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Standardized acoustic test fixtures for testing ear protection devices and noise cancelling headsets

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Abstract

Several acoustic test fixtures can be used for measuring the Insertion Loss of Hearing Protectors Devices (HPD) and Active Noise Cancelation (ANC) Devices. First, it is very important to have an Acoustic Test Fixture (ATF) with a very high self-insertion loss to insure that the measured insertion loss on the Device Under Test (DUT) is not influenced by false signals introduced in the ATF itself. Secondly, it is important to decide whether a more humanlike shape with a corresponding Head Related Transfer Function is needed, or a more simplified ATF can be used. In the first case, the ANSI standard s12.42 describes a proper method, while ISO 4869-3 describes the second method. The ANSI s12.42 ATF is designed with a special ear canal extension, which is longer than the standard extension, known from other ATFs like KEMAR, and is fitted with flesh-like material to better adapt In the Ear (ITE) devices. Thirdly, a large circum-aural pinna is included to ensure a perfect seal for all kinds of Over The Ear hearing protection devices. Furthermore, the total system consisting of ear simulator, ear canal extension and pinna are heated to body temperature. The ISO 4869-3 defines a more simple solution for circum-aural HPD's, but can as well as the ANSI standardized ATF bee combined with pinnas, ear canal extensions and ear simulators for testing ITE devices. The two types of ATF are especially good when testing the new high quality ANC hearing protectors and headsets, which is why this presentation also looks at the challenges when measuring on ANC devices.

1. Introduction

Hearing protection devices and modern active noise cancelling headphones are designed to reduce the background noise from entering the human ear either to protect the ear from damage or to decrease the perceived annoyance from the background noise and to improve the perception of the sound from the headphone itself in situations with high background noise.

While the perceived sound quality of the headphone is a more subjective parameter, the insertion loss of the headphone is an objective parameter which can be measured according to various standards. We will here focus on the measurements according to ISO 4869-3 (1) and ANSI S12.42 (2) as established standards. These standards define Acoustic Test Fixtures (ATF) with geometry similar to the human head and include artificial ears as defined in IEC 60318-4.

2. Test setup

The insertion loss of both hearing protection devices and ANC headphones are measured in a diffuse sound field. The ATF is placed in the sound field and the noise level as measured with the ATF with and without the Device Under Test (DUT).

The diffuse sound field was established in a large room (16 x 12 x 6m) with reflecting walls (Reverberation room) by four loudspeakers pointing away from the test object. The loudspeakers were driven by four power amplifiers and produced an SPL of about 90 dB (1/3 octave) from 50 Hz to 20 kHz. A comparison of the noise

levels measured with and without the loudspeakers turned on shows a difference of more than 60 dB. Fig.1 shows this result. This means that it should be possible to measure insertion loss levels up to about 50 dB. For higher insertion loss it would be necessary to increase the level generated by the loudspeakers for example by using more loudspeakers.

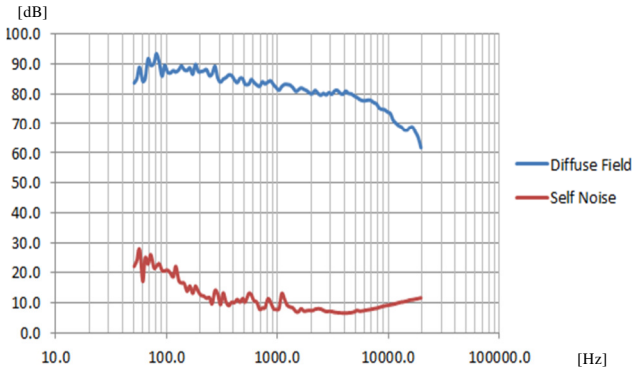

Fig.1 Comparison of the noise levels measured with and without the loudspeakers turned on

The ATF has a geometrical shape that resembles the geometry of the human head so that the diffraction around the ATF is similar to the diffraction around a typical human head. The ISO ATF is a more simplified model of the human head while the ANSI head is more complicated and more like the human head. See Fig.2 and Fig.3.

Fig.2 ATF (45CB) According to ANSI S12.42

Both the ISO and the ANSI head were equipped with rubber pinnae (the external ear structure), left and right side, with Shore 00 35 hardness. The ANSI ATF is equipped with heated ear canals so that the temperature can be maintained at levels as found in the human ear canal.

Fig.3 ATF (45CA) According to ISO 4869-3

This may be of importance when studying in–ear type hearing protection and in-ear headphones with rubber fittings, as the rubber may change properties with temperatures. It is then important that the measurements are performed with the in-ear type headphone at the same temperature as when mounted on a human ear.
While the rubber pinnae simulates the outer ear structure, the middle and inner ear is simulated by a standardized IEC 60318-4 coupler (formerly known as the “711-coupler”). See fig. 4.

