MOONEER SALEM K6AQ

MACHINE LEARNING AND FREEDV

ABOUT ME

- Been licensed since the early 2000s
  - KG6AOV was my original callsign
- Currently a software developer at a medical device company
  - Primarily C/C++ with some C# and Python thrown in
- Do open source development in my spare time
  - FreeDV being the biggest so far

WHAT IS DIGITAL VOICE?

- Like livestreaming, but for radio
  - Microcontroller or PC converts your analog voice into 1s and 0s
  - Data is then modulated into a signal that our radios can transmit
- Reverse process happens on RX
  - Device demodulates back to 1s and 0s
  - Sound card produces analog signal to speakers/headset

WHY USE DIGITAL VOICE?

- Less bandwidth than a similar analog signal
  - Many digital voice modes cut this in half or potentially more
  - Smaller bandwidth => higher power density => lower minimum SNR
- Digitization of received signal inherently adds some noise immunity
  - Forward error correction can potentially fix significant issues (with various tradeoffs)

DISADVANTAGES OF DIGITAL VOICE

- Your signal is either Q5 or Q0 (“digital cliff effect“)
  - Example: Analog TV vs. ATSC digital TV during DTV transition
- Traditionally didn’t sound as good as a 59 FM or SSB signal (for example)
  - “Robotic” quality to the audio
  - Still understandable but could be better

CHALLENGES OF DV ON HF

- To fit in the available spectrum, we have to drop stuff that's "unnecessary"
  - Very low frequencies (< 500 Hz), frequencies not possible on SSB (> 3-4 kHz)
  - Still need to reconstruct them at the other end
- For specific use cases (e.g. speech), we can simplify even further
  - Sinusoidal speech coding - sending just fundamental frequencies and "voicing" data (Codec2)

WHAT DOES FREEDV PROVIDE

- Digital voice optimized for HF band conditions
  - Narrow enough to not annoy other hams :)
  - Better able to handle fading, etc.
- A way to use digital voice with your existing radios
  - If you’re already using FT8, you can use FreeDV

FREEDV HISTORY

- Originally a program called FDMDV (mid-2000s)
  - Issues with company that created its codec killed the project
- Codec2 (open source DV library) created by David Rowe VK5DGR in response
  - Multiple different modes available (700-3200bps)
  - Integrated into the FreeDV application

FREEDV ISSUES

- The audio quality wasn't ideal
  - Same "robotic" type sound as DMR, etc.
  - Lower bitrate made the problem worse
  - Some voices sounded worse than others
- For example…

FREEDV ISSUES

- Different modes created for different HF band conditions
  - Adds confusion for the user
  - Most users coalesced around 1-2 modes anyway
- For some, SNR still needed to be fairly high to be able to be decoded

WHAT IS MACHINE LEARNING?

- A way for a system to generalize based on its training data
  - Typically requires a lot of training data (i.e. tens or hundreds of hours of audio)
  - Lots of math done during training and inference (i.e. matrix multiplication)
- Traditionally wasn’t viable on common hardware even a few years ago
  - ChatGPT et al now a click away
  - AI-optimized embedded microcontrollers becoming increasingly available

HOW CAN WE USE MACHINE LEARNING FOR DV?

- Better modeling of speech
  - Can use previously received audio as well as current audio slice to predict “next” slice
- Help better decode an OTA digital signal
  - Modeling various HF propagation conditions during the training process
  - Iterate the model based on real world testing

EXISTING MACHINE LEARNING CODECS

- Several efforts have been made to use ML for audio compression
  - EnCodec (https://github.com/facebookresearch/encodec)
  - Lyra (Google)
  - MLow (https://engineering.fb.com/2024/06/13/web/mlow-metas-low-bitrate-audio-codec/)
- Still need more bandwidth than available on HF

ENTER RADIO AUTOENCODER (RADE)

- Uses voice features (pitch, etc.) to generate PSK signals to send OTA
- Decoder converts back to features that the voice codec can use to generate audio
- Currently uses the FARGAN voice codec (Opus)
  - Theoretically could be used with most similar codecs

HOW DOES RADE SOUND?

