A Comparison of Amateur Radio Digital Voice Systems

We want to thank Roland Kraatz W9HPX of the Charlotte Digital Radio Group Who let us use some of these Slides from a presentation he gave at the Charlotte Hamfest
A Comparison of Amateur Radio Digital Voice Systems

Presented and Modified by:

Bill Neville------- WA7KMF
Cordell Smart -- KE7IK
Ted McArthur -- AC7II
Tyler Griffiths - N7UWX

BARC April 11th 2015 Club Meeting
Topics

• Digital voice description
• Technical comparison
• Operational features
• Programmability
• Radio choices
• Utah DV repeaters
• Information sources
• Q & A

See p30 April 2015 QST
Something to think about First!

- If you’re thinking of making the leap from analog FM to digital, the system that is best for you will depend on several factors.
- The most important question to ask is the most obvious: which modes are active in your area?
- Without a compatible digital repeater, you’ll be confined to simplex operation and maybe with no one to talk to but yourself!
What is Digital Voice?

- Digital data modulating an RF carrier
- The data is digitized audio from an A/D converter
- It is processed through a vocoder to compress the data and add forward error correction
- The data is sent serially in uniform length packets
- Header data is pre-pended to provide sync bits, routing instructions and user identity
- Other data is often interleaved or substituted for the voice to send text, pictures or other files
Digital Voice has Improved Performance
Pictorial view

### Radio Header

<table>
<thead>
<tr>
<th>Bit</th>
<th>Frame Syn.</th>
<th>ID</th>
<th>Callsign 1</th>
<th>Callsign 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>64bit</td>
<td>15bit</td>
<td>1</td>
<td>1</td>
<td>byte</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data</th>
<th>Voice</th>
<th>Data</th>
<th>Voice</th>
<th>Data</th>
<th>Voice</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Byte</td>
<td>Byte</td>
<td>Byte</td>
<td>Byte</td>
<td>Byte</td>
<td>Byte</td>
<td>Byte</td>
</tr>
</tbody>
</table>

### Error Correction

- 660 bit

### DMR Timing

- 30 ms
- 330 ms
- 30 ms

### Fusion

<table>
<thead>
<tr>
<th>FS</th>
<th>FICH</th>
<th>DCH (0)</th>
<th>VCH (0)</th>
<th>DCH (1)</th>
<th>VCH (1)</th>
<th>DCH (2)</th>
<th>VCH (2)</th>
<th>DCH (3)</th>
<th>VCH (3)</th>
<th>DCH (4)</th>
<th>VCH (4)</th>
<th>Number of bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>200</td>
<td>40</td>
<td>72</td>
<td>32</td>
<td>40</td>
<td>72</td>
<td>32</td>
<td>40</td>
<td>72</td>
<td>32</td>
<td>40</td>
<td>72</td>
</tr>
</tbody>
</table>

Total 960 bit
# Tech Spec Comparison

<table>
<thead>
<tr>
<th></th>
<th>D-STAR</th>
<th>DMR</th>
<th>Fusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocoder (see note)</td>
<td>AMBE+</td>
<td>AMBE+2</td>
<td>AMBE+2</td>
</tr>
<tr>
<td>Forward Error Corr.</td>
<td>Voice Only</td>
<td>Voice Only</td>
<td>Voice Only</td>
</tr>
<tr>
<td>Modulation</td>
<td>GMSK</td>
<td>4FSK</td>
<td>C4FM</td>
</tr>
<tr>
<td>Multiplex Method</td>
<td>FDMA</td>
<td>TDMA</td>
<td>FDMA</td>
</tr>
<tr>
<td>Transmission Rate</td>
<td>4.8 kbps</td>
<td>4.8 kbps x 2</td>
<td>9.6 kbps</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>6.25 kHz</td>
<td>12.5 kHz</td>
<td>12.5 kHz</td>
</tr>
<tr>
<td>Channels supported</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Standard Developer</td>
<td>JARL</td>
<td>ETSI</td>
<td>Yaesu</td>
</tr>
</tbody>
</table>

