

Speech Quality of Mobile Phones via Bluetooth Link

M. Lepage, F. Kettler, S. Kengne,

HEAD acoustics GmbH, Marc.Lepage@head-acoustics.de

Introduction

Communication via headsets and hands-free devices often uses the Bluetooth connection to a mobile phone for voice transmission. Control commands (AT-commands) are defined in order to configure the Bluetooth connection and disable internal signal processing in the mobile phone like echo cancellation or noise reduction. This is especially important for the automotive industry because such signal processing is provided by the automotive hands-free implementation and important to avoid cascaded signal processing from the terminals and additionally in the mobile phones. However, many mobile phones do not consider the AT-commands appropriately and leave internal signal processing active. This may significantly degrade speech quality of the complete system.

Cascaded signal processing

A typical setup for mobile communication in vehicles is shown in figure 1. The hands-free terminal (HFT) uses a Bluetooth connection (BT) to a mobile phone in order to connect to the mobile network. HFT and mobile phone use the hands-free profile (HFP) to configure the Bluetooth link.



Figure 1: Typical configuration in mobile communication in vehicles

Such configurations bear the risk of cascaded signal processing implemented in the HFT and the mobile phone. Figure 2 shows the schematic bloc diagram in such a setup. Important signal processing components like echo cancellation (EC), echo suppression (post processing, ES) and noise reduction (NR) are typically implemented in the HFT and the mobile phone itself.

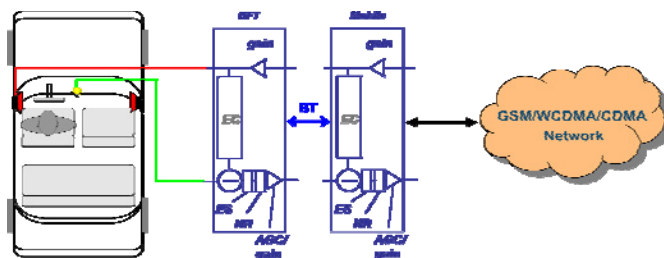


Figure 2: Cascaded signal processing, HFT and mobile phone

In case the mobile phone does not disable the internal signal processing, this leads to cascaded signal processing as shown in figure 2 which may significantly degrade conversational speech quality.

The diagram in figure 3 shows the information exchange between the hands-free device (HF) and the mobile phone which serves as an audio gateway (AG) in this configuration.

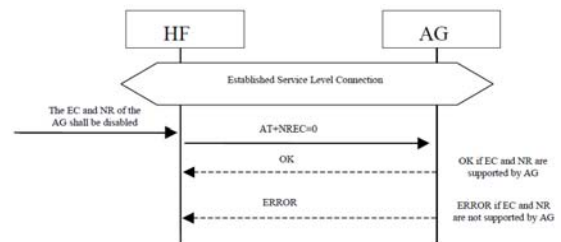


Figure 3: Configuration of Bluetooth connection via hands-free profile (HFP), from: Hands-Free Profile 1.5 [1]

The hands-free device sends the command “AT+NREC=0” to the audio gateway. This may answer with an “OK” indicating that it supports EC and NR but switches it off. Alternatively an “ERROR” can be replied in case the audio gateway does not support EC and NR. However, in practice this often means that the AT command is unknown or can not be interpreted by the mobile phone.

Discussion of test results

A typical test setup to verify the Bluetooth performance of mobile phones is shown in figure 4.

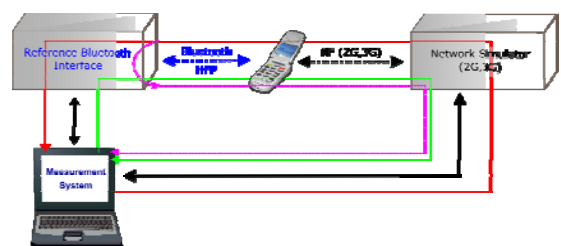


Figure 4: Test setup for Bluetooth performance measurements

A network simulator and a reference Bluetooth interface are used to interconnect to the mobile phone. The Bluetooth interface is capable to configure the Bluetooth link via the HFP and communicate to the mobile phone via the appropriate AT commands. Verification tests can then be carried out in sending direction of the mobile phone (green arrow), in receiving direction (red arrow) or under echo conditions (dotted magenta arrows). In this case the Bluetooth interface is capable to simulate an echo with a defined echo loss and delay.

Parameters like junction loudness rating (JLR), frequency responses and listening speech quality (TMOS) are

measured. Specific NR and EC tests are implemented in the test system and used to verify if the internal signal processing in the mobile phone is disabled. Such tests are defined in ITU-T Recommendation P.1100 [2]

61 mobile phones were tested under these conditions, 54 replied with "OK" and 7 devices sent back an "ERROR". This indicates that more than 10 % of the devices currently on the market do not support EC and noise reduction, or at least do not communicate according to the HFP specification. 34 devices really switched of the NR. Such a test result is shown in figure 5 on the left hand side.

