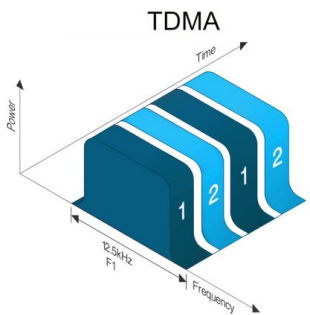




An Introduction to Digital Mobile Radio (DMR)



Ben Mills N4CV





About the Author

RF Engineer at SRC, Inc

Former MotoTRBO System Design Engineer
for Motorola Solutions Federal Division

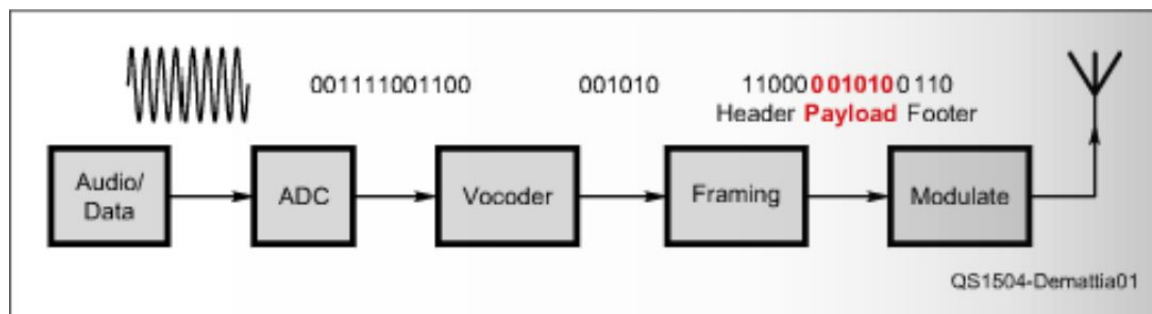
First licensed in 2001 as KG4QVP. Amateur
Extra Class since 2005, N4CV.

Amateur Radio interests include APRS, digital
modes, HF contesting, field operating,
emergency communications

Advanced Emergency Medical Technician with
Sterling Volunteer Rescue Squad (Loudoun)

What is Digital Voice?

- Microphone audio is digitized by an analog-to-digital converter
- Vocoder provides compression and forward error correction
 - Optimized for human voice
 - Broken into uniform-length packets
- Framing bits are added (header and footer) to include sync bits, identifying information, destination information, data messages, and other signalling
- This stream is passed to the modulator and on to the RF section and antenna



What is Digital Mobile Radio (DMR)?

- A open and published Standard for Digital Voice Communications
- Developed by European Telecommunications Standards Institute (ETSI)
- Three tiers:
 - Tier 1: Unlicensed Digital Radio (dPMR446)
 - **Tier 2: Licensed Conventional Radio Systems**
 - Tier 3: Trunked Radio Systems - Standards Based
- Non-vendor specific
- Manufacturers conform to agreements set up by the DMR Association

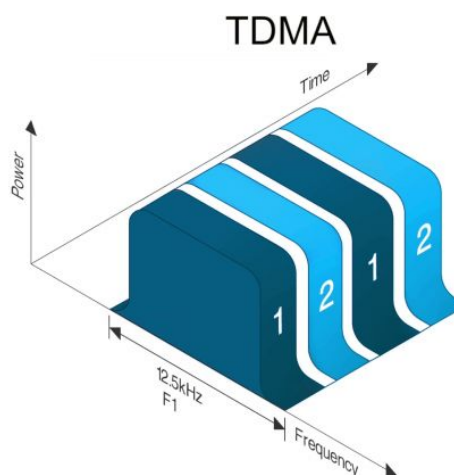
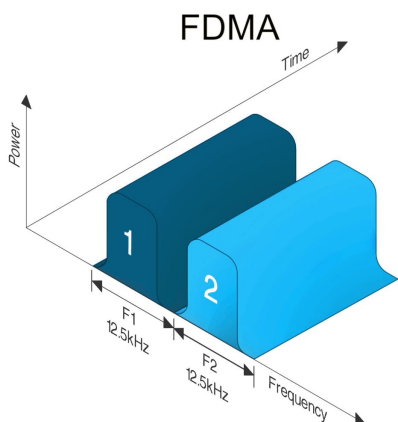


The DMR Standard

- Defines the Common Air Interface (CAI) for radio interoperability
 - Two “timeslot” TDMA
 - 12.5 kHz occupied channel bandwidth (6.25 kHz equivalent)
 - 4FSK modulation
 - Designed for RF frequencies between 30 MHz and 1 GHz
-
- DMR Association members have agreed to use the Advanced Multiband Excitation +2 (AMBE+2) vocoder. This is a proprietary vocoder owned by Digital Voice Systems, Inc. It is important to note that this is not specified in the ETSI standard but agreed upon by the manufacturers.

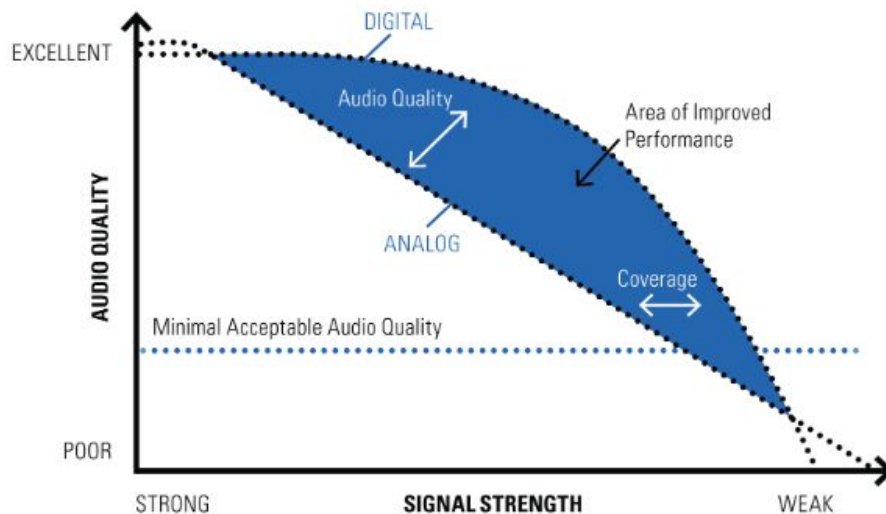
Timeslots and TDMA

- “Traditional” analog repeaters take up 25 kHz of spectrum to carry a single voice conversation in half-duplex. This means that if entire 2 meter band were allocated to FM repeaters, there are 80 repeater pairs available. This is known as frequency division multiple access (FDMA)
- TDMA (time division multiple access) offers two alternating “timeslots” in one 12.5 kHz wide RF channel (“6.25 kHz equivalent efficiency”). DMR timeslots are 30ms long and audio is compressed to fit.



DMR vs. Analog

- Two simultaneous conversations on a repeater
 - Subscriber units transmit only in one timeslot while repeaters transmit to fill both timeslots
 - Repeaters provide time sync for subscribers on the system
- More efficient spectrum utilization - 4x over 25 kHz “wideband” FM channel
- Improved audio performance*
 - Digital voice retains better quality than analog as signal strength decreases.
 - No noise bursts or “static” as signal level decreases
 - As signal level decreases, bit errors occur instead
 - Vocoder provides some forward error correction (FEC)

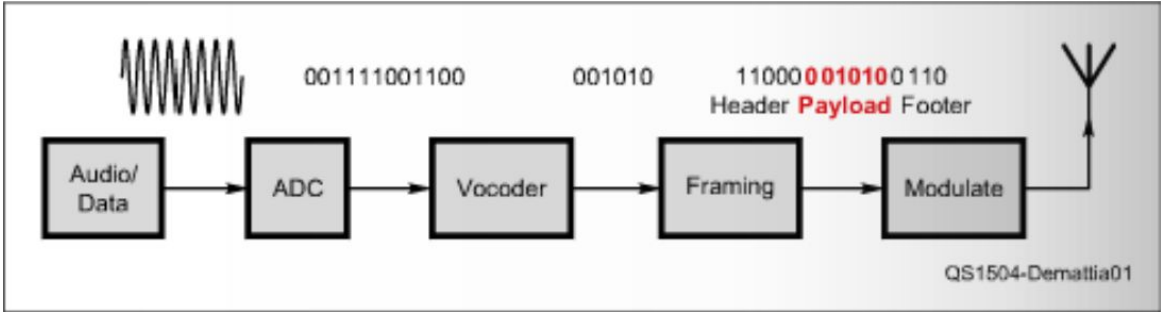


DMR vs. Analog

- Longer battery life*
 - Radio is only transmitting 46% of time
 - More DSP and vocoder power, though
 - DMR Association states “up to 40 percent improvement over analog radios.”
- Encryption*
- Simplex and Repeaters available
- Audio packet-based internet connection between repeaters
 - Repeaters forward digital packets (over the air and over the internet)
- Other features as available on professional radio systems

Digital Voice Mode Comparison

	D-STAR	DMR	Fusion	APCO25
Vocoder	AMBE+	AMBE+2	AMBE+2	AMBE+2
FEC	Voice	Voice	Voice	Voice
Modulation	GMSK	4FSK	C4FM	C4FM
Multiplex	FDMA	TDMA	FDMA	TDMA
Data Rate	4.8 kbps	4.8 kbps (x2)	9.6 kbps	9.6 kbps
Bandwidth	6.25 kHz	12.5 kHz	12.5 kHz	12.5 kHz
Channels	1	2	1	1



