Options in Defining Background Noise During Audiometric Testing

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Introduction

Background noise in audiometric testing continues to be a concern in the regulatory and audiological communities. A well-refined and scientifically tested ANSI standard (S3.1-1999) exists that clearly defines acceptable ambient sound pressure levels and the associated errors in threshold measurement that they create. Yet some in the hearing conservation community would like the permissible levels changed, arguing that the existing specifications are predicated on misassumptions. The facts are, however, that the S3.1 standard is based on objective measurements and includes options to adjust its tabled values, depending upon the amount of masking that the experimenter is willing to tolerate. This paper reviews the data and theory behind the standard, clarifies the proper interpretation of the tables in the standard and the options that it provides, compares its specifications to the values proposed by the National Hearing Conservation Association (NHCA) and the American Speech-Language Hearing Association (ASHA) (NHCA, 1994), and summarizes actual room noise measurements reported in the literature.

Background

The specification of permissible ambient noise during audiometric testing has been a matter of controversy since the Occupational Safety and Health Administration (OSHA) hearing conservation amendment was first proposed in 1981. The reasons are obvious. On the one hand, audiologists and scientists need to define noise levels that are low enough to allow the measurement of true thresholds that are unmasked by noise. On the other hand, industry and equipment manufacturers need to have a specification that can realistically be achieved in practice without undue hardship. The final decision in such matters is often a compromise, hopefully well grounded in scientific “facts.” In this particular case the situation becomes more controversial since the question of which unmasked thresholds are the important ones is open to debate. Although 500 Hz is generally the most troublesome frequency to test with respect to background noise problems, some argue that valid thresholds at 500 Hz are relatively unimportant for detection of standard threshold shifts (STS), and thus are either unconcerned regarding masking at that frequency or recommend deleting it altogether as a test frequency.

An American National Standard specifying permissible ambient noise levels during audiometric testing has existed since 1960 (S3.1-1960); it was later revised in 1977, 1991, and most recently 1999. The earliest of these standards specified levels based upon what was considered audiometric zero at that time. Since those standardized values for audiometric zero changed in the later 1960s (the thresholds became more sensitive) it became necessary in 1977 to reduce the ambient noise requirements as well. Changes occurred again in 1991 and 1999 due to new data for the noise-excluding characteristics of audiometric earphones, and revised procedures for predicting masking. In the most recent standard the procedure for computing masking is the one developed by Berger and Killion (1989) that has been validated in three separate experiments separated by over 10 years. The 1999 ambient-noise requirements are well grounded in experimental data using realistic background noises, and are defined so as to permit thresholds be masked by no more than 2 dB.

Those who wish to argue with the S3.1-1999 specifications are hard pressed to do so on factual grounds as the values are well supported by both theory and data. The contestable issues pertain to which audiometric test frequencies are important to accurately test, and whether more or less than 2 dB of masking is tolerable. A third point, and one often overlooked is that the values in the standard for the ears-covered conditions are based upon a listener who obtains average amounts of attenuation from the audiometric earphones used to administer the test. We will return to this point in a moment.

Application and Field Data

In Tables 1, 2, and 3, ANSI S3.1-1999 specifies the ears-covered (for supra-aural and for insert earphones) and ears-not-covered (i.e. sound field audiometry) octave-band and one-third octave-band sound pressure levels (SPLs) that are required in order to measure thresholds with no more than 2 dB of masking. These are called the maximum permissible ambient noise levels (MPANLs). Due to the upward spread of masking, noise levels are specified down to 125 Hz even when audiometric testing extends to only 500 Hz. This paper will focus on the most common condition, namely the ears covered by supra-aural earphones mounted in the MX41/AR or Type 51 cushions, with testing extending down to 500 Hz.

The MPANLs are shown in Figure 1 where they are compared to the 1991 ANSI standard as well as to NHCA (1994) and the OSHA (1983) regulation. Note the two ANSI standards agree within a decibel or so except at 2 and 8 kHz. The NHCA values are identical to the 1991 ANSI standard except for a 5-dB allowance at 500 Hz, to recognize the problems of meeting that requirement and the relatively lower importance of accurate threshold determinations at that frequency. The OSHA values, based on socio-political compromise, are 13 to 25 dB above the ANSI 1999 values, in particular 19-dB higher at the key masking frequency of 500 Hz. The inappropriateness of the OSHA values was verified experimentally by Berger and Killion (1989) who demonstrated that levels as high as those permitted by OSHA did indeed mask thresholds at all of the OSHA-required audiometric test frequencies by at least 12 dB.