GMSK = Gaussian Minimum Shift Keying  
4FSK = 4-level Frequency Shift Keying  
C4FM = Continuous 4-level Frequency Modulation  
FDMA = Frequency Division Multiple Access  
TDMA = Time Division Multiple Access

Note: Newer radios implement the vocoder in the DSP chip
Bandwidth Comparison

D-STAR: 6.25 kHz

DMR: 12.5 kHz

Fusion: 12.5 kHz
## User Identification

<table>
<thead>
<tr>
<th></th>
<th>D-STAR</th>
<th>DMR</th>
<th>Fusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registration required?</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>User identity</td>
<td>Call sign</td>
<td>Subscriber ID</td>
<td>Call sign</td>
</tr>
<tr>
<td>ID displayed on radio’s display</td>
<td>Call sign</td>
<td>Subscriber ID*</td>
<td>Call sign</td>
</tr>
<tr>
<td>Other text display options</td>
<td>4 characters 20 characters</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Adequate for FCC ID?</td>
<td>Yes†</td>
<td>No</td>
<td>Yes†</td>
</tr>
</tbody>
</table>

* Call sign displayed if the receiving station’s subscriber ID is in the radio’s contact list; otherwise subscriber ID appears.

† IDing by voice is still a good idea for the benefit of everyone listening.
Registration

www.dmr-marc.net

NU7TS.COM

Contact Us

How can we help?

Please choose one of the following:

- I have a general question or comment
- I’d like to report a system bug or suggest a feature to the Support Team
- I’d like a USER ID for my radio
- I’d like a REPEATER ID

https://nu7ts.dstargateway.org/Dstar.do

NU7TS D-Star Gateway Repeater
Self Registration Instructions
D-Star CallSign Settings

- 4 CallSign Settings needed
  - Your Call = Destination User or Command
    - CQCQCQ, WA7KMF, REF029CL, -------U
  - Repeater 1 = Originating User System
    - NU7TS B, N7RDS B, KF7VJO B, AC7O C
  - Repeater 1 = Local or Gateway
    - NU7TS G, N7RDS G, KF7VJO G, AC7O G, AC7O B
  - My Call = Originating User
    - AC7II
D-Star Reflectors

Server running application to receive one incoming signal and re-transmit VoIP data signal to all connected remote systems.
### Linked Gateways

<table>
<thead>
<tr>
<th>Module A</th>
<th>Module B</th>
<th>Module C</th>
<th>Module D</th>
<th>Module E</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC7O B</td>
<td>AC7O C</td>
<td>KF7YIX B</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>KF7YIX C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>KM7ARC B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>KM7ARC C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>NU7TS B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WR7AAA B</td>
<td>WR7AAA C</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Remote Users

<table>
<thead>
<tr>
<th>Callsign</th>
<th>User Message</th>
<th>Last TX on</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC7II</td>
<td></td>
<td>C</td>
<td>HotSpot</td>
</tr>
<tr>
<td>WA7KMF</td>
<td>Logan, Ut</td>
<td>C</td>
<td>HotSpot</td>
</tr>
</tbody>
</table>

### Last Heard

<table>
<thead>
<tr>
<th>Callsign</th>
<th>User Message</th>
<th>Last TX on</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>W7JZU</td>
<td></td>
<td>C</td>
<td>2015/04/06 14:47:10</td>
</tr>
</tbody>
</table>

Status as of 2015/04/07 11:47:49
DMR - Digital Mobile Radio
What is Digital Mobile Radio

- Commonly known as “DMR”
- A standard for digital voice communications
- Published by the European Telecommunications Standards Institute (ETSI) in 2005
- The goal of the standard is to create digital systems that are:
  - Low cost
  - Low complexity
  - Interoperable between vendors
DMR - Longer Battery Life

“For each hour of usage the TDMA radios show between 19% and 34% less battery capacity is required than for the FDMA models.”

“By cutting the effective transmit time in half, two-slot TDMA can enable up to 40 percent improvement in talk time in comparison with analogue radios.”