Terminology

- Naming conventions come from historical context in professional, public safety, and military radio
- Some terms may not be familiar to amateur radio operators
- Programming a radio to operate on DMR is not simple and the user needs to understand how the system operates in order to get the most out of their experience
- Radios cannot easily be programmed via the front panel and are instead configured on a PC where a **codeplug** is generated and loaded into the radio via a programming cable

Radio ID

- Every radio must have a unique numerical identifier -- **Radio ID**
- Sent as part of each transmission
- Other radios maintain a lookup table of Radio IDs
- Radioid.net maintains database and issues Radio IDs for amateur radio operators: <https://database.radioid.net/database/>
- Radio IDs for individuals will be eight digits

ONLY 100 Results will be returned from any search, looking for database dumps? Database Dump Files

DMR Radio ID Search	
DMR ID	<input type="text" value="Equals"/>
Callsign	<input type="text" value="Equals"/>
Surname	<input type="text" value="Equals"/>
City	<input type="text" value="Equals"/>
State/Prov	<input type="text" value="Equals"/>
Country	<input type="text" value="Equals"/>
<input type="button" value="Search"/>	

DMR Repeater Search	
DMR ID	<input type="text" value="Equals"/>
Callsign	<input type="text" value="Equals"/>
City	<input type="text" value="Equals"/>
State/Prov	<input type="text" value="Equals"/>
Country	<input type="text" value="Equals"/>
Frequency	<input type="text" value="Equals"/>
Trustee	<input type="text" value="Equals"/>
<input type="button" value="Search"/>	

NXDN User Search	
NXDN ID	<input type="text" value="Equals"/>
Callsign	<input type="text" value="Equals"/>
Surname	<input type="text" value="Equals"/>
City	<input type="text" value="Equals"/>
State/Prov	<input type="text" value="Equals"/>
Country	<input type="text" value="Equals"/>
<input type="button" value="Search"/>	

No Results, try searching for something

Search Results will appear here after you use one of the search areas above and click "search", if your looking for entire dumps of the database, please see the [Database Dump Files](#) section.

If your looking for something you can use programatically, I suggest you check out our API
Where you will find easy to query data in JSON output.

Talkgroup (TG)

- Common terminology in commercial and public safety radio
- “Squelch Groups” that allow groups of users to share a timeslot without disturbing other users
- Only one talkgroup can use the timeslot at a time
- DSTAR calls them “reflectors.” Fusion calls them “rooms.”
- Allows users on the channel to be separated by job, location, language, etc.
- Propagates the radio system and internet along with the voice data; other radios remain quiet unless the talkgroup they want to monitor is active
- Have their own different-looking Radio IDs
- Common talkgroups include:
 - 3151 - Virginia Statewide
 - 312 - TAC 312
 - 13 - Worldwide English

Channel

- Defines RF **transmit and receive frequencies**
- Defines “**color code**” that the system uses -- 1 through 16
- Selects which **timeslot** to use -- TS1 or TS2
- Includes **talkgroup** to transmit “to” and talkgroup(s) to receive
- Defines **admit criteria** -- color code free, channel free, always
- Other channel-specific settings like power level, scan group, etc.

Example Channel Configuration - MD380

The screenshot displays the 'Channels Information' dialog box for an MD380 radio. The dialog is divided into three main sections: Digital/Analog Data, Digital Data, and Analog Data. Several fields are highlighted with red boxes, indicating specific configuration values.

Digital/Analog Data

- Channel Mode: Digital
- Channel Name: VIE 2 VA 3151
- Band Width: 12.5kHz
- RX Frequency(MHz): 442.90000
- TX Frequency(MHz): 447.90000
- Admit Criteria: Color Code
- Scan List: None
- Squelch: Tight
- RX Ref Frequency: Medium
- TX Ref Frequency: Low
- TOT[s]: 120
- TOT Rekey Delay[s]: 0
- Power: Low
- Auto Scan: ☐
- Rx Only: ☐
- Lone Worker: ☐
- VOX: ☐
- Allow Talkaround: ☐

Digital Data

- Private Call Confirmed: ☐
- Emergency Alarm Ack: ☐
- Data Call Confirmed: ☐
- Compressed UDP Data Header: ☐
- Emergency System: None
- Contact Name: VA Statewide
- Group List: None
- Color Code: 1
- Repeater Slot: 1
- Privacy: None
- Privacy No.: 16

Analog Data

- CTCSS/DCS Dec: 00.0
- CTCSS/DCS Enc: 00.0
- QT Reverse: 180
- Tx Signaling System:
- Rx Signaling System:
- Reverse Burst/Turn-off Code: ☐
- Display PTT ID: ☐
- Decode 1: ☐
- Decode 2: ☐
- Decode 3: ☐
- Decode 4: ☐
- Decode 5: ☐
- Decode 6: ☐
- Decode 7: ☐
- Decode 8: ☐

308 of 353 | <- | <<- | -> | -> | Add | Delete

Example Channel Configuration - CS800

Channel Alias		ALEX LOCAL
Digital ID		3137000
Color Code		1
Repeater/Time Slot		Slot 1
Channel Voice Annunciation		Record 1
Scan List		Alexandria
Auto Scan Start		<input type="checkbox"/>
Rx Only		<input type="checkbox"/>
Talk Around		<input type="checkbox"/>
Lone Worker		<input type="checkbox"/>
VOX		<input type="checkbox"/>

Receive	Offset [MHz]	Transmit
Frequency [MHz]	5.000000	Frequency [MHz]
442.412500	Apply	447.412500

Ref Frequency [MHz]	Low	Ref Frequency [MHz]	Low
Rx Group List	None	Tx Contact	Local
Emergency Alarm Indication	<input type="checkbox"/>	Emergency System	None
Emergency Alarm Ack	<input type="checkbox"/>	Power Level	High
Emergency Call Indication	<input type="checkbox"/>	Tx Admit	Color Code Free
Encrypt		Tx Time-Out Time [s]	60
Encrypt	<input type="checkbox"/>	TOT Re-key Time [s]	0
Encrypt Type	Enhanced	TOT Pre-Alert Time [s]	0
Encrypt Key List	Key 1	Private Call Confirmed	<input type="checkbox"/>
		Data Call Confirmed	<input type="checkbox"/>

Zone

- A group of individual channels that the user defines for his own radio
- Many radios limit the zone to 16 channels
- Most radios have memory for many zones
- Traditionally, defined a geographical area of operation

Repeaters

- Repeaters operate similar to conventional analog repeaters
 - Provide two independent talk paths, one per timeslot
- Receive on both timeslots independently and transmit on both full duty-cycle
- Provide a time reference for subscriber radios
- Talkgroups can be designated per a fixed list or patch any valid talkgroup
- Do not require internet access for local communications
- Can be networked to extend range
- Typically UHF (70 cm) though VHF (2 m) is growing
- Two common brands: Motorola or Bridgecom



Networks and C-Bridges

- Repeaters can be networked together to share talkgroups
- Two configurations:
 - Brandmeister supports direct repeater connections
 - IP Site Connect (Motorola protocol) supports multiple repeaters on a single C-Bridge



Brandmeister Network

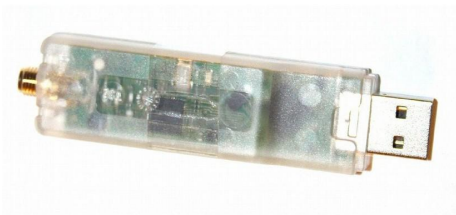
- Repeaters connect directly to the Brandmeister network
- TS2 for local communications
- TS1 offers any Brandmeister-available talkgroup on-demand (over 500)
- Web status interface at <https://brandmeister.network/>
- Web monitoring interface at <http://hose.brandmeister.network/>

Other Networks

- Group of repeaters use the IP Site Connect protocol to expand coverage area
- “Peer” repeaters connect to the internet and connect to a “master” repeater
- One peer can be a C-Bridge which maintains connections with other networks
- Many networks available and not geographically limited
- Common Networks:
 - DMR-MARC
 - K4USD
 - PRN
 - DMRVA
 - NoVA DMR

Hotspots

- Low-power personal RF-to-internet gateway, half-duplex
- Useful when out of range of a repeater or while traveling
- Accessed via any DMR-capable radio
- Typically connect to Brandmeister network unless agreement in place with C-Bridge operator
- Some cross-mode versions available (operate DSTAR, DMR, P25)
- Inexpensive access to DMR network \$100 to \$300
- Common models:
 - SharkRF OpenSpot
 - MMDVM
 - JumboSpot



Other DMR System Features

- Text Messaging and Telemetry
- Private Call
- GPS Tracking
- Scan and Nuisance Delete
- Roaming (manufacturer specific)
- Talk-Around Mode
- Simplex (single timeslot)

Quick Facts

- There are 164291 registered DMR amateur Radio IDs in the world
 - There are 74615 registered DMR amateur Radio IDs in the USA
 - There are 2167 registered DMR amateur Radio IDs in VA
-
- There are 7453 registered DMR amateur repeaters in the world
 - There are 3388 registered DMR amateur repeaters in the USA
 - There are 133 registered DMR amateur repeaters in VA

DMR Radios

- Manufacturers are members of the DMR Association
- Not yet available from familiar amateur radio brands
- Available from many sources, mostly online
- Generally have rich menu structures to allow user to access features and customize the radio configuration.
- Inexpensive and very expensive models available
- Important considerations:
 - Portable or Mobile
 - Used or New
 - Operating Band
 - Analog Capable
 - Programming software and cables
 - User interface - screen, knobs, keypad
 - DMR Compatibility

