Digitized Voice
Speech Synthesis and Vocoders

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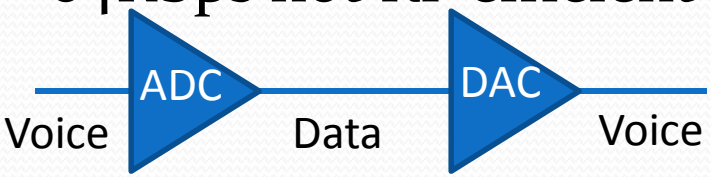
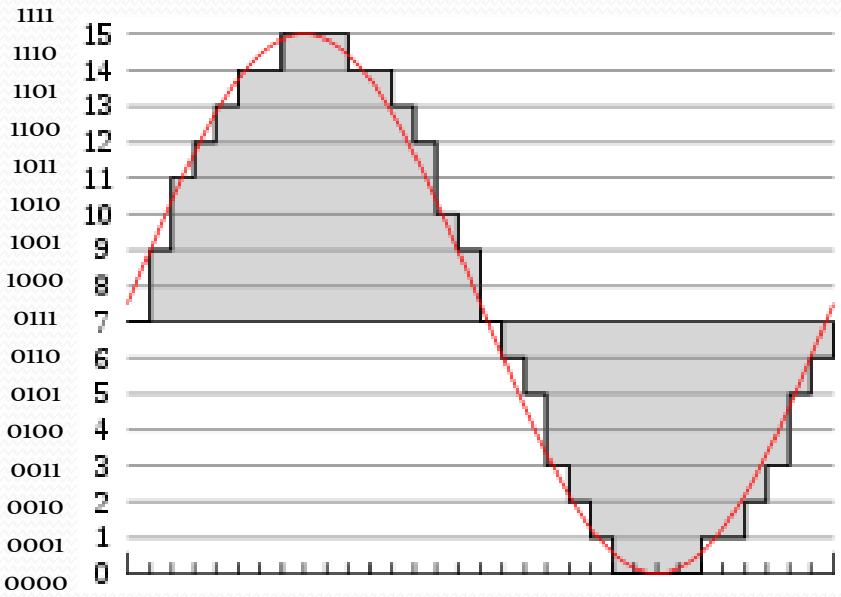
Why Digital Voice?

- Data speed or RF bandwidth reduction
- Transmission by shared digital media such as T1s
- Security and encryption
- PCM or ADPCM first US Patent in 1943 for Telco voice mux
- Speech Synthesis
  - Computers generating speech
  - Playing stream of pre-recorded phonemes
  - New systems can model the human vocal tract
- Vocoders
  - Compress voice into lower data speed without losing too much intelligibility
  - Reduce audible noise or interference

Pulse Coded Modulation

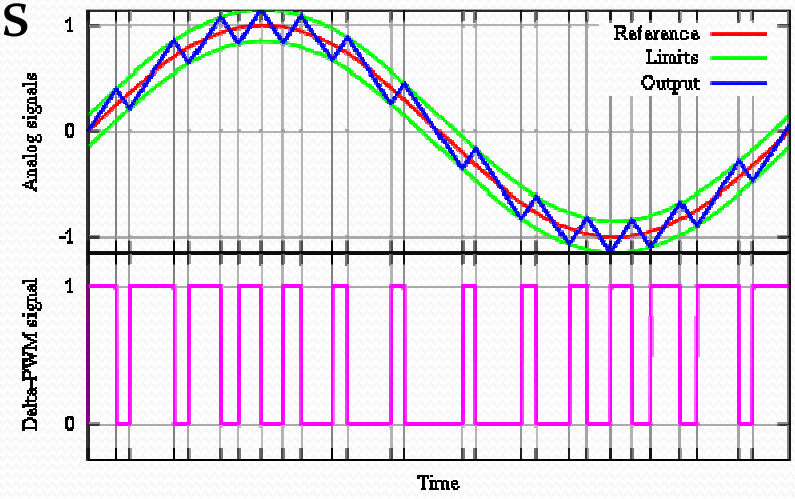
- Used by Telco to multiplex or combine multiple analog telephone lines onto a single pair of wires
- For complete reproduction you need to sample at twice the highest voice frequency (Nyquest Criteria)
- This is typically 8 KHz for a 4 KHz voice circuit and 8 bits per sample = 64Kbps
- This shows a 4 bit sampling 2 to 4th power = 16 levels
- More bits per sample means less “stair steps” (quantization errors)
- 64Kbps not RF efficient