- DMR Association
DMR Network Architecture
# DMR Talk Groups

<table>
<thead>
<tr>
<th>Repeater Info</th>
<th>Timeslot</th>
<th>Talkgroup ID</th>
<th>Talkgroup Name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>Worldwide</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>13</td>
<td>WW English</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3</td>
<td>N America</td>
</tr>
<tr>
<td></td>
<td>13149</td>
<td>13149</td>
<td>Utah 2</td>
</tr>
<tr>
<td></td>
<td>311</td>
<td>311</td>
<td>TAC 311</td>
</tr>
<tr>
<td></td>
<td>9998</td>
<td>9998</td>
<td>Echo Test</td>
</tr>
<tr>
<td></td>
<td>9999</td>
<td>9999</td>
<td>UV Meter</td>
</tr>
<tr>
<td>NU7TS Logan 447.000- CC1</td>
<td>2</td>
<td>2</td>
<td>Local</td>
</tr>
<tr>
<td></td>
<td>3149</td>
<td>3149</td>
<td>Utah 1</td>
</tr>
<tr>
<td></td>
<td>76</td>
<td>76</td>
<td>76ers</td>
</tr>
<tr>
<td></td>
<td>3177</td>
<td>3177</td>
<td>Mountain</td>
</tr>
<tr>
<td></td>
<td>310</td>
<td>310</td>
<td>TAC 310</td>
</tr>
<tr>
<td></td>
<td>3100</td>
<td>3100</td>
<td>Bridge</td>
</tr>
<tr>
<td></td>
<td>314900</td>
<td>314900</td>
<td>Salt Lake Local</td>
</tr>
<tr>
<td></td>
<td>314901</td>
<td>314901</td>
<td>Utah County Local</td>
</tr>
<tr>
<td>NU7TS Riverside 447.125- CC1</td>
<td>Timeslot 2</td>
<td>310</td>
<td>TAC 310</td>
</tr>
<tr>
<td></td>
<td>3100</td>
<td>3100</td>
<td>Bridge</td>
</tr>
<tr>
<td></td>
<td>314900</td>
<td>314900</td>
<td>Salt Lake Local</td>
</tr>
<tr>
<td></td>
<td>314901</td>
<td>314901</td>
<td>Utah County Local</td>
</tr>
<tr>
<td></td>
<td>222222</td>
<td>222222</td>
<td>All TG's On</td>
</tr>
<tr>
<td></td>
<td>111111</td>
<td>111111</td>
<td>All TG's Off</td>
</tr>
</tbody>
</table>
Repeater Connectability

<table>
<thead>
<tr>
<th></th>
<th>D-STAR</th>
<th>DMR</th>
<th>Fusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Talk locally</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Link to another repeater</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Multi-repeater connection</td>
<td>Reflectors</td>
<td>Talk Groups</td>
<td>Rooms</td>
</tr>
<tr>
<td>Selection method</td>
<td>UR entry</td>
<td>Channel Dial</td>
<td>DTMF</td>
</tr>
<tr>
<td>Route to another ham</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Echo test</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Request link status</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
# Radio Operating Features

<table>
<thead>
<tr>
<th></th>
<th>D-STAR</th>
<th>DMR</th>
<th>Fusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repeater channel selection</td>
<td>Dial</td>
<td>Dial</td>
<td>Dial</td>
</tr>
<tr>
<td>Repeater connection selection</td>
<td>Dial</td>
<td>Dial</td>
<td>DTMF code</td>
</tr>
<tr>
<td>Mode selection method</td>
<td>Key press</td>
<td>Program</td>
<td>Key press *</td>
</tr>
<tr>
<td>Radio programming complexity</td>
<td>Difficult/Easy</td>
<td>Difficult</td>
<td>Easy</td>
</tr>
<tr>
<td>Newbie learning curve</td>
<td>Steep</td>
<td>Fairly easy</td>
<td>Easy</td>
</tr>
<tr>
<td>User manual pages - older HT</td>
<td>131 (IC-91)</td>
<td>65 (CS-700)</td>
<td>247 (FT-1D)</td>
</tr>
<tr>
<td>User manual pages - newer HT</td>
<td>425 (ID-51)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Fusion radios have AMS (automatic mode select)

◊ Older D-STAR radios are more difficult to program. Newer ones are pre-programmed, but must be updated occasionally as repeaters change.
## Signal Readability

