Introduction to Digital Mobile Radio

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Amateur Radio Digital Voice (DV) Modes

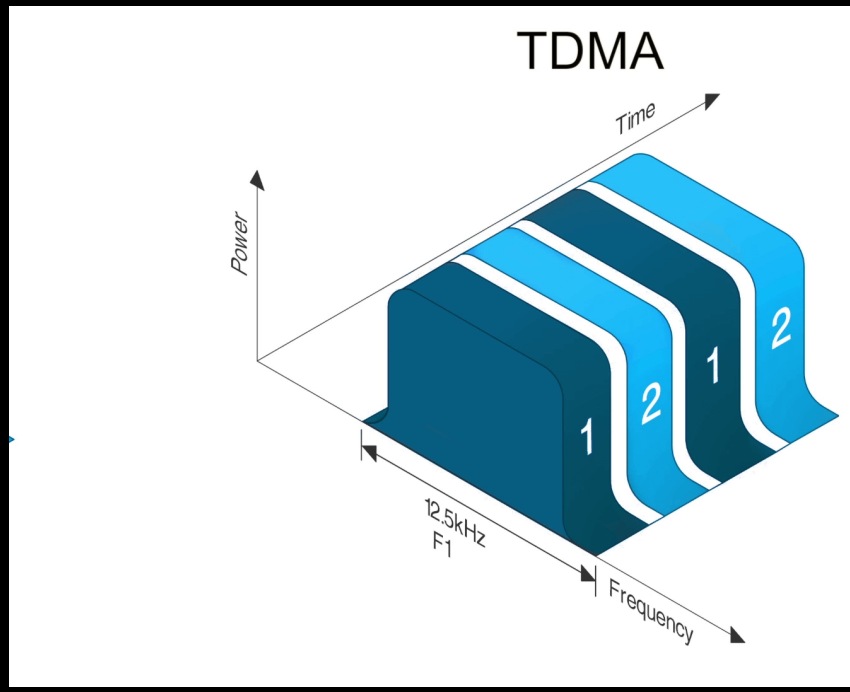
- Operation
  - Voice is compressed and digitized in the radio by a vocoder (Voice Coder) circuit using a specific codec (coder-decoder) algorithm.
    - There are hundreds of codecs used in radio and recording industries for voice and video information
  - Digital signal is sent out over RF using advanced modulation (C4FM or GMSK) and multiplexing (FDMA or TDMA)
  - Receiving radio decodes back into voice using the same codec
- A cell phone is an example of a radio that uses digital voice
- Different from digital text/data modes like Morse, AMTOR, Hellschreiber, MFSK (JT65, FT8, etc), APRS, PACTOR, PSKxx, etc.

Common DV Technologies used by Hams

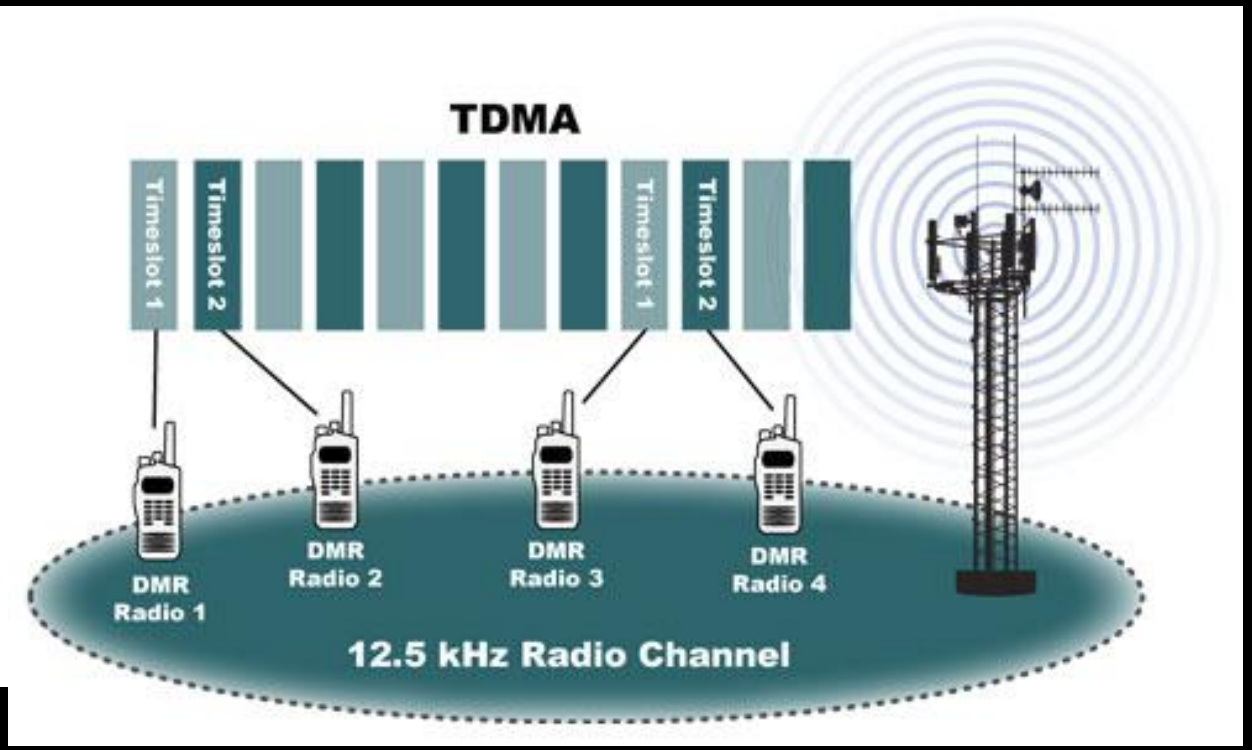
- **DMR** - Found in both commercial and public safety equipment from multiple vendors. (AMBE, 4FSK variant, TDMA)
- **D-STAR** - Open specification with proprietary vocoder system available from Icom and Kenwood Systems (AMBE, GMSK, FDMA)
- **System Fusion** - Open specification with proprietary vocoder system available from Yaesu. (AMBE, C4FM, FDMA)
- **APCO P25** - Found in repurposed public safety equipment from multiple vendors. (IMBE or AMBE, C4FM, FDMA or TDMA) [*Colorado DTRS is P25*]
- Advantages
  - Bandwidth efficient – two voice channels in the same bandwidth as one amateur FM channel
  - Extended range – some signal loss or interference can be corrected, usually see 10% or better range extension
  - No pulling the signal out of static – either there or not