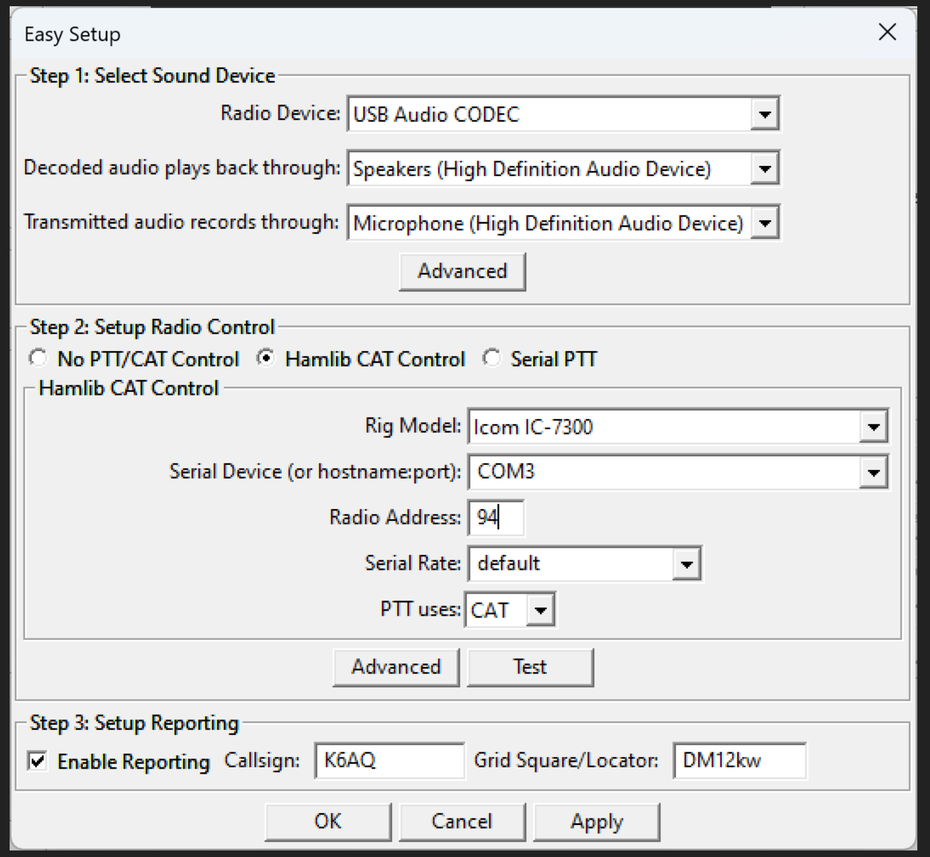
- RADE vs. SSB (low SNR)
  - SSB signal fairly noisy but RADE 100% intelligible
  - Test performed August 2024 (https://freedv.org/davids-freedv-update-september-2024/)
    - 25 watts (peak, including SSB compression) from Texas to Australia
    - More tweaks and updates made since then

GETTING ON THE AIR

- FreeDV client application
  - Available at https://freedv.org/
  - Binaries for Windows (32/64 bit) as well as Mac (Intel/ARM)
  - Source code on GitHub
- Requires two sound cards to transmit
  - One of them is likely the same one you use for other digital modes

