UNCERTAINTIES ASSESSMENT OF NOISE DOSE FOR TELMARKETING OPERATORS (HEADPHONE USERS)

Erasmo F. Vergara[1], Jovani Steffani[2], Samir N. Gerges[3], Marcos A. Pedroso[4]
[1 3 4] Federal University of Santa Catarina, Mechanical Dep.. Engineering, Laboratory of Industrial Noise
P.Box 476, Campus universitário, Trindade, CEP 88400-900, Florianópolis-SC, Brazil
55-48-3234 4074, 55-48-3369 9882, samir@emc.ufsc.br
[2] West University of Santa Catarina - UNOESC, Joaçaba-SC, Brazil

Resumen: The noise emissions from sources located close to the ear, such as the headset of the telemarketing operators are determined using ISO 11904. MIRE and manikin techniques are applied. The uncertainties from different sources are estimated for a determination of the diffuse-field related equivalent continuous A-weighted SPL from an earphone. There is a worldwide rapid increase in the use of call centers with headset phone operators for quick satisfaction of consumer demand. Operator's exposure to noise from communication headsets above specified limits can result in permanent hearing loss. Therefore measurement and monitoring noise dose for the operator is necessary. Exposure noise levels can be very different for the same headphone used by different operator, depending on head geometry, acoustic impedance of the ear, position of the headphone, etc. The noise dose of the operator depends not only on the type of headphone, but also on the ambient noise in the working place, including lay-out of the room, distance between operators, acoustic characteristics of the working place, quality of the headset, maintenance and volume of the headphone. The ISO 11904 standard is used for measurement the noise exposure of headphone users, considering two methods: Part 1 – mini microphone in real ear (MIRE technique) and Part 2 – manikin technique. The uncertainty calculation for these measurements is considered in this paper and comparisons of results are presented.

1. INTRODUCTION

The installation of call centers where phone operators use headsets is increasing rapidly worldwide, in order to provide quick satisfaction of consumer demand [1,2]. An operator exposure to noise from communication headsets above specified limits can result in permanent hearing loss. Adequate measurement and monitoring of an operator's noise dose is therefore necessary [3,4].

Noise exposure levels can be very different for the same headphone used by different operators, depending on head geometry, acoustic impedance of the ear, position of the headphone, etc. The noise dose of an operator depends not only on the type of headphone, but also on the ambient noise in the workplace, including the layout of the room, distance between operators, acoustic characteristics of the workplace, quality of the headset, and maintenance and volume of the headphone [3,4].

The ISO 11904 standard is used for measuring the noise exposure of headphone users, considering two methods: Part 1 – microphones in real ears (MIRE) technique; and Part 2 – manikin technique [5].

The uncertainty calculations for these measurements are considered in this paper and comparisons of results are presented.

2. NOISE DOSE ACCORDING TO ISO 11904

The ISO 11904 standard describes the methods for the determination of sound emissions from sound located close to the ears. In this situation the Sound Pressure Level (SPL) is measured at the position of the exposed person.

2.1. Microphone In Real Ears (MIRE) technique

In this technique a mini-microphone is positioned inside the outer human ear canal according to the MIRE description for the mounting of the microphone. The time-averaged equivalent sound pressure level $L_{ear,exp,f}$, in decibels (dB), ref. 20 μPa, is measured in third-octave frequency bands. This parameter is called ear canal equivalent continuous sound pressure level.

2.2. Manikin technique

In the case of the manikin technique, the sound pressure levels are obtained through the exposure of a manikin head equipped with an ear simulator to a test noise, measured in third-octave frequency bands, defined as $L_{M,\,exp,f}$. For both techniques each SPL band is adjusted to give a diffuse-field sound, where $\Delta L_{DF,f}$ corresponds to the real ear and $DL_{DF,f}$ to the manikin and the SPL frequency band for the diffuse-field sound $L_{DF,f}$ is determined. To calculate $L_{DF,f}$ the diffuse-field frequency response is subtracted from the ear canal sound pressure level $L_{ear,exp,f}$ using the following equation for the MIRE technique:

$$L_{DF,f} = L_{ear,exp,f} - \Delta L_{DF,f}\,. \qquad (1)$$

Similarly, for the manikin technique:

$$L_{DF,f} = L_{M,exp,f} - DL_{DF,f}\,. \qquad (2)$$

The standardized values of the diffuse-field frequency response for selected ear canal measurement positions of the MIRE technique and for the ITU-T P. 58 diffuse-field frequency response of the manikin technique are presented in Table 1, according to clause 9 of ISO 11904-1.