Time Division Multiple Access

- 30 ms slot for each channel
- Transmitter creates 30 ms chunks of digitized voice
- Receiver reassembles the chunks



Source: "What is DMR? Tait Radio Academy" (Accessed: http://www.taitradioacademy.com/topic/what-is-dmr-1/ : 8 Aug 2017)



Source: "Benefits and Features of DMR", DMR Association (http://dmrassociation.org/downloads/documents/DMR-Association-White-Paper_Benefits-and-Features-of-DMR_160512.pdf : accessed 10 Aug 2017)

DMR Specifics

- DMR technical standard (modulation, codecs, etc.) defined by European Telecommunications Standards Institute (ETSI) for 66 MHz – 960 MHz

- Equipment interoperability, certification, promotion and education is supplied by industry consortium: Digital Mobile Radio Association
  - 56 manufacturing members

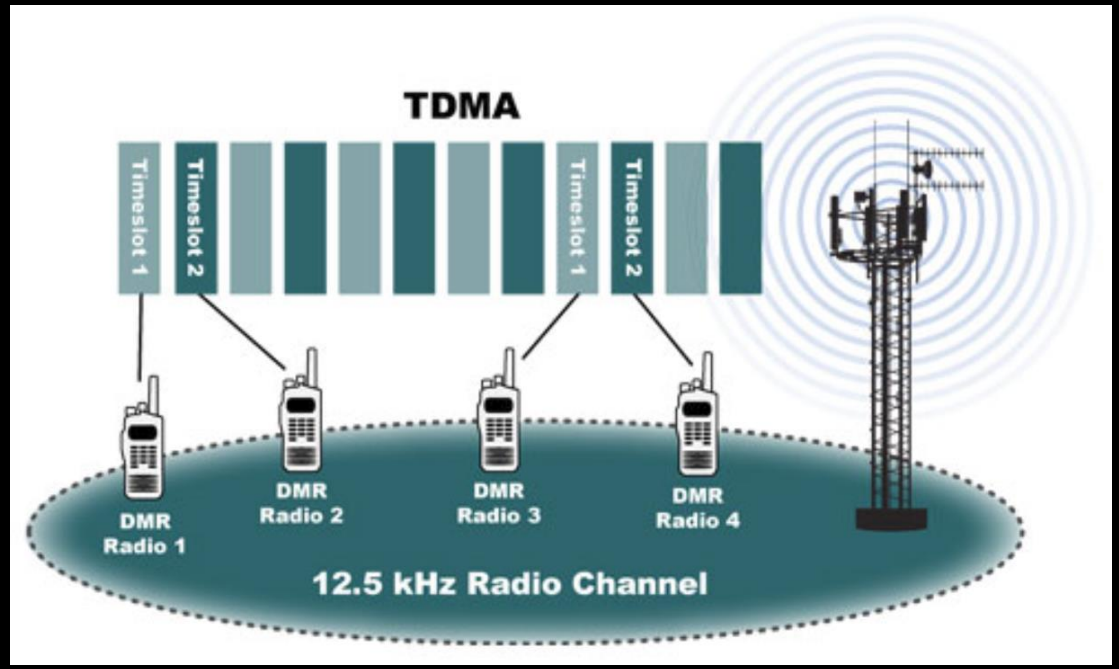
- Widespread global adoption by business, transportation, utilities, government, public service, etc.
- DMR invented by business for business
- Business radios work fine for hams, but they usually have features hams do not want and don't have features hams want… but they are cheap… because manufacturers build a LOT of them for business…
- If something about the terminology, the radio's features or the protocols seems weird, think about it from a business or public services communications perspective

Three DMR Types (Tiers)

- Tier I – Single slot TDMA – one voice channel in 12.5 kHz RF channel (2005) – consumer radios, unlicensed
- Tier II – Two-slot TDMA – two voice channels in 12.5 kHz RF channel (2005) – professional business market, licensed
- Tier III - Two-slot TDMA with trunking (2012) [Similar to P25] – professional business market, licenses
- Lower Tier radios cannot be used on higher tier systems
- Hams use Tier II – Two Slot TDMA

DMR Advantages compared to other DV modes

- Spectrum Efficient: One repeater can carry two voice channels simultaneously
  - 2 voice channels in 12.5 kHz is four times the capacity of current amateur UHF FM capacity (one voice channel in 25 kHz
- Power efficient: DMR radios only transmit during their 30 ms slot: approximately half the duty cycle of a regular FM transmission



Source: "Benefits and Features of DMR", DMR Association (http://dmrassociation.org/downloads/documents/DMR-Association-White-Paper_Benefits-and-Features-of-DMR_160512.pdf : accessed 10 Aug 2017)

There are 58,473 amateurs using DMR today

* Count of unique call signs registered in the worldwide DMR database as of 8/11/2017

DMR Modes

- Simplex
- Single Duplex Repeater
  - Voice packets are tagged by the radio with a “talkgroup” (virtual radio channel)
  - Each repeater can carry two voice streams / conversations / talkgroups simultaneously (one in each time slot)

Analog vs. DMR UHF Repeater Channel Config

Analog

PCRC Linked Repeater

- Output Frequency [448.5750]
- Input Frequency with -5 MHz offset [443.5750]
- PL tone [103.5 Hz]

