Voice Quality Testing
(POLQA v3, POLQA v2.4, PESQ)
Fundamentals of Perceptual Modeling

Opinion Scale for Speech Quality Tests

<table>
<thead>
<tr>
<th>Grade</th>
<th>Impairment</th>
<th>Quality of Speech</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Excellent</td>
<td>Imperceptible</td>
</tr>
<tr>
<td>4</td>
<td>Good</td>
<td>Perceptible but not annoying</td>
</tr>
<tr>
<td>3</td>
<td>Fair</td>
<td>Slightly annoying</td>
</tr>
<tr>
<td>2</td>
<td>Poor</td>
<td>Annoying</td>
</tr>
<tr>
<td>1</td>
<td>Bad</td>
<td>Very annoying</td>
</tr>
</tbody>
</table>

- The common idea behind perceptual quality measures is to mimic the situation of a subjective test, where human beings would have to score the quality of sound samples in a listening laboratory environment.
- Requires large number of subjects, very costly and time consuming; analysis based on human perception not accurate or repeatable.
PSQM - Perceptual Speech Quality Measure

Voice Quality Algorithm, ITU-P.861

PSQM (ITU-P.861) (introduced in 1997) where the voice analysis is based on an Objective algorithm, scoring 6.5 to 0 (with a conversion to the 1-5 scale). PSQM+ was also introduced to support VoIP slightly better.

- Automated algorithm
- Objectively rate both speech clarity and transmitted voice quality
- Consistency (results which are reliable and reproducible)
- PSQM uses a psycho-acoustic mathematical modelling algorithm to analyse
- Limitations
  - Not developed to account for things such as packet loss and jitter found in VoIP
  - Does not account for adverse performance in speech codecs.
Voice Quality Algorithm based on ITU-P.861

Provides both Listening Effort and Listening Quality and developed as an alternative to PSQM. Includes Time-Alignment algorithm.

### Listening Quality (LQ):
- 5 – Excellent
- 4 – Good
- 3 – Fair
- 2 – Poor
- 1 – Bad

### Listening Effort (LE):
- 5 – Complete relaxation possible (no effort needed)
- 4 – Attention necessary (no appreciable effort required)
- 3 – Moderate effort required
- 2 – Considerable effort required
- 1 – No meaning understood with any feasible effort
PESQ - Perceptual Evaluation of Speech Quality

Voice Quality Algorithm based on ITU-P.862

- PESQ (introduced in 2001) incorporates many new developments that distinguish this algorithm
  Level alignment
  - Input filtering
  - Auditory transform
  - Time alignment (adopted from PAMS)
  - PESQ LQ – closer to the Listening Quality subjective opinion scale – customer’s perception of quality
  - PESQ LQO (P.862.1) – Listening Quality Objective, correlating better to subjective test results
- PESQ WB (P.862.2) – support for WB codecs. However, PESQ had limitations with WB VoIP codecs where it was scoring too low.
GL’s PESQ Analysis

<table>
<thead>
<tr>
<th></th>
<th>Utterance 1</th>
<th>Utterance 2</th>
<th>Utterance 3</th>
<th>Utterance 4</th>
<th>Utterance 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>PESQ</td>
<td>4.25</td>
<td>4.26</td>
<td>3.75</td>
<td>4.02</td>
<td>4.06</td>
</tr>
<tr>
<td>PESQ LQ</td>
<td>4.35</td>
<td>4.36</td>
<td>3.84</td>
<td>4.15</td>
<td>4.19</td>
</tr>
<tr>
<td>PESQ LQO</td>
<td>4.37</td>
<td>4.39</td>
<td>3.88</td>
<td>4.18</td>
<td>4.21</td>
</tr>
<tr>
<td>PESQ WB</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**GL Communications**

Total Measurements: 3302
POLQA
Perceptual Objective Listening Quality Assessment

(POLQA v3, POLQA v2.4)
Voice Quality Algorithm based on ITU-P.863

POLQA (introduced in 2011) produces very similar scores as PESQ for NB codecs (uses similar mathematical techniques). However, POLQA was mainly introduced for SWB (and WB) support.

