sound frequencies, and to compensate for this, various filters or frequency weightings have been used to determine the relative strengths of frequency. The A-weighting is commonly used to approximate the frequency response to human hearing system.

It has long been recognized that high levels of wideband or ordinary noise, after sufficient duration, will damage the hearing of exposed individuals. In the occupational sense, the exposure will probably last several hours each workday over a period of years. The principal characteristics of occupational noise-induced hearing loss are [2]:

- It is always sensorineural, affecting the hair cells in the inner ear.
- It is bilateral; the audiometric pattern is similar in each ear.
- The earliest damage is manifest as a threshold shift (a loss of hearing sensitivity) at the audiometric frequencies 3, 4 and/or 6 kHz.
- During stable noise exposure conditions, the hearing losses at 3, 4 and/or 6 kHz will grow quickly over the first few years, and then develop more slowly to reach a maximum level after about 10-15 years. The losses are not expected to exceed 70 dB HL.
- Hearing loss in the lower frequencies takes much longer to develop.
- Once the noise stops, the noise component of the hearing deficit stops growing. Hearing loss due to natural ageing will, of course, continue.

In respect of hearing damage by very high frequency noise however, there is no such received wisdom. Noise may be of conventional bandwidth, or it may contain very high frequency or ultrasonic components. The hearing may be affected in the conventional audiometric frequencies or in the very high frequencies.

There are two ways of approaching noise-induced hearing loss in the very high frequencies: decay of the upper frequency limit of hearing and loss of threshold sensitivity. Both of these changes may be detected by periodic monitoring audiometry using suitable instruments. Table 1 below gives a summary of the upper frequency limit expected for persons in different age bands. The values represent the central tendency of several investigations, and show the steady reduction of the limit with age.

The age-associated loss of hearing sensitivity is summarized in Fig 2. Inspection of these values shows trends which follow on from the conventional audiometric frequencies up and including 8 kHz. The threshold shift (relative to the 20-29 year old baseline) increases from lower to higher frequencies for any age band. Also, the threshold shift increases with age for the any frequency of interest. Threshold shift data for the conventional frequencies suggests that another trend might well be happening in the very high frequency region: as age or frequency increases, one may expect the distribution of threshold shift (or indeed absolute thresholds) to become more disperse.

Table 1. *Upper frequency limit of hearing by age band* [2]

Age band (years)	f (kHz)
20-29	17.9
30-39	16.7
40-49	15.7
50-59	14.8
60-69	13.8
70-79	12.8

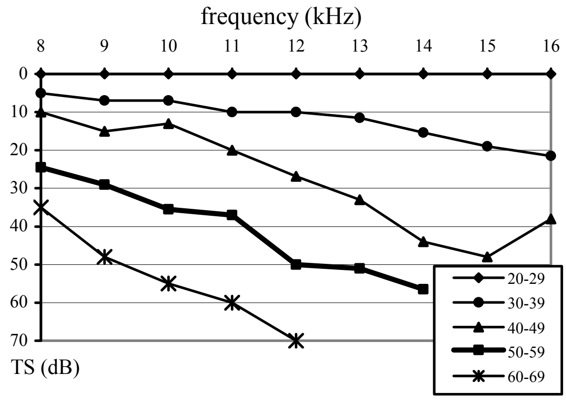

Figure 2. *Threshold shift by age band, relative to persons 20-29 years old*

HEARING DAMAGE RISK CRITERIA

There are a number of very high frequency damage risk criteria first recommended by research organizations and individuals, and later adopted by governmental bodies and by international organizations. These limits are given in Tables 2. The left-hand column of each table indicates the source of each recommendation; the remaining columns list Maximum Permissible Levels as one-third-octave band sound pressure levels. Any noise with a component exceeding one or more of the band limits would be deemed hazardous.

For the very high frequencies, 10-20 kHz, the limits were given as one-third-octave band sound pressure levels in the range 75-110 dB, to avoid unpleasant subjective effects in exposed persons; higher noise levels were found to cause annoyance, tinnitus, headaches, fatigue and even nausea.

The international labour organisation recommended that maximum sound pressure levels near workplace given in table 2. For any total duration of sound not exceeding 4 hours, these levels might be relaxed as follows: duration 1 to 4 hours 6 dB permitted increase, 15 minutes to 1 hour 12 dB, 5 to 15 minutes 18 dB, 1 to 5 minutes 24 dB.

Table 2. *Maximum permissible levels for high frequency sound set out by organizations or national government: limits for whole-day exposure* [2]

1/3 octave band centre frequency f(kHz)	8	10	12.5	16	20
International Labour Office	-	-	75	85	110
WHO					
Japan	90	90	90	90	110
Russia	-	-	75	85	110
US Air Force	-	-	85	85	85
Canada	80	80	80	80	80
Sweden	-	-	-	-	105
International Electrotechnical Commission and International Radiation Protection Association					
Occupational exposure	-	-	-	-	75
General public	-	-	-	-	74
Health Canada	-	-	-	75	75
American Conference of Governmental Industrial Hygienists	-	105	105	105	105

There is an attractive simplicity to the idea of a single number which describes the magnitude of any sound. In the field of noise in the workplace, hearing damage potential is conventionally measured in terms of daily personal noise exposure level ($L_{EP,d}$), which combines sound pressure level, the frequency response of the ear (by means of the A-weighting), and noise duration normalized to a 8 hour workday.

