eCall Testing & Certification – Lessons Learned

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Abstract

eCall modules are mandatory today and speech communication between driver, respectively passengers in the vehicle involved in the accident, and the emergency control center are extremely helpful to judge the severity of a crash. This is considered in the Russian certification process by audio tests according to the GOST 33468 specification that are mandatory for vehicle homologation. EU eCall refers to ITU-T P.1140, which highlights other parameters compared to the Russian GOST specification. The contribution discusses typical challenges and experiences gained from numerous audio tunings and homologation tests with almost all kinds of vehicle types.

Introduction

The acoustic part of eCall systems can be regarded as special case of normal hands-free telephony in cars. Instrumental testing of hands-free systems has been around for several years, beginning with the establishment of the VDA standard for hands-free telephony [1] in the 1990s up to recent ITU-T recommendations P.1100 [2], P.1110 [3] and P.1120 [4] that are direct derivatives from the original VDA specification. Instrumental testing augments and largely replaces the need of intensive subjective testing of hands-free systems on the road, which is time-consuming and hardly reproducible due to external factors such as network coverage, network load, weather conditions and concentration or distraction of the participating test persons, especially the driver of a car. A typical test setup including Head and Torso Simulator (HATS) according to ITU-T recommendation P.58 [5] and background noise playback system is shown in Figure 1.

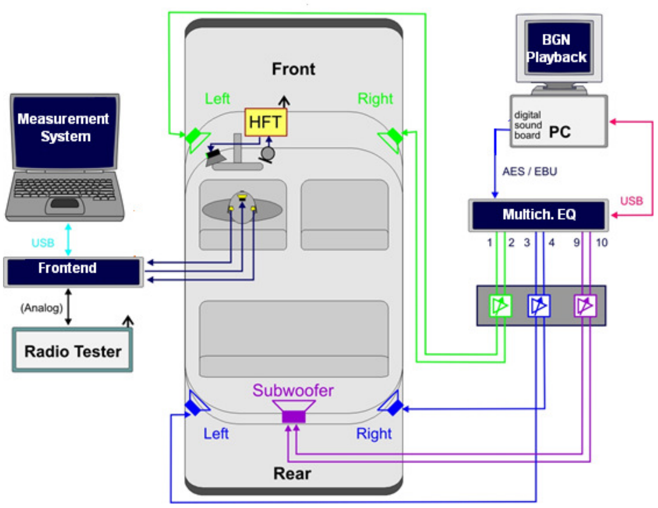

Figure 1: Principle Test setup for objective testing of hands-free systems (quality hands-free and eCall).

Correlation of Single Measurement Results

To understand how these tests are constructed it is worth taking a deeper look at e. g. the measurements for the single talk communication quality in sending direction. The two major aspects of single talk in sending direction are: The sending loudness rating (SLR) and the listening speech quality (MOS-LQO). The SLR measures the attenuation over the complete transmission and is therefore an indicator of the sensitivity in uplink. The listening speech quality can be calculated e.g. using the TOSQA2001 method [6] and describes the perceived quality on a scale between 1 and 5. If both results meet the limit, the communication quality in uplink can be regarded as sufficiently high. However, if the MOS does not meet the limit, no indication on the underlying problem is given by the MOS result alone. Therefore further measurements which describe technical aspects that contribute to the overall speech quality are carried out. These are e. g. the frequency response, the Total Harmonic Distortion (THD) for selected frequencies, the detection of out-of-band components or the analysis of the idle noise. In most cases, an evaluation of these test results reveals the root cause of insufficient speech quality and can provide valuable hints to the engineer to solve the problem. Finally, by testing all these aspects, the engineer's task is to obtain the best possible overall performance that can be achieved using the tools at hand. This can also include deliberately violating the requirements of single tests in order to improve the overall result.

Fundamental Differences between Quality HFT and eCall IVS

Even though the underlying technology is identical, the scope of quality hands-free terminals (HFT) and eCall in-vehicle systems (IVS) is different. To understand the problems arising during the certification process of eCall systems, it is crucial to keep these differences in mind. On one hand, HFT systems used in passenger cars are used frequently and may sometimes be part of a purchase decision for or against a certain vehicle. Especially if the car is considered a workspace, the quality of the installed hands-free system is important. Furthermore, the expectation of the quality of a hands-free system is related to the price of the system. E. g. the expectation regarding an integrated system of a luxury car is higher compared to an after market system installed in a small car. On the other hand, eCall systems are usually not part of the everyday experience; emergency calls are rarely performed, sometimes not at all for years. Second, the components of the eCall system must be crash-safe, so the positions of the microphones and loudspeaker must be chosen accordingly. This may imply that the acoustically preferred position is not an option. The system must fulfil the given regulations regarding the acoustic performance, but since there is no direct gain in customer satisfaction to be expected from an eCall system, cost efficiency is also an important factor.