The crux of the real-world issue is shown in Figure 2 which presents the percentage of industrial test booths in mobile vans (Lankford et al., 1999; 13 booths) and in fixed facilities (Frank and Williams, 1994; 490 booths) that fail to comply with allowable limits. Note that at the worst-case test frequency of 500 Hz, from 46 – 59% of the rooms fail to meet the requirement. According to Lankford et al., all of the rooms would pass the NHCA requirement at that frequency due to the 5-dB allowance. Frank and Williams did not evaluate that criteria (which appeared subsequent to their paper), but as shown in Figure 3 where the mean and maximum SPLs from the two studies are plotted against the OSHA and ANSI-1991 criteria, a 5-dB adjustment at 500 Hz would still leave some of the rooms evaluated by Frank and Williams in non-compliance.

Figure 4 presents the field data vs. the NHCA, current ANSI, and OSHA values. Clearly some booths have problems, especially if the ANSI data were applied as intended and levels at 125 and 250 Hz are also considered.

One reaction to these results might be to say the ANSI values are unreasonable. However, that suggestion is unsupported by the data. The ANSI values represent reality, and actually the facts are even worse than the data presented thus far indicate. A key component of the ANSI predictions is the level of attenuation of ambient noise that is presumed for the supra-aural test earphones. Although the estimates are based upon reliable real-ear attenuation data averaged across several studies, the values used, as mentioned above, are mean attenuation data. Normally when considering hearing protectors, the mean attenuation values less one or two standard deviations are those that are applied. This indicates what either 84% or 98%, respectively, of the population will achieve under those test conditions.

In keeping with such thinking the attenuation values used for the derivation of the MPANLs should be reduced by approximately 5 dB (for the 1-standard deviation case) or 10 dB (for the 2-standard deviation case). That would directly reduce the MPANLs by the same amount (Clause 5 of S3.1-1999). As is, without that adjustment, many persons who are tested actually obtain less earphone attenuation than suggested and hence experience greater masking than predicted.

Implications

The choice is clear. Reality cannot be ignored. The maximum permissible ambient noise levels in the standard must be met if thresholds masked by no more than 2 dB are to be measured. Arbitrarily raising the MPANLs to assure that more booths comply simply ignores the facts. If we cannot meet the required levels, the options are as follows:

1) Acknowledge that at lower test frequencies such as 500 Hz, we incur 5- or 10-dB of masking, or in other words that we can only test to hearing threshold levels of 5 or 10 dB at those frequencies, instead of 0 dB. In this case, Clause 5 of the ANSI-1999 standard tells us that the amount by which we are willing to raise the minimum thresholds that we can accurately measure is the exact amount that we can relax the MPANLs to which we must adhere. If we agree that measurement of thresholds to a maximum sensitivity of 5 dB is sufficient (with up to 2-dB of masking), then we can add 5 dB to the MPANLs. If we can accept thresholds that are no more sensitive than 10 dB, then we can add 10 dB to the MPANLs.
2) Eliminate, as has been proposed (Stephenson, 2004), testing of 500 Hz in occupational hearing conservation programs, both to save time, and because 500 Hz tells us little about the progression of noise-induced hearing loss.
3) Use audiometric earphones, such as insert earphones, that provide higher levels of ambient noise reduction. In that case, MPANLs can be increased from 13 – 29 dB, with the 29-dB gain occurring at the frequency at which typically the greatest masking occurs due to ambient noise, namely 500 Hz.

References

ANSI (1960). "Criteria for Background Noise in Audiometer Rooms," American National Standards Institute, S3.1-1960, New York, NY.

ANSI (1977). "Criteria for Permissible Ambient Noise During Audiometric Testing," American National Standards Institute, S3.1-1977, New York, NY.

ANSI (1991). "Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms," American National Standards Institute, S3.1-1991, New York, NY.

ANSI (1999). "Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms," American National Standards Institute, S3.1-1999, New York, NY.

Berger, E. H. and Killion, M. C. (1989). "Comparison of the Noise Attenuation of Three Audiometric Earphones, with Additional Data on Masking Near Threshold," J. Acoust. Soc. Am. 86(4), 1392-1403.

Frank, T. and Williams, D. L. (1994). "Ambient Noise Levels in Industrial Audiometric Test Rooms," Am. Ind. Hyg. Assoc. J. 55(5), 433-437.

Lankford, J. E., Perrone, D. C., and Thunder, T. (1999). "Ambient Noise Levels in Mobile Audiometric Testing Facilities," Am. Assoc. Occup. Health Nurs. J. 47(4), 163-167.

NHCA (1994). "Comments and Recommendations on Noise and Hearing Conservation Regulations," submitted November, 1994 by the NHCA and the American Speech-Language Hearing Association (ASHA).

OSHA (1983). "Occupational Noise Exposure; Hearing Conservation Amendment; Final Rule," Occupational Safety and Health Administration, 29CFR1910.95 Fed. Regist. 48(46), 9738-9785.

Stephenson (2004). "Is Testing 500 Hz Necessary When Monitoring for Occupational Hearing Loss?," Spectrum (1), Suppl. 1, 25-26.

