Introduction to Digital Voice and DMR
Presented at the San Diego Hamfest

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Contents

• Introduction to Digital Voice
  • Digital Voice Radio Implementation
  • Characteristics of DV systems
  • Wide Area Networking Methodologies
  • Available Equipment
  • On line resources

• Demos (if time permits)
Digital Voice for Amateur Radio

What is going on in a DV radio?
Digital FM Transmitter

Plain old “Analog FM Transmitter” (Just how Armstrong envisioned it)

Microphone → Signal Conditioning → Deviation Control

FM Modulator → Analog FM → TX RF Processing

Antenna

Digital Detour

Analog Voltage → A to D Converter → Speech Samples → VOCODER (Encoder) → Data Stream → Framer → Packet Stream → Modulation Formatter → M-Level Squarewave → Pulse Shaper

16 bits*8 kSPS = 128kb/S (DMR)

DSTAR: AMBE
DMR/FUSION: AMBE+2

3.6 kb/S (DMR)

Frame Sync, User ID, Destination ID, Data, etc.

Unique for all three modes

DSTAR: Gaussian LPF
DMR, Fusion: Root Raised Cosine (Nyquist) LPF
Digital FM Receiver

Plain old “Analog FM Receiver”

- RX RF Receiver FE
- IF Signal
- FM Demod (Limiter/Disc or PLL type)
- Audio Amplifier
- Speaker

Digital Detour

- Analog Voltage
- DSTAR: 2-PAM
- DMR/Fusion: 4-PAM

- Matched Filter
- PAM
- Clock and Data Regen
- Packet Stream

- Deframer
  - Unique for all three modes
  - Clock

- VOCODER (Decoder)
- Speech Samples
- Sync

- D to A Converter
- DSTAR: AMBE
- DMR/FUSION: AMBE+2

DSTAR: 5th order Butterworth LPF
DMR, Fusion: Root Raised Cosine (Nyquist) LPF
DSTAR Receiver signals

GMSK Receiver Eye Diagram
Showing decision region boundaries
4-FSK/C4FM Receiver signals

**Graph:**

- **FC:** 1944 Hz
- **H2:** 648 Hz
- **H1:** 648 Hz
- **H0:** 648 Hz
- **H-1:** 648 Hz
- **H-3:** 648 Hz

**Eye Diagram:**

- **Sample:** 10
- **Sample:** 00
- **Sample:** 01
- **Sample:** 11

**Flowchart:**

- **Antenna**
- **RX RF Receiver FE**
- **IF Signal**
- **FM Demod (Limiter/Disc or PLL type)***
- **DSTAR: 2-PAM**
- **DMR/Fusion: 4-PAM**
- **Matched Filter**
- **PAM**
- **Clock and Data Regen**
- **Packet Stream**
- **Deframer**
- **Audio Enable**
- **Audio Amplifier**
- **Speaker**
- **Analog Voltage**
- **Data Stream**
- **Sync**
- **Speech Samples**
- **D to A Converter**

**4-PAM Receiver Eye Diagram**

Showing decision region boundaries
Modulation Schemes for DV

- Five specifications, two different modulation schemes
  - C4FM (4FSK) based systems
    - DMR – ETSI administered Standard
    - Project 25 (P25) – APCO administered Standard
    - NXDN – Kenwood/ICOM Specification
    - Yaesu System Fusion – Yaesu Specification
  - GMSK (2FSK) based Systems
    - DSTAR – JARL administered Standard
- None of these are interoperable one to another
Spectrum Sharing Methods

- **Frequency Division Multiple Access**
  - Traditional Analog FM (25 kHz)
  - DSTAR (6.25 kHz)
  - NXDN (6.25 kHz)
  - P25 Phase I (12.5 kHz)
  - Yaesu Fusion (12.5 kHz)

- **Time Division Multiple Access**
  - DMR (12.5 kHz)
  - P25 Phase II (12.5 kHz)
  - Note that since these technologies offer two simultaneous transmissions they are *functionally equivalent* to a 6.25 kHz system.
TDMA Equipment Simplicity

TDMA saves licensing and equipment costs by enabling the equivalent of two 6.25 kHz channels within a single licensed 12.5 kHz channel.

Two-channel Analog or Digital FDMA System

- Repeater 1
- Combining Equipment
- Repeater 2

Frequency 1
Frequency 2

Two-channel Digital TDMA System

- Repeater

Frequency 1

Motorola
For each hour of usage TDMA radios require between 19% and 34% less battery capacity than FDMA models.

This translates to "40 percent improvement in talk time in comparison with traditional FM analog radios"
Better Signal Quality

- Better RF range than analog particularly at the fringes of coverage.
- True for all digital voice modes
- Demonstration

http://dmrassociation.org
Basic Communication Modes

- All systems support:
  - Basic Simplex
  - Basic Repeater Communication
  - Wide area Networking

Source: ICOM
Digital Voice for Amateur Radio

Wide Area Networking Methodologies
  Talk Groups
  Reflectors
  Rooms
Talk Groups

- Talk groups allow segregation of the user community
  - Allows a communication resource (a frequency or time slot) to be shared among multiple “User Groups” such that they hear only those calls intended for them.
  - This keeps user radio activity to a minimum for any specific group of users,
  - and prevents users from ignoring their radios .... if it squawks, it’s probably important for them.