Tytera



MD-380
UHF
\$100



MD-2017
VHF and UHF
\$160



MD-9600
VHF and UHF
\$280

Connect Systems



CS750
UHF
\$240

CS751
VHF
\$240



CS-800
UHF
\$280

CS-801
VHF
\$280

CS-800D
VHF and UHF
\$299

Anyone



AT-D868UV
VHF and UHF
\$170



AT-D878UV
VHF and UHF
\$240



AT-D578UV
VHF and UHF
\$400

Motorola Solutions



XPR6550
VHF or UHF



XPR7550
VHF or UHF



XPR3500
VHF or UHF



XPR4550
UHF or VHF



SL7550
UHF



SL300
VHF or UHF



XPR5550
UHF or VHF

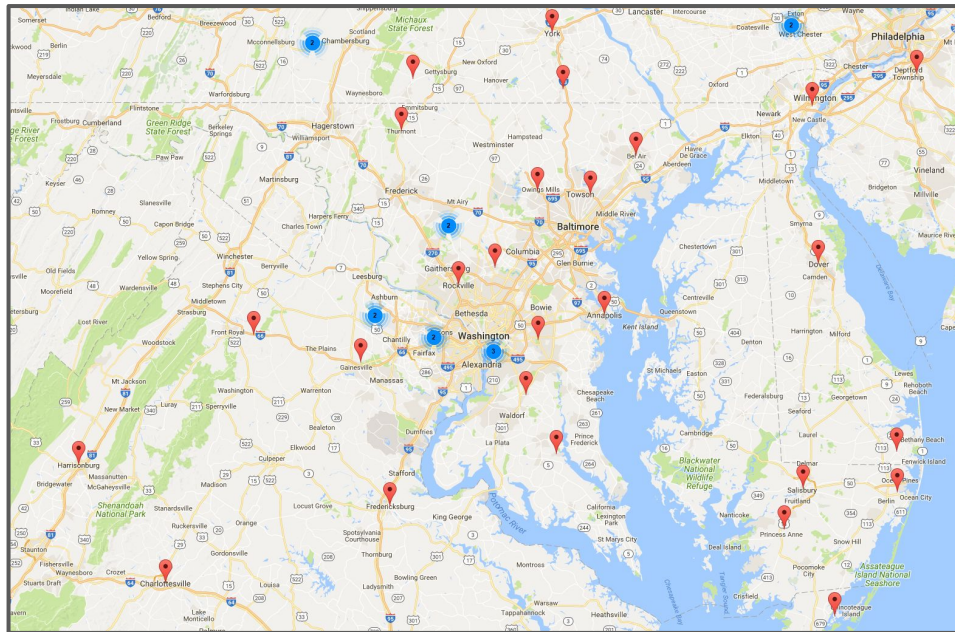
Other Models Available

- Kirisun
- Tera
- Kenwood (NX- and TK-Series)
- RFinder Android Radio



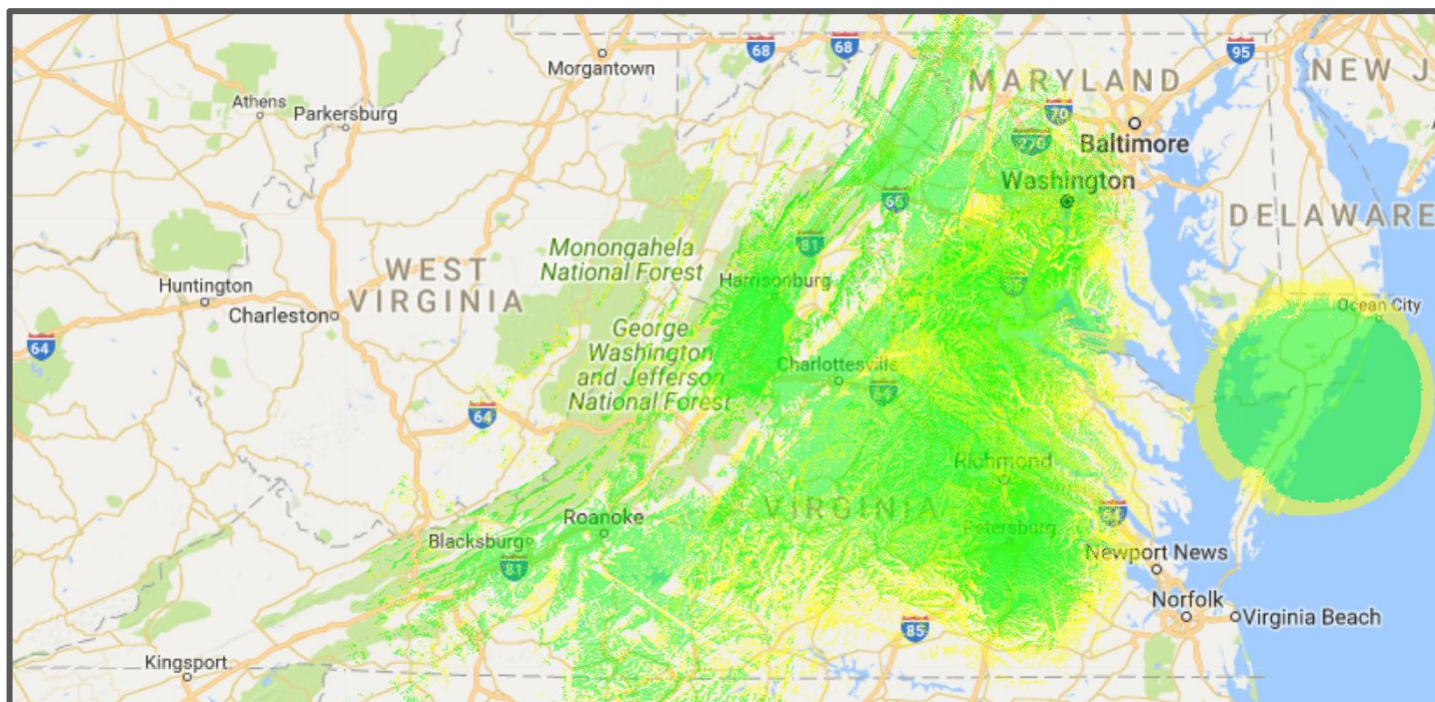
Local Repeater Systems

- DMRVA and NOVA DMR (AWS Virginia) in Northern VA
- K4USD, DMR MARC, and Brandmeister are nationwide with repeaters elsewhere in VA, MD, WV
- Interconnected via C-Bridges with other networks