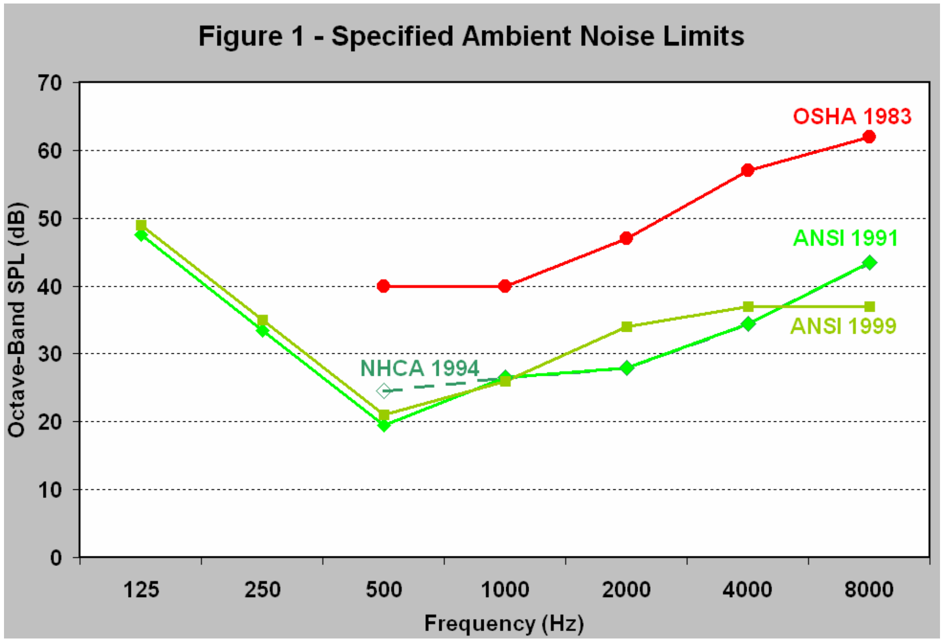

Figure 1 - Specified Ambient Noise Limits
Octave-Band SPL (dB)
0
10
20
30
40
50
60
70
125
250
500
1000
2000
4000
8000
Frequency (Hz)
OSHA 1983
ANSI 1991
ANSI 1999
NHCA 1994

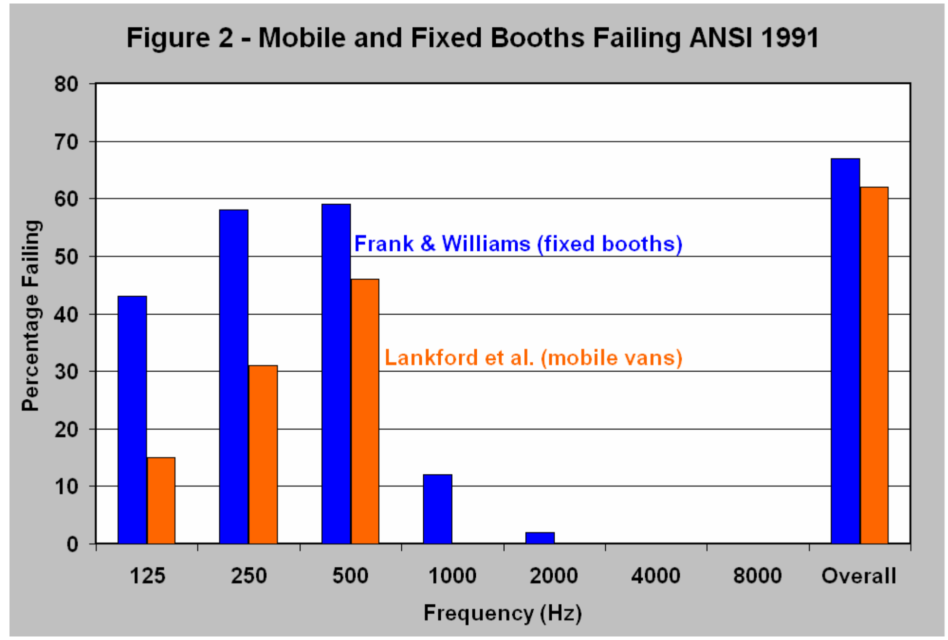

Figure 2 - Mobile and Fixed Booths Failing ANSI 1991
Percentage Failing
0
10
20
30
40
50
60
70
80
125
250
500
1000
2000
4000
8000
Overall
Frequency (Hz)
Frank & Williams (fixed booths)
Lankford et al. (mobile vans)

