ITU-T "Whitelist" to Guarantee High Quality Hands-free Performance in Vehicles

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Motivation

The influence of mobile phones on communication quality of vehicle mounted hands-free implementations is discussed since years between the automotive industry and the mobile phone industry. Mobile phones should provide gateway functionality with transparent transmission characteristics in conjunction with a car hands-free system. ITU-T, the International Telecommunication Union organizes test events to verify the performance of mobile phones in such connections and maintains a "Whitelist" of mobile phones fulfilling the requirements. The basis for these tests are the chapter 12 test cases of the ITU-T Recommendations P.1100 [1] and P.1110 [2]. The contribution discusses the experiences gained after the first test events over the period from 2014 to 2016 and describes the current situation.

Introduction

Vehicle mounted hands-free telephony systems (HFT) typically use a smartphone to connect to the mobile network. The smartphone is connected via Bluetooth® to the head unit. The hands-free profile [1] defines commands to configure the characteristics of the mobile phone in such a connection. In particular, the HFT sends the "AT+NREC=0" command to disable echo cancellation and noise reduction in the phone. This is necessary to avoid cascaded algorithms as the hands-free signal processing is typically provided by the HFT implementation in the vehicle. However, even though the AT command is acknowledged with "OK", many mobile phones do not completely bypass or disable the signal processing and thus, significantly impair voice quality in a hands-free communication from vehicles. This leads to severe problems for the car industry and hands-free suppliers who are trying to ensure high quality voice communication over the implemented hands-free systems in vehicles as the mobile phone may significantly impair this quality. ITU-T defines dedicated tests and requirements in chapter 12 of the ITU-T Recommendations P.1100 and P.1110.

Involved parties and their roles

The automotive industry provides integrated hands-free terminals, relying on transparent audio gateway functionality provided by the mobile phones.

The mobile phone industry provides smartphones to interconnect the hands-free telephone system in the vehicle and the mobile network. The mobile phones provide audio gateway (AG) functionality for the HFT.

Bluetooth® SIG: the special interest group specifies the hands-free profile (HFP) used for the connection between HFT and AG. Note that this HFP specification describes protocols and commands but neither the audio performance itself, nor audio verification tests.

ITU provides Recommendations P.1100 and P.1110 for hands-free quality tests for vehicle mounted hands-free systems with a dedicated chapter 12 to verify the audio performance of the AG in a short-range wireless (SRW) connection. Furthermore ITU-T hosts the "Whitelist" of mobile phones, which proved transparent transmission characteristics as recommended. This whitelist is public and can be used by the automotive industry as well as car customers to check the performance of individual mobile phones. Furthermore, the whitelist can also be used by mobile phone manufacturers as a marketing tool.

HEAD acoustics is currently selected as test lab for performing the ITU-T P.1100/P.1110 chapter 12 tests on mobile phones during test events.

Test setup

Figure 1 shows the typical test setup for a mobile phone according to ITU-T P.1100/P.1110, chapter 12 tests. The mobile phone is linked via Bluetooth® to a reference interface simulating the HFT in a vehicle. The interface and the mobile phone exchange AT commands ("AT+NREC=0" from the interface to the mobile phone and the acknowledgement from the mobile phone to the Bluetooth® interface). On the network side the mobile phone is connected to a network simulator in 2G or 3G mode (narrowband or wideband). The Bluetooth® connection can either be established in narrowband or wideband mode independent of the connection mode (narrowband or wideband) to the mobile network. A wideband Bluetooth® connection is established if both devices, the car mounted HFT and the mobile phone are wideband Bluetooth® capable independent of the configuration of the network access.

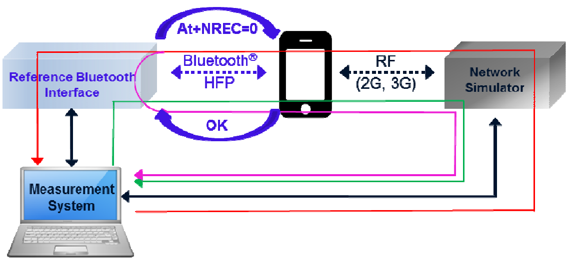


Figure 1: Laboratory test setup

Audio tests can then be carried out by applying test signals in uplink direction (from the reference Bluetooth® interface to the network simulator) or downlink (from the network simulator to the reference Bluetooth® interface). Tests under echo conditions simulate an echo at the reference Bluetooth® interface whereas double talk tests are carried out by applying test signal simultaneously in both directions.

