Digital Voice Modes
Compare and Contrast of the Mainstream Digital Voice Modes

Silvercreek Amateur Radio Association January 2019 Meeting

About N8CD

- John Wagner, N8CD
- Been a ham since 1978
- Do digital things for a living
- Have had a few QSOs on DMR, DSTAR, and YSF/C4FM

- Built some hotspots, repeaters & network things for all these modes, made them work on larger networks

What this presentation will cover

- DMR, DSTAR, Yaesu System Fusion/C4FM

- A little history

- Background on digital voice modes

- Differences & similarities between modes

What this presentation will NOT cover

- Deep technical details

- How to program your radio (in detail)

- Which one you should buy

Digital Voice Modes – the basics

- At their core - digital voice modes have two main parts

- Many of the differences between modes are in these 2 things

- **1)** The algorithms, protocols and codecs that move the audio
  - **Codecs, Vocoders**

- **2) Signaling** to make calls, join talkgroups & reflectors, etc
  - Data bits like IDs and routing info

EF:4A:8C:2B:23

330-555-1212

REF030C

W8WKY

TG 3139

- Audio and Signaling are combined into one stream
- Not just radio – VoIP phones, Skype, Facetime, etc. do this too
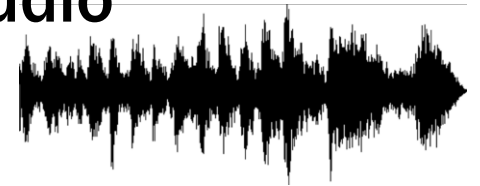
Digital Voice Modes – Audio

- Radio
  - Audio goes into your microphone and into a DSP
  - A DSP / CPU compresses it & encodes it (vocoder, AMBE chip)
  - FEC (Forward Error Correction) data calculated and put into the data stream to help fix errors the receiver might encounter

  - Generally
    - Newer codecs and vocoders mean better sound
    - More bandwidth dedicated to audio means better sound

  - Digital audio stream gets added to signaling data
  - Goes to RF section and is sent out on the air

Audio

- All use versions of DVSI's AMBE vocoders
  - Licensed chip / code that does a really good job of converting audio to digital

- All include FEC (Forward Error Correction)
  - Adds bits of data to the audio stream that can correct errors on the receiver

- Different vintages of AMBE – newer is usually better
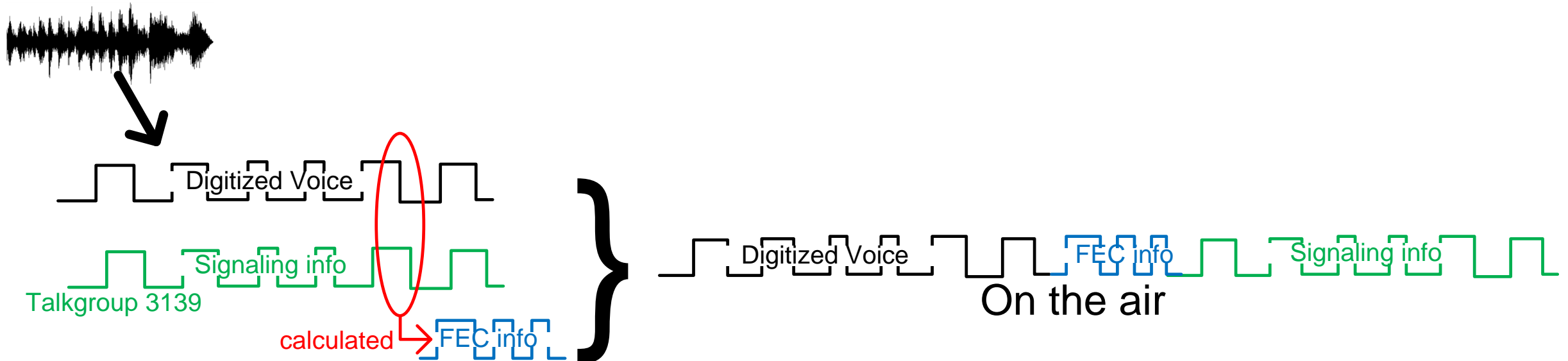
Digital Voice Modes – Signaling

- Radio channel programmed with:
  - User callsign or unique radio ID #
  - Destination info (talkgroup/gateway)
  - Maybe some info text like "John in N.E. Ohio" or "Net tonight"

- The repeater:
  - decodes ID or callsign and destination info from user signal
  - Connects to reflector or room if commanded to (DSTAR & YSF)
  - Routes user audio to reflector or room if connected (DMR)