DMR

Rocky Mountain Wide Badger

- Output Frequency [446.7625]
- Input Frequency with -5 MHZ offset [443.7625]
- Color code [7]
- TX Contact = Rocky Mountain Wide Talkgroup [700]
- Timeslot [1]

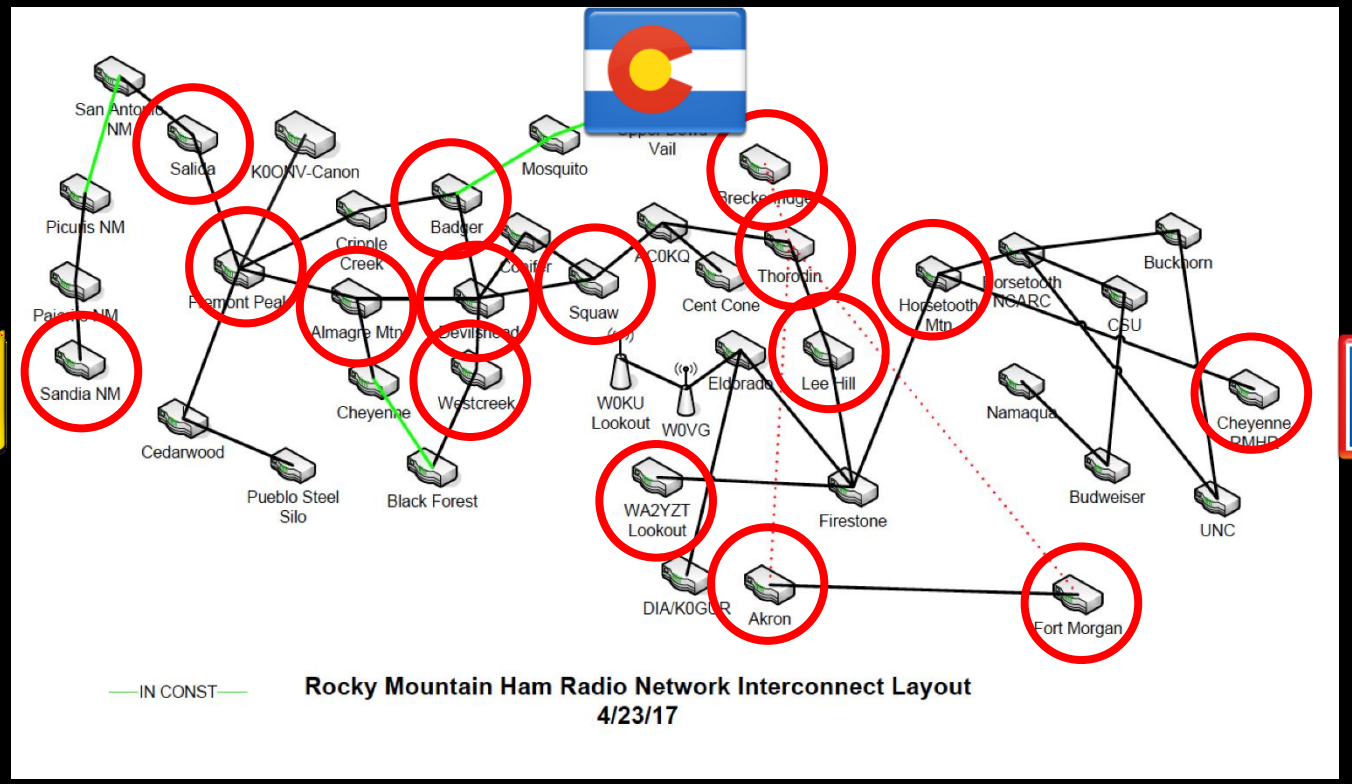
Colorado Central Badger

- Output Frequency [446.7625]
- Input Frequency with -5 MHZ offset [443.7625]
- Color code [7]
- TX Contact = Colorado Central Talkgroup [720]
- Timeslot [2]