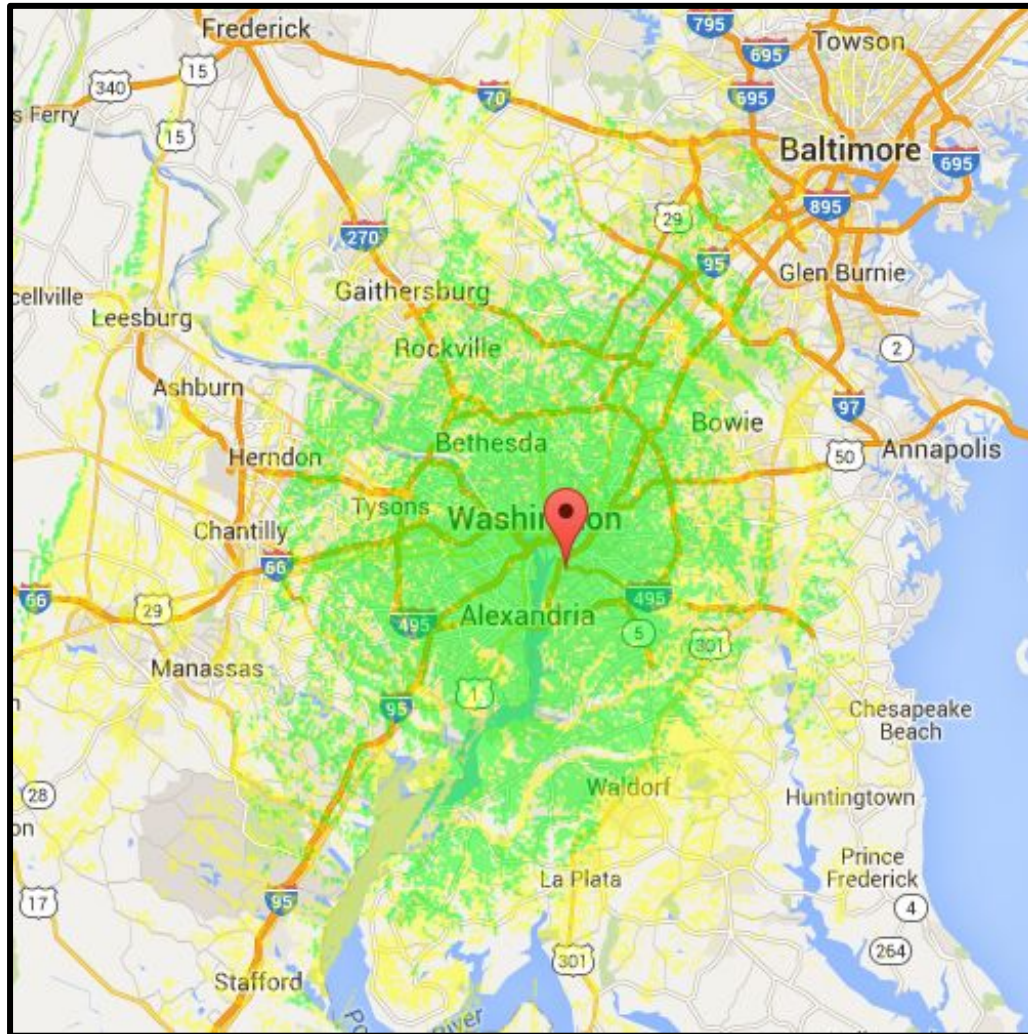


DMRVA

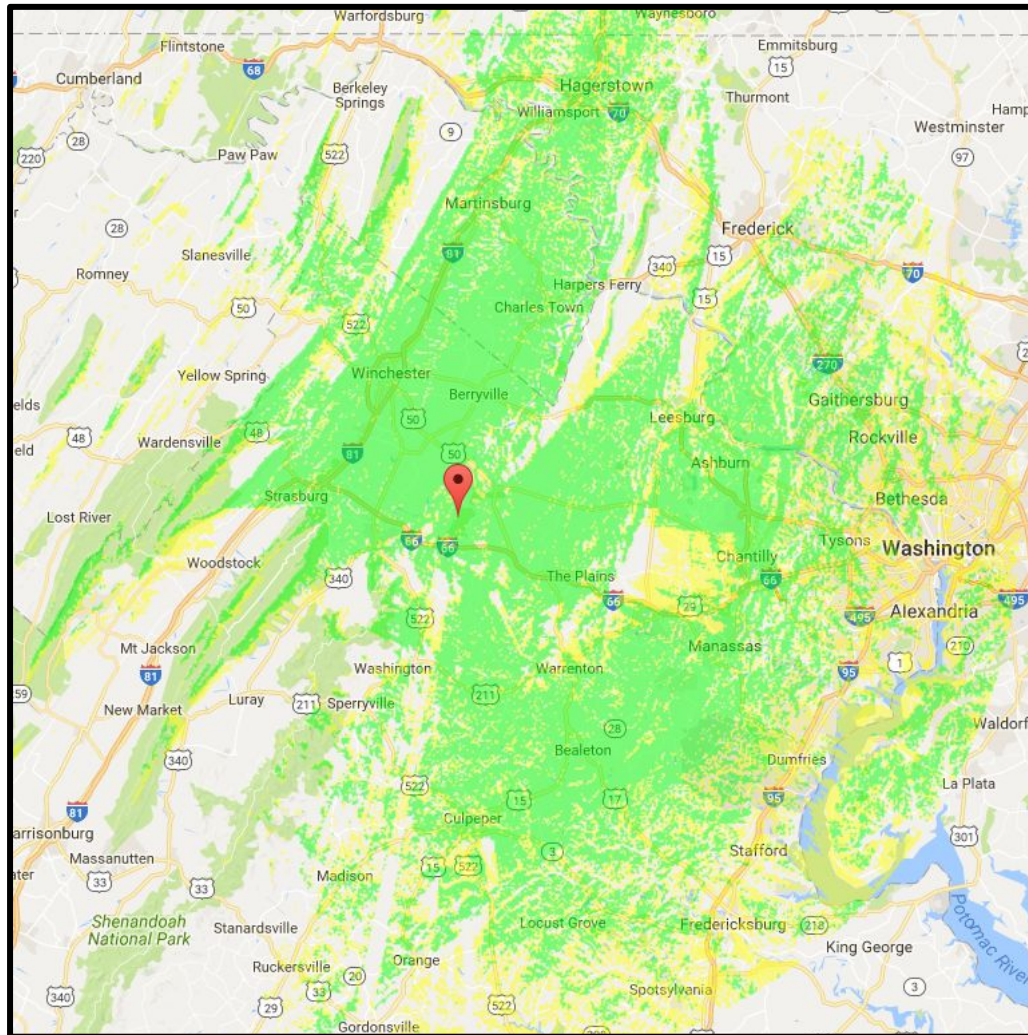
- Statewide network with 15 repeaters throughout Virginia
- Common talkgroups include VA Statewide, Local, TAC310, Two Virginia TAC Channels, Southeast Region, Mid-Atlantic Region
- More information at <http://www.dmrva.org/>
- Netwatch at <http://cbridge.dmrva.org/MinimalNetwatchBody>



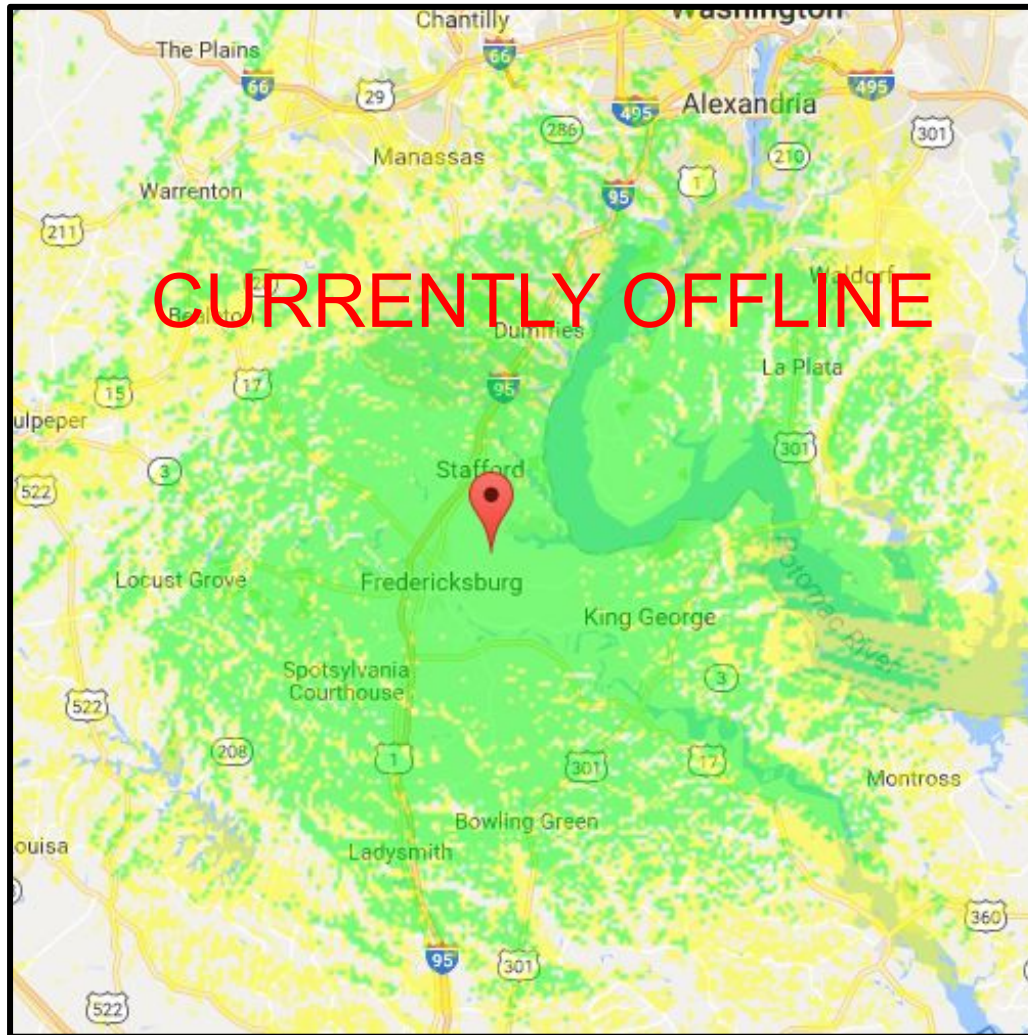
DMRVA: Washington, DC (W3AGB) 444.1625 MHz



