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Personal Radio Headsets
Hearing Loss Risk
Audiometric Evaluations

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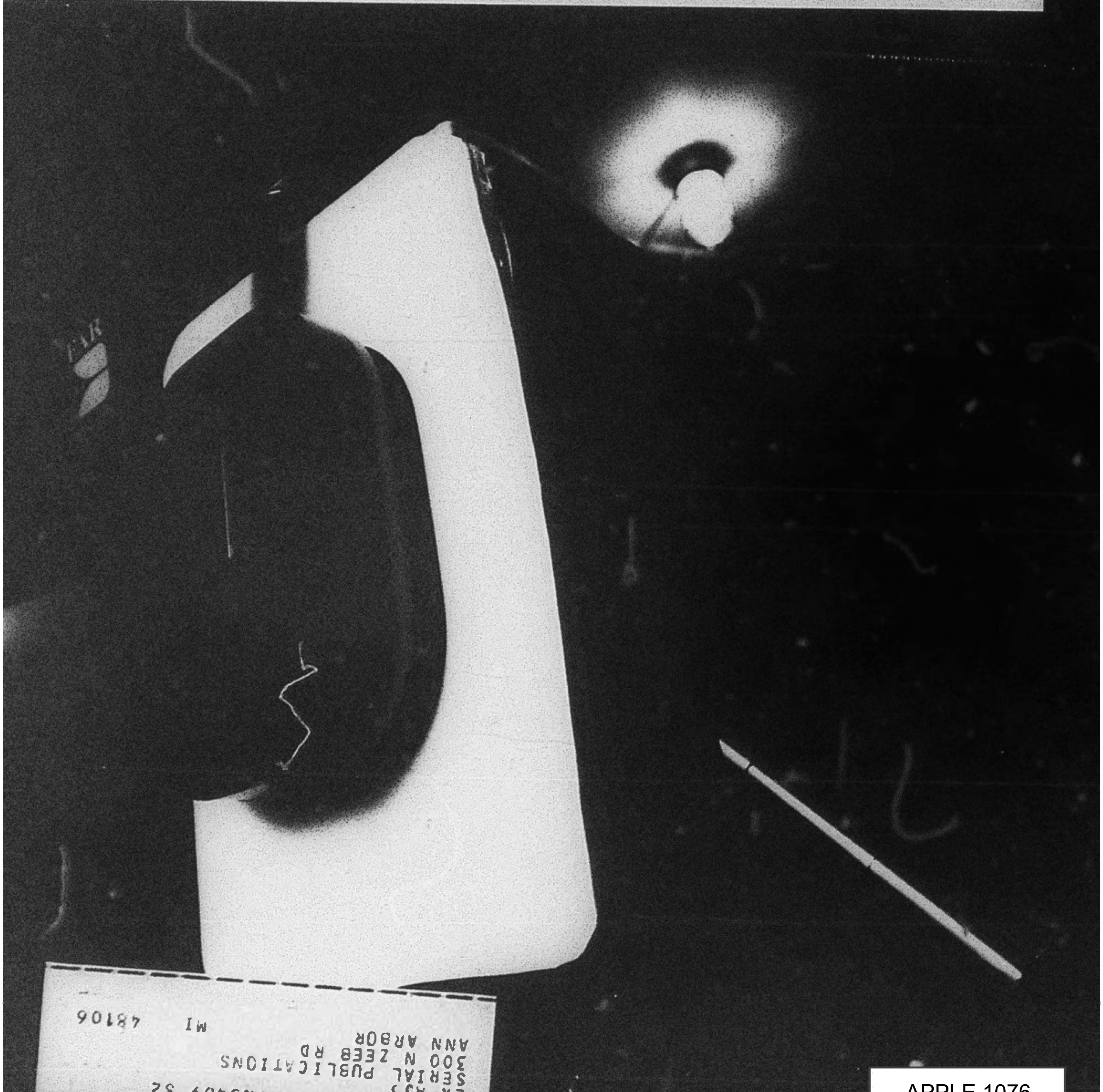

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One method of assessing the attenuation of circumaural hearing protection devices is the dummy head specified in the supplemental physical method of ANSI S3.19-1974. An 8-kg version of that head, machined from cast aluminum and covered with an experimental artificial flesh, is shown here during the testing of the insertion loss of a set of lightweight plastic earmuffs. *(Photo courtesy of E-A-R Division, Cabot Corporation, Indianapolis, IN.)*

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Do Personal Radio Headsets Provide Hearing Protection?