Performance trends after ITU-T test events

Narrowband transmission

Figure 2 shows the narrowband round-trip delay results for 33 devices tested during the 1st ITU-T test event in 2014 (see **figure 2**, [4]). For comparison **figure 3** shows the same results for 18 devices tested during the 2nd Event [5]. The red dashed line shows the round-trip delay limit applied during the events. Note that this limit was adapted from the 1st test event (210 ms) to the 2nd test event (190 ms).

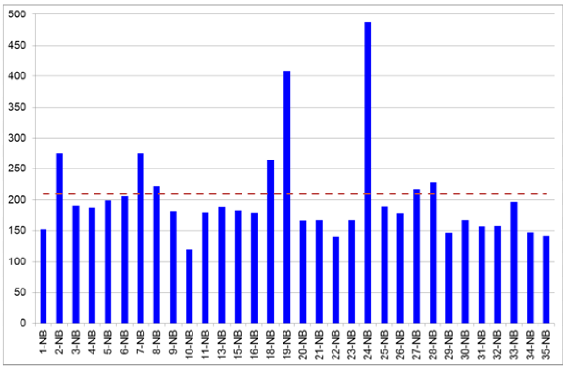


Figure 2: Narrowband round-trip delay overview, 1st event

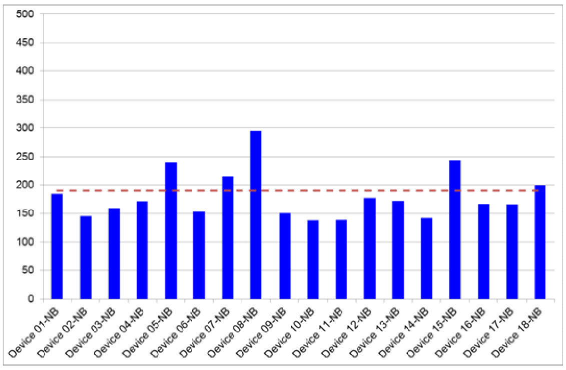


Figure 3: Narrowband round-trip delay overview, 2nd event

The analyses clearly indicate that the round-trip delays are very high (extrema up to > 400 ms during the 1st Event) and a significant number of tested mobile phones violate this limit. It needs to be considered that the mobile phones only act as network access (audio gateway) so the measured round-trip delays can in general be regarded as extremely high. As an example, a car-to-car communication would underlie the signal processing delay in both vehicle mounted HFTs, the round-trip delay of the AG on both ends plus the mobile network delay. This can lead to roundtrip delays of 600 ms and more, which is out of the recommended range.

Figure 4 shows the performance overview of 33 mobile phones after the 1st test event. The same analysis for the 2nd Event can be seen in **figure 5.** The first bar indicates the acknowledgment of the "AT+NREC = 0" command from the mobile phone. All devices tested during both events acknowledge with "ok", indicating that the internal signal processing (noise reduction and echo cancellation) is disabled. The bars indicated by "AGC" (renamed to "Linearity" in the 2nd Event), "NR off", "EC off" and "DT" show the results of the tests aiming on the verification of disabled signal processing. Most devices, but not all, turn off their echo cancellation and noise reduction, internal signal processing. The percentage of fails seems to be reduced during the 2nd Event compared to the 1st Event, which can be seen as a positive tendency.

