Acoustic Performance Testing of ANC Headsets

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Abstract

Active Noise Cancelling (ANC) headsets are quite popular today. They isolate the user from disturbing, tiring acoustic environments like workplaces or noisy trains or flights, while providing high quality music or speech playback at the same time. Additional features, such as Talk-Through capability, allow almost normal conversation with other persons in the vicinity of the user. These devices employ very sophisticated signal processing which cannot be comprehensively characterized by noise attenuation measurements alone. There are further parameters that influence the overall quality for the user, such as the effectiveness of noise attenuation in non-stationary scenarios, the influence of ANC on music playback, and the perceptibility of the users own voice. For users who employ these headsets for communication, conversational aspects like echo coupling between loudspeaker and microphone, microphone sensitivity, overall speech quality when connected via Bluetooth® to a mobile phone in an active phone call etc. also play a role in the overall quality of the headset. Therefore, the aim for this study was to devise a set of tests that can comprehensively characterize different headsets, and give indications on their overall performance.

Introduction

In this paper, the approach for devising such characterization tests is discussed, entailing the details of the different use cases, and their representative test cases. Exemplar measurement results for commercially available headsets are also discussed.

Use Cases

The various purposes for which ANC headsets are usually employed were categorized into four major use cases as shown below:

1. **ANC**: Using the headsets for noise cancellation purposes (e.g. in a flight)
2. **Playback**: Using the headsets for playback (e.g. 'Music' or 'Podcast')
3. **Ambient Listening**: Using the headsets to listen to speech/sound in the vicinity (e.g. loudspeaker announcements)
4. **Telecommunication**: Using the headsets as a communication device

Testing Environment

The principle measurement setup is shown in Figure 1. It consists of the following:

- **Artificial head according to ITU-T P.58** [1]: Used for binaural and monaural recordings of playback and background noise and speech playback from the artificial mouth
- **8-Channel background noise (BGN) Simulation System according to TS 103 224** [2]: Used for simulating different background noise scenarios, e.g. Airplane noise, Train noise, Café noise etc.
- **Headsets**: Used as Devices Under Test (DUT)
- **Measurement system including front-ends**: Used for generation and analysis of speech/audio signals.

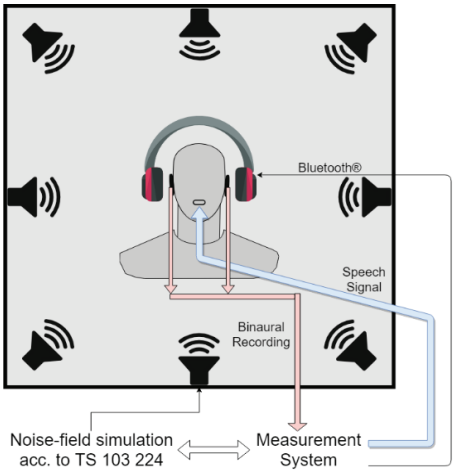


Figure 1: Measurement setup for testing headsets (Wireless Bluetooth®)

Testing Methodology

ANC performance

The ANC performance was tested in presence of various background noise scenarios, stationary and non-stationary. These noises were recorded using the artificial head, first without any headset, then with the headset but ANC functionality off, and then with ANC functionality on. The different ANC steps (if any) of the headsets were also tested. Examples for noise attenuation from two over-ear and two in-ear headsets are shown in Table 1.

Table 1: Passive and active (max. ANC) noise attenuation examples from 4 headsets

Headset	Noise Attenuation (dB)			
	Aircraft Noise (80 $dB_{SPL}(A)$)		Café Noise (69 $dB_{SPL}(A)$)	
	Passive	Active	Passive	Active
Over-Ear 1	5.0	21	6.1	21.1
Over-Ear 2	3.0	17.8	3.6	14.8
In-Ear 1	3.3	20.2	3.1	17.8
In-Ear 2	13.2	16.2	13.7	16.7

What is interesting to see from the above table is that all four headsets are quite robust in terms of stationary and non-stationary noise, providing similar degrees of attenuation in both the noise scenarios. What one can also see that the range of the ANC for the headsets lies between ~15 – 21 dB, which is much better as compared to only passive noise cancellation.