The tests that are to be carried out for eCall systems e. g. for the Russian GOST 33468 specification [7] are directly derived from the ITU-T P.1100 tests for the most parts, with the important exclusion of listening speech quality. Listening speech quality was not regarded as an important factor. However, the technical parameters related to the speech quality, such as frequency response, distortion or idle noise, are still included. Furthermore, each single test that is included in the test specification is mandatory and must be fulfilled, regardless of its importance for the overall performance. This is obvious, as these tests are relevant for the homologation and therefore require clearly defined pass/fail criteria. It should be also noted that during the certification process for the Russian market, the acoustic tests described by GOST 33468 have to be performed by an officially certified Russian test laboratory, so that results achieved during the audio calibration of the eCall system have to be reproduced and acknowledged by an official third party.

Measurement Examples

Several examples of real-life measurements show the problems that may arise from binary pass/fail decisions for all of the included measurements.

Example 1: Distortion in Sending Direction

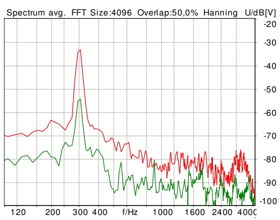

Figure 2: FFT analysis of a 300 Hz sine wave played back by the artificial mouth of a HATS and transmitted in uplink before (green curve) and after (red curve) adjustment of the HATS position on the driver's seat.

The first example deals with the case, when the measured THD in uplink has been measured to 3.5 % at 300 Hz, thus violating the requirement of ≤ 3 %. The test is carried out by playing the excitation frequency with the artificial mouth of the HATS and analyzing the transmitted signal in uplink. The FFT spectrum of the transmitted 300 Hz sine wave is shown in the green curve in Figure 2.

Analyzing the spectrum reveals that due to a weak transmission of the excitation frequency, the limit is violated by a low Signal-to-Noise Ratio rather than high Total Harmonic Distortion. However, looking at the frequency response in sending direction (Figure 3, left) does not show an attenuation of the frequencies around 300 Hz. Since the frequency response graph is measured in third octaves, it may be interesting to look at a final resolution of the frequency transmission. The right diagram in Figure 3 shows the FFT spectrum of transmitted speech in uplink direction.

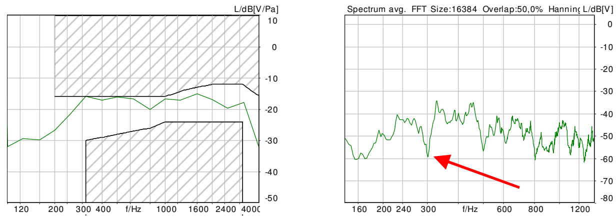

Figure 3: Sending frequency response (left) and high resolution FFT spectrum of transmitted speech in uplink (right). The red arrow points at cancellation at 300 Hz, originated by sound reflections in the vehicle cabin.

Analyzing this high resolution spectrum reveals, that there is a notable notch of the frequency transmission exactly at 300 Hz, which is likely to be responsible for the observed fail of the distortion test case. This attenuation of the 300 Hz frequency is most likely caused by reflections inside the vehicle cabin. To alter the transmission path between the artificial mouth and the IVS microphone, the HATS had to be turned on the seat by a few degrees towards the microphone. This way, the transmission of the 300 Hz excitation frequency could be significantly improved, as shown by the red curve in Figure 2.

Example 2: Frequency Response in Receiving Direction

Sometimes it may happen that measurements that have passed the requirements during the parametrization stage suddenly fail during the certification tests. In this example, this has happened with the testing of the frequency response in receive. During the pre-tests the frequency response curve has matched the given tolerance scheme, but during the

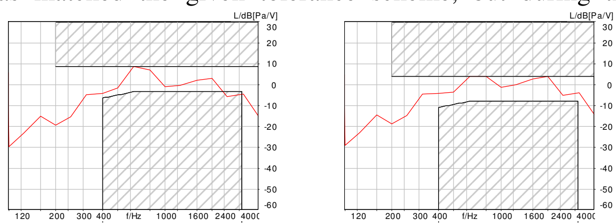

Figure 4: Receiving frequency response measured with the right ear of the HATS before (left) and after (right) adjusting the angle of the back rest of the passenger's seat.

certification tests, a violation of the tolerance scheme occurred for higher frequencies (Figure 4, left diagram). For the vehicle under test, the eCall speaker was positioned in the passenger footwell facing downwards. Thus, there is no direct transmission path between the speaker and the ear of the artificial head. It turned out that not only the position of the driver's seat was relevant for this test, but also the position and especially the angle of the backrest of the passenger's seat, since the reflection on the backrest obviously had significant influence on the frequency response curve. This also means that the measured frequency response will also be different when a person is sitting on the passenger seat and that this test represents only a snapshot of the possible acoustic conditions inside the vehicle. However, adjusting the passenger's seat position accordingly helped to meet the requirements for the certification process (Figure 4, right diagram).