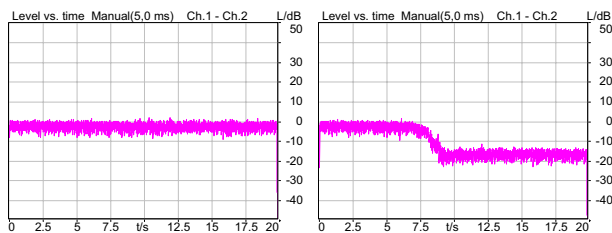


Figure 5: NR test results

A stationary noise is applied in sending direction of the mobile phone via the Bluetooth interface in figure 4. The transmitted level in sending direction at the output of the mobile network simulator is measured. The resulting sensitivity curve is given by the magenta curve. A constant sensitivity vs. time indicates that the level does not change, noise reduction does not suppress the stationary noise in sending direction. Another example for an active noise reduction can be seen in the right hand diagram. After approximately 7.5 s an attenuation of 15 dB is inserted by the implemented NR in the mobile phone.

Another 34 devices (not the same as the 34 mentioned above) switched off the EC. Two typical test results are shown in figure 6. For this test an echo path simulation with 20 dB ERL (Echo Return Loss) is simulated in the Bluetooth interface. The test result on the left hand side shows a nearly flat echo frequency response over the whole transmission range. The echo attenuation was determined to 19.7 dB for this device indicating that the EC is really deactivated.

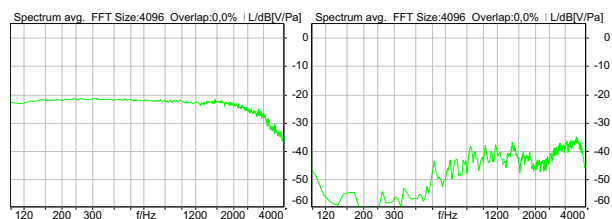


Figure 6: EC test results

Vice versa the example shown on the right hand side leads to a resulting echo loss of 37.1 dB and an echo frequency response with a very strong attenuation in the low frequency range which is typical for echo cancellers in general. This result clearly indicates that the EC is active and further attenuates the 20 dB simulated echo from the Bluetooth interface. Only 16 devices in total (25% of the tested devices) switched off all internal signal processing such as EC, NR and automatic gain control (AGC).

Result Representation

The test results can graphically be summarized in a "Quality Pie" according to ITU-T Recommendation P.505 [3].

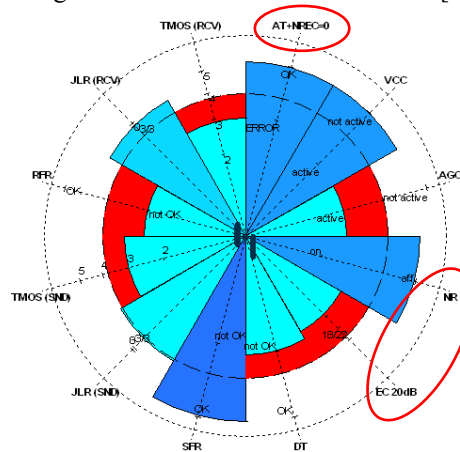


Figure 7: Quality Pie chart

The right half represents parameters related to the inter-connection and the signal processing of the mobile phone. The following parameters are represented clockwise:

- AT+NREC=0: The response of the device to the command „AT+NREC=0“
- VCC: Indicates if the volume control of the phone affects the Bluetooth link.
- AGC: Indicates if an Automatic Gain Control is active
- NR: Represents the Noise Reduction test result
- EC 20 dB: Indicates if Echo Cancellation is active
- DT: Represents an additional Double Talk test result

In the example in figure 7 the device answered with "OK" to the "AT+NREC=0" command. The tests using audio signals showed that noise reduction is actually deactivated. However, echo cancellation is still active in the mobile phone. The left half of the diagram represents three parameters for each transmission direction (Junction Loudness Rating, Frequency Response and Listening Speech Quality (TMOS)). These parameters are good indicators for the one way transmission transparency of the respective direction.

Conclusion

It needs to be stated that many Bluetooth implementations in mobile phones do not satisfy the Hands-Free Profile Specification. A large number of devices pretend to deactivate NR and EC but audio tests prove the contrary. This represents a real issue for HFT manufacturers and car manufacturers and emphasizes the need to run such verification tests.

References

[1] Bluetooth SIG, Car working group, Hands-free Profile 1.5 V10r00, Nov. 2005
 [2] ITU-T Recommendation P.1100, Narrow-band hands-free communication in motor vehicles, Oct. 2008
 [3] ITU-T Recommendation P.505, One-view visualization of speech quality measurement results, Nov. 2005