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A laboratory investigation was conducted to determine the acoustic attenuation of 18 personal radio headsets. Sixteen supra-aural, two semi-aural, and two circumaural headsets were included. Insertion loss was measured for grazing and perpendicular incidence using KEMAR. The data were corroborated by comparing the results to real-ear attenuation at threshold values derived via the methodology of ANSI S3.19-1974. The results demonstrated a range of NRR-like numbers from 0.3 to 2.6 dB. Across devices and angles of incidence, the circumaural devices provided up to 7 dB amplification at 800 Hz and all of the devices significantly affected the sound spectrum at frequencies above 2 kHz. The results of this investigation indicate that, in general, personal radio headsets do not significantly modify external sound fields as perceived at the eardrum.

Today it is almost impossible to miss seeing someone walking, running, cycling, driving, and in some instances, working while listening to a personal radio. Since their introduction to the commercial market in 1979 by the Sony Corporation, these devices, commonly referred to as "Walkmans," have become exceedingly popular.

In the past two to three years several articles have been written on personal radios and their potential dangers.[1-9] The general tone of these articles is that these units may present hazards in the following areas: 1. they distract the user's attention; 2. they interfere with the perception of incoming auditory information such as communication and warning signals; and 3. they may cause noise-induced hearing loss.

In 1982 the town of Woodbridge, New Jersey passed legislation prohibiting the use of personal radios on the streets of their town. The township council President was quoted as saying "I think it's a distraction."[6] The danger, they feel, is that users of personal radios will be oblivious to traffic hazards.[7]

The United States Postal Service, in a similar action, banned the use of personal radios, with few exceptions, by postal employees while on the job.[10] They contended that an individual's "concentration to traffic conditions can be compromised by headphones," and that "they (headsets) can also be a hazard when performing jobs where an auditory alarm or feedback is essential . . . "

We recently investigated[11] the potential for personal radios to contribute to noise-induced hearing damage. The study concluded that, at least for the one industrial noise environment investigated, the use of personal radios by employees did not present a significant additional health hazard and that their use should be allowed. However, the study did recommend certain criteria be followed to educate the employee population to the potential dangers of extended use of personal radios played at high volume levels, and to insure that potentially noise-sensitive employees are identified and refused permission to continue the use of personal radios while on the job.

When discussing the potential danger of personal radios interfering with incoming auditory information, one consideration is the attenuation characteristics of personal radio headsets. Huber strongly advocates that "none of the units on the market can reduce sound, nor could any of these headsets be rated able to attenuate sound as supplemental hearing protection."[4] Unfortunately, Huber did not supply objective data to substantiate his claim.

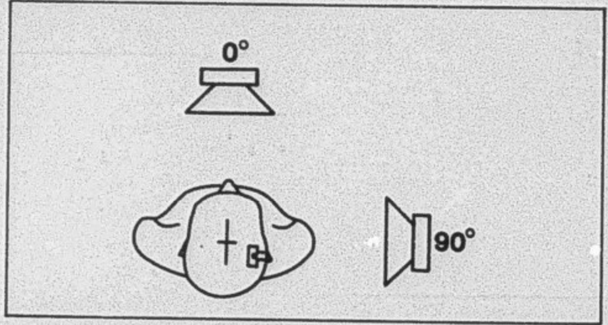

Figure 1. Orientation coordinates for sound sources relative to the KEMAR manikin.

Figure 2. Supra-aural, semi-aural, and circumaural headsets.

The purpose of this study, therefore, was to provide objective data concerning the insertion loss characteristics of personal radio headsets to facilitate management decision-making policy regarding personal radio use in industrial settings.

Methodology

The insertion loss, defined as the difference between the eardrum sound pressure levels (SPLs) with and without the headphones in place, was measured using KEMAR.[12, 13] KEMAR was specifically designed to simulate the acoustic characteristics of the human ear, head, and upper torso, including a Zwislocki coupler to model eardrum impedance. KEMAR includes geometrically accurate pinnas but was not designed to reproduce the dynamic properties of aural and circumaural flesh, nor the bone conduction pathways to the inner ear. Therefore, it was deemed important to justify the insertion loss data obtained using KEMAR with the results of real-ear attenuation at threshold values derived via the methodology of ANSI S3.19-1974.[14]

Measurements Using KEMAR. Measurements were taken in a semi-free field. KEMAR was exposed to white noise generated by a Calrad mini cube air-suspension speaker powered by a Realistic SA100B amplifier driven by a GenRad 1382 random noise generator. Measurements were taken at 0° and 90° incidence angles. These incidence angles follow Burkhard's convention[15] (reference Figure 1).

radio units were evaluated to determine their insertion loss characteristics. The labelling of headset style generally follows the definitions set forth in ANSI S3.19-1974.[14] In total, twenty test recordings were completed, sixteen using supra-aural headsets (having a headband and foam pads fitting lightly against the pinna), two using semi-aural headsets (earphones supported in the concha of the ear canal), and two tests using circumaural headsets (the earphone encloses the entire pinna) (reference Figure 2). Two of the headset units had removable headbands allowing the earphones to be used in the concha (semi-aural), or as typical open air headsets (supra-aural). For the purpose of this research the two dual-use headsets were tested as both supra-aural and semi-aural devices.