Example 3: Idle Channel Noise Spectrum in Receiving Direction

The test description states, that “individual spectral peaks in the frequency region shall not overrun the mean spectral envelope of the self-noise by more than 10 dB.”[7] To check this requirement, the idle noise spectrum is compared against its own smoothed and averaged spectrum, which is shifted by 10 dB upwards and used as a tolerance spectrum (see Figure 5). In contrast to the latest revision of ITU-T P.1140 [8] and also recent versions of ITU-T P.1100 – 1120, GOST 33468 does not distinguish, if the noise is coming from the eCall system or the interior of the vehicle itself. Modern vehicles often feature a multitude of electronic components that require active cooling by fans and large displays that

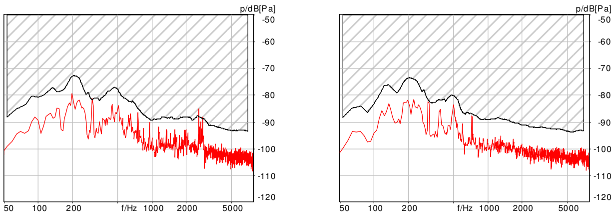

Figure 5: Tonal peaks in the idle noise spectrum caused by displays and fans, violating the requirements of GOST 33468 (left). The same measurement carried out after deactivating the noise sources (right) meets the tolerance.

also emit tonal noises. As a consequence, most DUT initially do not pass this test. If the measurement result is identical even without active call, the noise is not related to the IVS but to the vehicle itself. In this case, it is necessary to find out which components are responsible for the noise and to disable or dampen them as much as possible. This has to be done in cooperation with the certification lab to ensure that an acceptable solution can be found to pass this test. At the end, this leads to the same conclusion as the recent P.1140 recommendation, that these noise sources shall not be considered during the tests, as they are not relevant for the performance of the eCall system.

Example 4: Temporal Stability of Echo Signal Attenuation

The following test case has been designed to check whether the echo attenuation is constant and stable over time. A periodic sequence of composite source signal bursts is played in receiving direction and analyzing the echo attenuation in the transmitted uplink signal. During the transmission of each burst, the uplink signal should not vary more than 6 dB. This 6 dB deviation is indicated by the tolerance scheme in Figure 6. However, the violations of the tolerance are not necessarily caused by echo. In the given case a slightly varying idle noise floor leads to a violation of the tolerance scheme (see red arrow in Figure 6, left diagram). Since the echo performance itself is good and the requirements regarding idle noise are fulfilled, the test case could be considered as passed. However, for the homologation report it is required to fulfil all tolerances, so that the automated evaluation system states “OK” for every single test case. So in this case, efforts have been taken to reduce and stabilize the idle noise transmission during echo. This has been achieved by increasing the amount of noise

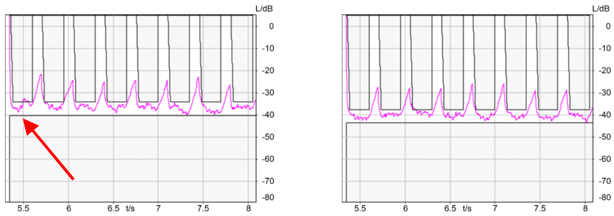

Figure 6: Echo attenuation vs. time, Composite Source Signal burst at -25 dB_{m0}. In the left diagram, the tolerance is violated by al slightly varying noise floor. The right diagram shows the same test after increasing the amount of noise suppression.

suppression (Figure 6, right diagram). This way, the test results meet the required tolerance. It has to be noted though, that from a pure performance view, no changes to the DSP parameters would have been necessary.

Example 5: Operation of Received Channel in Acoustic Noise Conditions

In GOST 33468 the Signal-to-Noise Ratio (SNR) in receiving direction under driving conditions is tested. For the tests the driving noise of the vehicle under test is recorded under various conditions and played back into the cabin using a background noise playback system according to ETSI EG 202 396-1[9]. In the current example, it was not possible to achieve a sufficient SNR to fulfil the given requirement of ≥ 6 dB. The maximum measured result was 5.6 dB in this case (red curve in Figure 8). It has to be noted that the measurement, like all measurements in GOST, is monaural and that the ear that is closest to the loudspeaker shall be used for testing.

