Performance evaluation method for high noise environment intercom headsets

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Intercoms' use in high noise environments (HNE) is typical since direct speech communication of individuals is difficult or even impossible. The headset selection for such an application is crucial since it serves both for noise attenuation and voice reproduction. It has been recently acknowledged in telecommunications (ITU-T/ P.380) that headset electro-acoustic measurements should be performed on Head and Torso Simulator (HATS). However, in military applications where headsets are mainly used in HNE there is not a standard performance evaluation method but only for the earphone elements (MIL-PRF-25670B), thus excluding the acoustics of the earcup cavity, absorbing materials and face fitting quality. It is well known that the reproduced speech level should be of about 10dB above noise level to achieve good intelligibility, so both sensitivity and noise reduction capability should be measured on a HATS to evaluate such a headset. In this work, a systematic methodology for measurement and performance evaluation of HNE headsets is proposed based on HATS. Critical aspects that may affect the test procedure, such as HATS response and the right headset placement are examined. Finally, a series of measurements prove the value of the proposed method. Large differences are revealed even for headsets following the same standard.

1 Introduction

Acoustic noise is a serious problem, which directly affects working and living conditions. As a consequence, a corpus of legislative regulations have been established, in National / European level, defining maximum permissible Sound Pressure Levels (SPL), both equivalent (Leq, A-weighted) and maximum (Lmax, C-weighted), for specific periods of exposure to noise, [1]. In high noise environments (HNE), like the interior of armored vehicles, the use of ear protection means is obligatory according to the active legislation. On the other hand, the direct communication is impossible imposing the use of intercoms. This is leading to the need for intercom headsets with good noise attenuation and good voice reproduction performance.

A situation characteristic of the importance of the personnel safety against noise nowadays is given by the German Army, where in the heavy armored vehicles the combined use of earplugs and headsets is established for years, since the use of their standard headsets alone is not ensuring on-ear noise reduction below 85dB(A). However, the use of earplugs is also reducing the reproduced voice level finally reaching the mid-ear and thus the intercom communications. In any case, the reproduced speech level should be of about 10dB above noise level (without serious distortion) to achieve good intelligibility. Therefore, both sensitivity, maximum reproduction level under specific distortion limit, and noise attenuation capability of headsets should be evaluated in combination to determine the performance of an intercom headset used under HNE conditions.

Unfortunately, in military applications where headsets are mainly used in HNE there is not a standard performance evaluation method taking into account both aspects of an intercom headset task. There are only a method for sensitivity measurements of the earphone elements [2], thus ignoring the impact of the acoustics of the earcup cavity, the absorbing materials, the face fitting quality and the headset positioning on sensitivity, and a physical ear method for the measurement of the noise attenuation characteristics [3] (cancelled without replacement since 1995).

In this work we propose a new performance evaluation method for HNE intercom headsets based on measuring both sensitivity and noise attenuation capability of the headset on a Head and Torso Simulator (HATS). This method is suitable for comparative measurements, while combined with more data about the in-ear noise attenuation performance of each type of headset and the output characteristics of the intercom to be used with leads to absolute results.

The paper is organized as follows: in section 2, common noise attenuation methods are briefly discussed, in section 3, the present earphone sensitivity military standard method is briefly presented, in section 4, the proposed method is analyzed, its effectiveness is evaluated in section 5 and finally the conclusions are given in section 6

2 Headset Noise Attenuation Measurement Methods

There are mainly three strategies for the measurement of headset noise attenuation, one based on human hearing threshold, and two based on microphone measurements, either placed on real ears or on HATS. ETSI guide [4] gives an idea of the use and comparison of the last two in noise exposure measurementsBasic formatting instructions

2.1 Real ear attenuation at threshold (REAT)

According to the specific method [5-10], the noise reduction introduced by the headset is measured as the difference between the sound levels at the hearing threshold of the subject, in occluded and unoccluded conditions. Since measurements are implemented upon human subjects, all the relevant sound paths to the protected ears (bone-conduction pathways, mechanical compliance of the human skin) along with the anatomical variations among real people are taken into account.

The main drawback of the method is that it is limited within 50 to 60 dB of the threshold of hearing. As a result the headset cannot be evaluated under high-level noise or high peak level impulses. Furthermore, the specific method is not suitable to highlight the headset non-linear behaviour, for high noise level environments. Finally, the involvement of human subjects increases the cost of testing and also limits the test conditions to avoid any potential hazard to the subjects. No military standard exist that is based on human subjects' hearing threshold, probably due to that the noise levels of interest for military applications are far higher than the covered with such methods.

