

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

The screenshot shows the 'Easy Setup' dialog box with three steps:

- Step 1: Select Sound Device**
 - Radio Device: USB Audio CODEC
 - Decoded audio plays back through: Speakers (High Definition Audio Device)
 - Transmitted audio records through: Microphone (High Definition Audio Device)
 - Advanced button
- Step 2: Setup Radio Control**
 - Radio Control: ☒ Hamlib CAT Control (Other options: No PTT/CAT Control, Serial PTT)
 - Hamlib CAT Control section:
 - Rig Model: Icom IC-7300
 - Serial Device (or hostname:port): COM3
 - Radio Address: 94
 - Serial Rate: default
 - PTT uses: CAT
 - Advanced and Test buttons
- Step 3: Setup Reporting**
 - ☒ Enable Reporting
 - Callsign: K6AQ
 - Grid Square/Locator: DM12kw
 - OK, Cancel, and Apply buttons

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

Audio Config

Input To Computer From Radio

Device	ID	API	Default Sample Rate
DAX RESERVED AUDIO TX (FlexRadio Systems DAX TX)	84	Windows WASAPI	48000
Microphone (USB Audio CODEC)	85	Windows WASAPI	48000
Microphone (High Definition Audio Device)	86	Windows WASAPI	44100
DAX Audio RX 8 (FlexRadio Systems DAX Audio)	87	Windows WASAPI	48000
DAX Audio RX 7 (FlexRadio Systems DAX Audio)	88	Windows WASAPI	48000
DAX IQ RX 2 (FlexRadio Systems DAX IQ)	89	Windows WASAPI	48000
DAX Audio RX 5 (FlexRadio Systems DAX Audio)	90	Windows WASAPI	48000
DAX IQ RX 4 (FlexRadio Systems DAX IQ)	91	Windows WASAPI	48000
DAX Audio RX 2 (FlexRadio Systems DAX Audio)	92	Windows WASAPI	48000
DAX IQ RX 1 (FlexRadio Systems DAX IQ)	93	Windows WASAPI	48000
DAX IQ RX 3 (FlexRadio Systems DAX IQ)	94	Windows WASAPI	48000
DAX Audio RX 1 (FlexRadio Systems DAX Audio)	95	Windows WASAPI	48000
DAX Audio RX 6 (FlexRadio Systems DAX Audio)	96	Windows WASAPI	48000
DAX Audio RX 3 (FlexRadio Systems DAX Audio)	97	Windows WASAPI	48000
DAX MIC Audio (FlexRadio Systems DAX MIC Audio)	98	Windows WASAPI	48000

Device: Microphone (USB Audio CODEC) Sample Rate: 48000

Record 2 Seconds

Output From Computer To Speaker/Headphones

Device	ID	API	Default Sample Rate
Speakers (High Definition Audio Device)	68	Windows WASAPI	48000
DAX RESERVED IQ RX 2 (FlexRadio Systems DAX IQ)	69	Windows WASAPI	48000
DAX RESERVED AUDIO RX 5 (FlexRadio Systems DAX Audio)	70	Windows WASAPI	48000
DAX RESERVED IQ RX 3 (FlexRadio Systems DAX IQ)	71	Windows WASAPI	48000
DAX RESERVED AUDIO RX 4 (FlexRadio Systems DAX Audio)	72	Windows WASAPI	48000
DAX RESERVED IQ RX 4 (FlexRadio Systems DAX IQ)	73	Windows WASAPI	48000
DAX RESERVED IQ RX 1 (FlexRadio Systems DAX IQ)	74	Windows WASAPI	48000
DAX RESERVED AUDIO RX 7 (FlexRadio Systems DAX Audio)	75	Windows WASAPI	48000
DAX RESERVED MIC AUDIO (FlexRadio Systems DAX MIC Audio)	76	Windows WASAPI	48000
Speakers (USB Audio CODEC)	77	Windows WASAPI	48000
DAX Audio TX (FlexRadio Systems DAX TX)	78	Windows WASAPI	48000
DAX RESERVED AUDIO RX 8 (FlexRadio Systems DAX Audio)	79	Windows WASAPI	48000
DAX RESERVED AUDIO RX 3 (FlexRadio Systems DAX Audio)	80	Windows WASAPI	48000
DAX RESERVED AUDIO RX 6 (FlexRadio Systems DAX Audio)	81	Windows WASAPI	48000
DAX RESERVED AUDIO RX 1 (FlexRadio Systems DAX Audio)	82	Windows WASAPI	48000