Variations of PCM

- u-LAW compression maps 13-14 sample bits into 8 bits
- LPCM – Linear PCM uses fixed sample levels
- DPCM – Differential PCM stores difference between actual sample value and a predicted value = saves 25% bits
- ADPCM – Adaptive PCM allows 8 bit u-LAW into 4 bits
- Delta Modulation only requires 1 bit per sample but requires a higher sampling rate = full quality with 24Kbps



Codec

- COder-DECoder
  - Used to digitize and reproduce audio, pictures, video signals
  - Codecs can be loss-less (full reproduction)
  - Codecs can be lossy (more efficient, sacrifice quality)
  - Examples: MP3, MPEG1-4, JPEG
- Vocoder is a Codec used to process voice signals
  - Some work better in different environments such as low signal to noise, fading circuits, etc.
  - Examples: AMBE (D-Star), AMBE+2 (MotoTRBO), IMBE (P25), VSELP (Astro), Codec 2 (FreeDV)

Vocoder Comparison

Name	Use	Kbps	Channel KHz	Quality	Commercial
AMBE	D-Star	4.8 (2.4 voice, .95 data)	6.25	OK	DVSI license proprietary
AMBE+2	MotoTRBO	4.8 (3.6 voice)	6.25e (2 slot TDMA)	Good	DVSI license proprietary
IMBE	APCO P25	7.2 (2.8 FEC)	12.5	Good	DVSI license proprietary
VSELP	Astro	8	12.5	Good	Earlier Cellular ITU Standard
Codec 2	FreeDV	1.4 (.025 ID)	1.125	OK	Open source
4bit ADPCM	IRLP	32	IP Ethernet only	High	Public Domain
GSM 06.10	Echolink	8	IP Ethernet only	OK	Public Domain

Did You Know This?

- New Icom IC7100 will have DV on HF frequencies?
- Perhaps just on 10 meters (spec sheet shows 28.0-29.7 MHz)
- Icom web site demo video mentioned DV on 80 meters
- Price?
- Availability?
- FCC Certification Pending

Codec 2 and FreeDV modem

- 50 baud 14 QPSK voice data
- One center BPSK carrier with 2x power for fast and robust synchronisation
- 1.125 kHz spectrum bandwidth (half SSB) with 75 Hz carrier spacing
- 1400 bps data rate with 1375 bps open source Codec 2 voice coding and 25 bps text for call sign ID and canned text
- No time interleaving or FEC philosophy provides low latency, fast synchronization, quick recovery from fades
- 44.1 or 48KHz sample rate sound card compatible

FreeDV Features

- Cross platform, runs on Windows or Linux
  - ports underway for MacOS and FreeBSD
- Open source, patent free Codec and Modem that anyone can experiment with and modify
- Waterfall, spectrum, scatter and audio oscilloscope displays
- Adjustable squelch
- Fast/slow S/N ratio estimation
- Microphone and Speaker signal audio Equalizer
- Control of Transmitter PTT via RS232 levels
- Works with one (receive only) or two (transmit and receive) sound cards, for example a built in sound card and USB headphones
- FreeDV most often found on 14.236 MHz