Table 1 *Diffuse-field frequency response for the MIRE ($\Delta L_{DF,\,f}$) and the manikin ($DL_{DF,\,f}$) techniques.*

Frequency (Hz)	Diffuse-field response (dB)	
	$\Delta L_{DF,\,f}$	$DL_{DF,\,f}$
100	0.0	0.0
125	0.2	0.0
160	0.4	0.0
200	0.6	0.0
250	0.8	0.5
315	1.1	0.5
400	1.5	1.0
500	1.7	1.5
630	2.1	2.0
800	2.5	4.0
1000	2.9	5.0
1250	3.6	6.5
1600	4.7	8.0
2000	6.4	10.5
2500	8.2	14.0
3150	5.8	12.0
4000	3.0	11.5
5000	5.1	11.0
6300	6.9	8.0
8000	5.6	6.5
10000	-0.9	10.5

(Adapted from standard ISO 11904)

In Fig. 1 shows an example of how to calculated the total noise dose $L_{DF,f+Af}$ considering the values for the diffuse-field frequency response of the manikin technique and the A-weighted correction curve.

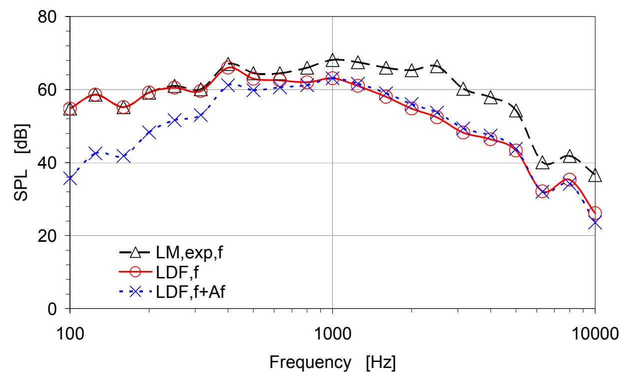

Fig. 1 *SPL of the manikin technique measurement, diffuse-field and A-weighting curves.*

For each of the operators, five measurements of the noise levels were taken, in third-octave frequency bands, in the range 100 and 10k Hz, these being adjusted with the diffuse-field frequency response. In Fig. 2 and 3 they are given as examples of the SPL results obtained with the MIRE and manikin techniques, respectively.