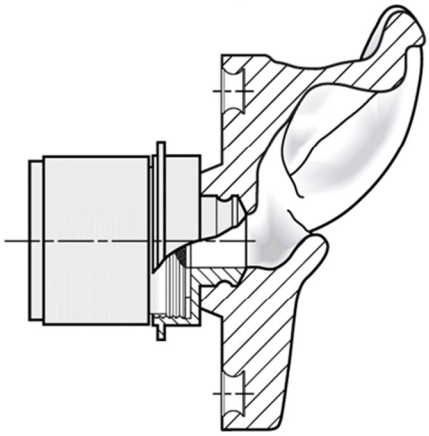

Fig.4 Pinnae and 711-coupler

This has the same input and transfer impedance as a typical human ear. This means that when the headphone is mounted on the ear, the ear protection devices and headphones will be loaded with the same impedance as for a typical human ear. The coupler is also equipped with a micro-

phone, in a position where the human eardrum would normally be. This means that the microphone will record the sound pressure as it would be at a typical ear drum of a typical listener. The signals from the left side and right side microphones was recorded and analyzed with a Dynamic Signal Analyzer.

Three different types of hearing protection devices: (Circum-aural, Soft flange In ear and simple Foam In-ear) and three different types of active noise cancelling headphones were tested: (Supra-aural, Circum-aural and In-ear). Each Device Under Test (DUT) type was tested on both the ISO ATF and the ANSI ATF.

Fig.5 DUT's: Hearing protection devices: In ear Soft flange (A), In ear Foam (B), Circum-aural (C). Headphones: Supra-aural (D), Circum-aural (E) and In-ear (F).

3. Hearing protection test results

For each test, the signal from the ATF was first recorded without the Hearing Protection Device (HPD) mounted, then with the HPD mounted. Under extremely noisy condition like on a jet carrier it is necessary to wear double protection so a test using both type B and type C at the same time was performed.

Fig.6 shows the results for the test of the HPD tested on both the ISO and the ANSI standardized ATF's. The circum-aural HPD show a peak in the damping around 100Hz - 200Hz which the in-ear devices doesn't show. This is caused by the resonance created by the leak from the external air to the air-volume inside the ear and headphone volume. In the test with double protection this resonance actually makes the damping worse around 100Hz - 200Hz, than just using the in-ear device alone. It can be seen that with both ATF's the HPD's exceed the standardized minimum SIL requirement at high frequencies, which emphasize how important it is to use ATF's with very high SIL when testing HPD's. It can also be seen that there is a reasonable good agreement between the measurements performed on the ISO ATF and the ANSI standardized ATF except for the circum-aural type. One explanation could be that the 45CA has a very geometrically shaped surface which gives a very good sealing that minimize leaks.

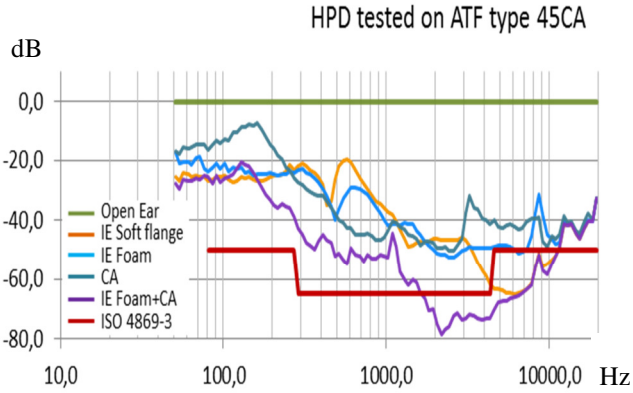

Fig.6(a) Hearing protection device test on 45CA

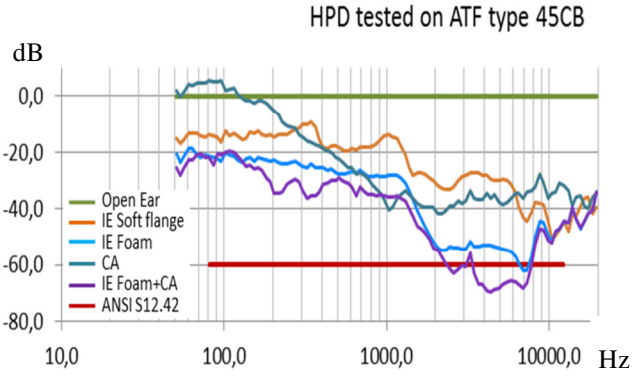

Fig.6(b) Hearing protection device test on 45CB

4. Headphone test results

For each test, the signal from the ATF was first recorded without the headphone mounted, then with the headphone mounted with the active noise cancelling function turned off (Passive mode) and then with the active noise cancelling function turned on (Active mode).

