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Exposure levels for parametric arrays in light of guideline ambiguities

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ABSTRACT

Recent revelations about ambiguities in guidelines for very-high frequency sound and ultrasound require many everyday devices to be revisited in terms of guideline compliance. One device that has a high ultrasound component but is designed for audio broadcast is a parametric array. Acoustic radiation for commercial parametric arrays was measured at a distance of 3.5 m in an anechoic chamber. The output of the device is compared against three international regulations and guidelines for ultrasound exposure. The authors found that the device was not compliant under the conditions tested in the laboratory.

Keywords: Ultrasound, Noise Exposure, Guidelines

1. INTRODUCTION

1.1 The rise of ultrasound

Recently, the number of devices that exploit ultrasound in our daily lives have increased (1). The availability of a wide variety of ultrasonic devices has increased as the cost for such devices have dropped. Ultrasonic parking sensors have revolutionized the automotive industry and we might soon see virtual keyboards with haptic feedback provided by ultrasonics (2).

The possible adverse effects that are claimed to be due to ultrasound exposure include annoyance, dizziness, nausea, anxiety, and hearing loss (3-5). The thresholds for onset of these symptoms and the frequencies to which individuals are sensitive vary widely (6, 7), making the determination of exposure guidelines difficult. Many of the guidelines that are in existence are based on limited data and lack a broad participant pool (1).

Despite the large number of devices used in public, there are few reported source levels for ultrasonic sources. Recent studies have been seeking to fill that gap (8-11). These studies provide half the key to safeguarding wellbeing, the other half being studies that determine the threshold of adverse effects (3, 12, 13). This paper expands on a previous study of ultrasonic deterrents (8) to include parametric arrays.

1.2 Parametric arrays

A parametric array is a sound source that uses high amplitude non-linear effects to create an acoustic signal with a very tight beamwidth. The first parametric arrays were underwater sources and have been heavily studied since the theory was introduced in the 1960s (14). The first known study of parametric arrays in air (15) was published in 1975, however they are now widely available commercially. Parametric speakers generally have a very narrow beamwidth, which makes them ideal for public spaces such as museums or positioned next to advertisements where the owner wants the signal to be audible to only a subset of an audience in a room.

1.3 Guidelines and ambiguities

Several reviews exist concerning regulations and guidelines intended for ultrasound and audible

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signals (1, 8, 16). Here guidelines concerning ultrasound in air above the 20 kHz third-octave-band (TOB) will be reviewed briefly. The expected highest levels produced by parametric arrays (all dB with a reference pressure of 20 µP) are going to be above the 20 kHz TOB. It is important to note, however, that most audible guidelines also apply to ultrasonic signals, since ultrasound extends down to 17.8 kHz and most guidelines and regulations concerning audible sound extend up to 22.4 kHz. The Occupational Safety and Health Administration (OSHA) in the USA publishes a set of recommendations (17) for ultrasound exposure in the workplace. The exposure level for each third octave band is assessed against a ceiling value (CV) which is defined as the "exposure limit that should not be exceeded even instantaneously" (18). This level is not the instantaneous or peak sound pressure level (SPL), but the TOB SPL from a sound level meter set to the slow detection setting, which indicates an averaging over a one second period. These CVs are shown in Table 1. One ambiguity in these guidelines is that they report they are based upon implies these levels can be increased by 30 dB if the subject's head is not in direct contact with the source (for example via water). Increasing the levels by that amount has been highly criticized (1, 8).

Table 1 – Ceiling values for OSHA and ICNIRP guidelines for occupational (Occ.) and public (Pub.) exposure.

	OSHA	ICNIRP	ICNIRP
TOB [kHz]	Occ. [dB]	Occ. [dB]	Pub. [dB]
20	105	75	70
25	110	110	100
31.5	115	110	100
40	115	110	100

Other guidelines(19) are published by the International Non-Ionizing Radiation Committee of the International Radiation Protection Association (ICNIRP). Unlike the OSHA guidelines, these contain recommended CV levels for both occupational and public exposure as summarized in Table 1.