Digital Voice Modes – Putting Audio and Signaling together

- **Signaling info (maybe GPS & text too) + Voice**

- **FEC data (like a checksum) is calculated**

- **It's put together and sent on the air as a stream while you transmit**

Digital Voice Modes – The receiver

- The repeater (or receiver):
  - Decodes the stream of data into audio and signaling
  - Uses FEC to fix bad data where it can
  - Figures out how to route audio based on signaling
  - Recombines repaired audio *data** with new signaling data
  - Sends data stream on its way either on RF and/or network

  *Repeaters generally don't *decode* digital audio into *actual* audio or process the audio
  - Just pass along the bits

The Modes

- The most common ham digital voice modes on VHF/UHF
  - Hams also use P25 and NXDN, but much less common

- Interoperability: Zero (but can be done on the network side)

DMR DIGITAL MOBILE RADIO ASSOCIATION	**D-STAR**	**System Fusion**
• Digital Mobile Radio • Commercial origins, mainly in Europe	• Digital Smart Technologies for Amateur Radio • Made for hams, first radios around 2004/2005 • Japan ARL partnered with Icom	• Yaesu's mode • "Fusion" because radios & repeaters do Digital & Analog • Made for hams

Signaling

- ## What is used to identify radios & operators?

- ## How do you tell the repeater & network what to do?

DMR

- Radios, Repeaters, Talkgroups have **ID numbers**
- *Every transmission* has talkgroup destination info
- Also can use reflectors
- Meets FCC ID? ❌

D-STAR

- Radios, Repeaters, use **callsigns**
- *Whole repeater* is connected to reflectors or other repeaters
- Meets FCC ID? ✓

System Fusion

- Radios, Repeaters, use **callsigns**
- *Whole repeater* is connected to rooms
- Meets FCC ID? ✓

Audio

- **Voice quality:** How natural and smooth does it sound?

- **Hang On:** at edge of coverage, does signal stay intelligible?

- **Recovery:** if you fall out during TX, how well does it come back?

DMR
DIGITAL MOBILE RADIO ASSOCIATION

- Voice quality: Good
- Hang On: Good
- Recovery: Good
- 2450 baud audio + 1150 baud FEC +
- 1200 baud data

D-STAR

- Voice quality: Good
- Hang On: Fair
- Recovery: Poor
    - "R2D2" on the fringes
- 2400 baud audio + 1200 baud FEC +
- 1200 baud data

System Fusion

- Voice quality: Good
- Hang On: Good
- Recovery: Good
- DN / VW
- 2450/4400 baud audio
- 1150/2800 baud FEC
- 3600/ 0   baud data

Audio Samples

- These are Not the whole story –This is audio under ideal conditions

- Weak "fluttery" signals behave differently in each mode

- Some microphone differences between the radios

DMR	System Fusion	D-STAR
• TX: Motorola XPR-4550 • RX: Anytone AT-D868UV	• TX: Yaesu FTM-400D • RX: Yaesu FT-70D	• TX: Kenwood TH-D74 • RX: Icom IC-91AD

Radios

- Some modes have more vendors than others

DMR
DIGITAL MOBILE RADIO ASSOCIATION

- Probably hundreds of manufactures
- Most mainstream don't target hams
- Motorola to Baofeng
- > $500 to < $100 💰

D-STAR

- Icom, Kenwood (1)
- Several dongle vendors, but not radios
- $600 to $270 💰💰💰
- (some HF radios with DSTAR ~$1000)

System Fusion

- Yaesu
- No one else (yet)
- $450 to $140 💰💰
- The $140 FT-70DR works, but isn't great
- (Some HF/VHF/UHF with Fusion ~$1000)

Repeaters

- Work mostly like analog repeaters –
  - RX → controller → TX

| DMR	D-STAR	System Fusion
• 10's of Manufacturers • Homebrew with a computer or Raspberry Pi • 12.5 KHz bandwidth • Bonus: 2 time slots = 2 repeaters in one	• Icom • Homebrew with a Raspberry Pi • 6.25 KHz bandwidth	• Yaesu • Homebrew with Raspberry Pi • 12.5 KHz bandwidth

Hotspots

- Simplex (usually)

- Very low power (couple of milliwatts)

- Lets you get on the network without a repeater

- ONLY lets you talk on the network (doesn't repeat you locally)

Nearly all hotspots will do all of the modes

Only get one timeslot
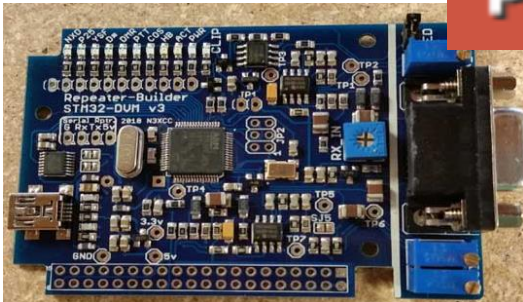
Openness

- How proprietary is the system?