DMR Networks – Expanding on DMR Repeaters

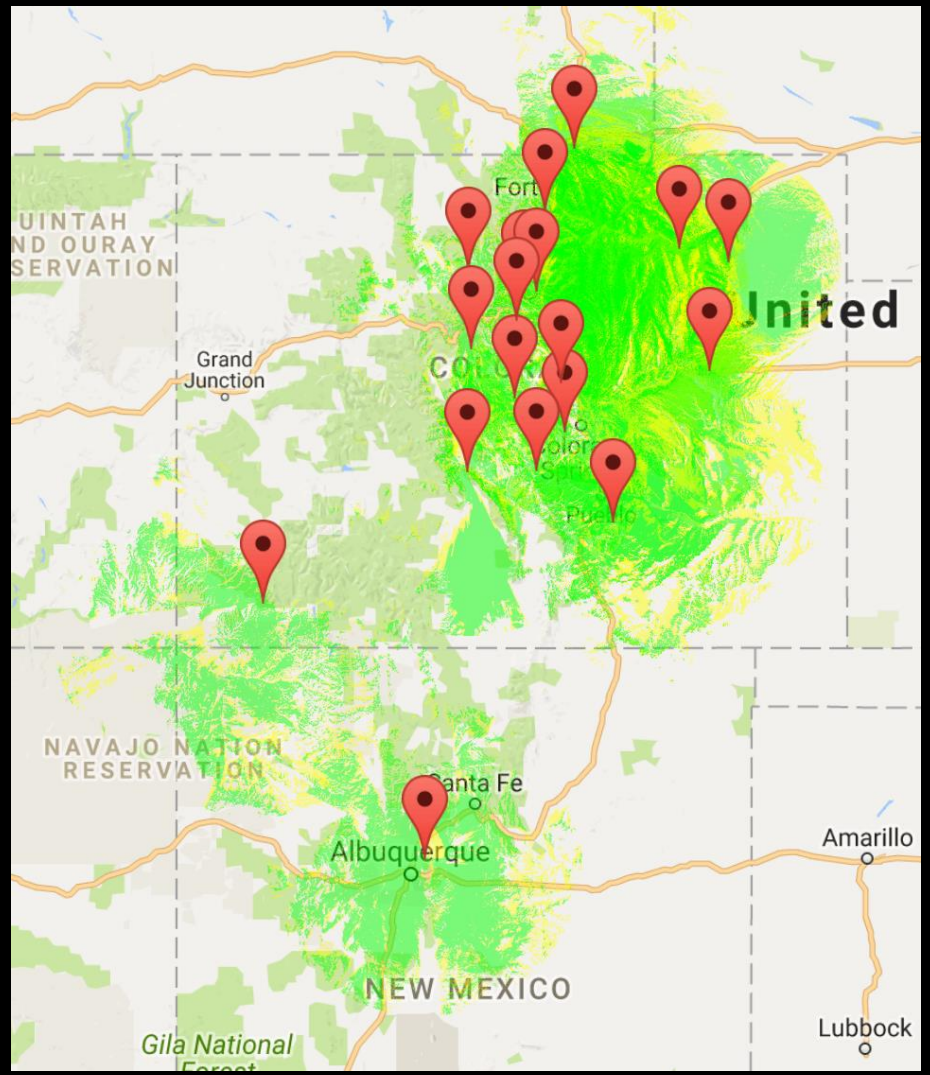
- Networked Duplex Repeaters and Simplex Hotspots with Controlling Servers
  - Voice packets are tagged with a "talkgroup" (virtual radio channel)
  - Servers route talkgroup packets to EVERY repeater or access point on the network that has subscribed to that talkgroup
  - By setting my radio to a specific talkgroup, I can talk to anyone else on the same network who has their radio set to that talk group.
  - Each repeater can carry two voice streams / conversations / talkgroups simultaneously (one in each time slot)
  - A repeater can be locked onto specific talkgroups (static) or allow users to select (key up) a talkgroup (dynamic).
    - Incoming traffic on a dynamic talkgroup continues to be broadcast by a repeater for 15 minutes after the last incoming RF for that talkgroup
    - These settings are the repeater owner's choice

Rocky Mountain Ham Radio DMR Network

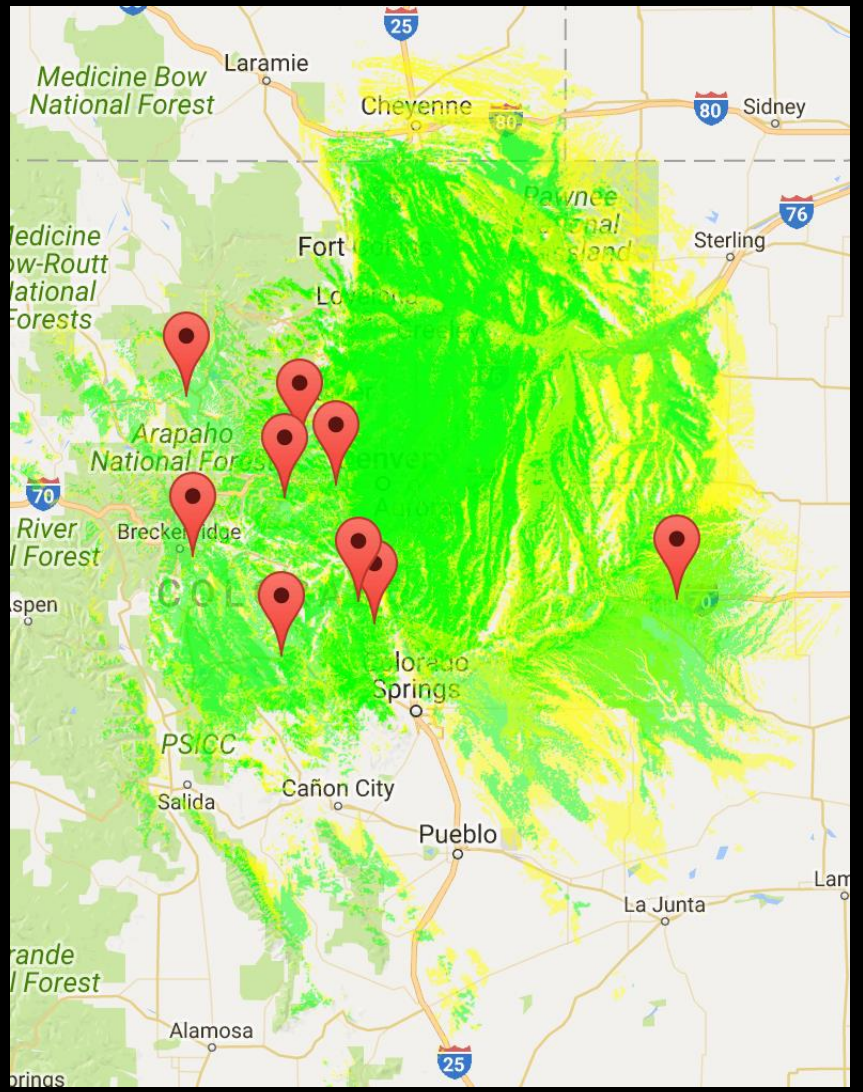


- Primary purpose is emergency communications, open for other use when no emergency traffic
- Closed network, tightly controlled by RMHAM admins. Private microwave network on amateur spectrum. Emergency power. NOT CONNECTED TO ANY OTHER NETWORK.
- Few talkgroups – one wide area on all repeaters plus regional talkgroups active only on repeaters in that region (North, Central, South). All talk groups are static – fixed to a repeater and timeslot.