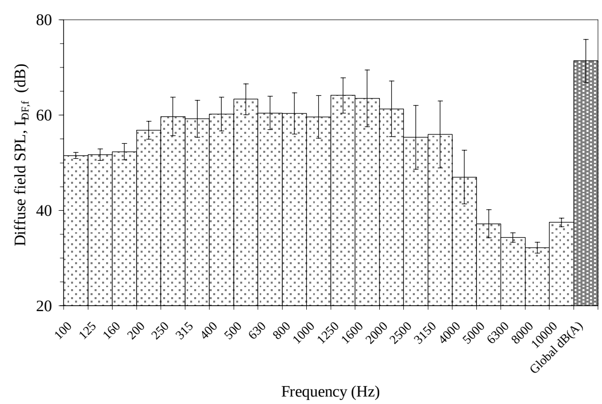

Fig. 2 *Diffuse field sound pressure level for the MIRE technique.*

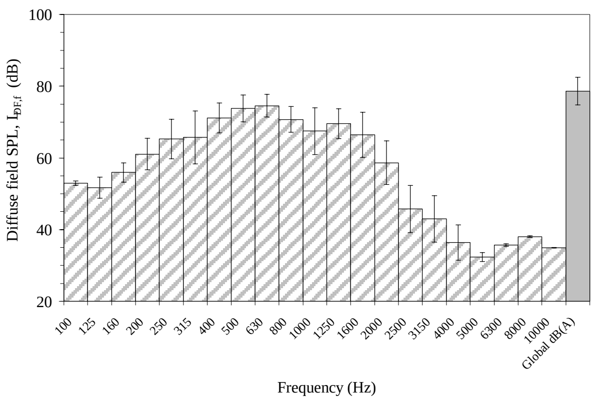

Fig. 3 *Diffuse field sound pressure level for the manikin technique.*

2.3. Noise dose for MIRE and Manikin techniques

The effect of the external ear canal frequency response function on MIRE and manikin technique measurements was corrected and adjusted by the A-weighting curve and then an equivalent global (total dose) value was calculated, as shown in Equation 3:

$$L_{DF,Aeq} = 10 \log \sum 10^{(L_{DF,f} + A_f)/10} , \qquad (3)$$

where $L_{DF,Aeq}$ is the diffuse-field related equivalent continuous A-weighted SPL in decibels, and the constant A_f is specified in the IEC 61672 standard. The range of third-octave frequency bands (f) from 100 Hz to 10 kHz was used in the measurements and calculations.

Fig. 4 shows the measurement set-up for the manikin and MIRE techniques, in the evaluation of sound exposure from sources placed close to the ear, i.e., telemarketing operator headphones. A Brüel & Kjær dynamic signal analyzer was used to record the sound pressure of the mini-microphone (real human ear) and ear simulator (manikin head). The DPA mini-microphone, model H17546 and microphone amplifier MPS 6010 were used in the MIRE technique. With the telemarketing operator in the actual workplace, the mini-microphone was placed at the entrance of the ear canal. The worker was requested to adjust the phone volume controls as desired, and carry out work activities as normal. The mini-microphone and the respective amplifier were connected to a portable computer to record the sound pressure using dynamic signal analyzer software. The SPLs produced by the earphone in the normal work situation were estimated in the third-octave frequency bands.

The standardized manikin head was equipped with a silicon external ear, with characteristics similar to the human ear and a Brüel & Kjær ear simulator, model 4157, coupled to the Brüel & Kjær external auditory canal simulator, model DB 2012, with a Brüel & Kjær, model 2804 microphone amplifier, manufactured according to the standards IEC 711-1981 and ANSI S3.25-1979.

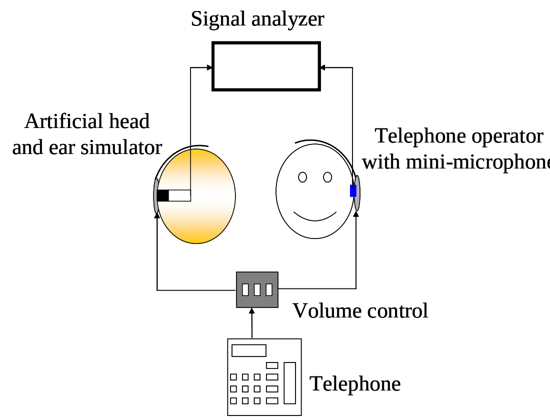

Fig. 4 *Measurement configuration in the MIRE and manikin techniques.*

The noise exposure test group was composed of thirty-two telemarketing operators, headphone users, of both sexes. Of the thirty-two operators selected, sixteen of them worked in the operator information section, called the receptive section. The other sixteen operators worked in the operator sales section, named the active section.

The values for the levels shown in Figures 5 and 6 represent the average of five measurements for each telemarketing operator and the standard deviations are also given.

The average levels and standard deviation values for the noise dose measurements were determined, for the 32 telemarketing operators, applying the two evaluation techniques: real ear with mini-microphone and manikin with ear simulator. The average total sound exposure using the MIRE measurement technique was 76.2 dB(A) with a standard deviation of 4.1 dB(A), and using the manikin technique it was 78.5 dB(A) with a standard deviation of 4.8 dB(A).