2. METHODOLOGY

The measurements presented here were recorded at the same time as measurements previously published (8) elsewhere. Recordings were made in the anechoic chamber at the Institute of Sound and Vibration Research at the University of Southampton, which was commissioned to have free field radiation up to 20 kHz, where it is certified to a 1 dB tolerance. The source was mounted on a pedestal which was covered with absorptive material to minimize reflections. A microphone was positioned on axis from the source 3.5 meters away. This is a practical distance at which such a speaker could be used, but a practical application would be in an environment with significant reflections. An anechoic chamber was used to minimize the effect of interference from reflections on the measurements.

A calibrated B&K type 4191 microphone was used in conjunction with a type 2669 preamplifier and a type 2690 Nexus signal conditioner. The Nexus has a built-in 100 kHz low-pass filter. The analog signal was digitized on a National Instruments USB-6212 16-bit recording system with a sampling rate of 250 kHz. The microphone was calibrated between 20 kHz and 50 kHz by the National Physical Laboratory (NPL). Calibration tones were recorded before and after the measurement session with an agreement within 0.02 dB.

The parametric array was a generic commercial unit that is expected to be representative of many commercial devices available. Measurements were made with a broadband input noise on both high and low gain settings.

3. RESULTS

A summary table of the sound pressure levels (SPLs) measured are presented in Table 2. There are inherent ambiguities in the application of an A-weighting and Z-weighting. Here both are applied with a rectangular filter with a high-frequency cut-off at the top of the 20 kHz TOB. The difference in the A-weighted output from the device between the low and high gain settings is 10 dB. Despite that, there is only 1 dB difference in the pump signal, which is at 40 kHz. A spectrum showing the broadband noise, the modulated signal, and the pump frequency are shown in Fig. 1.

Table 2 – SPL in dB (re: 20 µPa) of the A and Z weighted signal between the 20 Hz and 20 kHz TOBS and the SPL of four TOBs.

Source Condition	A-SPL	Z-SPL	20 kHz	25 kHz	31.5 kHz	40 kHz
Param. - H gain	64	66	53	56	69	118
Param. - L gain	54	59	53	56	63	117

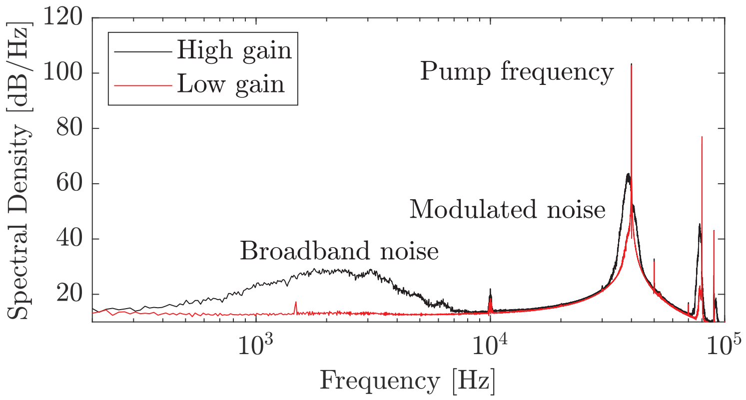

Figure 1 – Spectral density of microphone recording 3.5 m away from parametric array outputting broadband noise.

4. CONCLUSIONS

The pump signal recorded exceeds all guidelines discussed for the 40 kHz TOB. The only possibility for passing the OSHA guideline is if one interprets the guideline such that 30 dB can be added. The device exceeds the public exposure guidelines by at least 17 dB. The author is unaware of any legal requirements to prevent this exposure in public spaces and standard SPL meters are not required to be sensitive above 20 kHz. If someone suffered an adverse reaction for exposures to these levels it is unlikely that they would be able to identify the speaker as the source of the problem. A recent review of ultrasound exposure (1) suggested manufacturers should be held responsible for whether devices meet international guidelines and should be required to test and publish the results. More studies need to be conducted to determine the appropriate safe exposure levels.