Fig.7 shows the results for the type D, Supra-aural. This does not enclose the ear and is somewhat open to the rear. This results in very little insertion loss at low frequencies, and in the passive mode the sound is actually increased in the 300 Hz to 800 Hz. This is caused by the resonance created by the leak from the external air to the air-volume inside the ear and headphone volume. In the Active mode the noise cancelling improves the insertion loss in the frequency range from around 200 Hz to 1.2 kHz, and removes the amplification seen in the passive mode. It can also be seen that there is good agreement between the measurements performed on the ISO ATF and the ANSI ATF.

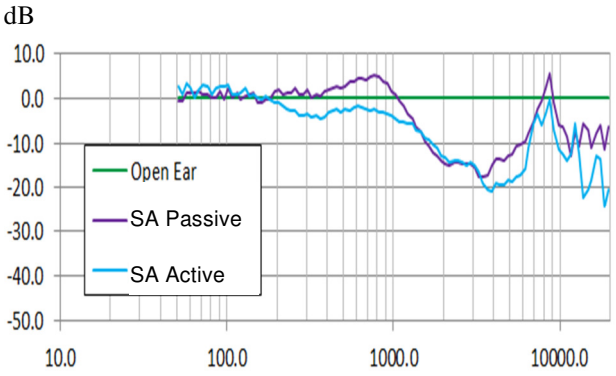

Fig.7(a) ANC Headsets tested on ATF 45CA

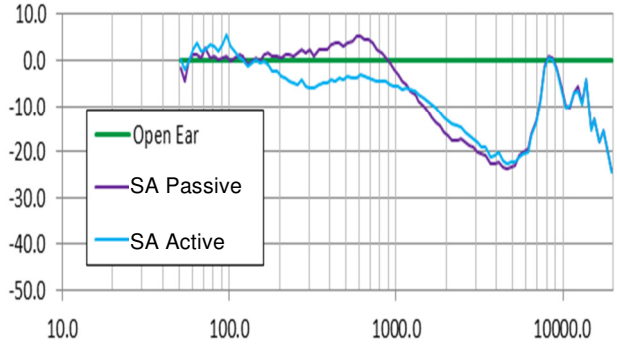

Fig.7(b) ANC Headsets tested on ATF 45CB

Fig.8 shows the corresponding results for the type E circum-aural headphone. As this type is completely surrounding the ear, the passive insertion loss is considerably better than for the supra-aural type. It has however again in the passive mode amplification at low frequencies around 200 Hz. In the active mode the insertion loss below 1 kHz is significantly improved.

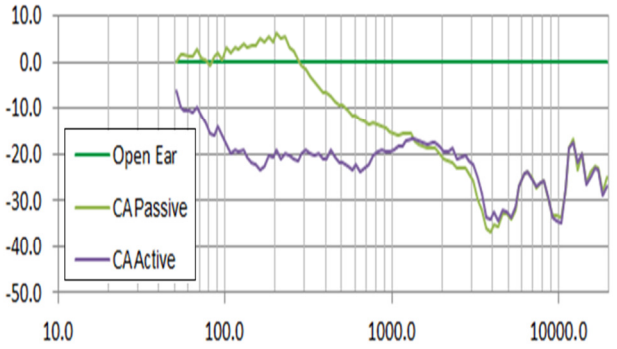

Fig.8(a) ANC Headsets tested on ATF 45CA

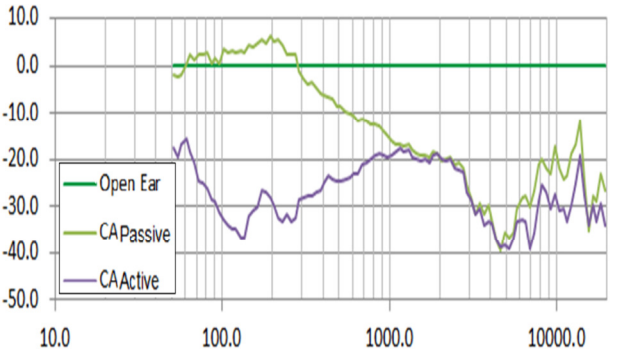

Fig.8(b) ANC Headsets tested on ATF 45CB

The results for the Type E circum aural headphones shows significant difference between the insertion loss measured with the ISO ATF and the ANSI ATF. This is most likely caused by leaks varying with fit on the two different ATF's or just by the actual differences in the ATF's.