A-weighted, C-weighted, and one-third octave band SPLs at the center band frequencies from 125 Hz to 8 kHz were measured with and without the headphones in place. An initial recording of the "no headphones" condition was conducted, followed by three repetitions of the "headphones on" procedure. A final recording of the "no headphones" condition concluded the measurements. All headsets were evaluated at each of the two incidence angles previously mentioned.

The average SPL values for the two test conditions ("no headphones" and "headphones on") at the two incidence angles for all the one-third octave band SPL recordings were determined. The average value for the "headphones on" condition was then subtracted from the average value for the "no headphones" condition at each test frequency. The resulting values established the insertion loss characteristics of the headphones (in dB) at one-third octave band center frequencies.

Comparison to Real-Ear Attenuation at Threshold Data. Although KEMAR has been utilized to measure the insertion loss of hearing protection devices, it was not intended for that purpose and results with certain types of devices have shown significant disagreement with real-ear data.[12, 16] We did not expect such problems with devices of the type included in this study due to their presumed low inherent attenuation and their method of interface to the ear. However, we decided to confirm the acceptability of using KEMAR for our purpose by measuring a circumaural and two supra-aural devices by the standardized real-ear threshold method of ANSI S3.19 and comparing the data to KEMAR measured insertion loss values.

The KEMAR data for a 0° angle of incidence are compared to the ANSI S3.19 values in Tables 1-3 and Figures 3-5. The slight differences observed in the measured insertion loss values by the two methods are probably primarily attributable to the directional sound field used for the KEMAR measurements versus the diffuse sound field required by the ANSI S3.19 methodology. These data confirm the suitability of KEMAR for measuring the insertion loss for the style of personal radio headsets investigated. The S3.19 testing was conducted at the E-A-R Div., Cabot Corp. acoustical labs. and the KEMAR studies were conducted at North Carolina State University.

Findings of Study

The predominant style of headphones accompanying personal radios are the supra-aural variety. The insertion loss characteristics of the sixteen supra-aural headsets are presented in Figures 6 and 7 along with the results from the two circumaural and two semi-aural headsets for comparison.

From Figure 6 (the 0° incidence angle) it is apparent that a small negative insertion loss (amplification effect) is evident in the 1 to 2 kHz region for the supra-aural headsets. This trend peaks at -2.1 dB at 2 kHz before beginning to drop off and show a positive insertion loss (attenuation effect) throughout the range from 4 to 6.3 kHz. At the 8 kHz band center frequency, a shift from a maximum positive insertion loss level of roughly 8 dB to a negative insertion loss level of approximately -5 dB is observed. However, due to the significant differences between the data obtained using KEMAR and the ANSI S3.19 test findings (displayed in Figures 3-5), the values at the 8 kHz test

Table 1. A comparison of the insertion loss characteristics of a Pickering OA-101P (supra-aural) headset measured in a diffuse sound field in accordance with ANSI S3.19 and in a directional sound field (0° incidence) using KEMAR.

One-Third Octave Band Center Frequency (Hz)	Insertion Loss (dB) ANSI Mean	ANSI Std. Dev.	KEMAR Mean
125	1.3	2.4	−0.2
160	−	−	−0.4
200	−	−	−0.3
250	0.7	2.1	−0.3
315	−	−	−0.3
400	−	−	−0.3
500	−0.1	2.7	−0.4
630	−	−	−0.7
800	−	−	−1.0
1k	−0.3	2.0	−1.5
1.25k	−	−	−2.4
1.6k	−1.5	2.9	−3.4
2k	−2.1	3.0	−3.5
2.5k	1.2	2.7	0.8
3.15k	3.6	3.0	1.2
4k	3.3	3.1	6.2
5k	9.3	3.4	13.6
6.3k	7.2	3.4	9.0
8k	5.5	3.8	−1.5

Table 2. A comparison of the insertion loss characteristics of a Pickering OA-88 (supra-aural) headset measured in a diffuse sound field in accordance with ANSI S3.19 and in a directional sound field (0° incidence) using KEMAR.