Why Open Source is Important

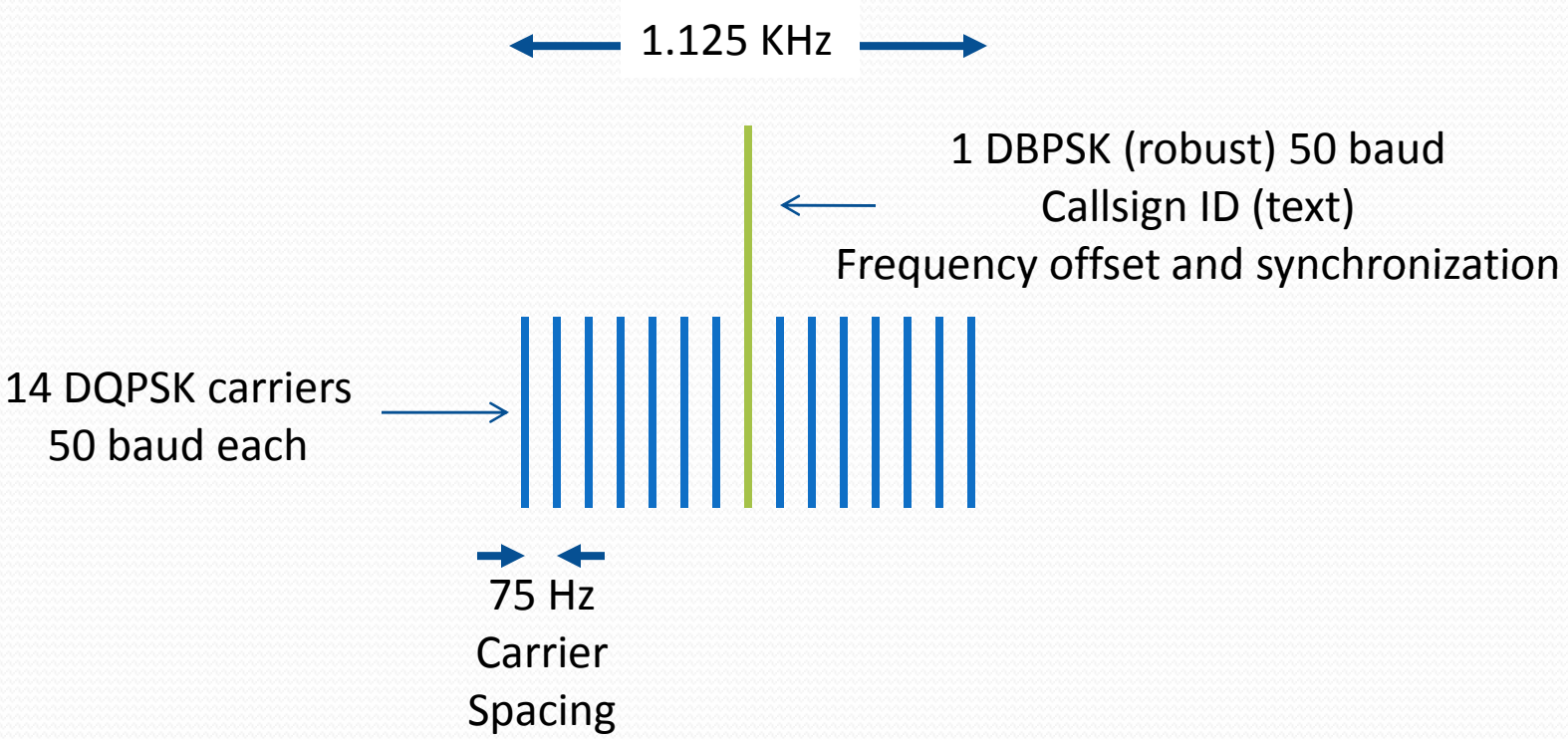
- Amateur Radio is transitioning from analog to digital
  - Similar to AM to SSB transition in 1960's
- How would you feel if one or two companies owned the patents for SSB, then forced you to use their technology, made it illegal to experiment with or even understand the technology, and insisted you stay locked to it for the next 100 years?
  - That's exactly what *was* happening with DVSI digital voice
  - But now, hams are in control of their technology again!
- FreeDV is unique
  - 100% Open Source Software, *including* the audio codec
  - No secrets, nothing proprietary!
  - FreeDV represents a path for 21st century Amateur Radio where Hams are free to experiment and innovate, rather than a future locked into a single manufacturers closed technology