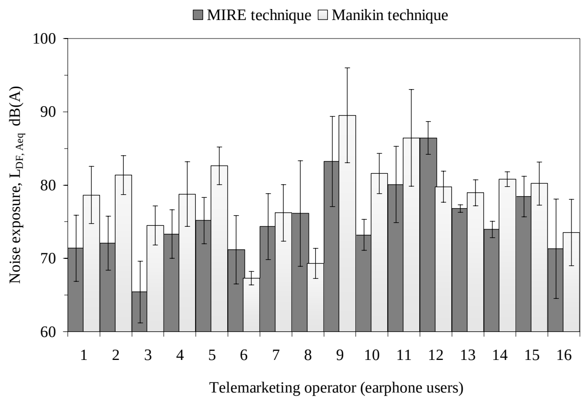

Fig. 5 *Noise dose level of the 1-16 telemarketing operators. Error bars show the standard deviation for the five measurements.*

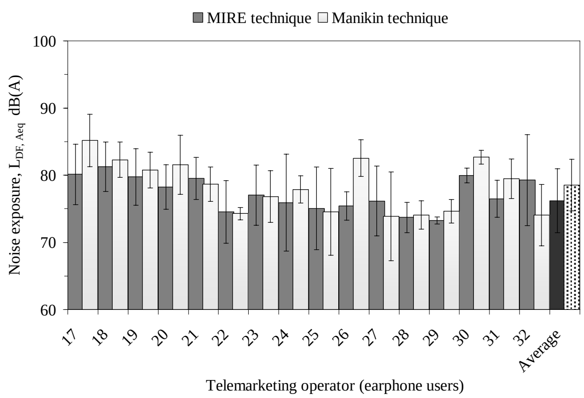

Fig. 6 *Sound exposure level of the 17-32 telemarketing operators and total average level. Error bars show the standard deviation for the five measurements. The average bars present the standard deviation for the 32 mean values.*

3. UNCERTAINTY ANALYSIS WITH ISO 11904

The uncertainty of the final results using the MIRE technique (Part 1 of ISO 11904) is the extent to which a limited number of subjects represent a population. For the manikin technique the uncertainty is the extent to which the manikin represents an average human.

For each of the techniques, the uncertainty depends on the diffuse-field frequency response, which was taken from tables in the respective standards or determined individually for the participating humans or the particular manikin used.

According to the standard ISO 11904 - Part 1 and ISO GUM, the uncertainties can be estimated for the level $L_{DF,Aeq}$ from a supra-aural, open-type earphone, considering the following characteristics:

- miniature microphones (mini-microphones);
- the individual diffuse-field frequency responses of the test subjects;
- pink noise or noise which simulates speech and music according to IEC 60268 1 as the test signal input to the earphone (headset);
- the mean result of measurements on both ears of eight test subjects;
- six measurements on one ear of each of eight test subjects;
- a supra-aural, open-type earphone using always the left capsule (speaker) on the left ear and/or the right capsule (speaker) on the right ear;
- the reference measurement of the frequency response should be repeated immediately after the measurement of the sound under test and should be carefully checked by comparison with the first measurement, if unexpected deviations occur the whole measurement procedure should be repeated.

From the documentation of the equipment used in the measurement set-up, it is possible to estimate the uncertainties or influences during the use of the measurement system. The form used to illustrate the sources of uncertainties associated with the calibration can be shown in a cause and effect diagram. Figure 7 presents the results of research on the sources of uncertainties related to the measurement techniques in the format of a cause-effect diagram.

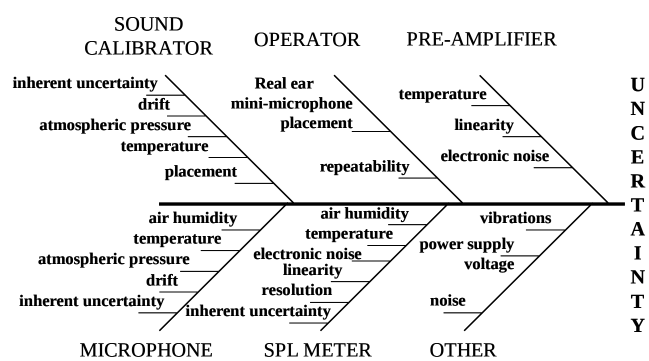

Fig. 7 *Cause-effect diagram of the uncertainty sources for MIRE and manikin techniques.*

Table 2 shows the uncertainties originating from different sources in the measurement system using the MIRE technique. The corresponding components are evaluated as type B uncertainties. The expanded uncertainty is based on the standard deviation multiplied by k=2, providing a confidence interval of approximately 95%.