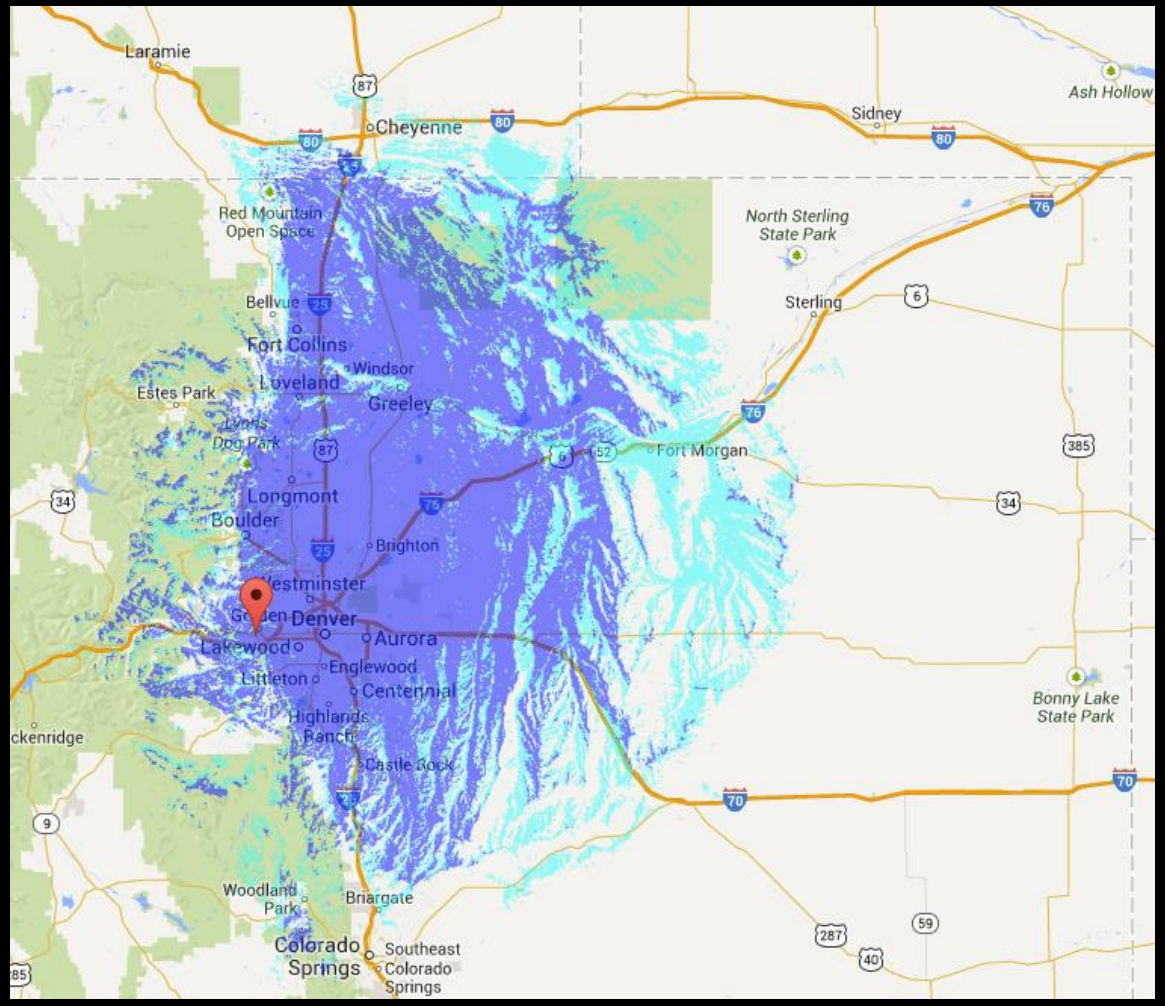
Rocky Mountain (TG700)
19 repeaters – always timeslot 1



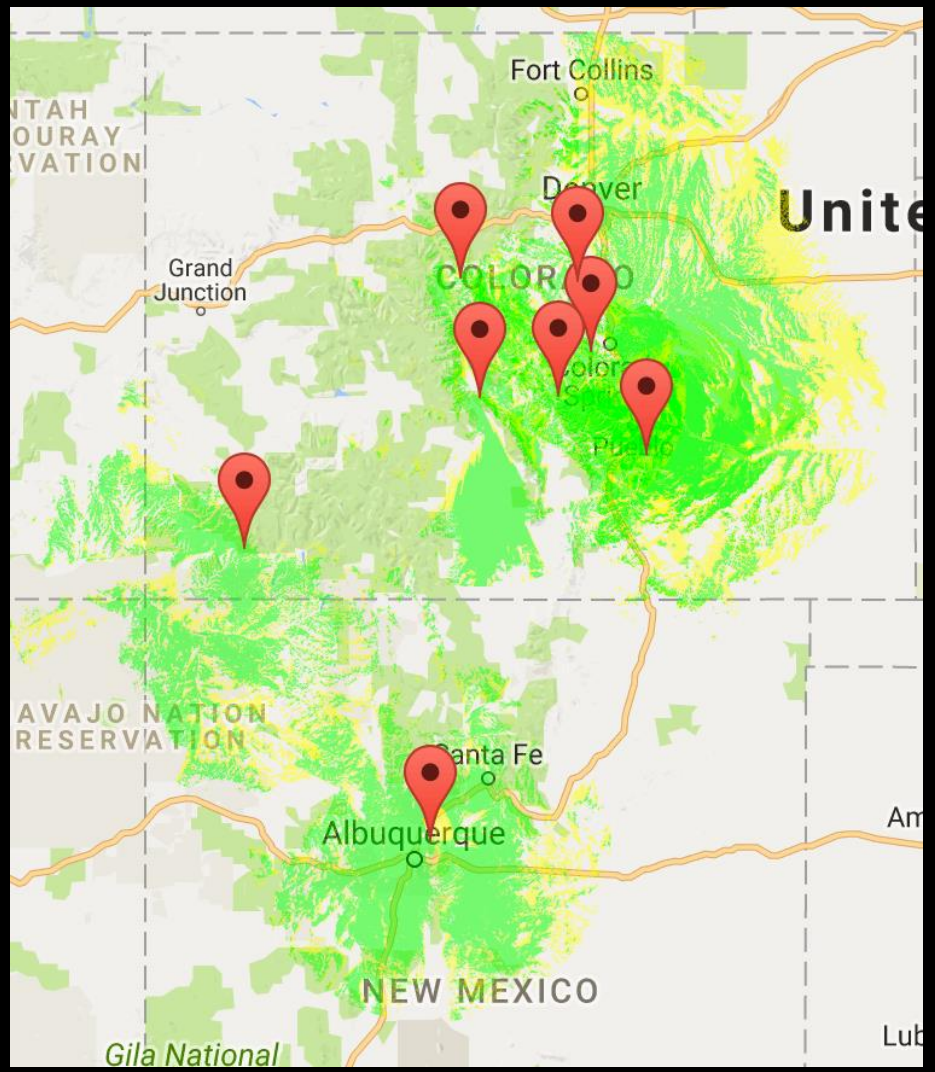
Central Colorado (TG720)
9 repeaters – always timeslot 2