<table>
<thead>
<tr>
<th></th>
<th>FM</th>
<th>D-STAR</th>
<th>DMR</th>
<th>Fusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voice naturalness</td>
<td>Good</td>
<td>Fair</td>
<td>Good</td>
<td>Best</td>
</tr>
<tr>
<td>Signal noise</td>
<td>Varies</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Sync robustness</td>
<td>N/A</td>
<td>Fair</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Sync recoverability</td>
<td>N/A</td>
<td>Poor</td>
<td>Best</td>
<td>Best</td>
</tr>
</tbody>
</table>

Sync robustness is the tendency to fall out of sync
Sync recoverability is the ability to recover sync quickly

The opinions shown here are highly subjective. Your opinion may be different.
Networking Characteristics

- **D-STAR**
  - User control capability - excellent
  - Networking options - G2, D-Plus, ircDDB, Quadnet
  - Innovation ability - open standard, many accomplishments

- **DMR**
  - Common Air Interface
  - Centrally controlled structure - inflexible
  - Networking options - c-bridge, Smart PTT, IP Site Connect
  - Innovation ability - limited

- **Fusion**
  - Yaesu controlled servers - inflexible
  - Networking options - WIRES-X
  - Innovation ability - limited
D-STAR HT’s

ID-91A
- Dual band Single Receive
- 5W
- 1304 memories
- Discontinued
- $400 new

IC-92AD
- Dual band
- 5W
- 1304 memories
- GPS Mic. Available
- Water Proof
- $450 new
D-STAR HT’s

ID-31A
- Single band (70cm)
- 5W
- uSD card record
- 500 memories
- Internal GPS
- Repeater geo search
- $295 new

ID-51A Plus
- Dual band
- 5W
- uSD card record
- 1300 memories
- Internal GPS
- Repeater geo search
- $450 new
D-STAR Mobile’s

Older - IC-2820

- Dual band Dual Receive
- Diversity Receive
- 50W VHF/UHF
- 522 memories
- $600 new
- Requires Add on GPS and DV Module
- Discontinued Model
D-STAR Mobile’s

Older - ID-880H
- Dual band
- 50W
- 1050 memories
- $420 new

Newer - ID-5100A
- Dual band Touch Screen
- 50W
- 1000 + 1200 DR memories
- Internal GPS & DPRS
- SD card recording
- Repeater geo search
- $600 new
DMR HT’s

**MotoTrbo - XPR-7550**
- 440 MHz band
- 4W
- 1000 channels
- $700 new

**Hytera PD782G-U1**
- 440 MHz band
- 4W
- 1024 channels
- $545 new

Ham Friendly Dealers
DMR Mobile’s

**MotoTrbo - XPR-5550**
- 440 MHz band
- 40W
- 1000 channels
- $ 600 new

**Hytera - MD782G-U1**
- 440 MHz band
- 45W
- 1024 channels
- $ 530 new
DMR HT’s (cont.)

Connect Systems - CS700 - Workhorse

- 440 MHz band
- 4W
- 1000 memories
- $200 new
- Programming Cable $15
New Connect System Radios

CS7000, CS700A & CS750
Yaesu System Fusion
System Fusion HT’s

Yaesu - FT-1DR
• Dual band
• 5W
• Automatic Mode Select
• 900 memories
• GPS & APRS
• $300 new

Yaesu FT-2DR (new)
• Dual band
• 5W
• Automatic Mode Select
• 1245 channels
• GPS & APRS
• Touch screen
• $600 new
System Fusion Mobile

Yaesu - FT-400DR

- Dual band
- 50W
- Automatic Mode Select
- 900 memories
- GPS & APRS
- Color Touch screen
- $400 new
What Makes it “Fusion”?

- What sets this new technology apart from Dstar, DMR (MotoTRBO), etc? It's automatic backwards compatibility with analog FM
  - Every Fusion radio and repeater is aware of the current QSO and it's mode
  - If a QSO input starts as FM, the repeater “repeats” FM
  - If the QSO input starts as C4FM, it “repeats” C4FM
  - Each endpoint (HT, mobile, etc) auto-switches
  - GM function
What is C4FM and Fusion? (continued)

- Fusion framing has been openly documented by Yaesu in 2013 (unclear if it's freely licensed)

- FM envelope uses 12.5Khz BW (narrow FM)

- Uses a similar DVS1 AMBE DSP chip used in DMR & P25 but newer than what's used in D*star - patent encumbered
Fusion's Wide Data mode - What can use it?