Fig 9 shows the corresponding results for the type F in-ear headphone. As this type completely closes the ear, the passive insertion loss is considerably better than for the supra-aural type. It has however again in the passive mode amplification at low frequencies around 200 Hz. In the active mode the insertion loss is below 1 kHz is significantly improved

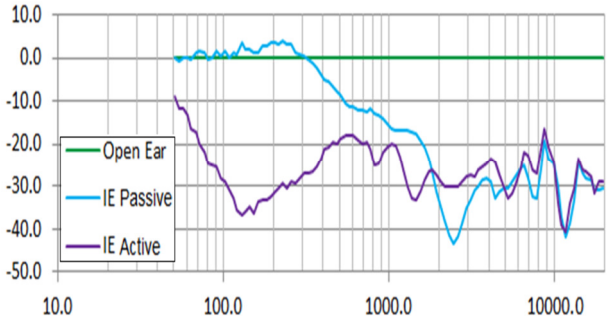

Fig.9(a) ANC Headsets tested on ATF 45CA

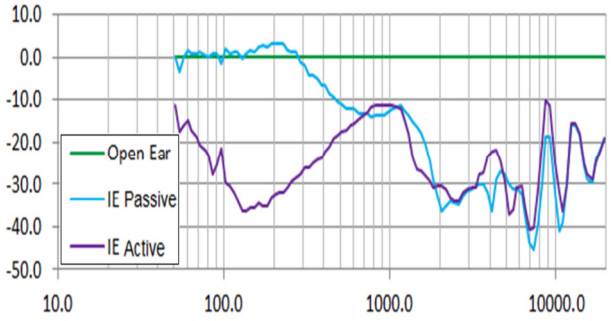

Fig.9(b) ANC Headsets tested on ATF 45CB

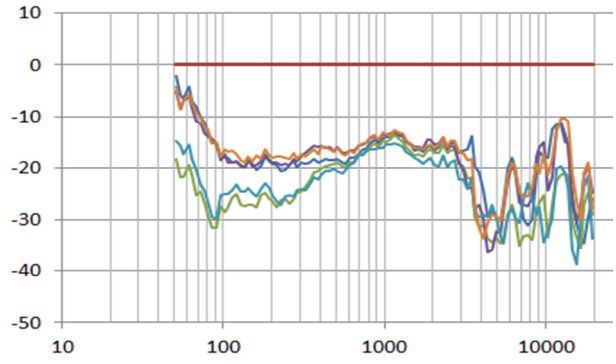

Fig. 10(a) Repeatability for type E headphone

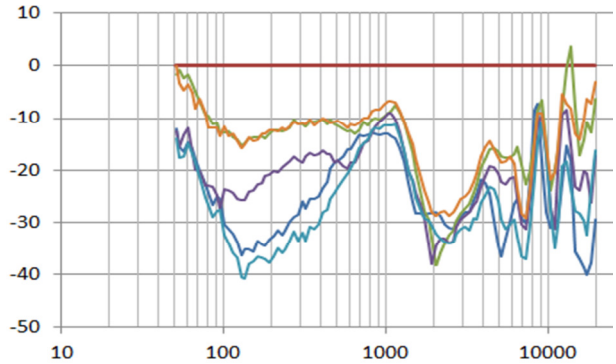

Fig. 10(b) Repeatability for type F headphone

Fig 10 shows repeatability of measurements in active mode for Type E and F headphones. It can be seen that for the circum-aural type F the repeatability is good in the mid-frequency range, while in the low frequency range the results fall in two groups, probably caused by leakage. This may occur if the headphone is not properly fitted to the ATF. For the In-ear type F, it is also critical how the headphone is fitted to the ear canal and the fit affects both the high frequency and the low frequency performance considerable.

5. Conclusion

The Insertion loss of hearing protection devices and active noise cancelling headphones can be measured and evaluated with Acoustical Test Fixtures according to ISO Standards or ANSI Standards. It can be seen that with both ATF's that the HPD's exceed the standardized minimum SIL requirement at high frequencies, which emphasize how important it is to use ATF's with very high SIL when testing HPD's. The results also show that the individual tests are quite sensitive to the exact mounting of the headphone on the test fixture. This variation is larger than the differences found for type of fixture.

6. References

(1) ISO Standard 4869-3: Acoustics - Hearing Protectors – Part 3: Measurements of insertion loss of ear-muff type protectors using an acoustic test fixture.

(2) ANSI/ASA Standard S12.42-2010: Method for the measurement of insertion loss of hearing protection devices in continuous or impulsive noise using microphone-in-real-ear or Acoustic test fixture procedures