***Table 2** Uncertainty budget of the measurement chain using the MIRE technique.*

Uncertainty sources	**Raw value (± dB)**	**Probability distribution**	**Dividing factor**	**Standard uncertainty (± dB)**
Sound level calibrator	0.4	Normal	2.0	0.2
Set-up Measurement adjustment	02	Rectangular	1732	0115
Resolution of the measuring instrument	0.05	Rectangular	1.732	0.029
Atmospheric conditions; temperature, humidity, and barometric pressure	0.4	Rectangular	1.732	0.23
Microphone frequency response	0.2	Rectangular	1.732	0.12
Uncertainty from analyzer and its frequency band filters	0.12	Rectangular	1.732	0.07
Power supply voltage	-	-	-	-
Background and electronic noise	-	-	-	-
Expanded uncertainty (95%)			**2.0**	**0.71**
Combined standard uncertainty				**0.355**

The uncertainty sources related to the sound level calibrator and the atmospheric influences on the set-up measurement gave the largest values in the uncertainty budget, 0.2 dB and 0.23 dB standard uncertainties, respectively. The global value of the uncertainty balance, expanded uncertainties U, is approximately 0.7 dB. If a white or pink noise were used, according to the standard characteristics, with appropriate stability, the expected values for the deviations would be between 0.7 dB and 2.2 dB, in other words, around the value calculated for the uncertainty of the set-up measurement and the value calculated in the example from the ISO 11904-1 standard.

4. CONCLUSIONS

The ISO 11904 standardized techniques were applied in the quantification of noise dose, for 32 telemarketing operators, headphone users, during the normal carrying out of activities in the workplace. A mini-microphone installed at the entrance of the operator ear and a manikin with an ear simulator were used to satisfy the criteria and recommendations of Parts 1 and 2 of this standard, respectively. The assessment of noise exposure from sound sources placed close to the ear was carried for two employment sections: receptive and active. The uncertainties of the noise dose measurement system for headphone users were calculated considering the ISO 11904-1.

There were differences in the results of the two techniques applied in telemarketing center. However, it can be concluded that these differences are small and the equivalent continuous levels of noise dose, determined in dB(A), from the Brazilian legislation point view, are very similar. For instance, there was a difference of 2.3 dB(A) between the average global values of the two measurement techniques.

In summary, for the measurement of the sound exposure levels for telemarketing operators, headphone users, it is possible to apply the technique that uses the placement of a mini-microphone in a real ear and/or the manikin technique with ear simulator, since the results obtained through the two methods are coherent.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the support of the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) of Brazil.

REFERENCES

[1] K. Broughton, J. A. Patel, Noise exposure levels in call centres, Proceedings of the Institute of Acoustics", Vol. 25 part 4, 2003, pp. 211-216.
[2] R. W. Alexander, A. H., Koening, H. S. Cohen, C. P. Lebo, The effects of noise on telephone operators, Journal of Occupational Medicine. Vol.1 No. 21, 1979, pp. 21-25.
[3] J. A. Patel, K. Broughton, Assessment of the noise exposure of call centre operators. Ann. Occup. Hyg. Vol. 46 No. 8, 2002, pp. 653-661.
[4] E. F. Vergara, S. N. Y. Gerges, R. S. Birch, M. Zindeluk, "Headset Noise Exposure of Call Centre Telephone Operators", Proceedings of the 34th International Congress and Exposition on Noise Control Engineering, Rio de Janeiro, 2005.
[5] ISO/DIS 11904. Acoustics – determination of sound immissions from sound sources placed close to the ears. Part 1: technique using microphones in real ears (MIRE-technique), 2002. Part 2: technique using manikin (manikin-technique), 2004.