2.2 Microphone in Real Ear (MIRE)

The MIRE procedure [11] utilizes a miniature microphone positioned in the auditory canal of the human subject and sound levels are measured with and without the headset in place. Compared to the REAT methodology the specific one is less subjective, since the human subject just ''lends'' his head during the test, while it provides evaluation of noise reduction over a wider range of sound levels.

One critical aspect in MIRE methodology is that the only sound path that can be sensed is down the earcanal, since there are missing pathways related to bone and tissue conduction. A military standard following the above philosophy is MIL-STD-912 [3].

2.3 Acoustical Test fixtures (ATFS)

An alternative way to evaluate headset performance is to employ an acoustical test fixture (ATFS) [11-15], like Head and Torso Simulators (HATS), which simulates the shape of a human head. ATF incorporates a microphone inside the artificial head, a pinna, and a tube, which simulates the auditory canal in a real human ear, connects acoustically the microphone to the outside.

The main advantages with the ATFS procedure are its simplicity, repeatability and cost effectiveness. Moreover ATFS provide the ability to test a headset under high-level (impulse or continuous) noises, to characterize any non-linear behaviour and to measure amplitude spectrum and peak pressure attenuations.

However ATF cannot efficiently simulate all the ergonomic characteristics of the human head and the auditory system. Although modern ATFS provides some realistic models of the "ear canal" tissues and even bone-conduction pathways with silicone-filled balloons, the overall result is still far from realistic.

In [16] the feasibility of using Acoustical Test Fictures (ATFS) for measuring noise reduction from Active Noise Reduction (ANR) headsets is examined. Unfortunately, no military standard for headset noise attenuation measurements based on HATS exist so far.

3 Headset Sensitivity Measurement Methods

In telecommunications has been recently acknowledged [17] that electro-acoustic measurements of headsets should be performed on HATS. Actually, the existing telecommunication related and standardized sensitivity and frequency characteristics measurement methods [18], are still used but HATS as a measurement apparatus is introduced. Key aspects of performing headset measurements on HATS are addressed, like headset positioning and test repeatability. Due to the sensitivity of the test results to the headset positioning, the tests shall be repeated at least 5 times by completely repositioning the headset, following specific rules. The use of positioning jigs (where possible) and statistical analysis are encouraged.

Unfortunately, related to military applications there is currently only a method for sensitivity measurements of the earphone elements [2], thus ignoring the impact of the acoustics of the earcup cavity, the absorbing materials, the face fitting quality and the headset positioning on sensitivity

4 Proposed Headset Evaluation Method

The proposed headset evaluation method is an objective evaluation method, mainly suitable for comparative study and quality control measurements. It is comprised of two HATS based measurement procedures, the first related to the headset sensitivity and the second related to headset noise attenuation.

Both these procedures combined, give an assess of the performance of an intercom headset used under HNE conditions, revealing whether the headset can achieve the goal of reproducing the speech 10dB above noise level without serious distortion, and thus achieving good intelligibility

4.1 Sensitivity, maximum SPL and harmonic distortion measurements

In order to measure the sensitivity of each headphone, the headphone is driven by an audio power amplifier reproducing a sinus signal stimulus generated by a signal generator. The headset is properly placed on the HATS and the microphone output of the HATS ear is captured by a Real Time Analyser (RTA). Using the test configuration presented in fig. 1, sensitivity (as Sound Pressure Level, SPL, @ 1kHz), harmonic distortion (HD) and maximum acoustic level under specific HD limit are measured. The laboratory test set-up is presented in fig. 2

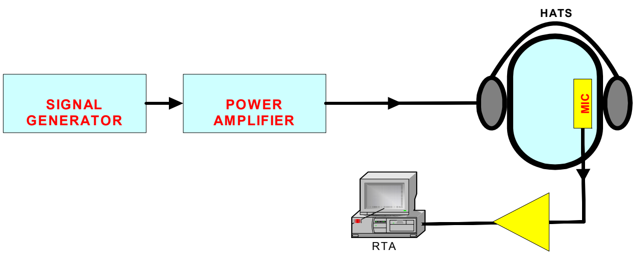

Fig.1 Test configuration for the measurement of the headset sensitivity, harmonic distortion and maximum acoustic output level under specific harmonic distortion limit

The 1mW input power for headset sensitivity measurements is adopted from [2] for the passive reproduction headphones, while the 1Vrms input voltage is chosen, as a typically used input for audio electronic systems, for the active (auto-amplified) reproduction headphones.