EASY SETUP

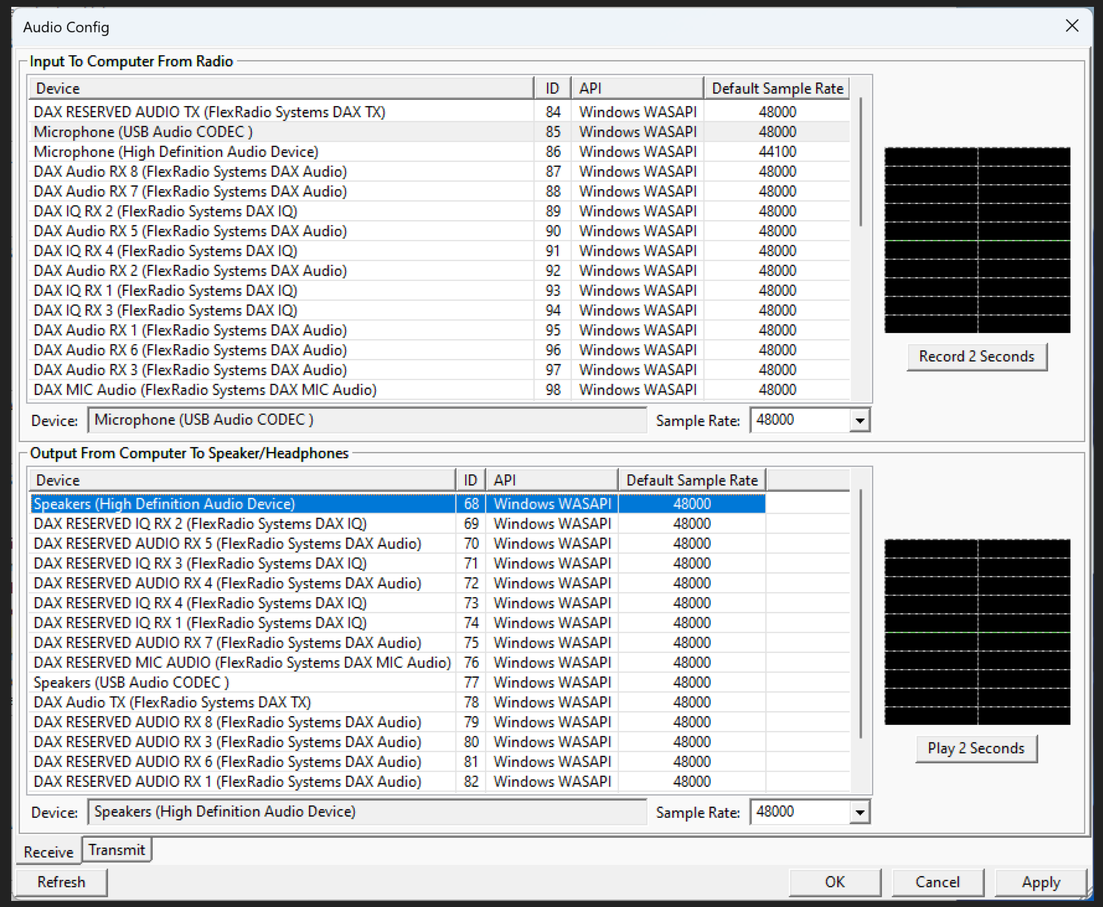
- Appears the first time FreeDV is started
  - Select radio's sound device, then your headset
  - Set up your callsign and CAT control as well
  - "Test" button keys radio and emits a constant carrier