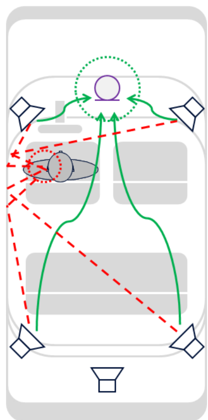

Figure 7: Equalized (green) and not equalized (red) transmission paths of background noise playback according to ETSI EG 202 396-1.

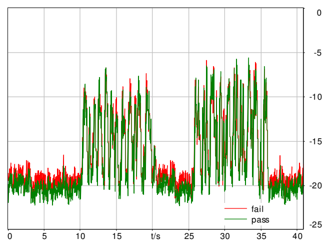

Figure 8: Signal-to-noise ration measurement in receive as implemented in GOST 33468 test case 7.10.2 using the same background noise but different speaker positioning and equalization.

In this particular case, the eCall speaker was located in the left part of the driver’s footwell, so that the left ear of the HATS is used. Furthermore, it must be noted that the background noise playback used for the tests is not calibrated for that special position, so care needs to be taken that the level at the left ear of the HATS is not too high due to sound reflections at the left side window (see Figure 7).

Checking the noise levels turned out that the measured noise level at the left ear is approximately 5 dB higher compared to the noise level present at the IVS microphone. Therefore it does not correctly reproduce the level distribution in the vehicle cabin. It has to be noted that more recent multi point background noise playback systems (MPNS according to ITU-T P.1100/P.1110/P.1120 Annex F and P.1140 Annex B [1, 2, 3]) can correctly reproduce the noise at multiple positions inside the vehicle, but have not been approved for GOST 33468 yet.

In fact, cross checking the equalization of the background noise system and repositioning the loudspeakers could lower the noise level at the HATS ear to a more realistic level and help to pass the requirements (green curve in Figure 8).

Example 6: Silent Call Performance

When designing eCall systems that conform to the UNECE approved ITU-T P.1140 recommendation, a transparent transmission of background noise is of major importance. Especially when nobody is talking, this helps operators on the Public Safety Answering Point (PSAP) to decide whether a real emergency has happened, or if the emergency call is established unintentionally. To judge the performance of the silent call transmission a noise of a car passing by is played back by the background noise system installed in the vehicle. This signal is recorded with a reference microphone near the eCall microphone. Additionally the same signal as transmitted by the IVS is recorded at the end of the transmission chain. The level versus time representation of both signals is calculated and compared to each other. The shape of both calculated curves should not vary more than 10 dB [10]. This is indicated by the tolerance scheme in Figure 9.

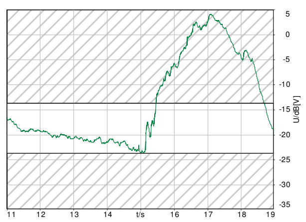

Figure 9: Silent call performance of an eCall IVS with deactivated noise suppression in the main DSP but additional noise suppression in the dedicated microphone DSP

In this example, even with deactivated noise suppression of the eCall system, it was not possible to meet this requirement. As Figure 9 shows, the non-linearity of the noise transmission is still around 20 dB. Further investigations revealed that in that vehicle an active microphone with its own DSP was used. The integrated microphone DSP also features its own noise reduction, which attenuates transmitted noise by approximately 20 dB. So in this case, since no access to the microphone DSP was given, there was no other solution but to exchange the microphone, so that the requirement for a transparent noise transmission under silent call conditions could be fulfilled.

Conclusion

In order to pass the requirements for the audio performance of eCall systems, a different approach is necessary compared to normal hands-free measurements in cars. Since the requirements are binding, no weighing up in favor of a better overall performance is possible; all test results have to meet the given limits without compromise. Especially for certification according to GOST 33468, care has to be taken, that results that have been measured during the parametrization can be reproduced by a third party certification lab. To ensure this, it is therefore highly recommended to exclude as many variables as possible to reproduce test results. Whenever possible, it is recommended to use the same vehicle for adjusting the DSP parameters and for certification. All relevant positions, especially the placement of the HATS in the vehicle should be documented carefully. The test results should meet the limits with some margin, if possible. Finally, a good cooperation with the responsible engineers of the certification lab and also some creativity of the test engineer are required to fix unexpectedly failing test results during the certification process.

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