Fig.2 Laboratory Test Set-up

HD measurements are performed providing the same stimulus as for the sensitivity measurement, while a repetitive HD measurement procedure with continuous input stimulus rise reveals the maximum SPL (reproduced acoustic level) that can be obtained for a HD upper limit of 5%, adopted from [19]. Maximum SPL measurements using standard voice or voice-simulating stimulus [20, 24] are also performed assuming the stimulus maximum peak voltage to be equal to the revealed maximum sinus peak voltage (for 5% HD).

Special care should be taken during measurements for the proper placement and fitting of the headset on the HATS and each measurement is repeated 5 times by completely repositioning the headset. All measurements are reported and as final result a mean value and a standard deviation are given.

Finally, it should be noted that if the measurement intends only to compare headset sensitivities or to be used as a quality measure during production, the amplification effect of the HATS ear is not necessary to be corrected through the sensitivity and maximum SPL measurements. The sound reproduction capabilities are considered comparatively among headsets and for this reason the absolute sound pressure level results need not to be calculated. However, if the absolute levels are required as then a correction of about -6dB [21] can be applied

4.2 Noise Attenuation Measurements

The laboratory setup shown in fig. 3 is employed, in order to measure the noise reduction capability of different types of headsets (headphones). The headsets are positioned as tight as possible to the HATS, using all available headset accessories (headband, neckband, straps, velcro, buttons, etc.), in order to regulate positioning and size achieve the best fitting onto the HATS and thus best performance out of each headset.

The ear of the HATS is used to measure the sound level under the headset, while a high pressure microphone is used to measure the outside noise level at the side of the specific ear, inline with the HATS shoulder. Special care has been taken to keep the sound source at equal distances from the ear and the outside microphone. The difference of the two measured levels (after the correction for the amplification of the artificial ear of the HATS for each type of noise) gives the noise reduction (NR) capability of each headset. However, insertion loss (IL) measurements are also easily performed by measuring the noise reaching the ear with and without the headset on and calculating the difference.

White noise, pink noise (from a noise generator) and real recorded field sound are successively fed to a wideband (down to almost 50Hz) loudspeaker system through an appropriate audio power amplifier to achieve the required high noise level environment.

Each of the used noises is producing an environment of 100, 110 and 120 dBA SPL at the measurement positions and the NR or IL measurements are repeated, for each noise type, 5 times by completely repositioning the headset. All measurements are reported and as final result a mean value and a standard deviation are given.

For comparative study or quality control measurements, no level correction needs to be performed. In order to correct the measurements for the amplification of the artificial ear of the HATS the generally acceptable rule of -6dB correction [21] could be followed.

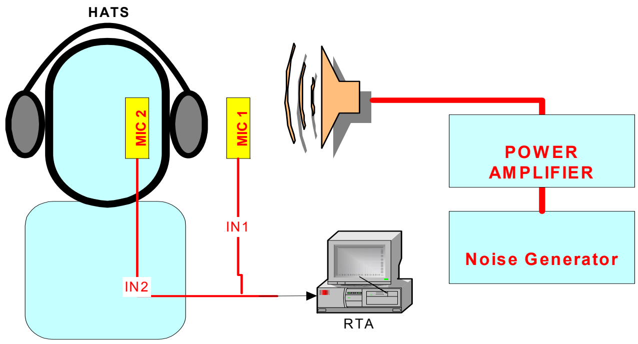

Fig.3 Test setup for the measurement of the headset noise attenuation

As already mentioned, this procedure is an objective evaluation method, mainly suitable for comparative study and quality control measurements. If absolute results on the NR or IL performance of a headset are the objective, a MIRE method has to be used [25, 26]

5 Evaluation of the Effectiveness of the Proposed Method

In order to evaluate the effectiveness of the proposed method, two military headsets of different vendors, but both following the Headset-Microphone Kit MIL-H-83511/4B [22] with earphone SM-B-933877 per MIL-H-49161 [23] have been employed. The HATS with one of the headset under evaluation, is illustrated in figure 4

Fig.4 HATS with headset under evaluation

Although, one would expect them to have similar performance, i.e. within 4dB, large differences were identified. Even when their earphones were interchanged, each headset performance did not change more than 1 dB. Of course the interchange of the earphones was just to verify that they were not accidentally damaged, since their conformance to [2] and [19] ensures their resemblance as electroacoustic transducer elements.