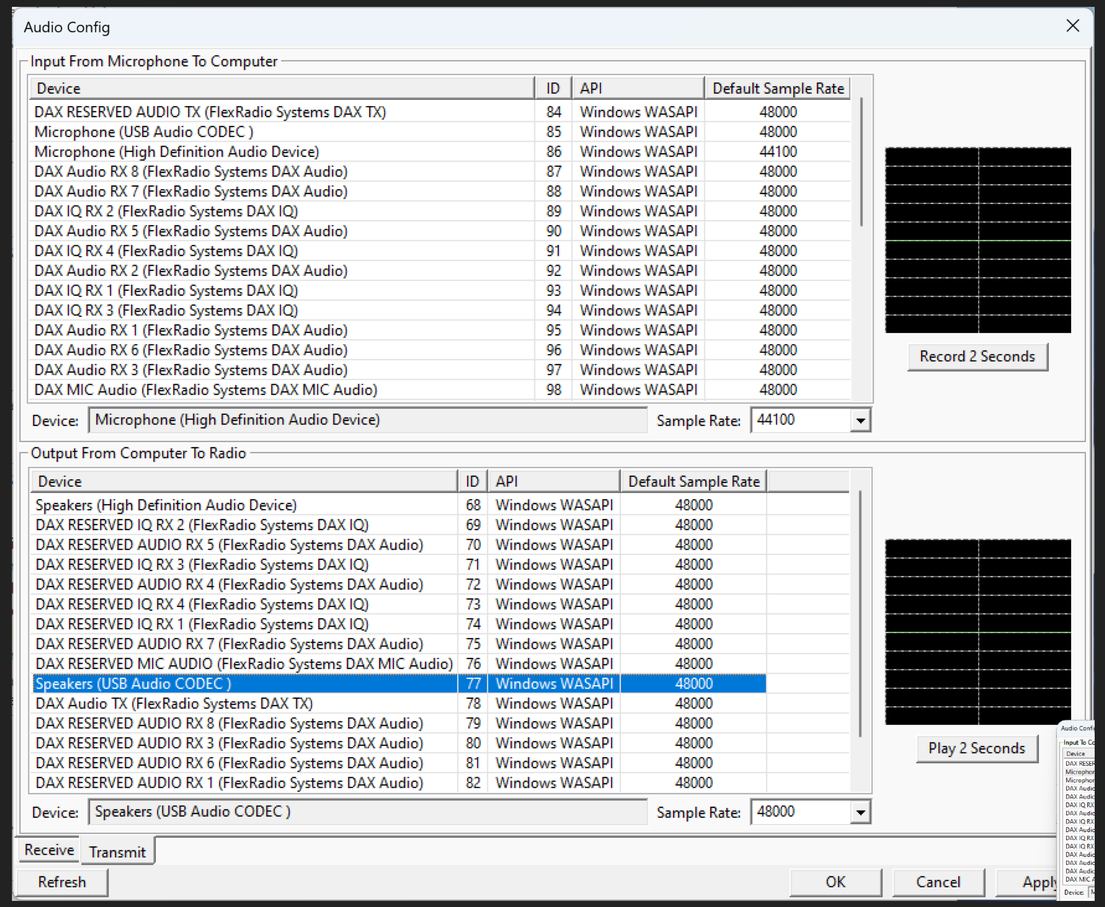


ADVANCED SOUND CARD CONFIGURATION

- May be needed depending on radio setup
  - Example: SDR radios using multiple virtual audio cables
- Tools->Audio Config (or Advanced button in Easy Setup)
  - Two tabs: Receive and Transmit
  - Typically audio devices are reversed on the Transmit tab