One-Third Octave Band Center Frequency (Hz)	Insertion Loss (dB) ANSI Mean	ANSI Std. Dev.	KEMAR Mean
125	1.0	3.1	−0.8
160	−	−	−0.6
200	−	−	0.0
250	1.0	2.4	−0.2
315	−	−	−0.5
400	−	−	−0.8
500	0.7	2.7	−0.8
630	−	−	−0.8
800	−	−	−0.5
1k	0.5	2.4	−1.0
1.25k	−	−	−1.3
1.6k	0.2	2.2	−1.8
2k	0.2	2.7	−2.0
2.5k	2.6	3.3	1.2
3.15k	4.1	4.3	1.5
4k	2.6	3.2	0.5
5k	2.5	3.1	3.5
6.3k	6.3	4.0	7.0
8k	7.6	3.4	−8.0

Table 3. A comparison of the insertion loss characteristics of a Tandy 12-185 (circumaural) headset measured in a diffuse sound field in accordance with ANSI S3.19 and in a directional sound field (0° incidence) using KEMAR.

One-Third Octave Band Center Frequency (Hz)	Insertion Loss (dB) ANSI Mean	ANSI Std. Dev.	KEMAR Mean
125	1.2	2.5	0.0
160	−	−	0.0
200	−	−	−0.7
250	1.1	2.1	0.0
315	−	−	−1.0
400	−	−	−1.1
500	−4.9	1.8	−3.3
630	−	−	−10.5
800	−	−	−9.2
1k	−0.1	2.6	−3.0
1.25k	−	−	6.2
1.6k	−	−	22.0
2k	17.3	3.6	27.3
2.5k	−	−	24.8
3.15k	17.5	2.2	15.0
4k	14.7	2.5	18.0
5k	−	−	19.5
6.3k	22.1	2.6	10.5
8k	19.6	2.7	−1.0

be established.

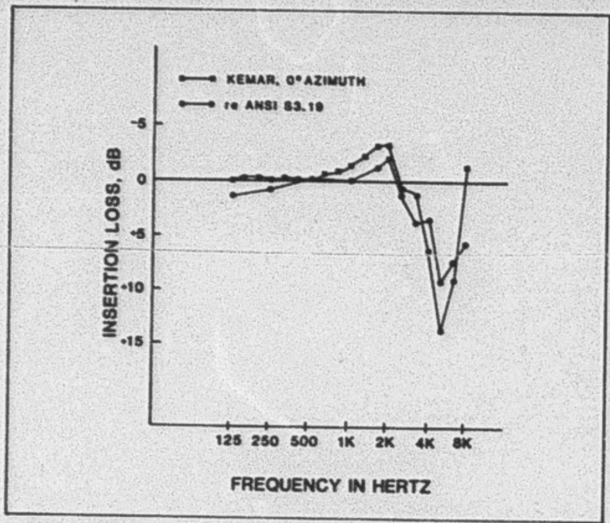

Figure 3. Insertion loss characteristics for a Pickering OA-101P supra-aural headset.

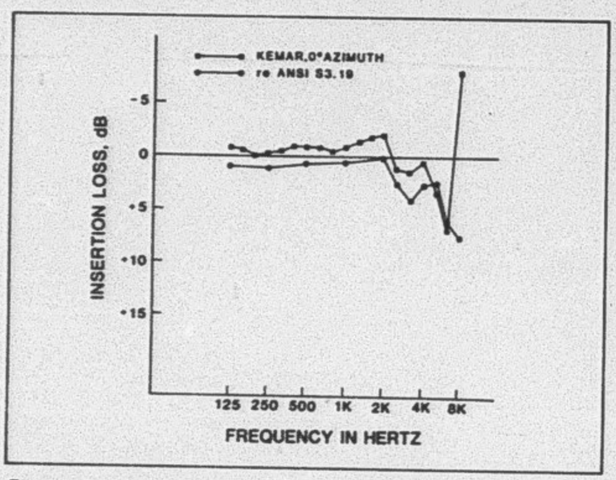

Figure 4. Insertion loss characteristics for a Pickering OA-88 supra-aural headset.