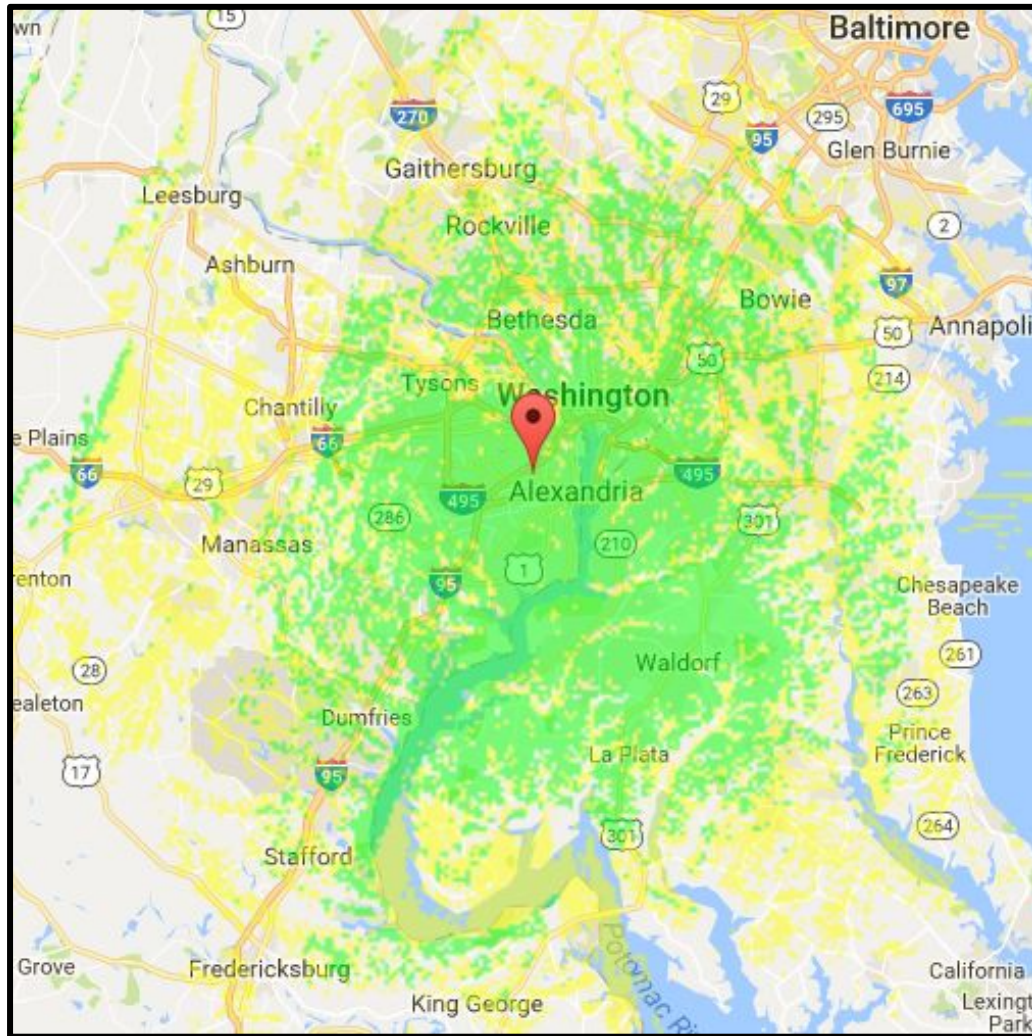
DMRVA: Linden (N8RAT) 443.1625 MHz



DMRVA: Fredericksburg (N8RAT) 442.1125 MHz

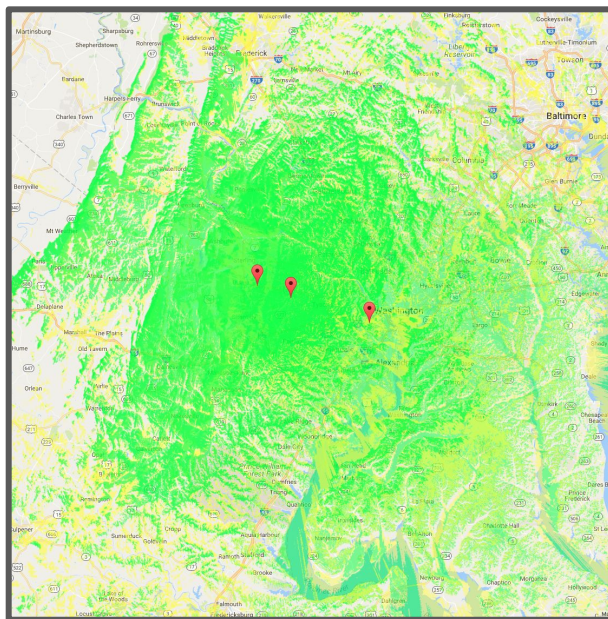


DMRVA: Alexandria (W4HFFH) 442.4125 MHz



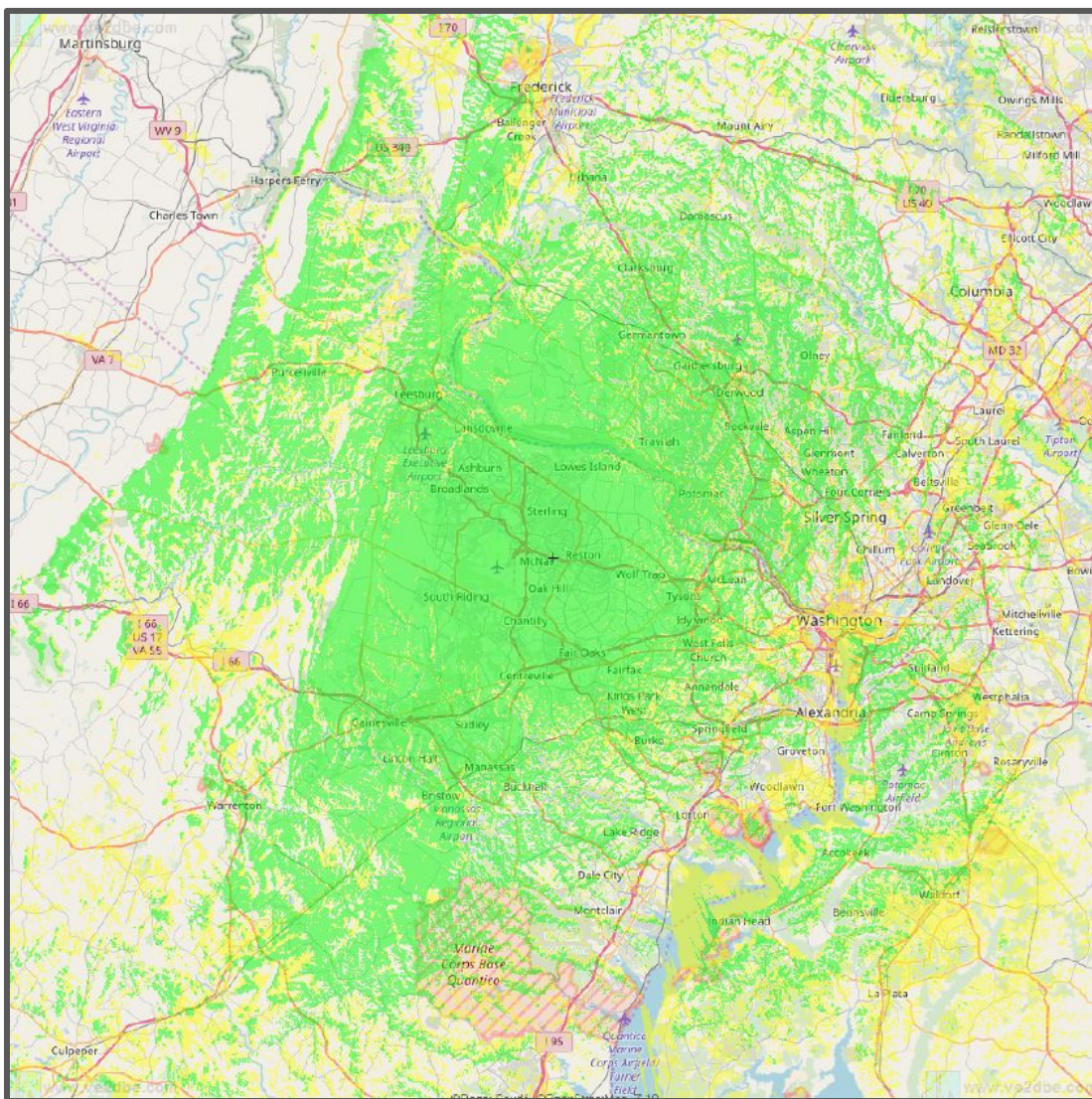
NoVA DMR (N3QEM)

- Local network with 8 repeaters throughout Northern Virginia -
 - VHF, UHF, 900 MHz
- Common talkgroups include DMRVA talkgroups as well as MD, PA, Worldwide, Wash-Baltimore Local, and additional TAC channels
- Talkgroup matrix at <http://www.dmrva.org/northern-virginia-repeater-system-talkgroup-matrix/>
- Netwatch at <http://34.202.6.66:42420/CallWatch>
- Recent call log at <http://dmr-mon.n4cv.net/index2.html>



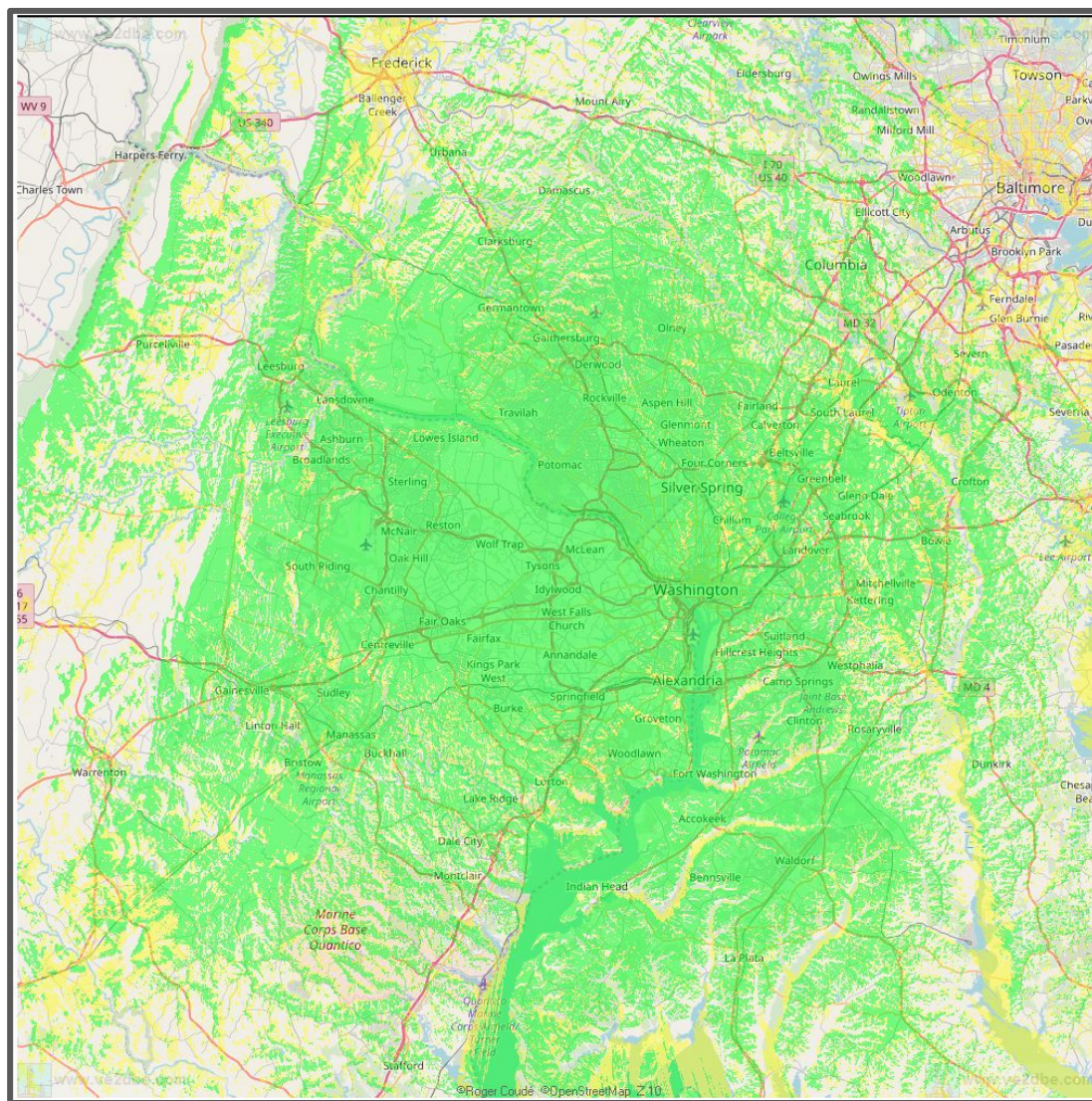
NoVA DMR: Herndon 442.43750 MHz (+5 MHz)