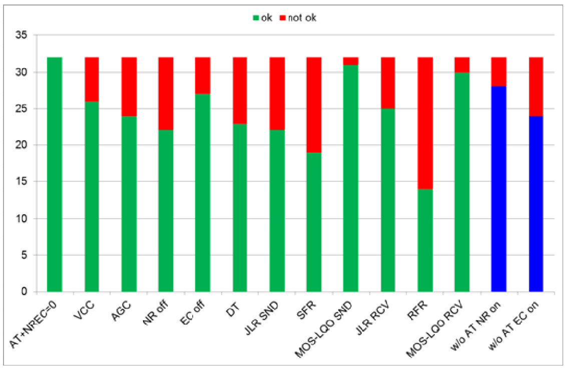


Figure 4: Summary of test results over all devices under test, 1st event

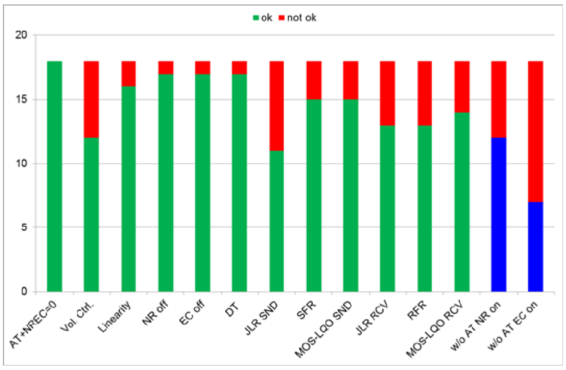


Figure 5: Summary of test results over all devices under test, 2nd event

The bars designated as "JLR SND" and "JLR RCV" (Junction Loudness Ratings) indicate, that the gains are often out of range in both direction (sending direction SND, receiving direction RCV). The two bars "SFR" and "RFR" represent the frequency response results and show that equalizers are not always bypassed or set to a flat transmission characteristic in both directions. This may significantly influence the sound perception, either for the driver in the vehicle or for the conversational partner. Furthermore, the last two bars verify informatively the noise reduction and echo cancellation state, if the AT command is not sent from the HFT to the mobile phone. A significant number of phones disable the internal signal processing, although the AT command it is not requested. This may be an indication that the deactivation is triggered by the detection of a Bluetooth® HFP connection and not by receiving the AT command.

Wideband

In principal, the same conclusions can be drawn for the mobile phones tested in wideband Bluetooth® connection. Again, the measured round-trip delay for 30 devices in total often violate the given requirement (see **figure 6** and **7**). Many devices introduce more than 200 ms roundtrip delay.

Also the wideband performance analyses for the mobile phones in both events (see **figure 8** and **9**) show a very similar tendency as for the narrowband mode.

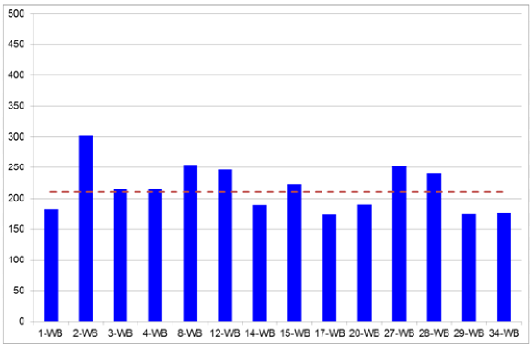


Figure 6: Wideband round-trip delay overview, 1st event

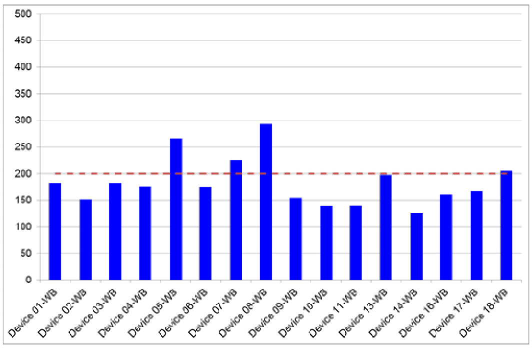


Figure 7: Wideband round-trip delay overview, 2nd event

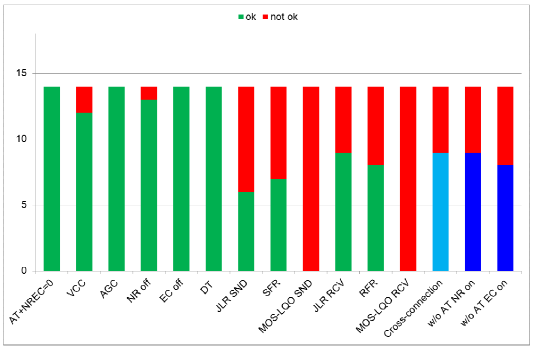


Figure 8: Summary of test results over all devices under test, 1st event

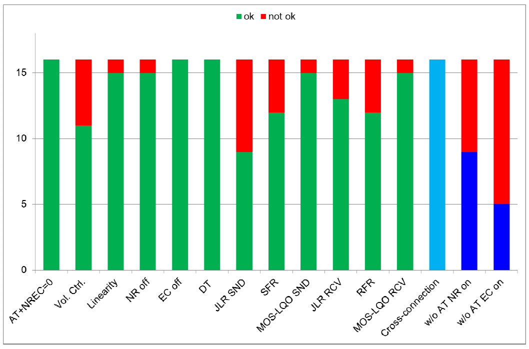


Figure 9: Summary of test results over all devices under test, 2nd event

Echo cancellation and noise reduction is often disabled (as requested) but other kind of signal processing is still active (gain, equalizers,…). Note that the two parameters "MOS-LQO SND" and "MOS-LQO" RCV are verified with new limits during the 2nd Event as the requirements for the 1st Event were not achievable. This also shows the feedback of the test results into the standardization process.