**Operations Performed by POLQA**
- Temporal alignment
- Sample rate estimation
- Resample
- Level alignment
- Frequency response and time alignment

**Results Provided by POLQA**
- MOS-LQO
- G.107 R-Factor / E-Model
- Attenuation
- Level and Background Noise Measurements
- Signal to Noise Ratio (SNR)
- Active Speech Ratio (ASR)
POLQA Algorithm

- POLQA is an objective model of subjective Listening Only Tests

- VQT POLQA supports analysis of 16-bit uncompressed PCM and WAV files, including NB (8000 sampling), WB (16000 sampling), SWB (48000 sampling)

- Revised Psycho-Acoustic and Cognitive Model

- Supports:
  - EVRC type codecs
  - Noise Reduction
  - Time-warping
  - VoIP
  - Non-optimal presentation levels
  - Filtering and spectral shaping
  - Recordings made at an ear simulator
POLQA v3 Algorithm

- POLQA v3 Upgrade Enhancements
- POLQA v3 Super Wideband (SWB) supports 14kHz to full audio bandwidth up to 24kHz.
- Full band analysis improves accuracy in assessment of codecs such as EVS, OPUS, AAC and LC3, as these codecs are used in many OTT applications.
- With Full band support the discriminative power of POLQA at the upper high-quality range of the MOS scale is increased.
- Current OTT voice services using VoLTE/5G include highly dynamic delay jitter which leads to variations of the duration of very short pauses during speech. POLQA v3 handles these variations with increased precision.
- POLQA v3 reacts with less sensitivity to linear frequency distortions than POLQA v2.4. This makes measurements less dependent on the frequency characteristics of headsets.
- Perceptual model of POLQA v3 is significantly improved and streamlined.
GL’s POLQA Analysis
POLQA Testing
• Support for WB (7kHz) and SWB (14kHz) codecs/networks
• Support for networks delivering HD-quality voice services including VoIP and Mobile
• Supports networks with variable delay and time scaling
Generate POLQA Score

Send Voice Files

Voice Channel

Record Voice Files

Dual UTA

VQuad™

Reference Voice Files

TCP/IP

VQT Analysis

TCP/IP

POLQA

POLQA Score

VQuad™ Probe

Degraded Voice Files
Centralized Voice Quality Testing

Wireless (Bluetooth®, Wi-fi, 3G, 4G, LTE, PT) Supports NB, WB

VQuad™ with Dual UTA HD

VoIP

Analog, TDM (2-wire, 4 wire)

VQuad™ Probe HD

POLQA PESQ

results

Voice Files

TCP/IP

VQT

Next Generation VQT

Central Location

Database

WebViewer™
GL Supported Connections

- USB
- T1 E1
- VQuad™ Probe HD
- Dual UTA HD
- GPS

Interfaces:
- (Bluetooth®, WiFi, 3G, 4G, LTE), Ethernet
- PTT
- Military Radios
- Balanced I/O
- HATS (Head and Torso)
- SIP/RTP
- VoIP
- PSTN/TDM
- 2-Wire FXO/FXS
- Analog & Digital Phones
POLQA Test Results

VoIP Network (NB and WB)

Polycom VoIP through G.722 Network

Polycom VoIP through NB (Skype) Network

<table>
<thead>
<tr>
<th>Polycom Tx/Rx WB Files</th>
<th>Fem Outbound</th>
<th>Fem Inbound</th>
<th>Male Outbound</th>
<th>Male Inbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fem Outbound</td>
<td>4.59</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fem Inbound</td>
<td>4.51</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male Outbound</td>
<td>4.15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male Inbound</td>
<td>4.07</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Polycom Tx/Rx WB Files</th>
<th>Fem Outbound</th>
<th>Fem Inbound</th>
<th>Male Outbound</th>
<th>Male Inbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fem Outbound</td>
<td>3.84</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fem Inbound</td>
<td>3.74</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male Outbound</td>
<td>3.58</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male Inbound</td>
<td>3.55</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
POLQA Test Results…

VoLTE (NB and WB)

Samsung4 to Samsung4 through AMR-WB Network

<table>
<thead>
<tr>
<th></th>
<th>Fem Outbound</th>
<th>Fem Inbound</th>
<th>Male Outbound</th>
<th>Male Inbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samsung4 to Samsung4</td>
<td>3.46</td>
<td>3.58</td>
<td>4.2</td>
<td>4.19</td>
</tr>
</tbody>
</table>