FreeDV Specifications

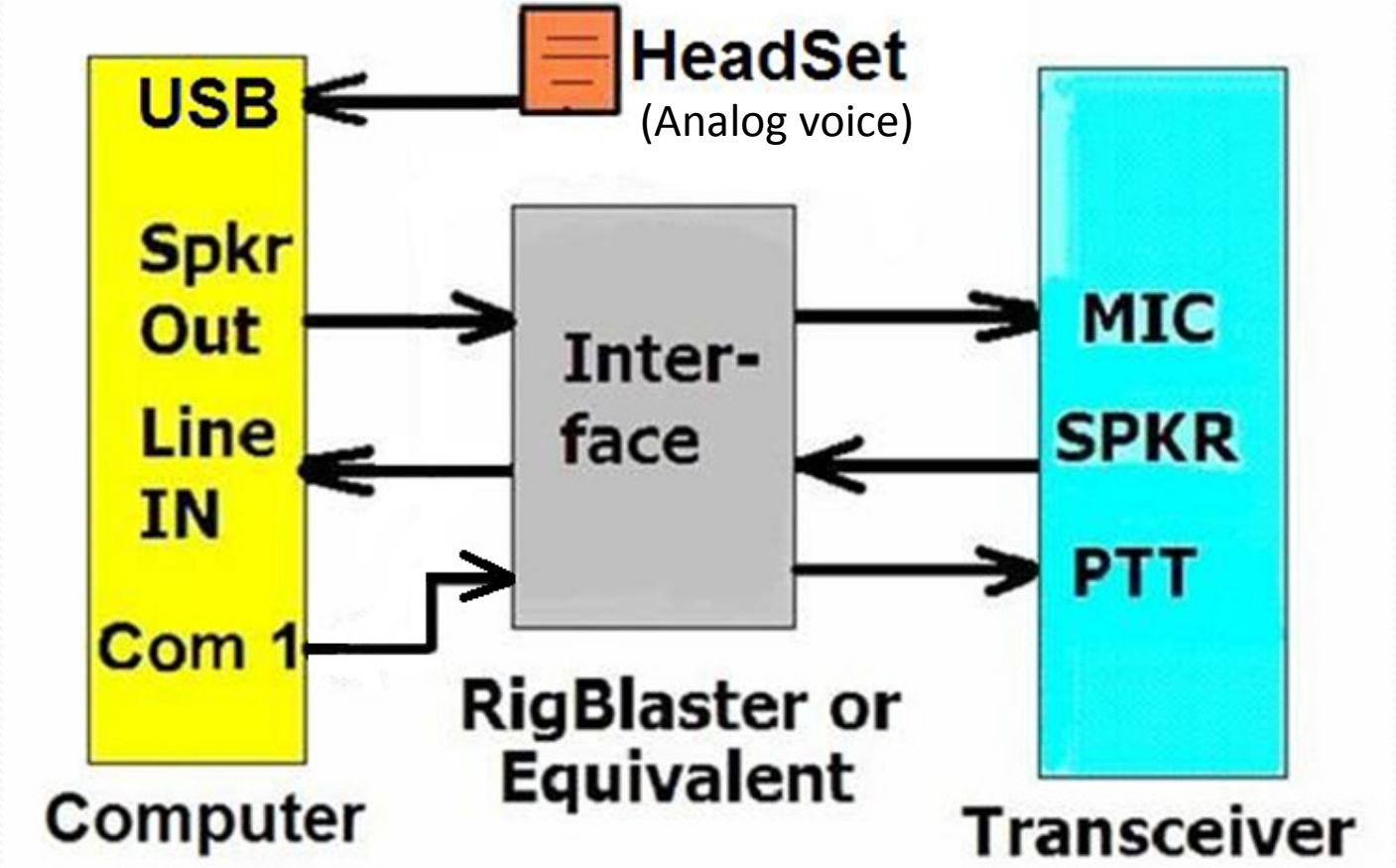
- Digital voice mode intended for HF radio
- Uses FDM modem with 15 carriers and no forward error correction (FEC)
- Codec 2 provides voice quality without listener fatigue caused by noise and interference normally associated with analog SSB voice
- One soundcard for receive only, two soundcards for analog and digital transceive
- Path simulation and on-the-air HF testing have shown that decoding voice is possible at a signal-to-noise ratio of 4 dB
- ITU emission designator 1K20J2E
- Modulator accurate to within +/- 5 Hz
- Demodulator automatically acquires signals with +/-200Hz frequency offset
- Manual tuning by clicking on watterfall and spectrum displays
- AFC capable of correcting frequency drift of up to 50 Hz/minute

- March 23 update
  - New version 0.96 provides a 1600 bps mode that communicates at *much* lower signal levels than previously
  - Communications should be readable down to 2 dB S/N, and long-distance contacts are reported using 1-2 w power
  - Compatibility mode for communication with older 0.91 version included
  - Windows version presently available, Linux and other platforms soon

