Factors impacting the speech quality in VoIP scenarios – and how to assess them

Dr.-Ing. H.W. Gierlich
HEAD acoustics GmbH
Ebertstraße 30a  D-52134 Herzogenrath, Germany
Tel: +49 2407/577 0  • Fax: +49 2407/577 99
http://www.head-acoustics.de

Overview

- Speech Quality in VoIP

- Parameters influencing speech quality – measurement procedures
  - Single talk - listening
  - Single talk – talking
  - Double talk
  - Background noise

- Summary
Speech Quality Parameters

... from the user's perspective

- talking situation
  - sidetone
  - echo
  - delay

- listening situation
  - speech quality
  - sound quality
  - naturalness
  - intelligibility

- conversational situation
  - delay
  - echo (during double talk)
  - duplex capability

Typical Signal Processing

... in terminals and gateways

- microphone
  - noise reduction
  - level switching
  - comfort
  - noise

- loudspeaker
  - coder
  - packet loss, delay, delay jitter
  - jitter buffers, PLC
### Typical IP Scenarios

- **IP - IP** connection between two IP phones
- **all kinds of signal processing in the terminal**

### Typical IP-Scenarios

- **PSTN - IP** connection between the PSTN and one IP phone
- **all kinds of signal processing in gateway and terminal**
**Typical IP-Scenarios**

- connection between two PSTN subscribers over IP
- all kinds of signal processing in gateways

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**Overview**

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Speech Quality Parameters

Listening Situation

Sound quality, intelligibility, naturalness:
- voice activity detection
- speech coders
- packet loss
- packet loss concealment
- noise reduction
- ...

Testing Techniques

Listening Situation

Analysis methods: “traditional” analysis & perceptual speech quality models
Testing Techniques

The „traditional“ numbers -

to be determined under realistic use conditions
- loudness ratings (SLR, RLR)
- frequency responses
- listener sidetone (LSTR)
- listener echo

Instrumental Measures based on Hearing Models:
Modeling the Results of Auditory Tests by Comparison of Reference Speech Signal with Processed Speech Signal

Typical Processing Steps (Schematic):

The ITU standard for electrical access
Typical Results 2nd ETSI VoIP

Test Signals and Analysis Methods

Analysis of packet loss and PLC implementation (example)
Relative Approach

- **Approach:** forward estimation based on signal history, comparison with actual signal value
  - Hearing model
  - Extrapolation in the time domain
  - Interpolation between critical bands
  - Display of estimation error = audible degradation

- **Relative Approach**

- **Relative Approach takes into account the sensitivity of the human ear**
  - on instantaneous signal variation in time
  - on dominant spectral structures
  - Relative Approach needs no reference signal

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**Basic principle of the Relative Approach:**

Comparison between short term and long term averaging of signal energies in critical bands (app. 2 s vs. 2 ms) based on a hearing model [Sottek]
Packet Loss and Concealment

The Reasons Behind the Scores...?

Transmitted time signal (5s)

Relative Approach

Cross correlation analysis vs. time

Packet Loss and Concealment
Testing Techniques

Background noise transmission - Influence of VAD

Example: Gateway - IP sim. - Gateway
- G.711 codecs
- no packet loss, no jitter
- no additional delay

*red: original test signal*
- noise sequence
- Hoth spectrum (P.800)
- increasing level vs. time

yellow, magenta, cyan: different implementations

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**Talking Situation**

...echo?

![Diagram](image)

**Delay and echo – also with background noise**
- round trip delay
- echo level and echo characteristic
- implementation of speech echo cancellers
- quality of background noise transmission

Testing Techniques

**Talking Situation**

...echo?