• Today, Yaesu sells a special hand-mic that includes a camera to send pictures to remote Fusion-enabled radios

• The radios also include a data cable to use the high speed data modes
  – Programs like D-RATS should be able to use this today
What's New & Next for Fusion?

- US Wires-X support for linking Fusion repeaters & Simplex nodes via the Internet

New base station radio: FT-991 that replaces the FT-897 with Fusion support

New FT-2D HT with touch Screen
Wires-X Internet Linking

- Wires-X was recently released in the US so overall details and impressions are still too early

- “Rooms” are like IRLP Reflectors or Echolink Conferences

- When in a room, you can download “news” which can be text files, audio, & pictures

- Admins can individually “kick” or even “ban” callsigns
Other Digital Voice Suppliers

DV Dongle
- Internet Labs
- D-STAR on your PC
- $200 new

Thumb DV
- Northwest Digital Radio
- D-STAR on your PC
- Uses AMBE 3000
- Other modes?
- $120 new
Other Digital Voice Devices

DV Access Point
- Internet Labs
- Hotspot repeater
- Single band
- 2M $240 new
- 70 cm $260 new

DV Mega
- Guus van Dooren PE1PLM
- Hotspot repeater
- Dual band
- $180 new

D-Hap
- Hardened Power Systems
- Self Contained Hotspot
- $235 - $365
Not near a D-STAR Repeater? Make your own - with this...
Raspberry Pi G4KLX GUI
D-RATS

A Communications Tool For D-STAR

http://www.d-rats.com/
D-RATS Message List
D-RATS Chat Display

[2009-05-11 15:06:45] [Ratflector] CQCQCQ: KK7DS - Ratflector - ref.d-rats.com:9000 - Please do not link RF to this repeater to keep it clean for testing and training

[2009-05-11 16:12:08] KK7DS: Now Online: Active

[16:12:09] OH3HWX: Now Online: Online (D-RATS)

Station OH3HWX is now Online: Online (D-RATS)
D-RATS File Transfer
D-RATS Map Display
D-RATS Forms

- Includes Form Editor to Create Any Form
- Only Data is Sent
- Fully printable ICS-213, ARRL Radiogram and NTS Forms Included
D Star Coverage
DMR Coverage

www.dmr-utah.net
Fusion Coverage

WA7MXZ

K7JL

Crossroads ARC

Provo

Salt Lake City

Ornden
Digital Voice Summary

- **D Star**
  - Mature - Open Source - ICOM only
  - Lots of Options to get on D Star
  - Easy Programming - Robust Routing

- **DMR**
  - Growing - International Standard
  - CS700/7000 - Commercial Vendors
  - Proprietary Programming - Fixed Talk Groups

- **Fusion**
  - New & Sure to Grow - Yaesu Only
  - Easy Programming - Chat Rooms
  - Better Audio Plus APRS
For More Information

- [www.nu7ts.com](http://www.nu7ts.com) - This is our web site. Register for D-STAR.
- [groups.yahoo.com/neo/groups/clt-dstar/info](http://groups.yahoo.com/neo/groups/clt-dstar/info)
  This is our Yahoo group, but search for other Yahoo groups of interest such as D-STAR, Fusion, DMR, Connect Systems, etc. There’s many.
- [www.dstar101.com](http://www.dstar101.com)
- [www.dstarinfo.com](http://www.dstarinfo.com)
- [www.dstarusers.org](http://www.dstarusers.org)
- [www.maryland-dstar.org](http://www.maryland-dstar.org) - for Raspberry Pi enthusiasts
- [www.dmr-utah.net](http://www.dmr-utah.net) - Web site for our area DMR repeaters & code plugs.
- [www.dmr-marc.net](http://www.dmr-marc.net)
- [www.trbo.org](http://www.trbo.org)
Questions?