Directive 2003/10/EC of the European Parliament and of the Council [3] cover the minimum health and safety requirements regarding the exposure of workers to risk arising from noise. The aim of the Directive is to ensure that workers' hearing is protected from excessive noise at their workplace, which could cause them to lose their hearing and/or to suffer from tinnitus (permanent ringing in the ears). The exposure limit values and exposure action values in respect of the daily noise exposure levels and peak sound pressure are fixed at:

a) exposure limit values: $L_{EX,8h}$ = 87 dB(A) and p_{peak} = 200 Pa (140 dBC);
b) upper exposure action values: $L_{EX,8h}$ = 85 dB(A) and p_{peak} = 137 Pa (140 dBC);
c) lower exposure action values: $L_{EX,8h}$ = 80 dB(A) and p_{peak} = 112 Pa (135 dBC).

The regulation on measures and norms for protection on work from noise in working rooms [4] defines the minimum health and safety requirements regarding the exposure of workers to risk arising from noise in Republic Serbia. Daily noise exposure level is fixed by this regulation at $L_{EP,d}$ = 85 dB(A). Daily noise exposure level calculated by considering the level of the noise, $L_{Aeq,Te}$ and duration at that level (time exposed), Te in seconds, as shown by the following equation:

$$L_{EX,d} = L_{Aeq,Te} + 10\log\frac{Te}{28800} \qquad (1)$$

The regulation also fixes allowed time of exposure to noise due to the duration of the noise level shown in table 3.

Table 3. *Allowed exposure time to noise levels* [4]

Exposure time (hour)	Noise level (dBA)
8	85
6	87
4	90
3	92
2	95
1 1/2	97
1	100
1/2	105
1/4	110
1/8	115

RESULTS OF ACOUSTIC TESTING MOSQUITO DEVICE

The results from National Physical Laboratory

National Physical Laboratory test report S 5341 deals with the acoustic output of the Mosquito device model 1050 [5].

The fundamental frequency of the Mosquito tone was determined ten times and found to have a mean of 16,6 kHz (range from 16.0 kHz to 17.2 kHz). The sound pressure level was measured 1 metre from the device and found to be 92.8 dB for a drive voltage of 11.9 V. A-weighting factor is 7.2 dB at the mean fundamental frequency. The A-weighted sound pressure level at 1m is therefore estimated to be 85.6 dB(A).

The average sound pressure level was measured at a distance of 2m and reduction in sound pressure level found to be 5.8 dB. At 2 m the level had dropped to 87 dB i.e. 79.8 dB(A). This is close to the ideal 6 dB expected for a point source radiating spherically into a free field.

The average sound pressure level was measured at a distance of 3m and reduction in sound pressure level found to be 9.6 dB. At 3m the level had dropped to 83.2 dB i.e. 76.0 dB(A).

From this date it is possible to estimate the variation in sound pressure level with distance from the source in a free-filed environment (Fig. 3).

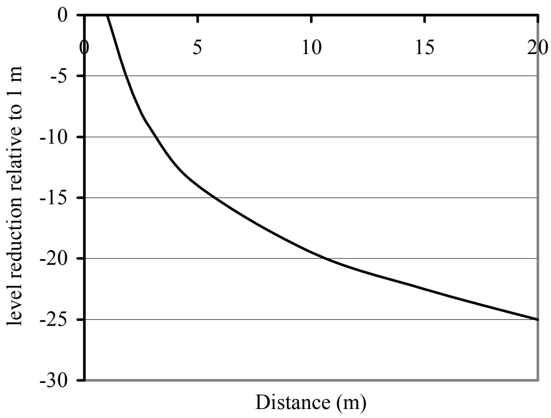

Figure 3. *Sound pressure level versus distance from the Mosquito device*

The sound pressure level was varied during one modulation cycle. Figure 4 shows the variation in microphone output voltage measured at a distance of 1m with a drive voltage of 11.91 V applied to Mosquito device. The corresponding average sound pressure level was found to be 92.4 dB.

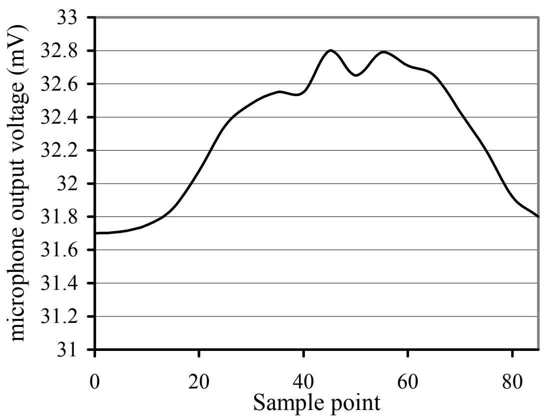

Figure 4. *Variation on output level during one modulation cycle*

The sound pressure level was varied depending the voltage used to drive the Mosquito device. The results of measurements made at a distance of 1m are given in Table 4.