Device 'In-Ear 2', however, is an exception to this, wherein its passive noise cancellation in itself is relatively high, that the difference between active and passive noise cancellation is clearly smaller, but it still provides approx. 16 dB noise attenuation when ANC is active.

Robustness of the ANC performance of the headsets was also tested. The condition that we explored was the deterioration of the ANC performance of over-ear headsets in presence of spectacles/sunglasses, which depends on the amount of noise leakage caused due to the glasses.

Passive noise cancellation is usually only effective for frequencies above 200 Hz, since it is much more difficult to passively damp the lower frequencies. This can also be seen in Figure 2, where the lower frequencies are dampened only when the ANC is active.

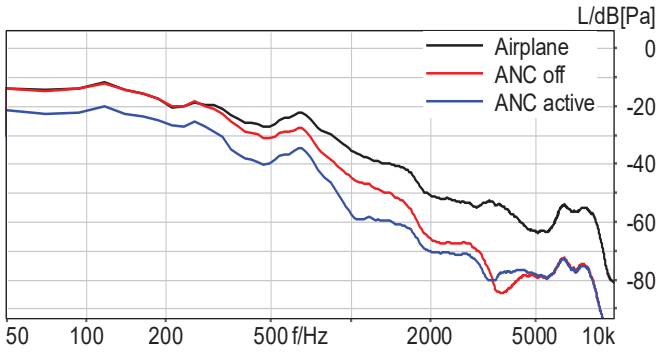


Figure 2: Noise spectra comparison with ANC off and ANC on for one of the headsets (in-ear)

However, such an ANC performance as depicted above is not always the case. There are some headsets whose ANC had much less effect on noise cancellation. One such example is shown in Figure 3 below.

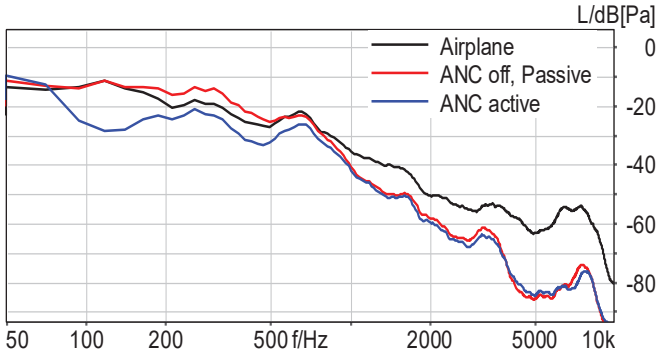
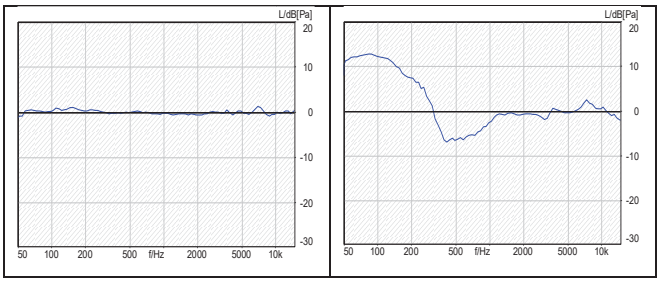


Figure 3: Noise spectra comparison with ANC off and ANC on for one of the headsets (over-ear)

Playback performance

For the playback performance, a royalty free 'Pop' music sample was played back via the headsets. This was recorded at the artificial head, and the difference in loudness (Phon) [3] and frequency response was analysed with and without ANC functionality. Again, all the ANC steps available for the particular headset were analysed. In Figure 4, one can see this delta of the frequency response of music playback with and without ANC from two headsets. The ANC functionality in the right hand analysis is boosting the lower frequencies up to 300 Hz, with a small dip from 300 Hz up to 1 kHz, whereas we see no effect of the ANC for the device on the left.