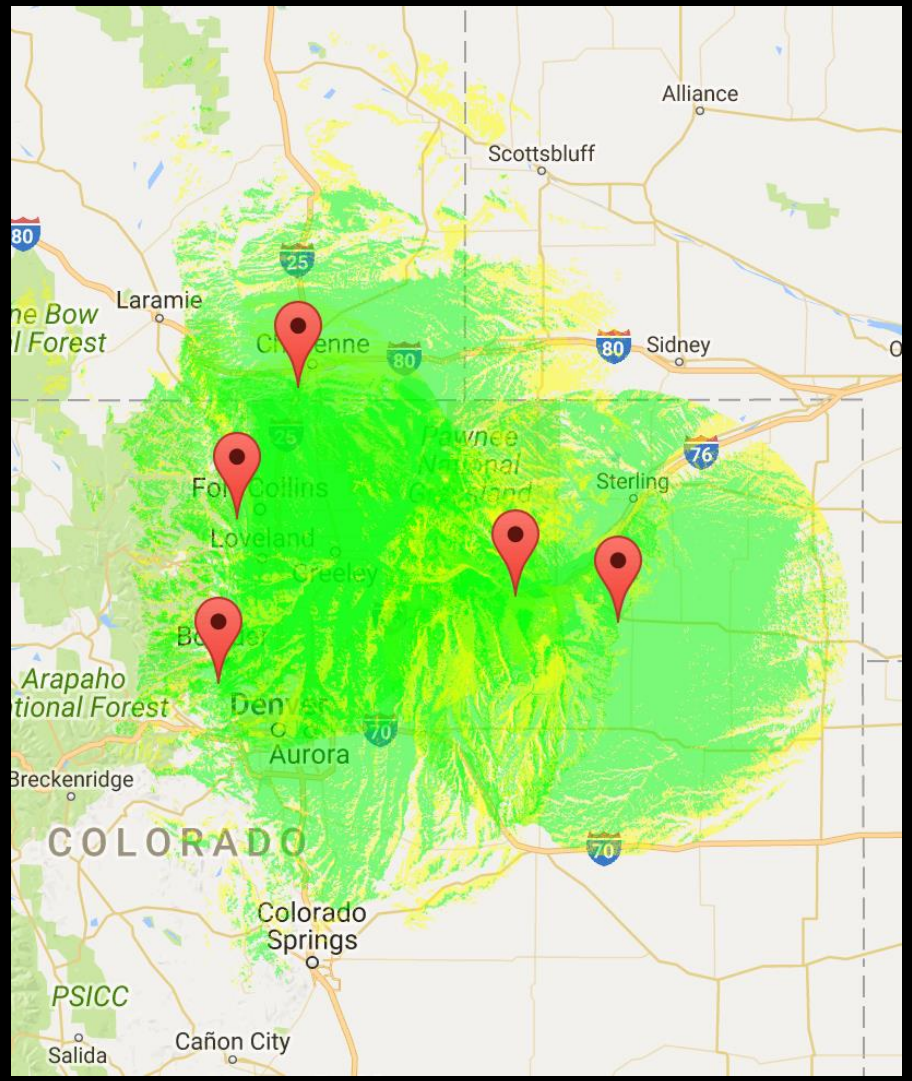
Lookout Local (TG710)
1 repeater



Southern Colorado (TG719)
7 repeaters – always timeslot 2



Northern Colorado (TG721)
5 repeaters – always timeslot 2



Southeastern Colorado (TG718)
0 repeaters

Future

Location	700 Rocky Mtn Wide	719 Southern Colorado	720 Central Colorado Region	721 Northern Colorado Region
Akron	TS1			TS2
Sandia Crest (Abq, NM)	TS1	TS2		
Badger Mtn	TS1		TS2	
Lee Hill	TS1			TS2
Mt. Baldy	TS1		TS2	
Fremont Peak	TS1	TS2		
Cheyenne, WY	TS1			TS2
Almagre Mtn	TS1	TS2		
Squaw Mtn	TS1		TS2	
Thorodin Mtn	TS1		TS2	
Devils Head		TS2	TS2	
Caviness Mtn	TS1	TS2		
Horsetooth Mtn	TS1			TS2
Fort Morgan EOC	TS1			TS2
Genoa	TS1		TS2	
Mt Chauncey	TS1		TS2	
Pueblo	TS1	TS2		
Methodist Mtn	TS1	TS2		
Westcreek	TS1		TS2	

Talkgroups: The Virtual Channel

- They are virtual frequencies or virtual channels
- Program a channel (frequency, color code, talkgroup, timeslot) into a radio
- Be within range of a repeater that carries that talkgroup
- Talk to anyone whose radio is also tuned to that talkgroup and within range of ANY other repeater in that network that carries that talkgroup.

- Talk from Cheyenne to Albuquerque with a 5W handi-talkie on the Rocky Mountain Ham Radio DMR network!