Device: Speakers (High Definition Audio Device) Sample Rate: 48000

Play 2 Seconds

Receive

Transmit

Refresh

OK

Cancel

Apply

Audio Config

Input From Microphone To Computer

Device	ID	API	Default Sample Rate
DAX RESERVED AUDIO TX (FlexRadio Systems DAX TX)	84	Windows WASAPI	48000
Microphone (USB Audio CODEC)	85	Windows WASAPI	48000
Microphone (High Definition Audio Device)	86	Windows WASAPI	44100
DAX Audio RX 8 (FlexRadio Systems DAX Audio)	87	Windows WASAPI	48000
DAX Audio RX 7 (FlexRadio Systems DAX Audio)	88	Windows WASAPI	48000
DAX IQ RX 2 (FlexRadio Systems DAX IQ)	89	Windows WASAPI	48000
DAX Audio RX 5 (FlexRadio Systems DAX Audio)	90	Windows WASAPI	48000
DAX IQ RX 4 (FlexRadio Systems DAX IQ)	91	Windows WASAPI	48000
DAX Audio RX 2 (FlexRadio Systems DAX Audio)	92	Windows WASAPI	48000
DAX IQ RX 1 (FlexRadio Systems DAX IQ)	93	Windows WASAPI	48000
DAX IQ RX 3 (FlexRadio Systems DAX IQ)	94	Windows WASAPI	48000
DAX Audio RX 1 (FlexRadio Systems DAX Audio)	95	Windows WASAPI	48000
DAX Audio RX 6 (FlexRadio Systems DAX Audio)	96	Windows WASAPI	48000
DAX Audio RX 3 (FlexRadio Systems DAX Audio)	97	Windows WASAPI	48000
DAX MIC Audio (FlexRadio Systems DAX MIC Audio)	98	Windows WASAPI	48000

Device: Microphone (High Definition Audio Device) Sample Rate: 44100

Record 2 Seconds

Output From Computer To Radio

Device	ID	API	Default Sample Rate
Speakers (High Definition Audio Device)	68	Windows WASAPI	48000
DAX RESERVED IQ RX 2 (FlexRadio Systems DAX IQ)	69	Windows WASAPI	48000
DAX RESERVED AUDIO RX 5 (FlexRadio Systems DAX Audio)	70	Windows WASAPI	48000
DAX RESERVED IQ RX 3 (FlexRadio Systems DAX IQ)	71	Windows WASAPI	48000
DAX RESERVED AUDIO RX 4 (FlexRadio Systems DAX Audio)	72	Windows WASAPI	48000
DAX RESERVED IQ RX 4 (FlexRadio Systems DAX IQ)	73	Windows WASAPI	48000
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DAX RESERVED AUDIO RX 6 (FlexRadio Systems DAX Audio)	81	Windows WASAPI	48000
DAX RESERVED AUDIO RX 1 (FlexRadio Systems DAX Audio)	82	Windows WASAPI	48000

Device: Speakers (USB Audio CODEC) Sample Rate: 48000

Play 2 Seconds

Receive

Transmit

Refresh

OK

Cancel

Apply

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

CAT and PTT Config

VOX PTT Settings

☐ Left Channel Vox Tone

Hamlib Settings

☒ Enable CAT control via Hamlib

Rig Model:

Icom IC-7300

Serial Device (or hostname:port):

COM3

Radio Address:

94

Serial Rate:

default

PTT uses:

CAT

PTT Serial Device:

COM3

Serial Port Settings

PTT Port

☐ Use Serial Port PTT

☐ Use DTR

☐ DTR = +V

☒ Use RTS

☒ RTS = +V

Serial Device:

PTT In

☐ Enable PTT Input

Serial Device:

☐ CTS = +V

OmniRig Settings

☐ Enable CAT control via OmniRig

Rig ID:

1

Test PTT

OK

Cancel

Apply

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

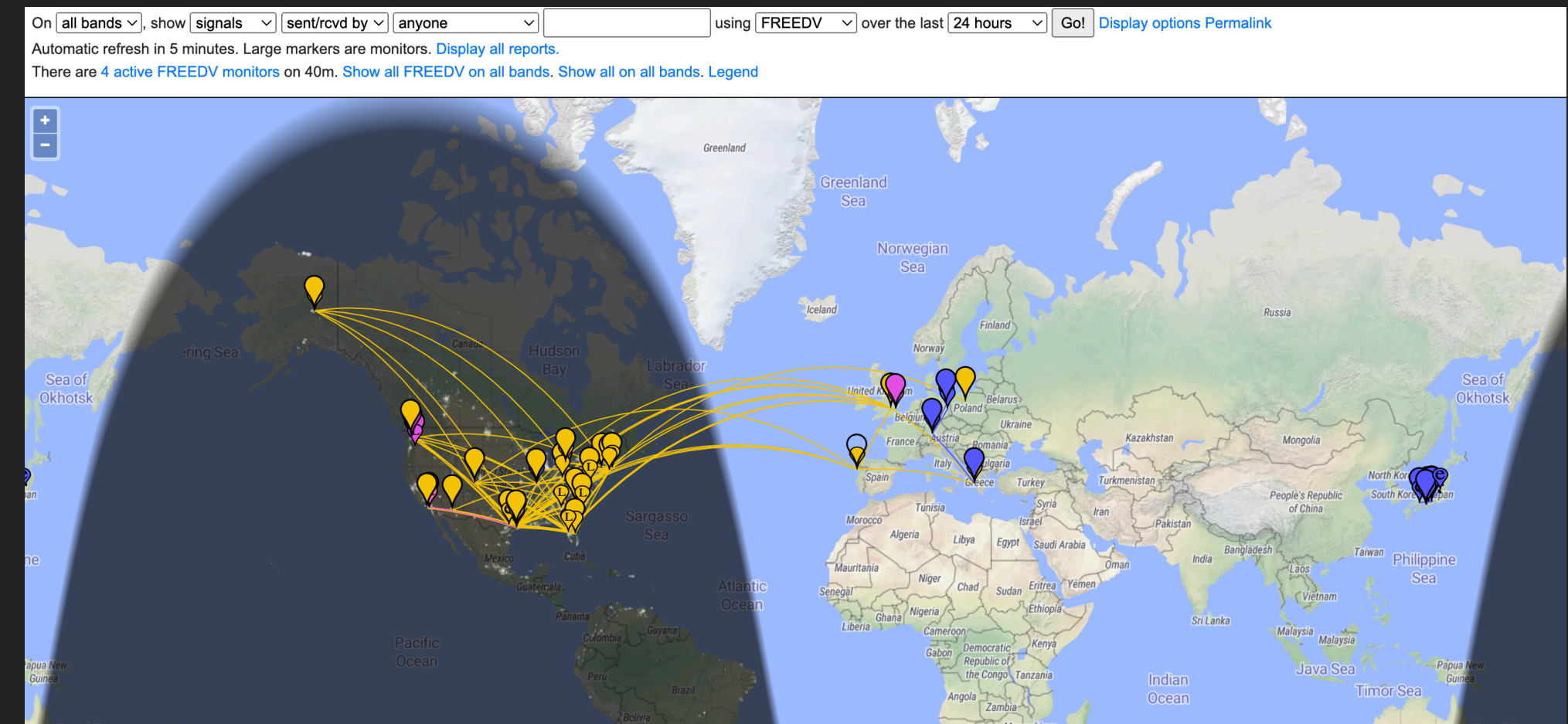
HOW TO FIND CONTACTS

- ▶ 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)