No effect of ANC on Music Playback | Significant effect of ANC on Music Playback

Figure 4: Δ Music Frequency Response (ANC on – ANC off)

Ambient listening performance

When using ANC headsets in public places, like trains or flights, it is sometimes necessary to be able to hear the surroundings (e.g. in-flight announcements or an additional talker to the side). In case of an additional talker, the conversation is usually in both directions, in which case the person wearing the headset would also want to be able to hear his/her own sidetone (naturally). Real life settings were simulated using an external loudspeaker, placed at a fixed distance from the artificial head, and a 2nd artificial head on the side to represent the additional talker. Signals were played back through the external loudspeaker and the 2nd artificial head (separately), and the receiving signal at the 1st artificial head was analysed in the following conditions: without headsets, with headsets in passive mode, and with headset with ANC active.

Headsets, that have a strong ANC, may also end up attenuating higher frequency speech signals (including sidetone). In such cases, the 'Talk-Through'/'Ambient Mode' functionality of the headset can be quite handy, as it can enhance the speech signals/ambient acoustics when turned on. This feature is also usually employed while using the headsets in offices. One can clearly see in Figure 5 that the overall speech level is increased after turning the Ambient Mode on (blue curve). For comparison, the black curve represents the speech level of at the artificial head without any headset, and the red curve shows the speech level analysis at the artificial head with mounted headset and ANC active.

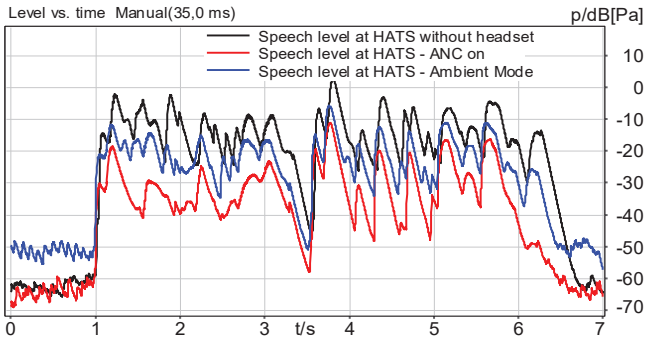


Figure 5: Example showing the increase in speech level after switching the 'Ambient Mode' of the headset on.

Telecommunications performance

The ANC headsets are usually connected to one's smart phone, and therefore can also act as a medium of communication. To verify the headsets' performance in this use case, their performance in sending (uplink) and receiving (downlink) directions was tested, along with echo and double-talk. With proper tuning of the DSP of the headset, reliable and robust communication can be achieved. The headsets were paired with the measurement system via Bluetooth® connection in Hands-Free Profile mode, and a virtual wideband (if possible) call was established to open uplink and downlink channels.

One of the very critical parameters for any communication system is its echo performance. Uplink echo signals are caused when the receive signal is not effectively cancelled in the uplink path. This is especially difficult for these ANC headsets as the loudspeaker and the microphone are often located close to each other. The parameter that has been used to rate the echo performance is E-MOS [4] as shown in Table 2.

Table 2: E-MOS Score Interpretation

Degradation Category Rating Scale	
E-MOS	**Impairment**
5.0	Imperceptible
4.0	Perceptible but not annoying
3.0	Slightly annoying
2.0	Annoying
1.0	Very annoying

Four out of the twenty devices tested had an E-MOS score of less than 4.0. Figure 6 shows the echo performance from two headsets, with an EMOS score of 2.3 and 4.5. The grey signal represents the downlink or receive signal, while the echo signal is indicated by the green signal.