EXAMPLE AUDIO CONFIGURATION

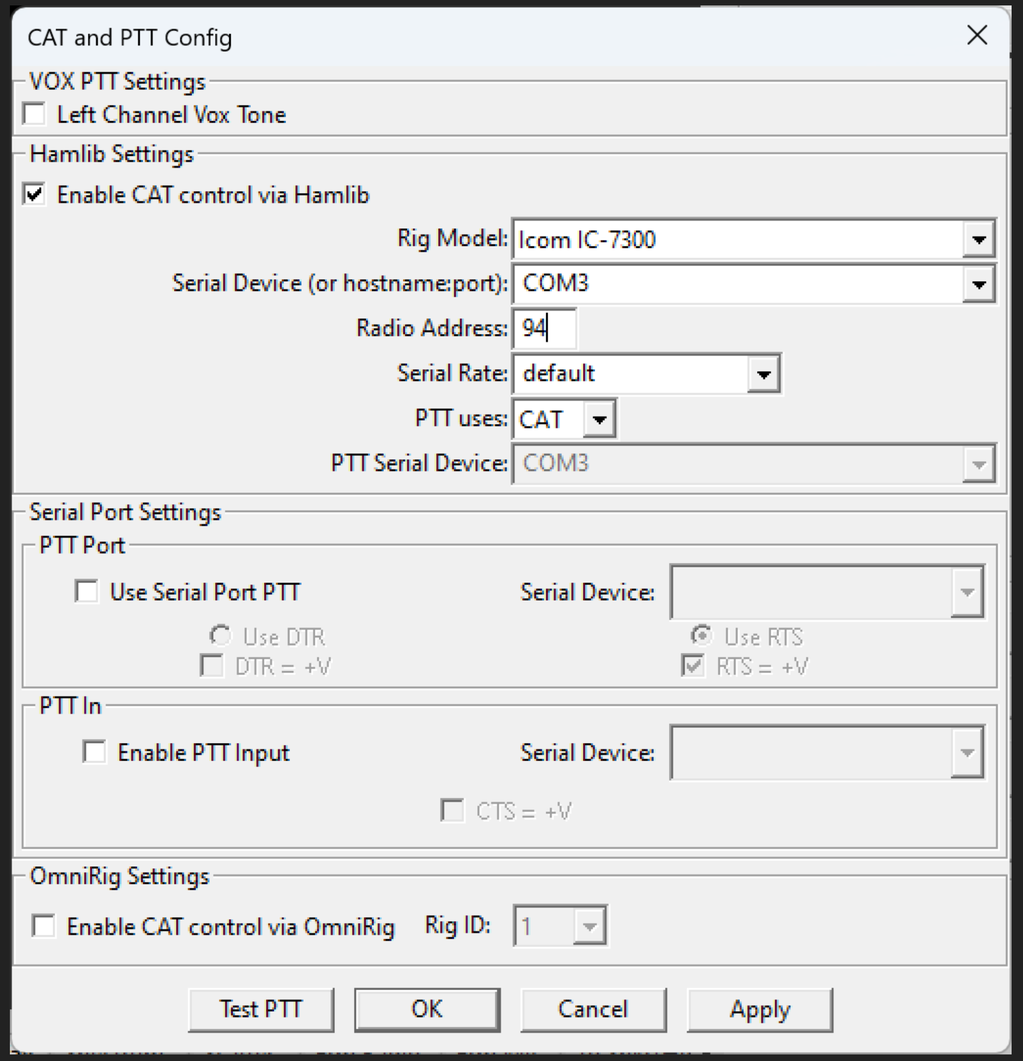




ADVANCED CAT/PTT SETUP

- Tools->CAT and PTT Config (or Advanced button in Easy Setup)
  - Supports all radios that Hamlib and OmniRig do
  - Can also use serial PTT if preferred
  - Supports PTT input as well (e.g. foot switches)

EXAMPLE PTT CONFIGURATION



DRIVE AND AUDIO LEVELS

- Same rules apply as with other digital modes
  - ALC generally should *not* indicate on your radio during TX
  - Use TX Attenuation slider to dial back power output as needed
- Overdriving your microphone reduces audio quality on the other end
  - Use Windows, etc. audio settings to adjust

IS IT LEGAL?

- Disclaimer: I am not a lawyer! Please seek expert legal advice.
  - This will also vary for operation outside of the US
- The ARRL considers digital voice as having designator J2E
  - J = SSB, 2 = single channel with digital information , E = telephony
- See “Practical HF Digital Voice”, May/June 2000 QEX

IS IT LEGAL?

- J2E is considered a “phone” emission per §97.3(5)(c)
  - §97.305(c) thus governs where DV can be used on HF
  - 60 meters is not allowed (§97.307(f)(14)(i) limits phone to J3E)
- Is FreeDV actually J2E?
  - Theoretically don’t need a SSB radio to transmit it
  - Even if not, §97.3(5)(c) gives a lot of leeway on what’s “phone”

NOT RELATED TO LEGALITY (BUT STILL A GOOD IDEA)

- The standard “considerate operator” practices still apply
  - ID every 10 minutes, only as much power as needed, etc.
  - Some/many of these are actually FCC rules too
- Reminder: Listen before transmitting!
  - Spectrum is shared and people unfamiliar with FreeDV may end up transmitting on the calling frequencies