Chile Chat

Greg KoMGL

Talkgroup = RckyMtnWide

Talkgroup = RckyMtnWide

Badger Repeater

Digital Microwave Link

Sandia Crest Repeater

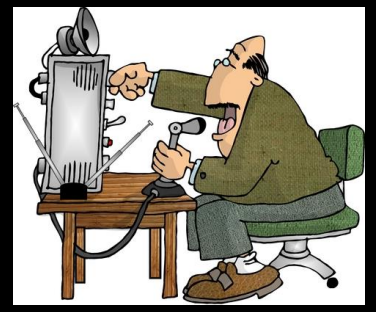
Talkgroup = RckyMtnWide

Chile Man KC5HIL

Jeff NoXCR

Talkgroup = RckyMtnWide

Squaw Mtn Repeater



Dan WoDFU

How to Get on the Air

- Are you close to a DMR repeater?
- Get a DMR ID – required for networked repeater systems and to implement "private" calls (person-to-person)
- Get a DMR radio with programming cable and software
- Program the radio with talkgroups (repeater frequencies, color code, talkgroup number, timeslot).
  - Run the software (usually MS Windows)
  - Enter the data into form fields or import from another file or import from a spreadsheet
  - Push the data into the radio from your PC over the cable
- If you call the data file with all your radio settings in it a "code plug", everyone will know you are a DMR geek

Radios – RMHAM tested

- Tytera or TYT MD380, MD2017
- Retevis RT3, RT82 (same radio as TYT)
- Connect Systems CS750, CS760 [CS800, CS800D]
- Tera TR7400
- Vertex VXD720, EVX539 [VXD7200, EVX5400]
- Hytera PD782 [MD782]
- Motorola XPR6550, XPR7550 [XPR5550]

- Newer Radios
  - TYT MD-9600
  - Anytone AT-868UV
- NOT ALLOWED – these are Tier I – single slot
  - Baofeng DM-5R
  - Radioddity GD-55
  - TYT MD-398

Key

Yellow = VHF/UHF Analog/Digital

White = UHF Analog/Digital

[] = Mobile

Source: Rocky Mountain Ham Radio (Accessed: http://www.rmham.org/wordpress/dmr-hardware-listing/ : 8 Aug 2017)

Definitions

- Network – a collection of repeaters, access points and servers that are connected to each other
- Bridge or Reflector – A server that connects one talkgroup on one network with one talkgroup on another network
- Repeater – receives an RF transmission and re-transmits it on a different RF frequency in real time. A DMR repeater ALSO send the packet stream over the network to the network servers for re-distribution
- Access Point or Hot Spot – Same as a repeater EXECPT it does not re-transmit the RF stream on a different frequency. Does send the packet stream over the network

What about other DMR Networks?

- Each network has its own numbering scheme for talkgroups
- Each network has its own rules:
  - who can connect
  - Repeater software
  - Types of devices that can connect – Just repeaters? Repeaters running only certain software? Hotspots?
  - talkgroup numbering, meaning and use
  - Mapping talkgroups to repeaters and timeslots
- A talkgroup on one network can be bridged or connected to a talkgroup on another network – if the network admins allow it

What's a Hotspot

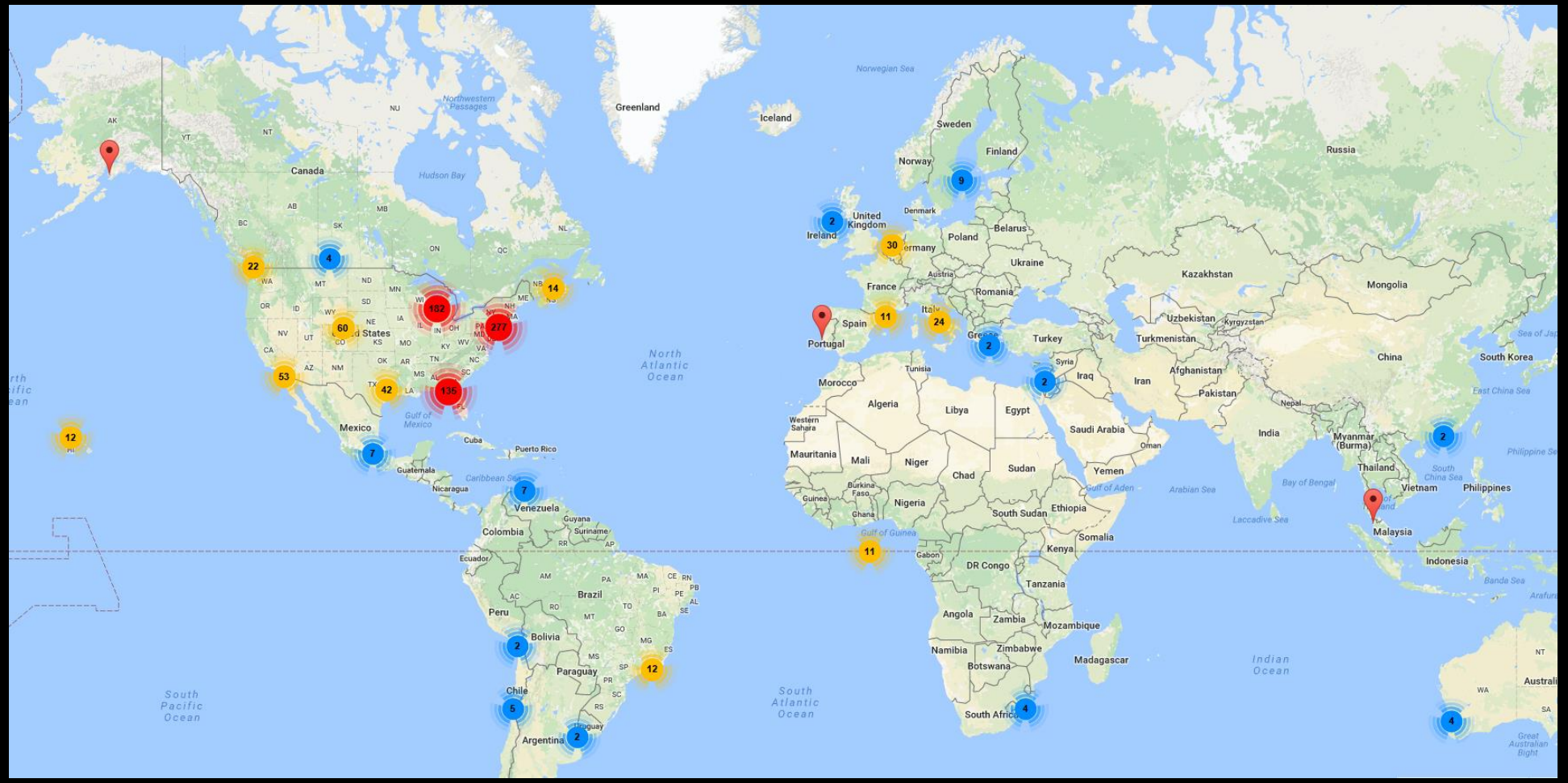
- A simplex radio that connects a user's radio to a DMR network
- Low power (20 mW) RF, usually 70 cm
- Single radio can connect at a time
- Static and dynamic talkgroups – YOU are the owner, YOU decide

