IWCE College of Technology Training March 2011

Vocoders and P25 Audio Quality
Chris Wilson

MOTOROLA SOLUTIONS
Agenda

• Turning voice to bits
• P25 Digital Vocoder
• Audio Performance Working Group
VOICE TO BITS
TURNING VOICE INTO BITS – LEGACY

- Waveform encoder (PCM)
  - Pulse Code modulation – invented in 1937
  - Encode the shape of the audio signal
    - Voice, tones, noise energy all processed the same
  - Samples the voltage level of the audio signal
  - Converts the voltage level into 8 bits per sample (64kbit ulaw)
  - 8,000 samples per second
  - 8 bits/sample \( \times \) 8,000 samples/second = 64,000 bits/second
TURNING BITS INTO VOICE - LEGACY

- The 8-bit waveform samples are converted to discrete voltages
- These discrete voltages are the ‘quantized’ levels
- The imperfect waveform contains ‘quantification noise’
- Voice band filtering rejects the higher frequency quantification noise
- Process results in very good waveform reproduction
TURNING VOICE INTO BITS – CELL PHONES

- Various schemes to increase utilization of RF bandwidth
  - Change the speech coder rate and processing based on system and user conditions
- 3GPP defined a Adaptive Multi Rate speech coder (AMR) family
  - Has eight coder rates from 12.2kb/s to 4.75 kb/s
  - Use techniques such a discontinuous transmit, voice activity detection and ‘comfort noise’
- 3GPP2 defined a Enhanced Variable Rate Coder (EVRC) family
  - EVRC-B uses four different coding rates 8.5, 4.0, 2.0, and 0.8 kbps
  - Higher rate used for voice, lowest for noise; different speech coders as well
  - Other rates used for balancing system loading
TURNING VOICE INTO BITS – P25

- P25 voice encoders (xMBE)
  - Voice energy is analyzed according to a complex MBE speech model
  - The MBE model divides the speech spectrum into separate frequency bands
  - Each band is analyzed separately
  - The MBE model determines the voice energy to noise energy by band
    - High ratio of periodic energy to noise-like energy = **Voice**
    - Low ratio of periodic energy to noise-like energy = **Unvoiced**

P25/TIA-102.BABA Vocoder Description
P25 DIGITAL VOCODER

- Multi-Band Excitation (xMBE)
- 4,400 b/s Ph1 (FDMA) vocoder data rate
  - 7,200 b/s with forward error correction bits
  - Referred to as ‘FULL RATE’ vocoder
- 2,450 k/s Ph2 (TDMA) vocoder data rate
  - 3,600 b/s with forward error correction bits
  - Referred to as ‘HALF RATE’ vocoder
- Low Bit Vocoders required for P25 Narrowband Radio channels
DIGITAL ‘VOCODER’

• ‘Vocoder’ is an acronym
  – Vocoder = Voice Coder/Decoder
  – The ‘Coder’ is used to ‘encode’ the analog voice into a digital format
  – The ‘Decoder’ is used to decode the digital format into analog voice

• What does a vocoder do?
  – Digital encoding and decoding of human speech usually performed by Digital Signal Processor (DSP) hardware and software
  – The vocoder’s purpose is to synthesize a speech signal that contains the same perceptual information as the original speech signal
  – The low bit rate vocoders are optimized for the encoding of human speech, not tones or background noise
  – Additional software capability added to transfer tones and reduce background noise before encoding
P25 Vocoder Block Diagram

- Significantly more details available in the P25/TIA Vocoder Standard documents
  - P25/TIA-102.BABA Vocoder Description
  - P25/TIA-102.BABA-1 Half-Rate Vocoder Annex
ENHANCED VOCODER FOR TDMA

• Background noise reduction now included of vocoder software
• Improved forward error correction
• DTMF, call progress and Knox Box tone signaling can be transferred through the vocoder
• Specific single tones can be transferred through the vocoder
TIA-102 ENHANCED VOCODER TESTING

• P25/TIA has developed standardized performance tests for the P25 Enhanced vocoder
  – TIA-102.BABG Project 25 Enhanced Vocoder Methods of Measurement for Performance
• Intention of the testing is to verify the software version of an implemented vocoder has the same resulting performance as the software version of the reference dual rate vocoder used in the Phase 2 vocoder selection process
• SDoCs and STRs for P25 CAP require manufacturer to state which version of the vocoder is contained in the product being declared compliant
P25/TIA VOCODER TESTING

• The P25 Enhanced Vocoder is tested for defined ‘listener quality objectives’ with background noises.

• The following noise environments are listed in TIA-102.BABG Project 25 Enhanced Vocoder Methods of Measurement for Performance

<table>
<thead>
<tr>
<th>Noise Environment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pink</td>
<td>Helicopter</td>
</tr>
<tr>
<td>Babble</td>
<td>Boat</td>
</tr>
<tr>
<td>Car</td>
<td>Fire Truck Pump</td>
</tr>
<tr>
<td>Street</td>
<td>Dual PASS Alarm</td>
</tr>
<tr>
<td>Police Siren</td>
<td>Low Air Alarm</td>
</tr>
<tr>
<td>Fire Siren</td>
<td>Fog Nozzle</td>
</tr>
<tr>
<td>Fire without Siren</td>
<td>Rotary Saw</td>
</tr>
<tr>
<td>Chainsaw</td>
<td></td>
</tr>
</tbody>
</table>
AUDIO PERFORMANCE WORKING GROUP (APWG)
APWG
Past, Present and Going Forward

• Audio Performance Work Group was formed under the APCO Project 25 Interface Committee (APIC)
  – Continues the investigations and testing done started in the Digital Project Working Group (DPWG)
  – DJ Atkinson from the PSRC (Boulder, CO) has lead and authored the next experiment with APIC review meetings covering the experiment scope and testing methods
• APWG developed a new test plan (APWG Experiment 1) to compare analog vs. digital voice
  – Measuring voice intelligibility (MRT) in the presence of various background noises
  – Public Safety Practioners are the test ‘ears’
• The APWG will make recommendations to APIC following the completion of the performance benchmark testing
APWG - EXPERIMENT 1

• The APWG looks into public safety scenarios where digital radio intelligibility performance could be improved when referenced to analog performance

• ‘Experiment 1’ benchmarks performance of analog 25, analog 12.5 and a new version of the Enhanced P25 vocoder with background noise

• ‘Experiment 1’ also compares performance between different SCBA masks; one with the mic outside, one with the mic inside

• This experiment uses software simulations of
  – Radio reference models (25, 12.5 and P25 – full rate and half rate vocoder)
  – RF channel environments (Strong RF signal, weak RF signal)

• The use of software reference models for the radios and RF channel environments allows the test plan to focus on specific tests while reducing the variability of the results
DIGITAL AUDIO AT IWCE EXPO

- Two Conference sessions on digital audio
- Wednesday March 9th
- Digital Radio for Firefighters
  - Session W17 3:00 pm – 4:15 pm
    - Part 1: Digital Audio Quality Review
      - DJ Atkinson from PSCR
  - Session W23 4:30 pm – 5:45 pm
    - Part 2: The Impact of Technology
      - Moderator: Donald Jackson
QUESTIONS?
THANK YOU... 

Chris Wilson
chris.wilson@motorolasolutions.com
847-576-6345