Table 4. *SPL during the modulation cycle as a function of drive voltage* [5]

Drive voltage (V)	Max. SPL	Min. SPL
12.0	92.3	91.8
12.5	93.6	93.2
13.0	94.1	93.9
13.5	94.9	94.4
14.0	94.9	94.4
17.0	99.4	96.8

The results from Medical Physics Department

The NPL report gives no information on the directivity of the Mosquito device. Therefore the acoustical test report of Medical Physics Department in Gloucester, UK, was also examined [6].

The measurements were made in the gymnasiums with the device mounted 80 cm from the floor. The measurements were made with no weighting and with A-weighted filter at a variety of distances and at different angles to the front of the Mosquito device. The A-weighted filter is used to represent subjective loudness of the human ear.

The measurements were a combination of the sound coming directly from the device and reflections from the walls of the gymnasiums. Ambient noise was measured to be of the order of 49 dB(A) and no correction was made since the noise from the Mosquito device was over 10 dB greater than the ambient noise.

The measurements showed that the Mosquito device has a measurable output around 16 kHz to 20 kHz, pulsing regularly at about 2 Hz. The sound pressure level measured at a distance of 3m fluctuated between 85.2 dB to 86.2 dB and 73.1 dB(A) to 77.4 dB(A) and was in agreement to those carried out by National Physical Laboratory. The noted fluctuations were a consequence of cyclical nature of the noise produce by the Mosquito device [6].

Spectral components of sound pressure level measured 1.5m away at 0° to the device are given in table 5.

Table 5. *Spectral components of sound pressure level* [6]

f(kHz) 1/3 octave band	SPL(dBA)	SPL(dB)
12.5	66	72
16	96	92
20	74	80

Used spectrum analyser was not capable of measuring beyond 20 kHz so it cannot say if there were any components above 20 kHz. But if it exists it would be inaudible to all humans of any age.

The angular dependence of sound pressure level is shown in figures 5.

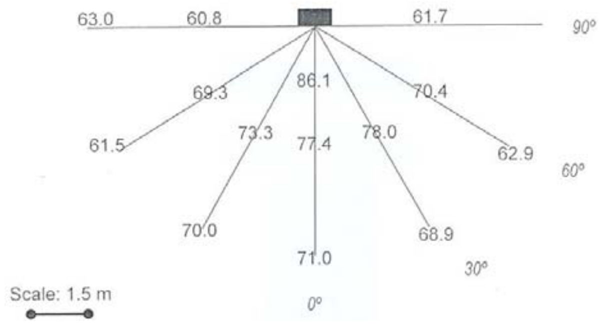

Figure 5. *Angular dependence of sound pressure level indicated in dB(A)* [6]

The claim that the device lowers output after 15 minutes was also tested. After 22 minutes of the device being on, the sound pressure level measured 6m away at 90° to the device changed from fluctuating between 57.0 dB(A) – 61.0 dB(A) to 53.4 dB(A) – 57.0 dB(A). A 4 dB drop is not going to sound very different considering a rule that the sound pressure level must be decreased by 10 dB for sound to be perceived as twice as quieter.

CONCLUSION

Report [2] shows the limits values for very high frequency noise levels between 8 kHz to 20 kHz. The limits are related to both the onset of unpleasant, but not necessary harmful, subjective effects, and actual hearing damage. The limit values vary between 75-90 dB. Limit values for occupational hearing damage are also given between 75 dB(A) to 85 dB(A) for 8 hour working day and between 84 dB(A) to 97 dB(A) for 1 hour exposure. The Serbian regulation specifies a level of 85 dB(A) for an 8 hour working day, equivalent to 100 dB(A) for 1 hour exposure and 110 dB(A) for 15 min exposure.

The Mosquito device emits high frequency pulses ranging between 16 kHz – 19kHz, with a sound pressure level of 76 dB(A) at 3m from the device.

The Mosquito device should be installed at least 2.5 m above ground level to prevent people's ears from coming within 30 cm of the device where the sound pressure level could be as high as 97 dB(A) corresponding the maximum permitted exposure limit for 90 minutes exposure time according to the Serbian regulation.

The Mosquito device is advised by the manufacturer to be placed 3 m above ground level to avoid vandalism. For a tall person, the ear could be 1.5 m on axis from the Mosquito device. At this distance from the device, the sound pressure level would be 82 dB(A), or 89 dB. For off-axis listening, the level should be lower as at any greater distances from the device. The Mosquito signal should be audible to young people but this level would not be recognised as injurious to hearing because the maximum permitted exposure limit is 85 dB(A) for 8 hour daily exposure time.

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