- ALL of these systems have at least one licensed component
  - The DVSI AMBE Vocoder chip and/or code

DMR
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- Open Standard

D-STAR

- Open Standard

System Fusion

- Published Standard

Is DMR More Open?

DMR has lots of radio vendors, makes it appear more "open"

Reality is any vendor could build a DSTAR or Fusion radio too if they wanted to

Networks – Connecting things together

- Repeaters repeat locally

- Networks connect repeaters (and hotspots) together

- Talkgroups
- Reflectors (not used a much)
- Radio ID routing (Brandmeister)
- Some Talkgroups bridged to other modes

- Reflectors
- Callsign routing
- Some reflectors bridged to other modes

- Rooms
- Some rooms bridged to other modes

Networks

- Interconnecting things over IP data networks (Internet usually)

- As reliable as the Internet and your connection to it

- Possible to do private (non-Internet) networks on all 3 modes

DMR

- Partly centralized
  - Brandmeister, DMR-MARC, DCI, K4USD...
  - Many other local networks
  - Bridges between networks
  - Repeaters homed to one master at a time

D-STAR

- Mostly decentralized
  - Dplus, DExtra, XRF
  - Repeaters have no master per se
  - Anyone can host reflector

System Fusion

- Mostly decentralized
- Rooms
- Some rooms bridged to other modes
- Repeaters have no master
- Anyone can host a room

Networks - Registration

- Repeaters repeat locally ... but

- Networks connect repeaters (and hotspots) together

- Registration keeps networks to just licensed hams

- You don't need to register if you're not using the networks

DMR
DIGITAL MOBILE RADIO ASSOCIATION

- Pretty straightforward
  - RadioID.net
  - Was DMR-MARC
- You get a radio ID

D-STAR

- A bit convoluted
  - US-Trust database
    - Find a repeater near
    - Sometimes they go away

System Fusion

- As easy as it gets
  - None needed for users or repeaters!
- Put your callsign in your radio!

Networks - Transcoding

- Since none of these modes talk directly to each other

    - People have done it on the network side

- Transcoding – a server with AMBE dongle chips plugged in

- Can interconnect DSTAR, DMR, YSF, Analog, Echolink and Allstar

- Audio quality is about as good as you might imagine

    - Especially between analog and digital

Phone and Computer Apps

- Can you use your phone directly into these networks?

- Analog has Echolink
  - and Allstar has Zoiper if you're a masochist

- Hoseline is RX only
- No TX app?

- Peanut
  - Android app – sends all traffic through PA7LIM's servers
  - New
  - Sounds fantastic
  - Both Loved & Hated

- None?

Internet Connectivity and Firewalls

DMR

- Does not require port forwarding for Brandmeister, 👍

BUT

- Requires static UDP **source** ports on firewall 👎
  - Probably works on your Linksys router
  - But "real" firewalls care
- Fixed ports mean 1 repeater per IP address 👎

D-STAR

- Requires a few UDP ports forwarded for *inbound* connectivity
- Fixed ports mean 1 repeater per IP address 👎

System Fusion

- Requires a few UDP ports forwarded for *inbound* connectivity
- Fixed ports mean 1 repeater per IP address 👎

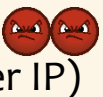**Contrast:**

Echolink: also 1 repeater per IP address 👎

Allstar: Flexible ports mean more than 1 repeater per IP address 👍

The Big Picture

	DMR	D-STAR	System Fusion
Voice quality/hangon/recover (0=bad to 9)	7 / 8 / 8	6 / 5 / 4	(DN) 7 / 8 / 8 (VW) 8 / 6 / 6
Cost per VHF/UHF radio	$100-$500	$220-$550	$140-$450
Radios from multiple vendors?	Yes (many)	Yes (only 2 in reality)	No
User link directly to another repeater?	No	Yes	No
Private networks without Internet?	Proprietary:Yes Open: No	Yes	Yes
Data besides voice	GPS, TXT	GPS & TXT standard, Data with computer	Yes GPS, TXT standard, pictures w/accessories
Favorite Unique Features 👍	- 2 time slots = 2 QSOs - TDMA allows permit	- Can be used on HF - Well developed	- Has 2 voice quality modes - No registration
Most Disliked Features 👎	- Bridged, but separate networks - Buggy radios and software	- Older audio vocoder - Few non-Icom radios	- WIRES-X has to be bridged to YSF - No non-Yaesu radios
Registration Process	Easy	Convoluted	None
IP Network Admin Hate Factor	Static source ports and fixed port forwarding 😡😡😡	Fixed port forwarding required (1 repeater per IP) 😡😡	Fixed port forwarding required (1 repeater per IP) 😡😡
Openness (other than AMBE)	Good	Good	Fair (WIRES-X vs YSF)

And the winner is...

NONE OF THEM!

- They all have flaws

- Pick your Poison

- But learning and playing with them is still fun