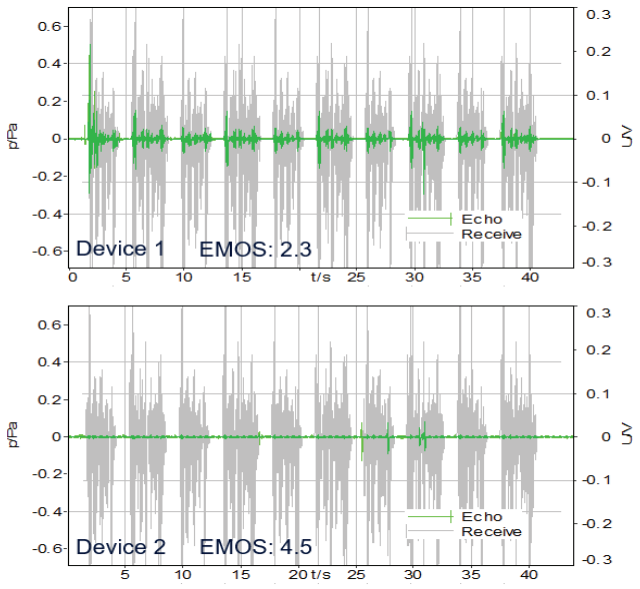


Figure 6: Bad vs. good echo performance from two headsets

Device 1 will most likely lead to customer complaints when used as a communication device, since the person in the far end will hear his/her own voice.

Result Representation

To comprehensively characterize the headsets, several tests were performed for each of the four use cases. A subset of these tests were summarized and represented through ITU-T P.505 [5] recommended "Quality Pie" as shown in Figure 7. The "Quality Pie" has been divided into 12 slices, with each slice representing a test case. The better the result of the test, the bigger and greener the "slice" of the "pie". The inner red circle represents recommended limits for each of the parameters.

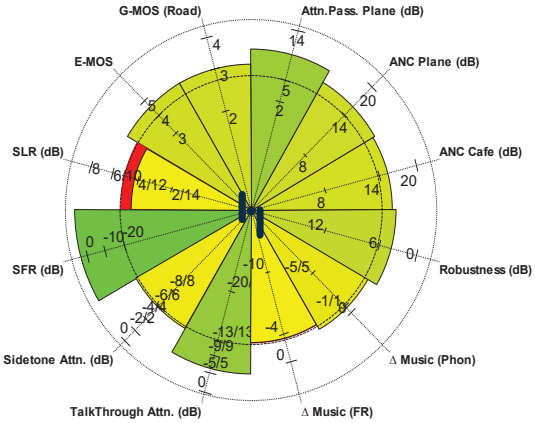


Figure 7: „Quality Pie" representing different test results from ANC headset tests

Most of the test cases in the first three use cases are new, so there is no reference for them in any existing standard, unlike the telecommunications use case, whose tests refer to existing standards.

The representative test cases from the "Quality Pie" have been defined as follows (clockwise):

1. **ANC**

a. **Attenuation "Passive" Plane (dB)**: Binaural BGN (Airplane) level difference (dB) at the artificial head without headset and with headset, using no ANC functionality. Lower limit: 5 dB

b. **ANC Plane (dB), ANC Café (dB)**: Binaural background noise (Aircraft, Café) level difference (dB) at the artificial head without headset and with headset using ANC (max.) functionality. Lower limit: 14 dB

c. **Robustness (dB)**: Binaural background noise level difference (dB) at the artificial head with headset (ANC on), with and without (sun)-glasses. Upper limit: 6 dB

2. **Playback**

a. **Δ Music (Phon)** [3]: Binaural psychoacoustic loudness difference (Phon) of music playback between ANC off and ANC on. Limit: ±1 Phon

b. **Δ Music (Frequency Response):** Binaural averaged frequency response difference (music playback recordings) between ANC off and ANC on. Limit: -3 dB