Samsung4 to Samsung4 through AMR Network

<table>
<thead>
<tr>
<th></th>
<th>Fem Outbound</th>
<th>Fem Inbound</th>
<th>Male Outbound</th>
<th>Male Inbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samsung4 to Samsung4</td>
<td>2.27</td>
<td>1.96</td>
<td>3.08</td>
<td>2.69</td>
</tr>
</tbody>
</table>
GL VQT Highlights

• Supports ITU Standards (POLQA v2.4 / POLQA v3.0, PESQ LQ/ LQO / WB, PAMS, & PSQM (+))
• Auto-Measurement Capabilities
• Detailed Results / Statistics
  ➢ Delay Measurement
  ➢ Noise/Signal Levels (Activity, Peak, etc.)
  ➢ Jitter (Min, Max, Average per Utterance)
  ➢ Clipping (front, back, all) (PESQ Only)
  ➢ PESQ/Delay per utterance
  ➢ Impairment Factor (Ie) measurement (PESQ only)
• Criteria Rating System
• Remote Access Capabilities
GL VQT Software
Auto Measurement

Automatically analyze the degraded files using GL VQT Software

- Detailed results including Jitter (min / max / avg), Clipping (front/back/all), Latency, and Noise / Signal Measurements (activity / peak)
- VQT uses the File Monitor to perform automated measurements on remote locations
Auto Measurement

VQT Solutions
VQT Command Line Interface

```
Administrador:C:\Windows\system32\cmd.exe - vqtcli 192.168.1.18

Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.

C:\Documents and Settings\Poornan\cd\n
C:\>cd C:\Program Files\GL Communications Inc\VQT

C:\Program Files\GL Communications Inc\VQT>vqtcli 192.168.1.18

VQT Remote Access <client> v.4.8.0

VQT IP Address: 192.168.1.18

VQT: Connecting...
Deamon: Connecting...

VQT: Connected.
VQT: Connecting...
Deamon: Connected.

vqt C:\VQT_Reference\UQuad_Auto\Raw\fem1.pcm C:\VQT_Degraded\1\record_20130321124609_1_Port1ToPort0_f2_20130321124601_p.pcm 1 1

VQT: Message sent.

PAMS LE: 4.96
PAMS LQ: 4.90
PSQM PLUS: 0.00
PESQ: 4.44
PESQ LQ: 4.47
PESQ LQD: 4.51
PESQ VB: -1.00
POLQA: 4.50
EModel: 100.00
```
## POLQA Test Results in WebViewer™