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REFERENCES

1. Leighton T, editor Are some people suffering as a result of increasing mass exposure of the public to ultrasound in air? Proc R Soc A; 2016: The Royal Society.

2. Wilson G, Carter T, Subramanian S, Brewster SA. Perception of ultrasonic haptic feedback on the hand: localisation and apparent motion. Proceedings of the 32nd annual ACM conference on Human factors in computing systems; Toronto, Ontario, Canada. 2557033: ACM; 2014. p. 1133-42.

3. Fletcher MD, Jones SL, White PR, Dolder CN, Leighton TG, Lineton B. Effects of very high-frequency sound and ultrasound on humans. Part I: Adverse symptoms after exposure to audible very-high frequency sound.

The Journal of the Acoustical Society of America. 2018;144(4):2511-20.

4. Acton WI, Carson MB. Auditory and subjective effects of airborne noise from industrial ultrasonic sources. Br J Ind Med. 1967;24(4):297-304.

5. Skillern CP. Human response to measured sound pressure levels from ultrasonic devices. Industrial Hygene Journal. 1965;26:132--6.

6. Rodriguez Valiente A, Trinidad A, Garcia Berrocal JR, Gorriz C, Ramirez Camacho R. Extended high-frequency (9-20 kHz) audiometry reference thresholds in 645 healthy subjects. International journal of audiology. 2014;53(8):531-45.

7. Stelmachowicz PG, Beauchaine KA, Kalberer A, Jesteadt W. Normative thresholds in the 8- to 20-kHz range as a function of age. J Acoust Soc Am. 1989;86(4):1384-91.

8. Dolder CN, Fletcher MD, Jones SL, Lineton B, Dennison SR, Symmonds M, et al. Measurements of ultrasonic deterrents and an acoustically branded hairdryer: Ambiguities in guideline compliance. The Journal of the Acoustical Society of America. 2018;144(4):2565-74.

9. Ueda M, Ota A, Takahashi H. Investigation on high-frequency noise in public space. 2014.

10. Mapp P. Ultrasonic surveillance monitoring of PA systems, A safety feature of audible hazzard? Proc IOA. 2016;38(2):1--16.

11. Fletcher MD, Jones SL, White PR, Dolder CN, Lineton B, Leighton TG. Public exposure to ultrasound and very high-frequency sound in air. The Journal of the Acoustical Society of America. 2018;144(4):2554-64.

12. Leighton T, editor Comment on 'Are some people suffering as a result of increasing mass exposure of the public to ultrasound in air?'. Proc R Soc A; 2017: The Royal Society.

13. Fletcher MD, Jones SL, White PR, Dolder CN, Leighton TG, Lineton B. Effects of very high-frequency sound and ultrasound on humans. Part II: A double-blind randomized provocation study of inaudible 20-kHz ultrasound. The Journal of the Acoustical Society of America. 2018;144(4):2521-31.

14. Westervelt PJ. Parametric Acoustic Array. The Journal of the Acoustical Society of America. 1963;35(4):535-7.

15. Bennett MB, Blackstock DT. Parametric array in air. The Journal of the Acoustical Society of America. 1975;57(3):562-8.

16. Lenhardt ML, editor Airborne ultrasonic standards for hearing protection, 2008. 9th International Congress on Noise as a Public Health Problem (ICBEN) 2008; 2008; Foxwoods, CT.

17. (OSHA) OSaHA. OSHA Technical Manual Appendix C—ULTRASOUND. 2015.

18. (ACGIH) ACoGIH. 2012 ACGIH Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs). Cincinati: ACGIH; 2012.

19. ICNIRP. Interim guidelines on limits of human exposure to airborne ultrasound. Health Physics. 1984;46(4):969--74.