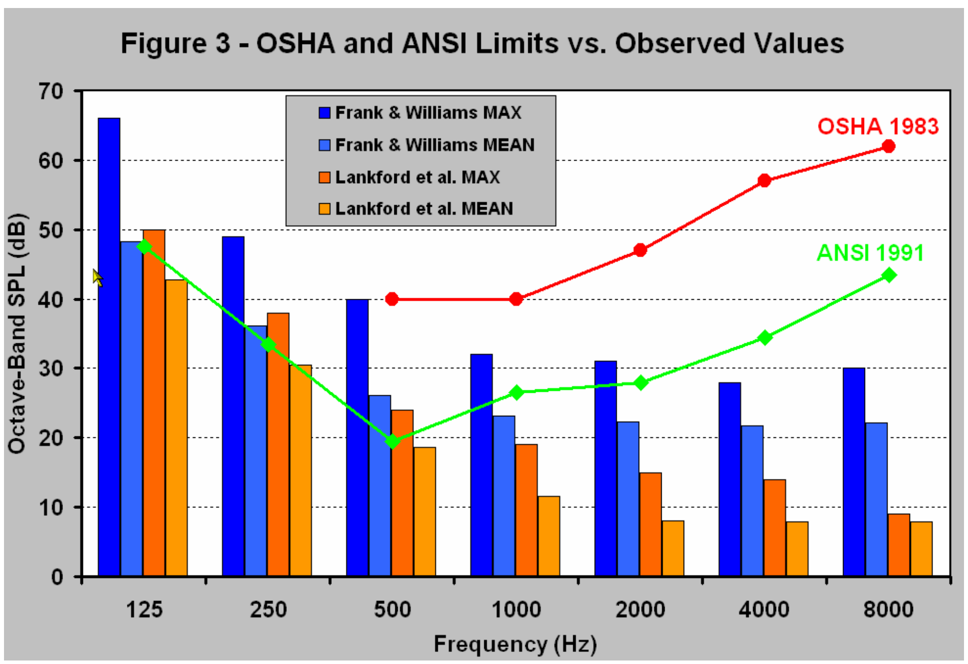

Figure 3 - OSHA and ANSI Limits vs. Observed Values
Octave-Band SPL (dB)
0
10
20
30
40
50
60
70
125
250
500
1000
2000
4000
8000
Frequency (Hz)
Frank & Williams MAX
Frank & Williams MEAN
Lankford et al. MAX
Lankford et al. MEAN
OSHA 1983
ANSI 1991

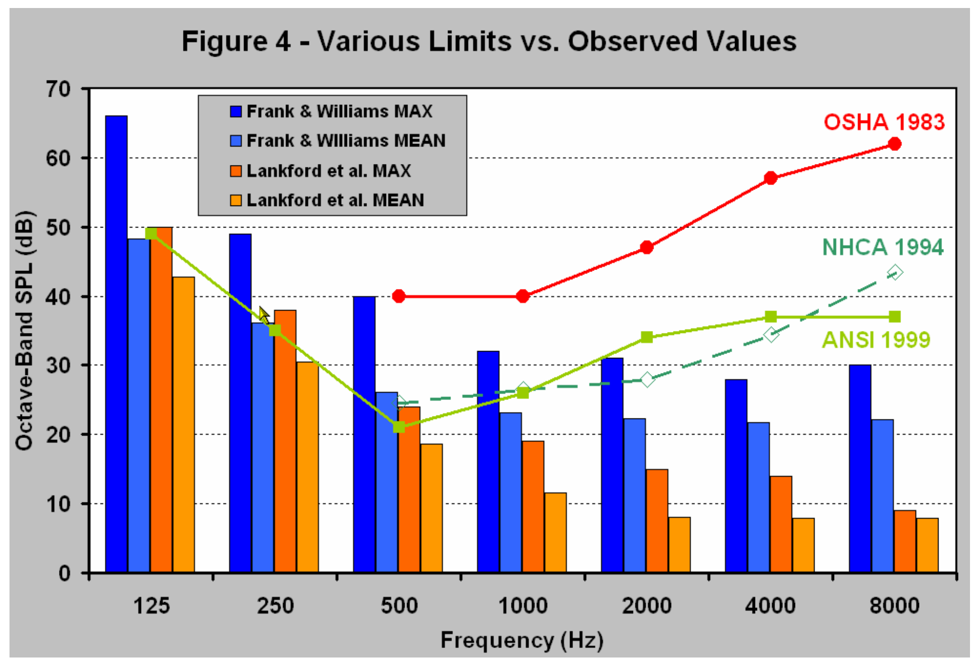

Figure 4 - Various Limits vs. Observed Values
Octave-Band SPL (dB)
0
10
20
30
40
50
60
70
125
250
500
1000
2000
4000
8000
Frequency (Hz)
Frank & Williams MAX
Frank & Williams MEAN
Lankford et al. MAX
Lankford et al. MEAN
OSHA 1983
NHCA 1994
ANSI 1999