**VQT POLQA** (Display duration: 08-10-2015 03:22:52 - 08-17-2015 03:25:52)

| VQT POLQA Timestamp | Call Timestamp | VQuad Location | VQuad PhoneID | VQuad Lat/Long | Degraded Filename | Rating | POLQA Score | E-Media (R-Factor) | Speech Gain (dB) | Noise Gain (dB) | Inter-Aur (ms) | Inter-Min (ms) | Inter-Max (ms) | Active Speech Rate (%) | Active Speech Rate (%) |
|---------------------|---------------|----------------|---------------|---------------|-------------------|--------|-------------|------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|---------------------|---------------------|
| 08/16/2015 08:37:35 | 08/16/2015 08:33:03 | WebViewer™ TV | VQFXX0-7DBF4527 | 7077/12/57 | fem1PQOA.PCM Good | 3.31 | 64.15 | -7.89 | 5.15 | 3.81 | 0 | 7.62 | 0.57 | 0.41 | 2 | _GLRbdfvQX0Test_VQFXX0-2_20150816083303 |
| 08/16/2015 08:37:35 | 08/16/2015 08:33:03 | WebViewer™ TV | VQFXX0-7DBF4527 | 7077/12/57 | fem1PQOA.PCM Fair | 2.99 | 57.96 | -9.80 | 3.85 | 2.25 | 0 | 4.50 | 0.57 | 0.41 | 2 | _GLRbdfvQX0Test_VQFXX0-1_20150816083303 |
| 08/16/2015 08:37:36 | 08/16/2015 08:33:03 | WebViewer™ TV | VQFXX0-7DBF4527 | 7077/12/57 | fem1PQOA.PCM Good | 3.31 | 64.07 | -8.81 | 5.21 | 2.50 | -5 | 0 | 0.57 | 0.41 | 2 | _GLRbdfvQX0Test_VQFXX0-2_20150816083303 |
| 08/16/2015 08:36:42 | 08/16/2015 08:33:03 | WebViewer™ TV | VQFXX0-7DBF4527 | 7077/12/57 | fem1PQOA.PCM Good | 3.02 | 58.47 | -8.11 | 3.97 | 0 | 0 | 0 | 0.57 | 0.41 | 2 | _GLRbdfvQX0Test_VQFXX0-1_20150816083303 |
| 08/16/2015 08:37:00 | 08/16/2015 08:33:03 | WebViewer™ TV | VQFXX0-7DBF4527 | 7077/12/57 | fem1PQOA.PCM Good | 3.14 | 64.29 | -8.82 | 5.21 | 2.10 | 0 | 0 | 0.57 | 0.41 | 2 | _GLRbdfvQX0Test_VQFXX0-2_20150816083303 |
| 08/16/2015 08:32:09 | 08/16/2015 08:33:03 | WebViewer™ TV | VQFXX0-7DBF4527 | 7077/12/57 | fem1PQOA.PCM Good | 3.11 | 60.28 | -8.11 | 3.72 | 3.94 | -7.88 | 0 | 0.57 | 0.40 | 2 | _GLRbdfvQX0Test_VQFXX0-1_20150816083303 |
| 08/16/2015 08:31:52 | 08/16/2015 08:33:03 | WebViewer™ TV | VQFXX0-7DBF4527 | 7077/12/57 | fem1PQOA.PCM Good | 3.17 | 61.39 | -8.82 | 5.15 | 1.25 | 2 | 2.50 | 0.57 | 0.41 | 2 | _GLRbdfvQX0Test_VQFXX0-2_20150816083303 |
| 08/16/2015 08:31:33 | 08/16/2015 08:33:07 | WebViewer™ TV | VQFXX0-7DBF4527 | 7077/12/57 | fem1PQOA.PCM Good | 3.01 | 58.38 | -9.82 | 3.96 | 1.94 | -3.88 | 0 | 0.57 | 0.41 | 2 | _GLRbdfvQX0Test_VQFXX0-2_20150816083303 |
| 08/16/2015 08:31:16 | 08/16/2015 08:33:07 | WebViewer™ TV | VQFXX0-7DBF4527 | 7077/12/57 | fem1PQOA.PCM Good | 3.00 | 59.09 | -9.02 | 2.02 | 4 | -9 | 0 | 0.57 | 0.41 | 2 | _GLRbdfvQX0Test_VQFXX0-1_20150816083303 |
| 08/16/2015 08:30:26 | 08/16/2015 08:33:07 | WebViewer™ TV | VQFXX0-7DBF4527 | 7077/12/57 | fem1PQOA.PCM Good | 3.15 | 60.09 | -8.60 | 5.52 | 3.88 | 0 | 7.75 | 0.65 | 0.41 | 2 | _GLRbdfvQX0Test_VQFXX0-2_20150816083303 |
| 08/16/2015 08:30:00 | 08/16/2015 08:33:07 | WebViewer™ TV | VQFXX0-7DBF4527 | 7077/12/57 | fem1PQOA.PCM Good | 3.02 | 58.48 | -8.60 | 3.87 | 1.88 | -3.75 | 0 | 0.57 | 0.41 | 2 | _GLRbdfvQX0Test_VQFXX0-1_20150816083303 |
| 08/16/2015 08:28:35 | 08/16/2015 08:33:07 | WebViewer™ TV | VQFXX0-7DBF4527 | 7077/12/57 | fem1PQOA.PCM Good | 3.30 | 55.42 | -7.99 | 5.00 | 0 | 0 | 0 | 0.57 | 0.41 | 2 | _GLRbdfvQX0Test_VQFXX0-2_20150816083303 |
POLQA Statistics

![POLQA Chart]
VQT Results over Time
Google Map Plotting
Thank You