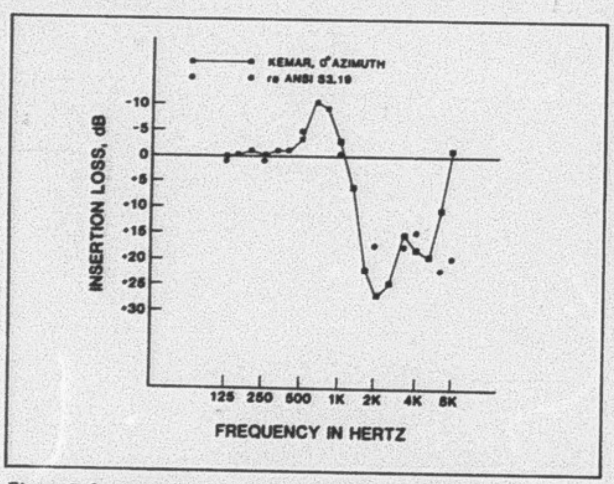

Figure 5. Insertion loss characteristics for a Tandy 12-185 circumaural headset (Note: change in scale in comparison to Figures 3 and 4).

set variety at a 0° incidence angle are also presented for comparison in Figure 6. Again, a negative insertion loss is observed through the frequency range of 500 Hz to 1 kHz. The magnitude of this amplification, reaching -6 dB at roughly 630 Hz, is greater than that of the supra-aural variety. A positive insertion loss is evident begining at a lower frequency than that of

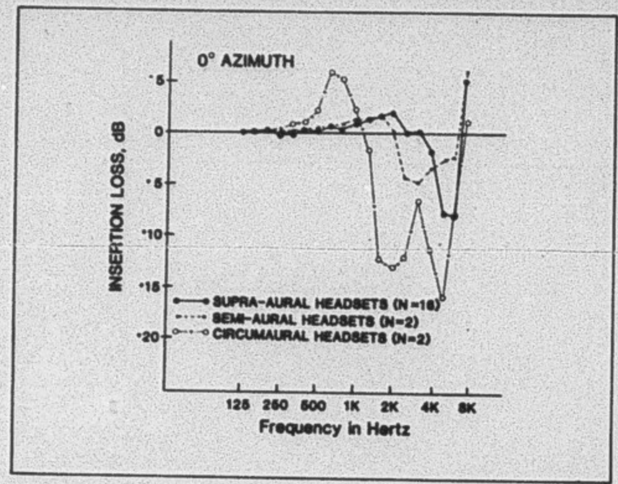

Figure 6. Insertion loss characteristics of personal radio headsets at 0° azimuth.

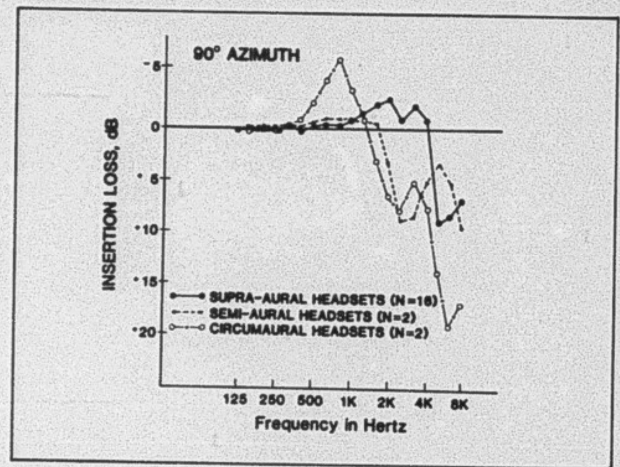

Figure 7. Insertion loss characteristics of personal radio headsets at 90° azimuth.

the supra-aural headsets (1.25 kHz) providing a greater magnitude of attenuation through the frequency range of 1.25 to 5 kHz than for the supra-aural headsets.

Figure 6 also shows the insertion loss characteristics of the two semi-aural headsets at the 0° incidence angle. There is a very slight trend towards negative insertion loss beginning at approximately 500 Hz, reaching a maximum of roughly -1.7 dB at 1.6 kHz. A crossover to a positive insertion loss occurs at roughly 2 kHz, reaching a maximum positive insertion loss of approximately 5 dB at 3.15 kHz.

Figure 7 shows a graphic illustration of the insertion loss characteristics for the supra-aural, circumaural, and semi-aural headsets at a 90° angle of incidence from the noise source. At the 90° orientation a slight increase in the magnitude in sound transmitted to the eardrum is observed over the frequencies exhibiting amplification. This should be anticipated since the sound wave can more effectively couple to the headsets at this angle. A similar increase in the eardrum to the free-field transformation ratio is observed.[11]

The average overall effect of the personal radio headsets on an individual's noise exposure was determined by assuming an exposure to a flat (pink) noise spectrum. The reduction in this noise spectrum was calculated by subtracting the headset insertion loss values from it to determine the interior (under-the-headset) noise levels. The difference between the exterior C-weighted and interior A-weighted SPLs was then computed. These values are similar to Noise Reduction Ratings (NRR).[17] They do not include a spectral uncertainty contribution and

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