Specific test items

Delay

The acknowledgment of the "AT+NREC=0" command could lead to a significantly lower round-trip delay in the mobile phone as the AT command initiates disabled or bypassed signal processing. For verification purpose, round-trip delay measurements were carried out during the test events with and without "AT+NREC=0" being sent at connection setup. The resulting round-trip delay comparison is shown in **table 1** for 10 randomly chosen devices, which disable EC and NR.

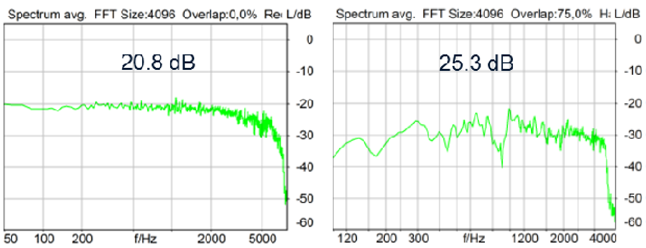
Table 1: Round-trip delay [in ms], comparison "AT+NREC=0" sent vs. "AT+NREC=0" not sent

	Device 1	Device 2	Device 3	Device 4	Device 5
AT+NREC=0 sent	151.7	181.6	175.6	181.7	265.5
AT+NREC=0 not sent	166.8	215.0	170,9	173,.8	281.5
Δ ($AT_{not\ sent}$-AT_{sent})	15.1	33.4	-4,7	-7.9	16.0
	Device 6	**Device 7**	**Device 8**	**Device 9**	**Device 10**
AT+NREC=0 sent	174.9	225.0	292,9	154.7	139.3
AT+NREC=0 not sent	164.2	238.1	352,8	156.3	140.2
Δ ($AT_{not\ sent}$-AT_{sent})	-10.7	13.1 ms	59.9	1.6	0.9

In the majority of tests the delay is not significantly influenced by the AT command or the fact, that the mobile phone disables internal signal processing. This is an indication, that the phones do not "bypass" the internal signal processing but configure it to an "idle" configuration. Consequently, the delays are not reduced. This is a very sobering fact as the round-trip delays are high, keeping in mind that the devices only provides AG functionality.

Echo cancellation and noise reduction

The echo cancellation test uses a simulated echo path between the downlink and uplink signal of the mobile phone, realized in the Bluetooth® reference interface (as indicated by the magenta path in **figure 1**).



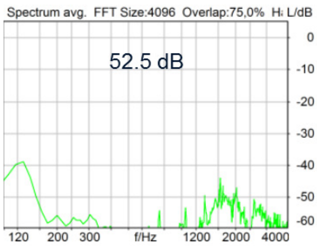


Figure 10: Echo control test results

A simulated echo loss of 20 dB is adjusted and should appear as a 20 dB ± 2 dB echo loss during the echo measurement on the mobile phone. **Figure 10** shows three typical results for mobile phones: The 20.8 dB echo loss indicates a disabled echo cancellation. The 25.3 dB violate the limit of 20 ± 2 dB, but is influenced by automatic gain control (AGC) rather than an active echo cancellation. A high echo loss of > 50 dB (third example), is a clear indication of an enabled echo cancellation algorithm.

Figure 11 shows three analysis results for the verification of disabled noise reduction. A stationary noise signal is applied in sending direction of the mobile phone from the Bluetooth® interface to the network simulator. A constant level vs. time analysis as shown in the left-hand figure in **figure 11** indicates a disabled noise reduction algorithm. Vice versa the two other figures analyze a very strong attenuation of the transmitted noise. The noise reduction algorithm is still active in both cases.