FreeDV Waveform



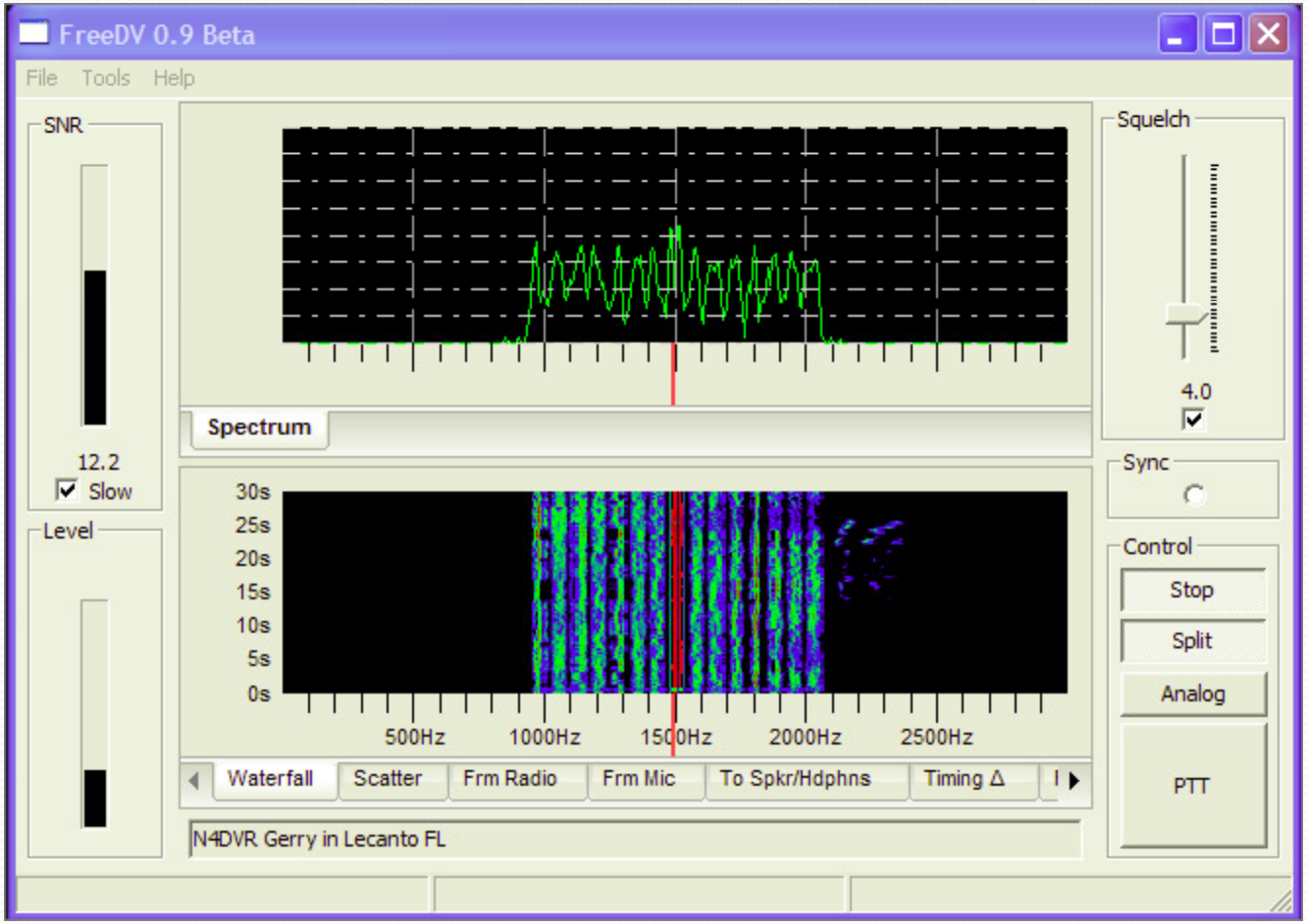
FreeDV Wiring Diagram



Just like other digital modes except you need a separate headset with microphone for analog voice

Windows FreeDV GUI

Need
2-10dB
For good
quality



Received callsign and other canned text

FreeDV Authors and contributors

- FreeDV coded from scratch
  - David Witten (GUI, architecture)
  - David Rowe (Codec 2, modem implementation, integration)
- FreeDV design and user interface is based on FDMDV
  - Developed by Francesco Lanza, HB9TLK
  - Modem design advice from Peter Martinez G3PLX
- FDMDV design, testing, promotion
  - Mel Whitten, KoPFX
- Alpha testers
  - Gerry, N4DVR; Jim, K3DCC; Rick, WA6NUT; Tony, K2MO
- Open source, patent free inspiration
  - Bruce Perens

Demo videos

Windows User Guide Web Page

http://freedv.org/tiki-index.php?page=Microsoft+Windows+Quick+Start+Guide

Windows Video User Guide

http://www.youtube.com/watch?feature=player_embedded&v=zijJ556cs08

DV Microphone settings

http://www.youtube.com/watch?v=7pSj7IZfGKI

Software available at www.freedv.org