![Diagram](image)

**Analysis methods: echo measurements based on Composite Source Signals (CSS) under single and double talk conditions**
**Testing Techniques**

*Echo under single talk conditions - ITU-T G.131*

Requirement on echo loss depends on transmission delay

<table>
<thead>
<tr>
<th>SLR</th>
<th>JLR</th>
<th>JLR</th>
<th>RLR</th>
</tr>
</thead>
<tbody>
<tr>
<td>7dB</td>
<td>0dB</td>
<td>0dB</td>
<td>3dB</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RLR</th>
<th>JLR</th>
<th>JLR</th>
<th>SLR</th>
</tr>
</thead>
<tbody>
<tr>
<td>3dB</td>
<td>0dB</td>
<td>0dB</td>
<td>7dB</td>
</tr>
</tbody>
</table>

TELR = 10dB

*Requirement on echo loss depends on transmission delay.*

*Echo Tests according to G.168*

- Convergence and steady state residual and returned echo level tests
- Convergence test in the presence of background noise
- Leak rate test
- Infinite return loss convergence test
- Non-divergence on narrow-band signals
Overview

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Speech Quality Parameters

Conversational Situation

- propagation delay - conversation dynamics impairments
- double talk detection (EC implementation)
- echo during double talk
- level variations during double talk
**Testing Techniques**

**Conversational Situation**

- Analysis methods: double talk measurements based on two uncorrelated Composite Source Signals

**Requirements on echo and switching during double talk:**

<table>
<thead>
<tr>
<th>MOS</th>
<th>≥4.0</th>
<th>4.0-3.5</th>
<th>3.5-3.0</th>
<th>3.0-2.5</th>
<th>2.5-2.0</th>
<th>≤2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>TELR_{OT} [dB]</td>
<td>≥37</td>
<td>≥33</td>
<td>≥27</td>
<td>≥21</td>
<td>≥13</td>
<td>&lt;13</td>
</tr>
<tr>
<td>a_{Atot} [dB]</td>
<td>≤3</td>
<td>≤6</td>
<td>≤9</td>
<td>≤12</td>
<td>≤15</td>
<td>&gt;15</td>
</tr>
<tr>
<td>a_{Rtot} [dB]</td>
<td>≤3</td>
<td>≤5</td>
<td>≤8</td>
<td>≤10</td>
<td>≤12</td>
<td>&gt;12</td>
</tr>
</tbody>
</table>

TEL_R_{OT}: talker echo loudness rating during double talk

\( a_{Atot} \): attenuation range sending during double talk

\( a_{Rtot} \): attenuation range receiving during double talk
Double talk evaluation: Test result 1

Note strong echo components which occurred only during double talk but not under single talk conditions.

green: measured signal
red: original test signal
yellow: overlap

Double talk evaluation: Test result 2

Note clipping at beginning and end of most bursts and comfort noise during pauses.

green: measured signal
red: original test signal
yellow: overlap
Testing Techniques

Analysis of echo during double talk

- Analysis method: Separation of echo and near end signal by appropriate filtering

Original test signal in receiving direction

Near end signal

Echo components

Example: Measured power density spectra between 400 Hz and 1.2 kHz
**Background Noise – Double Talk**

**The work in ETSI STQ WI 011**

- Advanced measurement procedures, taking into account the conversational situation
  - Quality of background noise transmission
  - Double talk performance
  - Switching characteristics
  - Level Adjustments by Companding or AGC
  - Additional Echo disturbances
  - Speech Sound Quality
  - Loudness and Noise

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**Double talk signal**

**Background noise**

ERL 6 dB, ERL 40 dB and infinite

Testsystem ACQUA

Mouth to Ear Speech Transmission Quality Including Terminals
Automated Testing with ACQUA

MFE VI: USB-frontend for acoustical and electrical access including echo path simulation
Summary

- **Listening situation**
  - “Overview” speech quality tests => P.862 PESQ or TOSQA with acoustical components
  - Detailed investigations => Specific test signals and analysis procedures e.g. “Relative Approach”

- **Talking situation**
  - G. 168 Tests
  - Additional background noise tests

- **Double talk/conversational tests**
  - Delay tests
  - Double talk echo tests using specific test signals and analysis procedures
  - Switching tests using specific test signals and analysis procedures
  - Background noise tests during double talk

- **To do:**
  - Tests methods for noise reduction, single number for speech quality...