Digital Voice in Amateur Radio

John DeGood NU3E
nu3e@arrl.net

Trenton Computer Festival
Sat 3 May 2003
David Sarnoff Radio Club
Tue 20 May 2003

1936 Bell Labs Voice Coder

- World's first electronic speech synthesizer
- Required an operator with a keyboard and foot pedals to supply "prosody" — the pitch, timing, and intensity of speech

from http://www.bell-labs.com/org/physicalsciences/timeline/span6.html

Early History of Digital Voice

- 1936 - Bell Labs “Voice Coder” (Voder)
- 1940s - Public Switched Telephone Network (PSTN) digital trunk lines
- 1940s - Delta Modulation (DM)
- 1960s - NASA Apollo waveform clipping
- 1970s - Continuously Variable Slope Delta Modulation (CVSD)
- 1980s - Adaptive Differential Pulse Code Modulation (ADPCM) - ITU G.721

Choosing Sample Rate

- Nyquist Criterion
  - 300-3300 Hz -> minimum sample rate 6.6 kHz
  - to simplify anti-aliasing filter, typically use 8 kHz

Choosing Bit Resolution

- Quantization limits Signal-to-Noise Ratio (SNR)
  - SNR ≈ (6N - 1.75) dB, where N = bits/sample
  - typically use 8 bits ≈ 46 dB for “good” quality

Choosing Bit Rate

- 8 bits/sample * 8 kHz = 64 kbps

Shannon's Information Theorem

- Typical voice mode bandwidths
  - HF SSB = 3 kHz
  - VHF NBFM = 12 kHz
- 64 kbps @ 3 kHz BW ≈ 64 dB SNR
- 3 kbps @ 3 kHz BW ≈ 10-15 dB SNR

Voice Compression Schemes

- Waveform Coders
  - can represent any waveform
- Model Based Speech Coders
  - exploit the nature of human speech and hearing
  - use a parametric model to approximate short (10-40 ms) segments of speech
  - may be language-specific
  - may sacrifice recognition of who is speaking