The following comparative table proves that the military standards followed for the production of these two headsets resulted to unacceptably different performances when measured with the proposed method. All results are produced calculating the difference (value for X) – (value for Z), where “X” and “Z” are the two headsets

Sensitivity = +7.5dB Max repr. level @ 1kHz @ 5% = +4dB			
	White Noise	Pink Noise	PzH2000 Noise
NR (Leq-A) @ 110dBA	+9	+8	+6.9
NR(Peak-C) @ 110dBA	+9.5	+7.6	+5.6
Max voice signal (<5% HD) Intrusive Noise @ 110dBA	+12dB	+12.5dB	+9.5dB

Table 1 Comparative results on the performance of two headsets (“X” and “Z”) following MIL-H-83511/4B with earphone SM-B-933877 per MIL-H-49161

6 Conclusions

A new method is proposed for the evaluation of high noise environment intercom headsets, taking into account both noise attenuation and voice reproduction capabilities. This method is mainly aiming to comparative testing and quality control applications. The effectiveness of this method is proved by the comparative measurements of two headsets following the same military standard which finally were found to present performance difference of up to 12.5dB, even with their transducers interchanged.

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7 REFERENCES

[1] European Norms 2003/10/EC, 2002/49/EC

[2] MIL-PRF-25670B, “Performance Specification Sheet: General Specification for Earphone Elements”, 30 May 1997

[3] MIL-STD-912, “Military Standard: Physical Ear Noise Attenuation Testing”, 11 Dec. 1990.

[4] ETSI DEG/STQ-00019

[5] ANSI "Methods for Measuring the Real-Ear Attenuation of Hearing Protectors," American National Standards Institute, S12.6-1997 (R2002), New York, NY, (1997).

[6] ISO "Acoustics - Measurement of Sound Attenuation of Hearing Protectors - Subjective Method," International Organization for Standardization, ISO 4869, Switzerland, (1981).

[7] ISO "Acoustics - Hearing Protectors - Part 1: Subjective Method for the Measurement of Sound Attenuation," International Organization for Standardization, ISO 4869-1:1990(E), Switzerland, (1990).

[8] JSA "Ear Protectors," Japanese Industrial Standard, JIS T 8161-1983, Tokyo, Japan, (1983).

[9] Berger, E. H. "Review and Tutorial - Methods of Measuring the Attenuation of Hearing Protection Devices," J. Acoust. Soc. Am. 79(6), 1655-1687, (1986).

[10] Berger, E. H. "Exploring Procedures for Field Testing the Fit of Earplugs," in Pro-ceedings, 1989 Industrial Hearing Conservation Conference, Off. Eng. Serv., Univ. Kentucky, Lexington, KY, 7-10, (1989).

[11] ANSI "Microphone-in-Real-Ear and Acoustic Test Fixture Methods for the Meas-urement of Insertion Loss of Circumaural Hearing Protection Devices," American National Standards Institute, S12.42-1995, New York, NY, (1995)

[12] Schroeter, J. and Els, H. "On Basic Research towards an Improved Artificial Head for the Measurement of Hearing Protectors," Acustica 50(4), 250-260, and 51(6), 302, (1982).

[13] Schroeter, J. and Poesselt, C. "The Use of Acoustical Test Fixtures for the Measurement of Hearing Protector Attenuation. Part II: Modeling the External Ear, Simulating Bone Conduction, and Comparing

Test Fixture and Real-Ear Data," J. Acoust. Soc. Am. 80(2), 505-527, (1986).

[14] Russell, M. F. and May, S. P. "Objective Test for Earmuffs," J. Sound Vib. 44(4), 545-562, (1976).

[15] May, B. S. and Dietz, A. J. “Skull Simulator for Design of Hearing Protection Systems for Bone-Conducted Sound,” J. Acoust. Soc. Am. 116 (4), Pt. 2, p. 2625, (2004).

[16] Jie Cui, Alberto Behar, Willy Wong, Hans Kunov “Insertion loss testing of active noise reduction headsets using acoustic fixture”, Applied Acoustics 64, 1011–1031, (2003)

[17] ITU-T-REC-P.380

[18] ITU-T-REC-P.64

[19] MIL-PRF-25670/5

[20] ITU-T-REC-P.501

[21] http://www.fh-regensburg.de/index.php

[22] MIL-H-83511/4B 1

[23] MIL-H-4916

[24] ITU-T-REC-P.50

[25] HVBG, BGILI 5024

[26] HVBG, BGFE, BGR 194