- CTCSS was originally implemented for this purpose
  - Motorola “Private Line”, GE: “Channel Guard”, RCA: “Quiet Channel”
Analog Talk-Groups using PL

- PL Tones: 50, DPL Codes: 99, Fusion DSQ Codes: 99,
  available DMR Talk Group ID’s: > 16 million
Talk Groups in the DMR world

TG ID 3106: California Statewide
TGID 31066: Southern California
TGID 310: TAC (Tactical) 310 Server Backbone
Talk Groups on DMR (PAPA)

- **TS1**
  - **Time Slot 1**
    - California
      - TG 3106
    - California-1
      - TG 31061
    - Cali Zone 6
      - TG 31096
    - North America
      - TG 93
    - Worldwide
      - TG 91
    - Nationwide
      - TG 3100
  - California Statewide

- **TS2**
  - **Time Slot 2**
    - PAPA
      - TG 97272
    - SoCal
      - TG 31066
    - SoCal 1
      - TG 31067
    - Local
      - TG 2
    - Reflectors
      - TG 9
      - Unlink 4000
      - Link 4xxx
      - Status 5000
  - National and Worldwide
  - Regional and Club
  - Local and Reflectors
Reflectors (YSF, DSTAR)

Source: ICOM
Reflector basics

- The reflector is essentially a “VoIP packet repeater” which connects repeaters or gateways.
- The reflector maintains a “list” of subscribers which consists of currently connected gateways (repeaters).
- VoIP packets sent to the reflector from a subscribing gateway are re-sent (shotgun style) to each of the other subscribers (i.e. connected gateways).
- The “users” communicate with the repeater which is, itself, linked to the reflector as a “subscriber”. Users do not communicate directly with a reflector only indirectly via the gateway.
Reflector Operation (DSTAR):

Gateways A, B, C and D are “Linked” (or subscribed) to Reflector REF012A.

Note: The reflector interaction is strictly with the repeaters (or “gateways”), it knows NOTHING about the users. Any user on any linked gateway is heard by all users on other linked gateways. The reflector receives packets from subscribed GATEWAYS and “reflects” packets to subscribed GATEWAYS.

Subscriber Database:
Woodson – K16KQU^G,
San Marcos – K16FCH^G,
Otay – KW6HRO^G,
San Jose – W6PW^BBG

Note: ‘^’ represents a blank
Typical YSF/FSC Network

There are two “Non-Yaesu” reflector methodologies currently available for Fusion:
1. FSC Server 001, 002 ... 005
2. The YSF server

To access these reflector systems the user must have an access point of some sort with the appropriate gateway software running on his computer. There are many options for the access point HW such as DV4Mini, DV Mega, ZumSpot, Shark RF Open Spot, etc. Many of these use the Raspberry Pi platform to host the gateway application. At the present time, the most popular gateway application seems to be Pi-Star. The OpenSpot is fully self contained and accessible via a web interface.

You set your access point up for a simplex channel and use the gateway SW to select the target reflector.
Typical Wires-X Network
Hot Spots

These things allow you to establish a local RF network “access point” wherever you have an internet connection.

DV Access Point Dongle (DSTAR only) Need a Raspberry Pi

All Modes, wherever you may be

Shark RF Open Spot (DSTAR, YSF, DMR) Needs Wired Internet

No Repeater? No Problem!

Zum Spot (DSTAR, YSF, DMR, P25) Needs a Raspberry Pi

$269

$199

$140
Digital Voice for Amateur Radio

Appendix One
Available Equipment
Popular 50 W DMR Repeaters

Motorola SLR-5700 Repeater
$2000

Hytera RD-982 Repeater
$1800

Motorola XPR-8400 Repeater
$1800
Popular DMR Mobile Radios

- Motorola XPR5550: $589
- Vertex Standard VXD7200: $400
- Hytera MD78XG: $489
- Connect Syst CS800: $260
Some Popular DMR Portables

- **Tytera MD380**
  - VHF or UHF
  - $99

- **AnyTone ATD UV688V**
  - VHF/UHF
  - $179

- **Hytera AR482G**
  - UHF
  - $320

- **Hytera PD982**
  - VHF or UHF
  - $700

- **Motorola XPR7550E**
  - VHF or UHF
  - $725
Popular DSTAR Radios

ICOM ID-51a Plus
$349

Kenwood TH-D74A
$610

ICOM ID-880
$299

ICOM ID-5100
$520
Popular Yaesu FUSION Radios

- Yaesu DR1 Fusion Repeater: $500
- Yaesu FTM-400: $499
- Yaesu FT-2dr: $369
- Yaesu FT-70dr: $199
- Yaesu FTM-100: $299
Ham Friendly Dealers

- Sandy’s Communications (Motorola), 866-993-9011, Contact: Jeff Samuels, N0WTF
- Two Way Digital Radio Communications (Motorola), 828-389-5000, Contact: Ken Bryant, K1DMR
- Raynet Communications, (Hytera / TYT), 626-475-5926, Raymund Reyes, KJ6RAY
- Connect Systems, Inc., (Connect Systems), 818-889-0503, Contact: Jerry Wanger
- Ham Radio Outlet, Inc. (Vertex Standard, Tera, Hytera, Icom, Kenwood, Yaesu, Wuxon, Hot Spots)
- GigaParts (Icom, Kenwood, Yaesu, Others)
Further Information

- PAPA System: http://www.papasys.com/
- DMR:
  - Brandmeister: https://brandmeister.network/
  - Hoseline: http://hose.brandmeister.network/
  - DMR-MARC: http://www.dmr-marc.net/
- DSTAR
- Yaesu System Fusion
  - SoCal Link Society (Fusion): http://www.johnbushwebsite.com/wb6aje/
Questions

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