- SLR5700 Repeater
- Crescend 100w Amp
- DuraComm 12V Power Supply
- TX/RX Systems Duplexer
- Microlab Combiner + Isolator
- Advanced Receiver Research P432VDG +12dB Pre-amp
- Stridsberg Engineering Receiver Multicoupler
- DB420-B Antenna
- Remote RX Sites:
 - Vienna
 - Sterling
 - Tysons
 - McLean
 - Arcola
 - Arlington (planned)
 - Leesburg (planned)



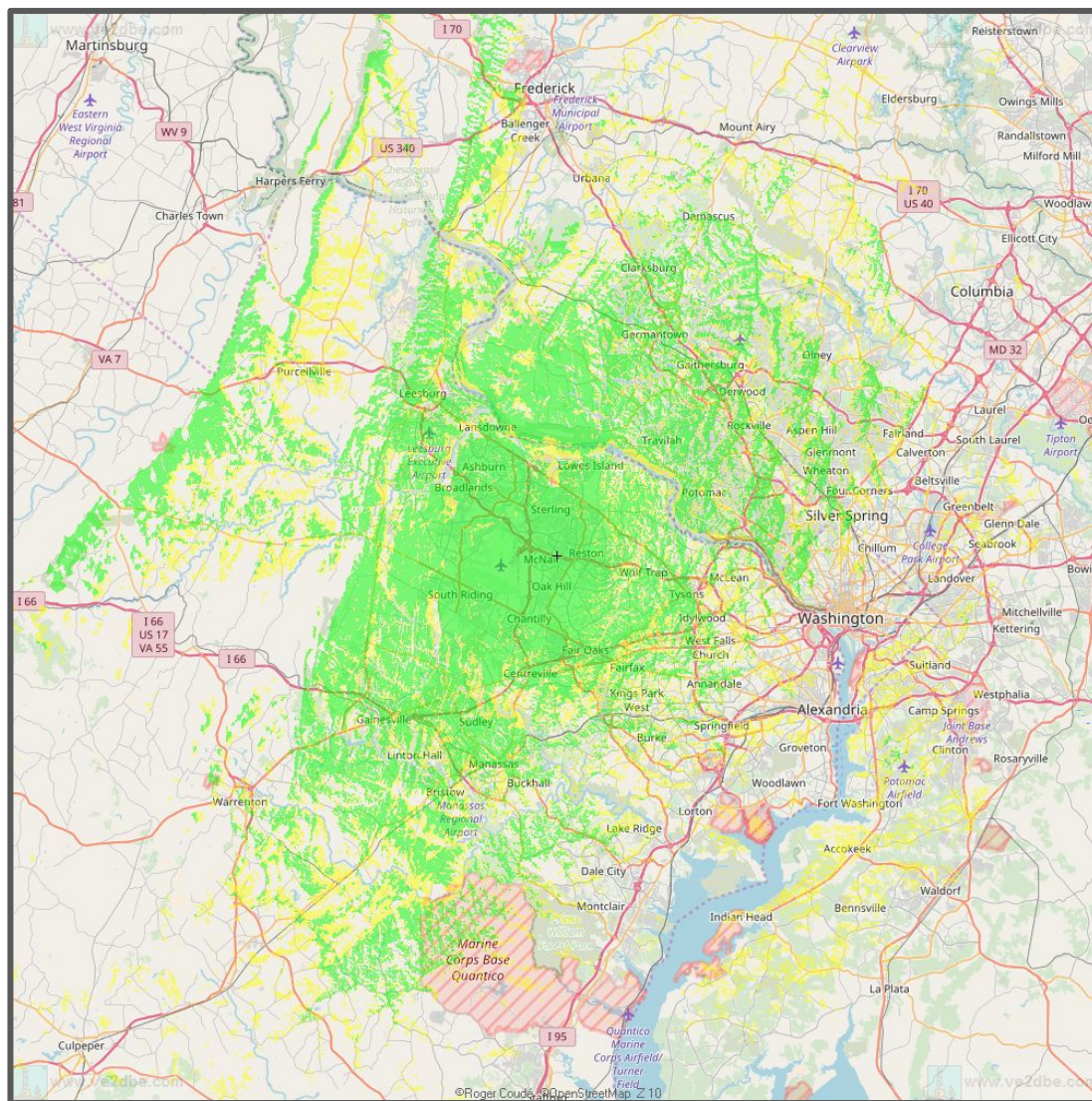
NoVA DMR: Tysons 441.3375 MHz (+5 MHz)

- N9KET
- SLR8000 100w Repeater
- Motorola Duplexer
- TX/RX Systems Multicoupler
- APC UPS
- FIOS Internet, firewall/VPN, Ethernet switch, Pi for remote programming and monitoring
- DB420-B Antenna
- Remote RX Sites:
 - Vienna
 - Herndon



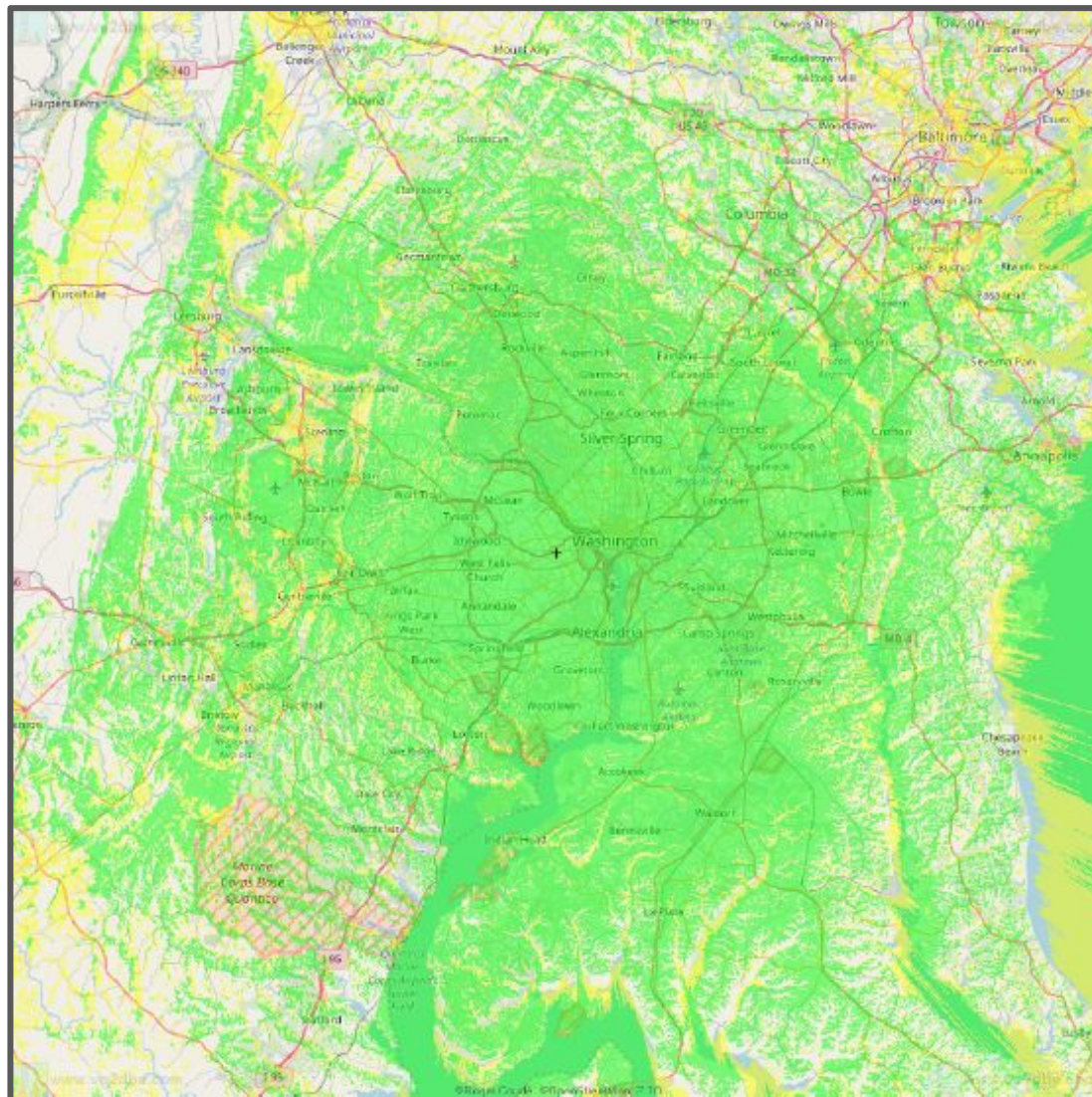
NoVA DMR: Herndon 927.6625 MHz (-25 MHz)