Speech Coding Timeline

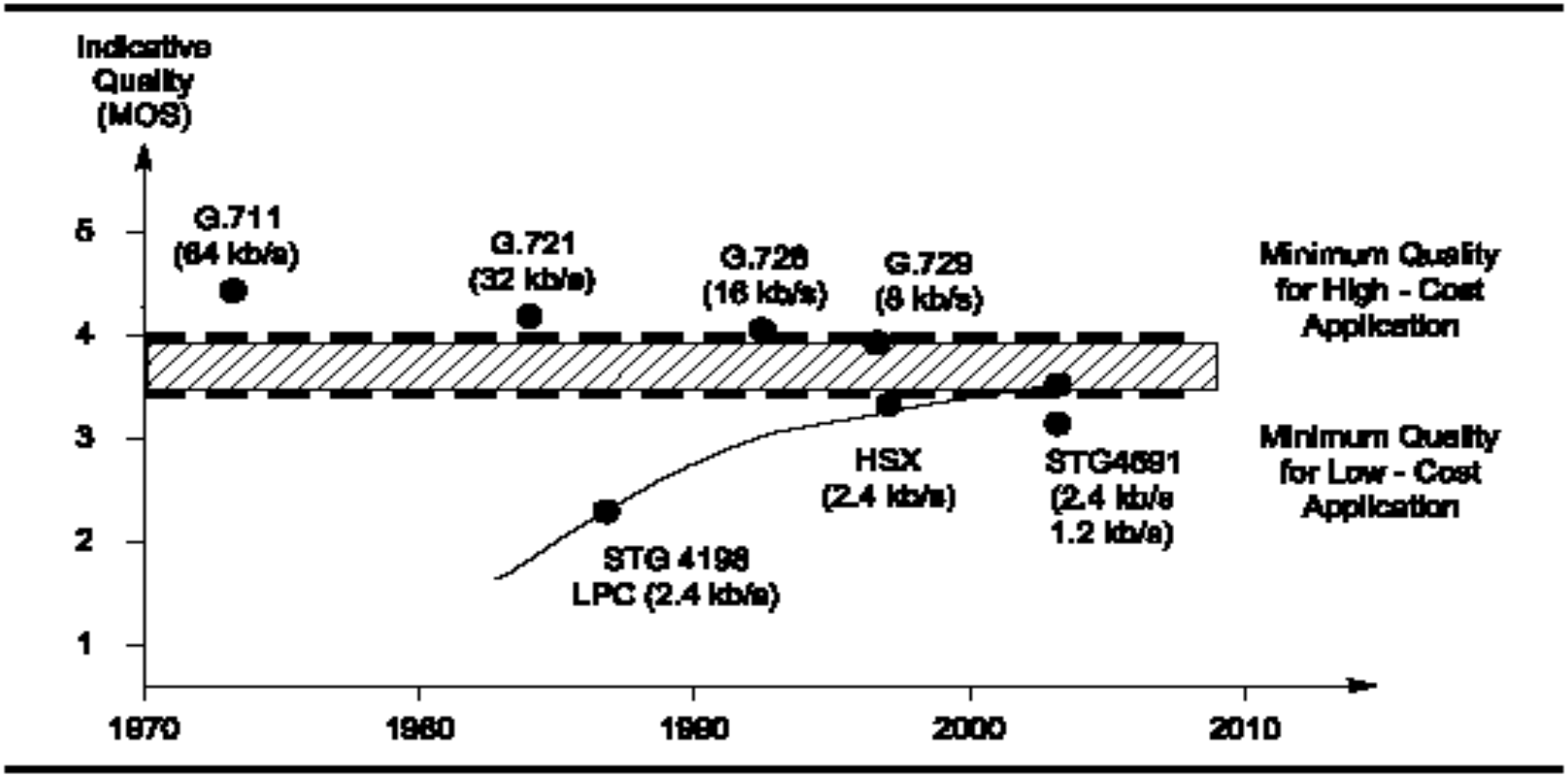


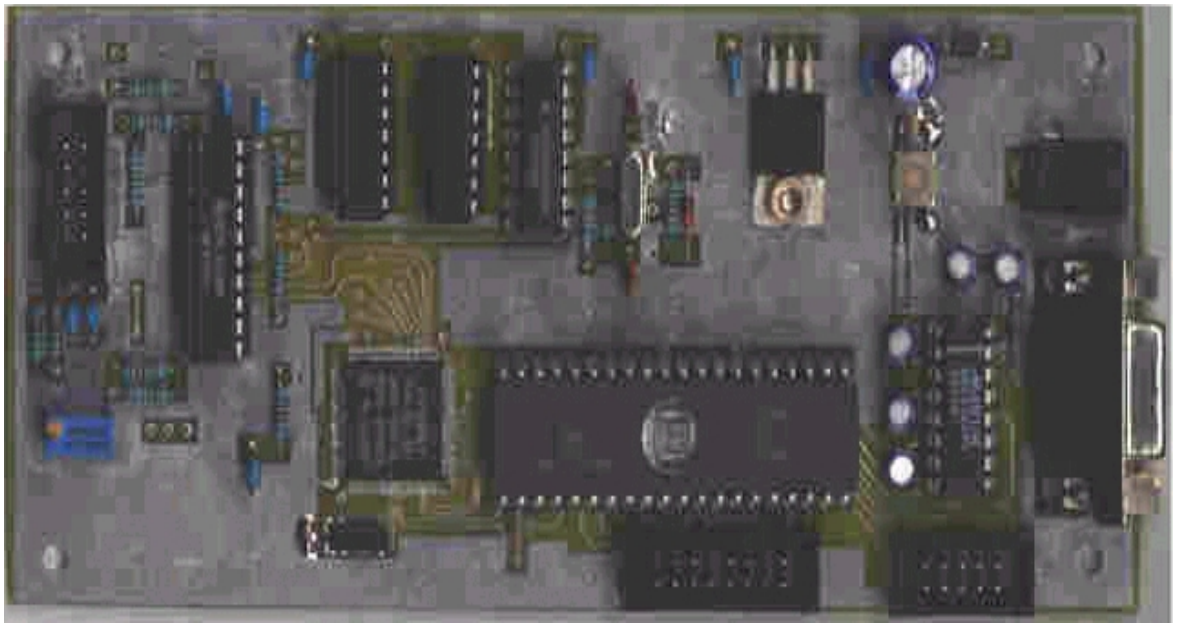
Fig 5—Evolution of voice coders quality through time.

from "International Digital Audio Broadcasting Standards: Voice Coding and Amateur Radio Applications", Cedric Démeure and Pierre-André Laurent, QEX Jan/Feb 2003