Hotspots

- Work with multiple digital voice modes
- Good comparison at http://arrl-ohio.org/digital/Amateur%20Radio%20Digital%20Hotspot%20Comparison.pdf

Hot Spot	Modes Supported	Additional Device Required	Cross Mode	Cost
DV Mega with Raspberry Pi / MMDVMHost Software	DMR / DStar / Fusion (YSF) / P25 (no cross mode)	Raspberry Pi to run MMDVM	No	$190
DVMega with Bluestack / BlueDV Software	DMR / DStar / Fusion (YSF and FCS) (no cross mode)	Windows or Android to run BlueDV	No	$190 + Windows or Android device
DV4Mini on Raspberry Pi or Windows	DMR / DStar / Fusion (FCS) / P25 / dPMR	Windows, Linux or Pi	No	$130 + PC
Shark RF openSpot	DMR / DStar / Fusion (YSF / FCS) / Shark RF IPconn	None	DMR-Fusion	$215-$235

Amateur DMR Networks – DMR-MARC



DMR-MARC Network

- 500 repeaters in 73 countries
- Operated by Motorola Amateur Radio Club
- Based on Motorola commercial servers and protocols – no hotspots, no homebrew servers
- The creation and use of talkgroups is regulated by DMR-MARC administrators. Routing of traffic controlled by admins
  - Static and dynamic talkgroups
  - About 130 different talkgroups worldwide – organized by geographic region and language

Amateur DMR Networks – Brandmeister

Brandmeister Network

- 1220+ repeaters, 2550+ hotspots, 41 master servers
- Vendor neutral software
- Hotspots and homebrew servers welcome
- Talkgroups can be created by anyone
  - Thousands of talkgroups are available
  - Organized by worldwide, regional, country, state, region within a state, local to repeater, specialized uses (ARES R1D5, TG 310842)
- Open dashboard to set your hotspot and see the status of the network https://brandmeister.network/
- Brandmeister Hoseline (radio traffic like water from a firehose) allows you to monitor traffic anywhere in the network from your computer (via web browser) https://hose.brandmeister.network/

Code Plug Basics

- Contacts
  - Private – Links a DMR ID with a callsign and a name (1108008, K0MGL, Greg)
  - Group – Describes a talkgroup (3108, Brandmeister Colorado)
- Channels
  - Repeater or hotspot frequency & offset
  - Color Code
  - TX Contact (must be from the contact list created in the first step) – usually a talkgroup
  - Timeslot
- Zones
  - A zone is a folder of channels
  - A channel can be in more than one zone or folder
  - Most radios on the market today allow only 16 channels per zone – because the rotary dial on top of the radio has 16 positions
  - The radio can be set to one zone at a time, but you can change zones from the front panel

Code Plugs

- Each radio has limits
  - Channels – 1000 or 2000 are typical
  - Contacts – 1000 (MD-380) up to 65,000 (CS-750)
  - Channels per zone – usually 16
  - Zones – 254 is typical
  - Older models and models specifically designed for business have very low limits. Newer radios and those designed for the ham market, like the new dual banders, have very generous limits
- Creating a code plug takes some planning BEFORE you start entering data
  - What talkgroups do you want
  - What private contacts (call signs) do you want
  - How do you want to organize your channels into zones?
    - By purpose of the talkgroup – all my Germany talkgroups are in one zone
    - By repeater – all the talkgroups I want to use on the Castle Rock Brandmeister repeater
    - By purpose – all the Colorado ARES talkgroups

Best Practice – Start with an Existing Code Plug

- Rocky Mountain Ham Radio
- Local Amateur Club
- Other hams

Other Settings in Code Plugs

- Timings – repeater hang time, scan pause, etc.
- Menu items
- Customization for buttons
- Tones – on/off
- Available settings vary by manufacturer

Brandmeister Repeaters in Colorado

Sponsor	Location	Freq	CC	TS 1 Wide Area & Dynamic	TS 2 Local
Parker Radio Association	The Pinery, Parker	445.0750	1		TG310844
Denver Radio Club	Centennial Cone, Golden	446.7875	1		TG310804
NOCO DMR Group	Timnath	446.7750	2	TG31090	TG3018
NOCO DMR Group	Horsetooth Mtn, Fort Collins	145.2650	2	TG93, TG8953, TG31089	TG3108, TG3171
Douglas & Elbert ARES	Silver Heights, Castle Rock	446.8250	1		TG310842
RMHAM - NoSZ	Lee Hill	445.0500	1		
RMHAM - NoSZ	Cheyenne Mtn, Colorado Springs	445.0625	1		
KToL	Fort Collins	446.7750	2	TG31090	TG3108