3. **Ambient Listening**

a. **Talk-Through Attenuation (dB)**: Binaural Active Speech Level (ASL) [6] difference (dB) with and without

headset (ANC on), with fixed (calibrated) sound source (external loudspeaker) placed close to the artificial head, representing a loudspeaker announcement system. Limit: ±12 dB

b. **Sidetone Attenuation (dB)**: Binaural Active Speech Level (ASL) difference (dB) with and without headset (ANC on), with artificial head's mouth used as sound source, to simulate sidetone. Limit: ±6 dB

4. **Telecommunication**

a. **Sending Frequency Response (SFR (dB))**: Calculated according to ETSI TS 103 739 [7].Limit: Distance to tolerance -20 dB

b. **Sending Loudness Rating (SLR (dB))**: Calculated according to ITU-T P.79 [8]. Limit: 5 dB ≤ SLR ≤ 11 dB

c. **Echo Mean Opinion Score (E-MOS)**: Perceptual echo assessment based on a 5 point Degradation Category Rating (DCR) Scale [4]. Limit: MOS ≥ 4

d. **Global Mean Opinion Score (G-MOS)**: Overall quality of speech and background noise in uplink based on a 5 point Absolute Category Rating (ACR) scale according to ETSI TS 103 106 [9]. Limit: MOS ≥ 2.7

The results from two headsets have been displayed in Figure 8. 'Device 1' has weak noise cancelling, but quite a strong performance in other aspects like playback performance, and telecommunications. On the other hand, 'Device 2' has quite good noise cancelling, but has some major issues in telecommunications, and also some problems with the playback performance.

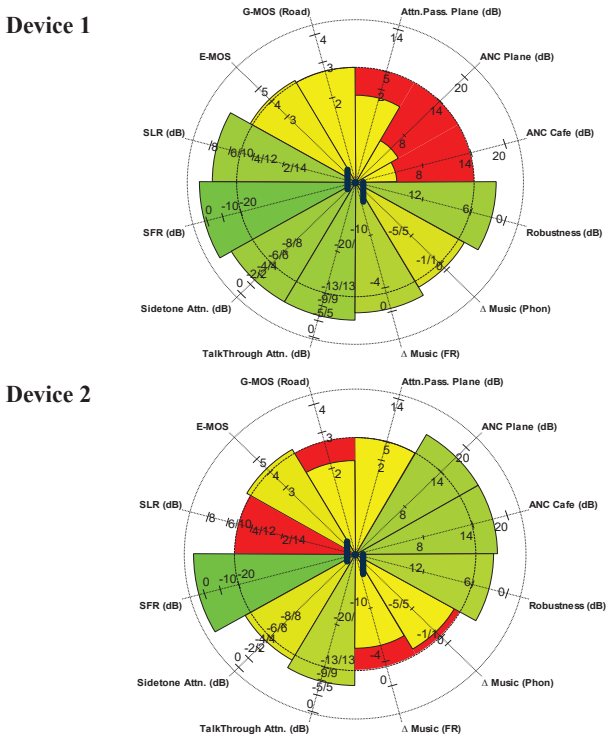


Figure 8: Result representation from two headsets

Conclusion

The popularity of ANC headsets is increasing by the day. As more and more people use them, they are being marketed with a variety of additional features such as Talk-Through/Ambient Mode. When considering testing such devices, one needs to make sure to devise a test set which can comprehensively characterize all the use cases. To achieve this, the tests were divided into four major use cases: ANC, Playback, Ambient listening, and Telecommunication. Tests were performed on various ANC headsets, both In-ear and Over-ear (kindly provided by CHIP Communications) [10], that varied in their performance for the different tests. While some of them had excellent ANC performance, but lacked in telecommunications, others were worse in attenuating ambient noise, but performed reliably in a call.

The test results were then summarized into a 'Quality Pie', for a quick overview of the headsets' performance.

With time, the variety of features such headsets offer will increase, making the testing even more demanding. The tests need to be adapted further to be able to cover the entire range of features provided by the headsets and their accompanying mobile phone applications.

References

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