Practical HF Digital Voice

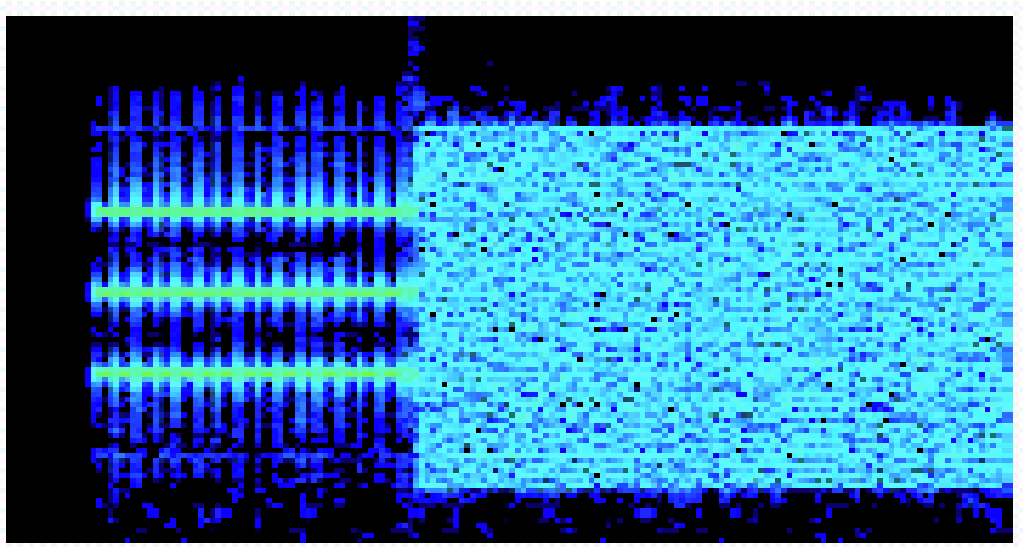
- Charles Brain G4GUO and Andy Talbot G4JNT [QEX, May/June 2000]
- First QSO: 27 Mar 1999, 70 km, 40 meter band
- Requires about 25 dB of SNR to function
- “Telephone conversation” quality
- Tolerant of CW and multipath selective fading
- Intolerant of SSB interference

G4GUO AMBE Vocoder



- DVSINC AMBE1000+ speech vocoder @ 2400 bps
- Motorola MC14LC5480P μ-law codec
- FEC (Hamming + Golay coding) @ 1200 bps
- PIC 17C44 @ 29 MHz

G4GUO Modem



- 3-Tone BPSK preamble
- Start-of-Message BPSK sequence
- Voice Data
- End-of-Message BPSK sequence

Is Digital Voice Legal on the Amateur Bands?

- FCC Part 97
  - phone signals [analog or digital] must remain in the phone subbands [47 CFR 97.305]
  - no transmission shall occupy more bandwidth than necessary for the information rate and emission type being transmitted, in accordance with good amateur practice [47 CFR 97.307(a)]

International Broadcasting Standards

- Digital Radio Mondiale (DRM)
  - ITU standard for digital radio broadcasting below 30 MHz
  - proposed AM Broadcast Radio replacement
  - COFDM transmission
  - choice of 3 audio coding methods
    - MPEG4 AAC audio
    - MPEG4 CELP speech
    - HVXC speech (very low bit rate)
  - http://www.drm.org

Factors Limiting Adoption

- Little commercial availability
- Vocoder licensing issues
- Poor weak signal performance
- High computational requirements
- Soundcard latency in PC/Windows architecture
  - limits fast turn-around applications like digital voice
- Regulatory questions
  - simultaneous voice & data (SVD) may not be allowed
  - some systems use symbol rates > 300 baud on HF

The Future of Digital Voice

- May supercede FM in most VHF/UHF applications
- May be used with advanced signal processing to send voice (much) slower than real time
  - Use for EME (moonbounce) voice contacts
  - Use for voice over meteor scatter and other transient propagation modes
  - Use to shatter voice distance records!

Reference Information

- ARRL Digital Voice Information, including many downloadable articles
  - http://www.arrl.org/tis/info/digivoice.html
- G4GUO HF Digital Voice on HF
  - http://www.chbrain.dircon.co.uk/dvhf.html
- Temple University Digital Voice Project
  - http://www.temple.edu/k3tu/digital_voice.htm

Reference Information

- TAPR Digital Voice Information
  - http://www.tapr.org/tapr/dv/
- TAPR Digital Voice Mailing List
  - http://www.tapr.org/cgi-bin/lyris.pl?enter=digi-voice&text_mode=0
- DVS AMBE Vocoder Information
  - http://www.dvsinc.com/