- XPR-8380 Repeater (35W)
- Wacom WP687-3943 Duplexer



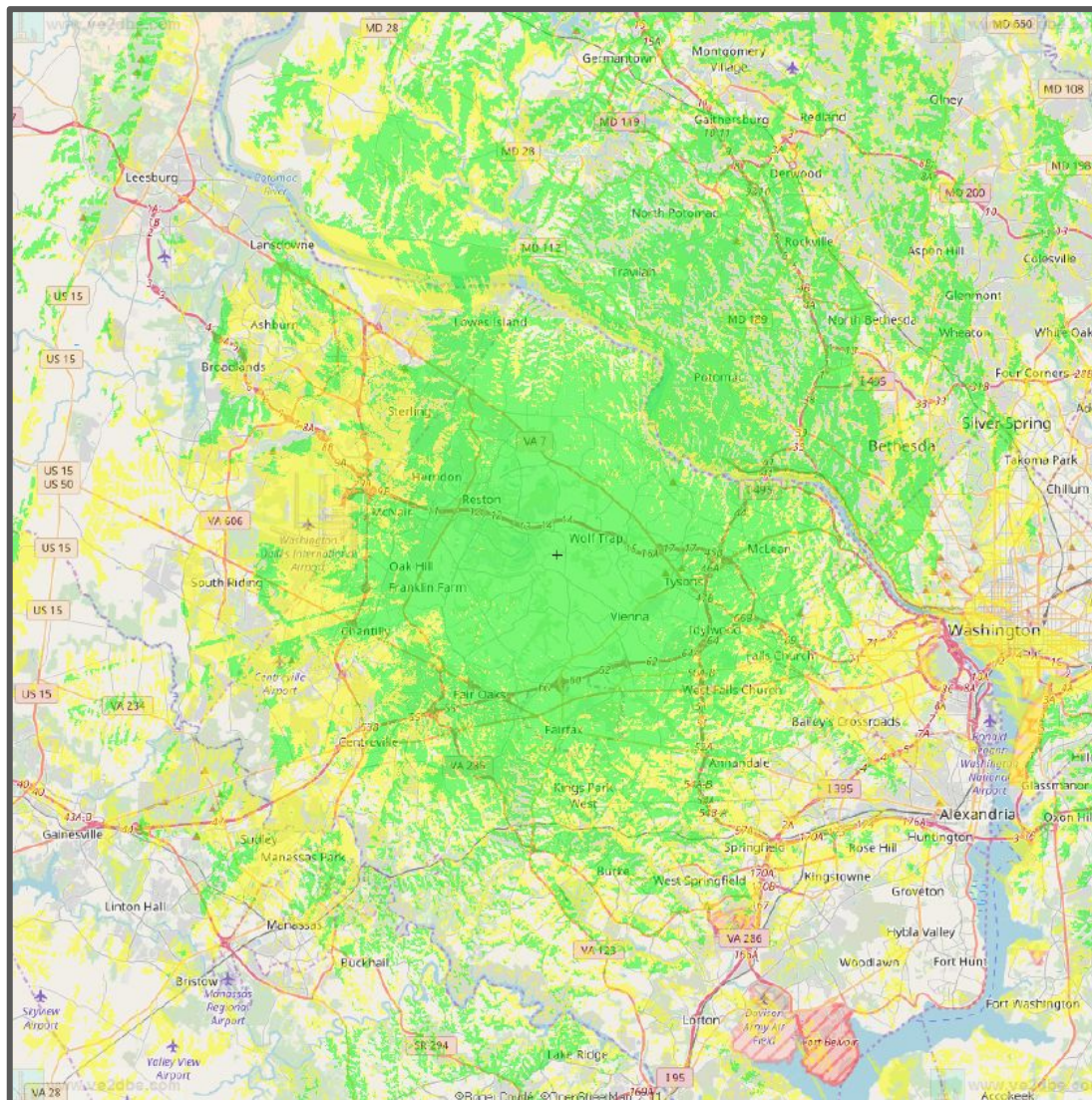
NoVA DMR: Arlington 443.06250 MHz (+5 MHz)

- SLR8000 Repeater (100W)
- TX/RX Systems Duplexer
- Advanced Receiver Research P432VDG +12dB pre-amp
- Stridsberg Engineering receiver multicoupler.
- DB408-B Antenna
- Remote Receiver:
 - Herndon



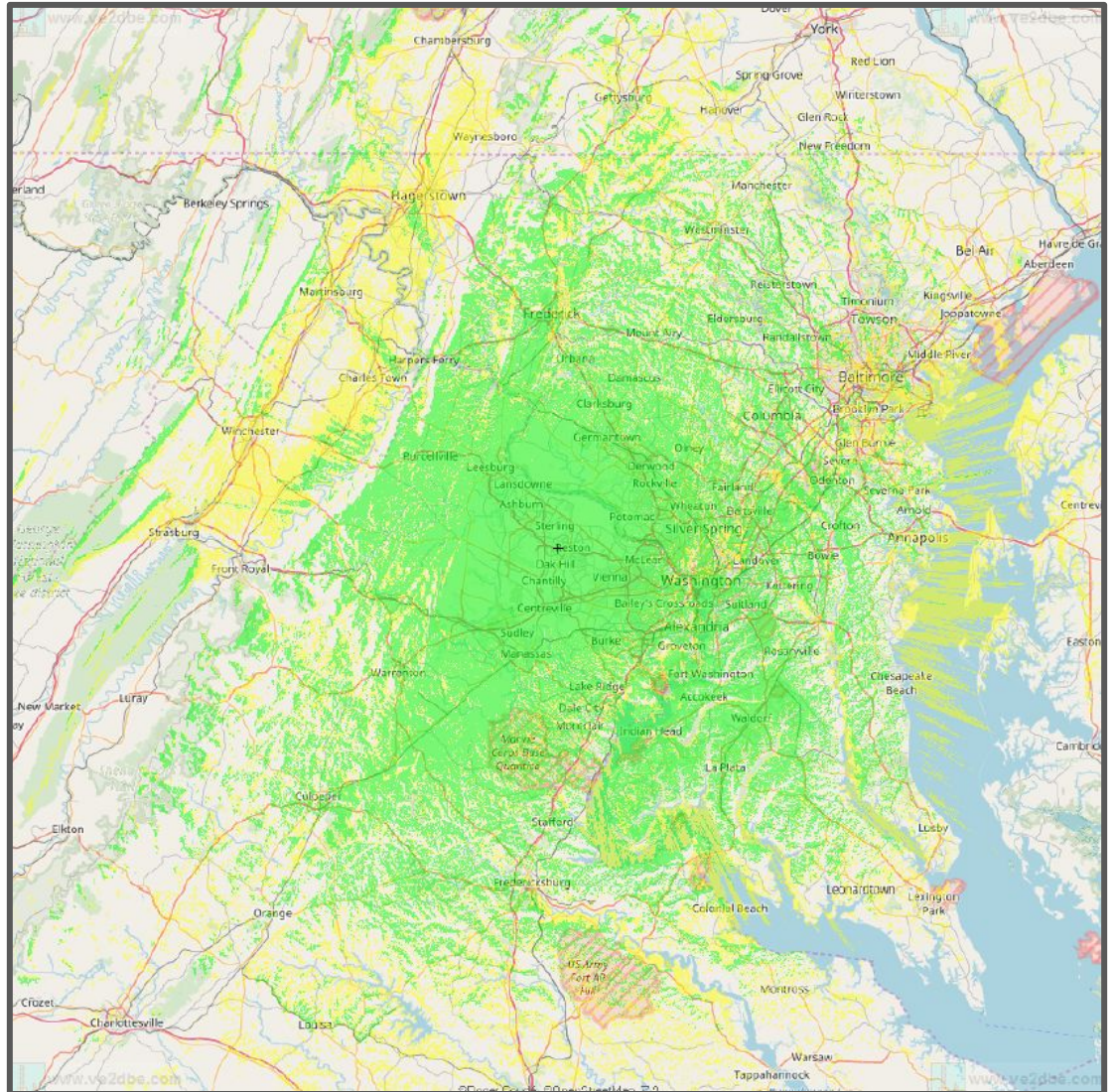
NoVA DMR: Vienna 442.9000 MHz (+5 MHz)

- SLR5700 Repeater
- TX/RX Systems Duplexer
- TX/RX Systems Combiner + Isolator
- Advanced Receiver Research P432VDG +12db pre-amp
- Stridsberg Engineering Receiver Multicoupler
- Comet GP-6 antenna.



