Speech Quality of Mobile Phones via Wideband Bluetooth Link

Marc Lepage, Frank Kettler, Tobias Vorländer

HEAD acoustics GmbH, 52134 Herzogenrath, E-Mail: marc.lepage@head-acoustics.de

Introduction

The automotive industry „meets" the mobile phone industry when drivers communicate via their vehicles' hands-free system. The most common use case is that the driver's mobile phone linked via Bluetooth provides the mobile network access. Control commands (AT-commands) are defined to configure the Bluetooth connection, disable internal signal processing in the mobile phone in this case and provide a fully transparent audio gateway functionality of the phone. Signal processing is handled in the hands-free system. Although many phones disable echo cancellation or noise reduction, they often show severe limitations (discussed also at DAGA 2011 [1]). Today it can even be observed that it is hardly possible to find any up-to-date mobile phone that behaves fully transparently in wideband (WB) communication. This contribution discusses typical results from a number of WB capable mobile phones. As this inappropriate behavior of mobile phones hampers speech quality tuning of hands-free systems, it remains a very critical aspect for the automotive industry and demands stronger focus on standardization.

Motivation

The situation addressed in this contribution is represented in **figure 1**. A mobile phone is connected to a hands-free terminal (HFT) using the Bluetooth hands-free profile (HFP 1.6 [2]). The HFT sends the dedicated AT-command "AT+NREC=0" to deactivate the signal processing provided by the mobile phone (noise reduction (NR) and echo control (EC)). All signal processing is provided by the hands-free system which is attuned to the specific acoustical environment e.g. the vehicle cabin.

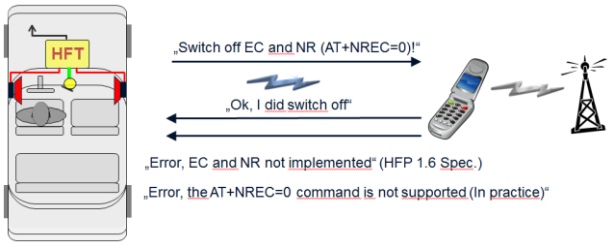

Figure 1: Basic setup of a mobile phone connected to a HFT using the Bluetooth HFP: "AT+NREC=0" sent to disable signal processing in the phone.

Verification tests based on the analysis of transmitted audio signals as described in e.g. ITU-T P.1100 [3] and P.1110 [4] show that many mobile phones do not provide a correct implementation of this mechanism. And even among those implementations which disable internal signal processing, many devices show severe limitations such as strong level adjustment, AGC or equalization in the frequency domain. An example of two state-of-the-art mobile phones tested in a narrowband connection is shown in **figure 2**.

A „quality pie" chart (for details, see [1]) summarizes the test results of a nearly transparent phone in the left hand graph. Only slight level adjustments by an automatic gain control ("AGC") are detected.

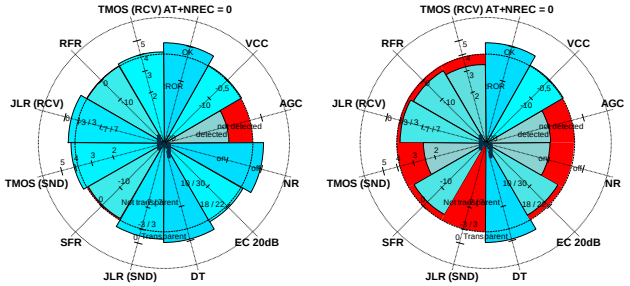

Figure 2: „quality pie" chart of two phones in narrowband Bluetooth connections: nearly transparent device (left) vs phone with strong limitations (right)

The right hand diagram represents another commercially available device that also responded with "Ok" to the command "AT+NREC=0". However, the tested device still provides active noise reduction (NR) and also strongly impacts the levels of the transmitted signals leading to significant degradations of speech quality.

Similar tests are performed today for WB connections. In such tests a WB enabled Bluetooth connection is set up which is using the mSBC codec instead of the narrowband CVSD codec. On the mobile network side the AMR-WB codec is used for a complete WB connection.

As WB speech transmission in mobile networks is rapidly developing and this technology is expected to provide a significantly improved speech quality, the WB Bluetooth connection should not lead to speech quality degradation.

Wideband Audio Test Results

A high number of WB Bluetooth capable mobile phones are commercially available. This section describes results of audio tests performed on four devices. All four phones replied with "OK" to the "AT+NREC=0" command indicating that signal processing has been deactivated. In the following figures the upper diagrams represent "phone 1" (left) and "phone 2" (right). The lower graphs show the results for "phone 3" (left) and "phone 4" (right).

Figure 3 shows the frequency response characteristics in uplink - signal sent via Bluetooth link and recorded at the output of the network simulator – for the four phones.

Phone 2 and 3 show a relatively constant sensitivity over the entire frequency range from 100 Hz to 7 kHz. Phone 1 shows a distinct high pass characteristic below 300 Hz which slightly limits speech quality. The junction loudness rating in sending direction (JLR SND) is close to 0 dB for these three phones indicating level transparency.

Phone 4 shows much stronger limitations. In addition to a high pass below 300 Hz, the transmission is limited to 4.5 kHz; higher frequencies are practically not transmitted. Furthermore, the JLR of -12.4 dB indicates an amplification of more than 12 dB in uplink leading to strong clipping and reduced listening speech quality.