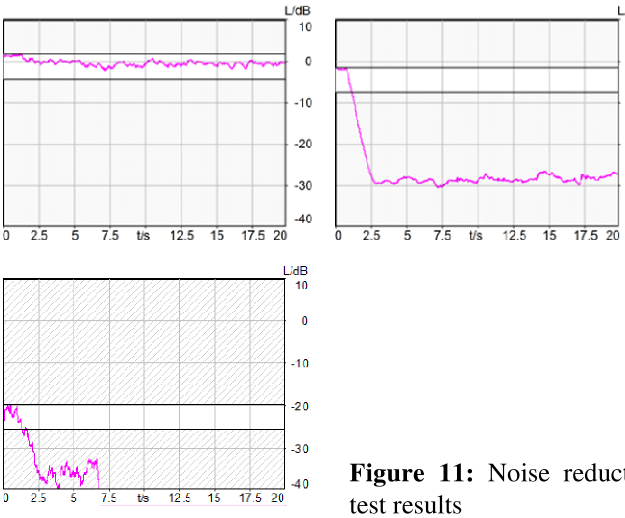


Figure 11: Noise reduction test results

However, further signal processing aspects like equalizers, gain settings, AGC and also volume control features need to be verified in order to guarantee transparency of the AG. Such tests are also described in chapter 12 of the ITU-T recommendations.

Junction loudness ratings

The uplink and downlink sensitivities are determined based on the Junction Loudness Rating (JLR). A JLR of 0 ± 2 dB as measured for device A in **table 2** is recommended in both directions for a mobile phone in a SRW connection.

Table 2: JLR results for three devices (examples)

	Device A	Device B	Device C
JLR SND	0 dB	-5 dB	-10 dB
JLR RCV	0 dB	-5 dB	12 dB

However, device B with a JLR result of approximately -5 dB in **table 2** (5 dB amplification) is representative for a couple of smartphone models. Individual devices may even insert stronger amplifications or attenuations, as shown by device C (10 dB amplification in the microphone path, 12 dB attenuation in the loudspeaker playback). This leads to saturation and distorted speech in the microphone path and an insufficient signal-to-noise ratio for the driver. while driving.

Remote audio volume control and phone volume control

The remote audio volume control (RAVC) is an optional feature which allows the HFT audio playback volume to be remotely controlled by the mobile phone via dedicated AT commands. However, some mobile phones keep their own volume control active applying a strong attenuation in downlink of the Bluetooth® audio path. Apparently, this is a remainder from the support of older headset devices without own integrated volume control and that do not support the RAVC feature. **Figure 12** shows two examples of mobile phones with enabled volume control in receiving direction.

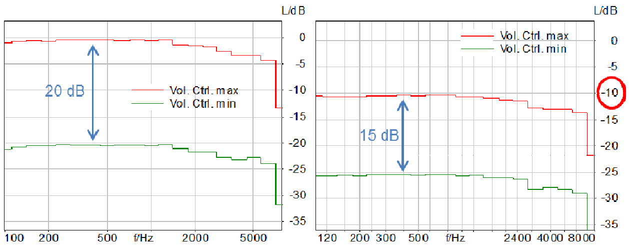


Figure 12: Sensitivity control range (2 examples)

Device A (left) provides up to 20 dB attenuation which leads to a too low signal playback in the vehicle. The analysis result of device B (right) shows a static attenuation of 10 dB (red circle) plus an attenuation of 15 dB due to the active volume control. This can be seen as a very critical aspect as the user may be incited to re-adjust the volume on the mobile phone while driving. It is therefore in general recommended to operate a mobile phone always with maximum volume when connected to a car mounted HFT.

Conclusions

The non-transparent audio performance of mobile phones in a Bluetooth connection to car mounted hands-free systems is still an issue in the automotive industry. The ITU-T test events show, that the major part of mobile phones does not provide a completely transparent audio transmission although disabling EC and NR. In general, the delay can be regarded as very high, considering that the devices should only provide audio gateway functionality. The ITU-T Whitelist is continuously updated by transparent mobile phones with phone model and firmware version. The intensive discussion, initiated by ITU-T between automotive industry, hands-free suppliers and mobile phone industry may hopefully solve this in future.

References

[1] Hands-Free Profile 1.7, Bluetooth Profile Spec. SIG

[2] ITU-T P.1100, Narrowband hands-free communication in motor vehicles, 01/2015

[3] ITU-T P.1110, Wideband hands-free communication in motor vehicles, 01/2015

[4] Test Report: Performance assessment of vehicle-mounted mobile phones in conjunction with hands-free terminals based on Recommendations ITU-T P.1100 and ITU-T P.1110, Geneva 12 – 16 May 2014

[5] Test Report: 2nd ITU Test Event - Performance of Mobile Phones as Gateways to Car Hands-free Systems, Geneva 23 – 27 May