WHERE CAN IT BE USED

- Standard conventions match analog voice
  - USB > 10MHz, LSB < 10MHz
- Most activity is on 14.236 MHz +/- QRM
  - 7.177 MHz, 28.330 MHz also common

HOW TO FIND CONTACTS

- FreeDV Reporter: https://qso.freedv.org/
  - Live TX/RX status of stations using the FreeDV application
  - Chatroom style interface to allow of live coordination with other users

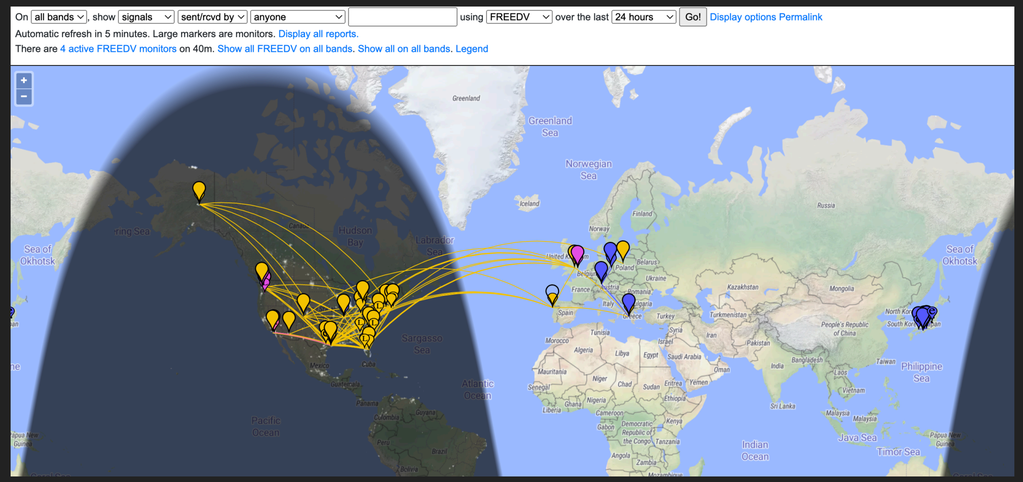
FreeDV Reporter

Active Stations | Chat (6) | Calling Frequencies

Callsign	Locator	Version	Frequency	Status	Transmit Mode	Last TX	Last RX Callsign	Last RX Mode	SNR	Last Update
VK2ZIW	QF56HG	FreeDV 1.9.1	14.2360 MHz	Receiving	700D	--	--	--	--	10/7/2023 11:34:18 PM
N4YKU	EM79	FreeDV 1.9.2	14.2360 MHz	Receiving	700D	--	--	--	--	10/10/2023 6:29:24 PM
JA3JHG	PM85AC	FreeDV 1.9.1	10.1470 MHz	Receiving	700E	10/10/2023 11:26:58 PM	--	--	--	10/11/2023 12:07:22 AM

HOW TO FIND CONTACTS

- PSK Reporter
  - Map based view of who can decode your signal
  - Good for determining propagation



HOW TO FIND CONTACTS

- FreeDV Activity Day
  - Third weekend of every month (both Saturday and Sunday)
  - 12AM Pacific (0700Z) - 11:59PM Pacific (0659Z)
  - Not a contest! Just a time for people to get together on the air

HOW TO FIND CONTACTS

- Eastern US FreeDV Net
  - Tuesdays 10pm Eastern time @ 7.182 MHz LSB
  - Brand new as of the end of July 2025
  - Now up to >30 weekly check-ins and growing :)
- Other nets for various countries, etc. listed on freedv.org

NEXT STEPS

- Integration with radios
  - External devices currently allow integration with Flex and Icom radios over Wi-Fi (with modes other than RADE)
  - Full integration improves ease of use—no need to configure anything or keep track of additional hardware
- Radio manufacturer or have connections to one? Reach out after the talk :)

Q&A

THANK YOU!

- Contact me anytime with questions
  - Email: mooneer@gmail.com
  - Discord (Scan QR code to join or visit link from freedv.org)