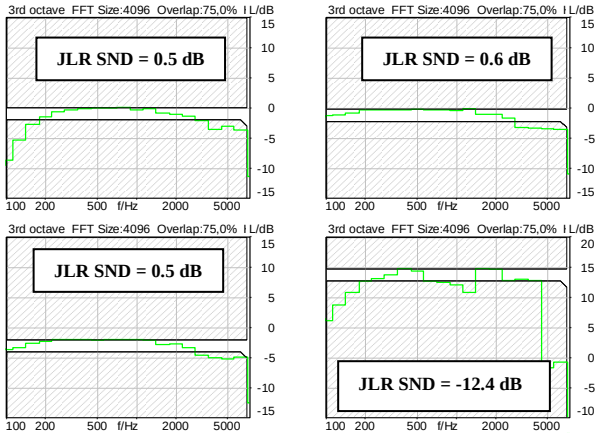

Figure 3: Bluetooth WB sending frequency resp. character.

Figure 4 illustrates the NR activity analysis. For this test, a stationary noise is applied on the Bluetooth side of the device under test and the transmitted signal is recorded at the output of the network simulator.

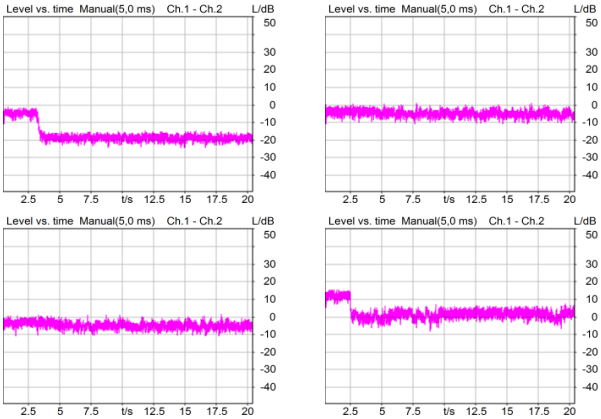

Figure 4: Noise reduction (NR) activity analysis results

The Δ level vs. time representation between the transmitted signal and the originally applied noise clearly highlights the attenuations introduced by the active NR in Phone 1 and 4 whereas Phone 2 and 3 show a transparent behavior.

Another test case simulates an echo path with 20 dB attenuation on the Bluetooth side. Echo attenuation tests on the four mobile phones, corrected by the JLR in both transmission directions, should lead to a result of 20 dB if no additional EC is active in the devices. The echo spectrum as shown in **figure 5** should be constant over the entire frequency range.

For Phone 2 and 3 the expected result is detected. The echo spectra are rather constant from 100 Hz up to 7 kHz and the echo attenuations of 20.0 dB respectively 20.7 dB indicate that all EC signal processing is deactivated.

The analysis result for Phone 1 shows frequency dependent attenuation introduced by the phone. The averaged echo attenuation value of 31.3 dB also indicates active EC.

Taking into account the strong spectral limitations in uplink of Phone 4 and the gain of more than 12 dB applied by the device, the echo spectrum and the corrected echo attenuation value of 17.4 dB indicate that all EC is deactivated. The slight deviation from the expected value of 20 dB is most likely due to additional non-linear effects such as level adjustments due to AGC or signal saturation in uplink.

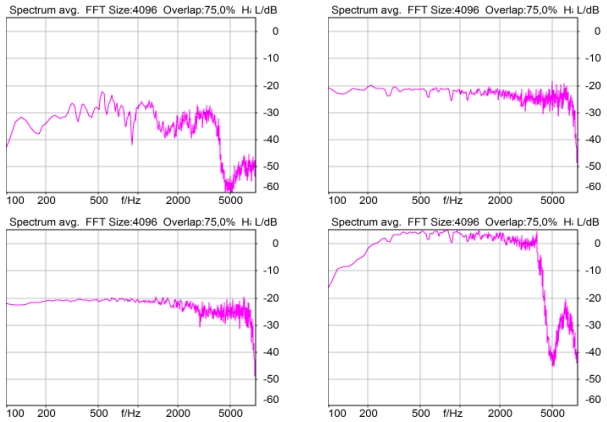

Figure 5: Echo control (EC) activity analysis results

Further interesting behavior can be observed if tests are repeated in a new Bluetooth connection without sending the "AT+NREC=0" command. In this case it is expected that signal processing such as NR and EC is active in all devices.

Surprisingly, the test results for Phone 3 and 4 show exactly the same behavior as in the previous tests. Phone 3 deactivates all signal processing while phone 4 disables NR but keeps EC active. This is an indication that the deactivation of signal processing is triggered by a mechanism which differs from the one described in [2].

Conclusions and Outlook

Audio test results of four WB Bluetooth enabled mobile phones show that the issues described for NB speech transmission via Bluetooth link ([1]) also occur in WB connections. This is not only problematic for the automotive and headset industry relying on transparent audio performance to tune the signal processing of their hands-free car kits. It is also an issue considering the high customer expectation on improved speech quality to be provided by WB connections.

This topic is addressed by ITU-T in an international test event [3] with the aim of bringing together the automotive industry, mobile phone manufacturers and standardization bodies to discuss and hopefully solve it.

Literature

[1] Lepage, M., Kettler, F., Kengne, S.: Speech quality of mobile phones via Bluetooth link, DAGA 2011

[2] Bluetooth Telephony Working Group: Hands-free Profile 1.6

[3] ITU-T Test event,
URL: `http://www.itu.int/en/ITU-T/C-I/Pages/test_event_Feb14.aspx`