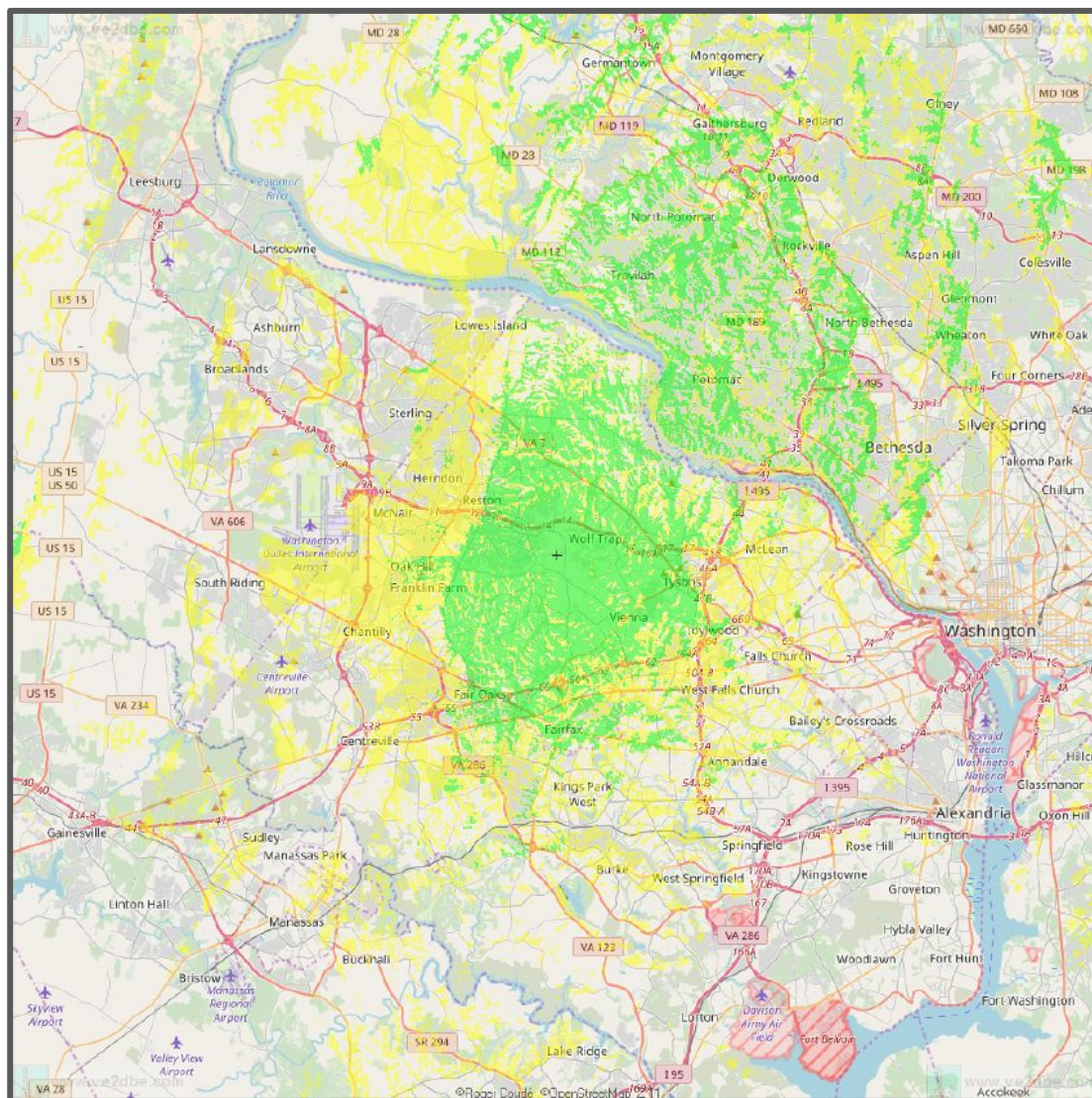
NoVA DMR: Vienna 145.1700 MHz (-600 kHz)

- SLR5700 Repeater
- Wacom Duplexer




NoVA DMR: Vienna 927.7000 MHz (-25 MHz)

- XPR8380 Repeater (35W)
- Wacom WP68703943 Duplexer



Finding Other Repeaters




[SEARCH](#)
[SUBMIT UPDATE](#)
[REVIEW/COMMENT](#)
[RADIO MEMORY](#)
[CHECK IN](#)
[CONTACT](#)

Richmond, VA

WA4FC

Repeater ID: 51-15845



Downlink: 443.5375
 Uplink: 448.5375^a
 Offset: +5.0 MHz^b
 Uplink Tone:

DMR Enabled

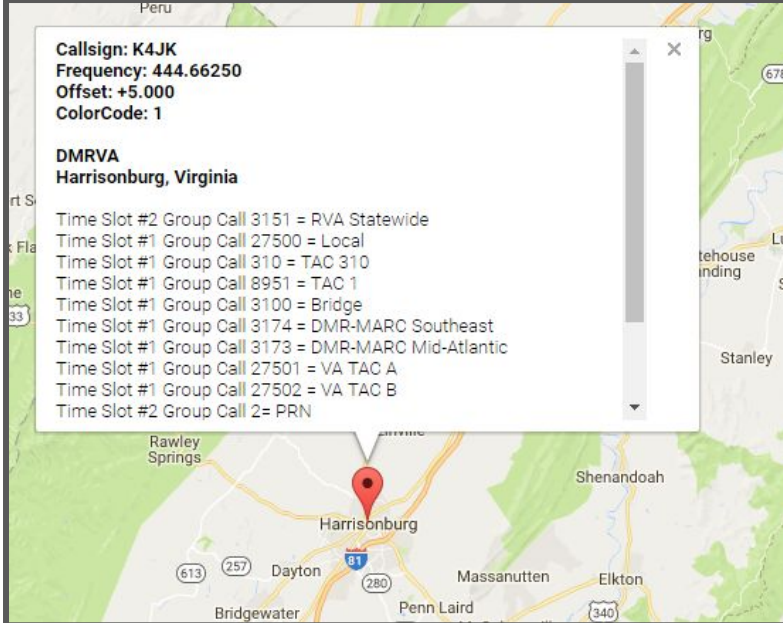
Color Code: 1

Wide Network:

Local Network: **DMRVA**

Talkgroups: [Open Talkgroup View](#)

Assignment	TS	TG	Access
TAC 310	1	310	PTT
DCI Bridge	1	3100	PTT
Mid-Atlantic Region	1	3173	PTT
Southeast Region	1	3174	PTT
TAC 1	1	8951	PTT
Parrott	1	9998	PTT
Local	1	27500	Full-Time
TAC A / Chat 1	1	27501	PTT
TAC B/Chat 2	1	27502	PTT
NCPRN	2	2	PTT
Virginia Statewide	2	3151	Full-Time



Callsign: K4JK
Frequency: 444.66250
Offset: +5.000
ColorCode: 1

DMRVA
Harrisonburg, Virginia

Time Slot #2 Group Call 3151 = RVA Statewide
 Time Slot #1 Group Call 27500 = Local
 Time Slot #1 Group Call 310 = TAC 310
 Time Slot #1 Group Call 8951 = TAC 1
 Time Slot #1 Group Call 3100 = Bridge
 Time Slot #1 Group Call 3174 = DMR-MARC Southeast
 Time Slot #1 Group Call 3173 = DMR-MARC Mid-Atlantic
 Time Slot #1 Group Call 27501 = VA TAC A
 Time Slot #1 Group Call 27502 = VA TAC B
 Time Slot #2 Group Call 2 = PRN

<https://www.dmr-marc.net/repeaters.html>

<https://www.repeaterbook.com/repeaters>

Simplex

- Common simplex channels are defined by DMR user community:
 - UHF
 - 441.0000
 - 446.5000
 - 446.0750
 - VHF
 - 145.7900
 - 145.5100
- Configure the channel for:
 - Talkgroup: 99
 - Color Code: 1
 - Timeslot: 1
 - Admit Criteria: Always
 - In-Call Criteria: TX or Always

Getting on the Air

- Apply for a Radio ID (<https://www.radioid.net/register>)
- Locate the repeaters in your area (RepeaterBook or DMR-MARC)
- Configure the radio codeplug:
 - Set your Radio ID
 - Turn off Automated Registration Service (ARS)
 - Create contact list including individual calls (other hams) and group calls (talkgroups)
 - Create a channel with repeater frequency and color code, timeslot and group call
 - Assign the channel to a zone so you can access it in the radio
- Talk Permit Tone
- Busy or Access Denied Tone
- Stick to local channels if possible; use Local or TAC channels for QSOs
- Radio ID is not your callsign...you still need to ID

Further Reading

- [Amateur Radio Guide to Digital Mobile Radio](#), John S. Burningham, W2XAB
 - Overview of DMR and how-To to getting on the air
- [VA3XPR Website](#)
 - News and product reviews
- [DMRVA](#)
 - Virginia-based repeater network with sample codeplugs
- [ARRL QST Article](#), John S. Burningham, W2XAB (2015)
- [Amatuer Radio Notes](#) (on [Hotspots](#))
- [DMR For Dummies](#)

Get Involved

- Nationwide and Worldwide Nets
- Emergency Communications
- Interoperability
- Local Hotspots
- Microwave Linking
- Telemetry Features
- GPS Tracking/APRS

Questions?

Ben Mills N4CV
n4cv@arrl.net