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# Amateur Radio Guide to Digital Mobile Radio (DMR)



By  
John S. Burningham, W2XAB  
February 2015

# Talk Groups Available in North America

Host Network	TG	TS*	Assignment
DMR-MARC	1	TS1	Worldwide (PTT)
DMR-MARC	2	TS2	Local Network
DMR-MARC	3	TS1	North America
	9	TS2	Local Repeater only
DMR-MARC	10	TS1	WW German
DMR-MARC	11	TS1	WW French
DMR-MARC	13	TS1	Worldwide English
DMR-MARC	14	TS1	WW Spanish
DMR-MARC	15	TS1	WW Portuguese
DMR-MARC	16	TS1	WW Italian
DMR-MARC	17	TS1	WW Nordic
DMR-MARC	99	TS1	Simplex only
DMR-MARC	302	TS1	Canada
NATS	123	----	TACe (TAC English) (PTT)
NATS	8951	----	TAC-1 (PTT)
DCI	310	----	TAC-310 (PTT)
NATS	311	----	TAC-311 (PTT)
DMR-MARC	334	TS2	Mexico
	3020-3029	TS2	Canadian Provincial/Territorial
DCI	3100	TS2	DCI Bridge
	3101-3156	TS2	US States
DCI	3160	TS1	DCI 1
DCI	3161	TS2	DMR-MARC WW (TG1) on DCI Network
DCI	3162	TS2	DCI 2
DCI	3163	TS2	DMR-MARC NA (TG3) on DCI Network
DCI	3168	TS1	I-5 (CA/OR/WA)
DMR-MARC	3169	TS2	Midwest USA Regional
DMR-MARC	3172	TS2	Northeast USA Regional
DMR-MARC	3173	TS2	Mid-Atlantic USA Regional
DMR-MARC	3174	TS2	Southeast USA Regional
DMR-MARC	3175	TS2	TX/OK Regional
DMR-MARC	3176	TS2	Southwest USA Regional
DMR-MARC	3177	TS2	Mountain USA Regional
DMR-MARC	3181	TS2	New England & New Brunswick
CACTUS	3185	TS2	Cactus - AZ, CA, TX only
DCI	3777215	TS1	Comm 1
DCI	3777216	TS2	Comm 2
DMRLinks	9998	----	Parrot (Plays back your audio)
NorCal	9999	----	Audio Test Only <a href="http://norcaldmr.org/listen-now/index.html">http://norcaldmr.org/listen-now/index.html</a>

**\* You need to check with your local repeater operator for the Talk Groups and Time Slot assignments available on your local repeater.**

# Amateur Radio Guide to Digital Mobile Radio (DMR)

by John S. Burningham, D.I.T.  
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<http://www.dmr-marc.net> <http://www.trbo.org> <http://www.w4cjl.com>  
<http://www.caldmr.org>

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# Forward

I was first licensed as WB8GZR when I was a college freshman, and later as WB9QOM, WB8PUF, and currently as W2XAB. I built my first analog FM repeater (GE Progress Line) in college and I have been active over the last 44 years in many aspects of amateur radio including FM, Packet, D-Star™ and now DMR. I worked in the Aerospace industry and spent a short time at Motorola before embarking on a career teaching computer technology spanning the last 15 years.

I strongly believe in supporting local and national amateur radio organizations, including membership in the ARRL, AMSAT, and QCWA. To keep our hobby active and growing, it is important that users support our clubs and individual repeater operators.

We need to bring more youth and young adults into our hobby; the reality is that we are all getting older and many of us are closer to being silent keys than we wish to think about. I have passed my genes on to my harmonic (W2JEN), my knowledge on to my students, and I hope I will leave Amateur Radio better off than when I first arrived on the scene.

Amateur Radio is made up of many special interest groups (SIGs), CW, AM, SSB, FM, HF, VHF, UHF, microwave, contesting, DXing, public service, ARES, RACES, repeaters, education, clubs, fox hunting, RTTY, Packet, APRS, Satellite, SDR, D-Star™, P25, DMR, NXDN, kit building, and Elmering, just to name a few. There will always be something new that generates interest in our hobby.

There are three levels of involvement in DMR. The first is as a **user**, where you begin with a single radio, and later, possibly you'll add a second or third. The next level is as a **repeater operator**. You generally undertake this because there are no repeaters in your area or because you want better coverage. The third level of DMR participation is as a **network operator**. As a network operator, you purchase and manage your own IPSC bridge (such as the c-Bridge™) and build regional networks that interconnect to the other DMR networks.

Amateur Radio is a hobby; Webster defines a hobby as *a pursuit outside one's regular occupation engaged in especially for relaxation*. I consider *relaxation* the most important part of a hobby. A second important part of any hobby is the friendships that are developed through participation in the hobby.

## Dedication

I dedicate this book to all my ham buddies, but especially WA9TKK (my Elmer), W9JW (ex WB8KLO), W2JEN, and silent keys: W8HQQ, K8QOE, and W8JGP.

I need to also mention my thanks to all my wives (1.1, 2.1, 3.1, 4.1, and 3.2) for tolerating my hobby both at home and in the car. I especially thank my late father for sparking my interest in technology and for buying me my first computer kit, the IMSAI 8080.



## Thanks to the Following

I would like to thank KC6OVD for being my local and first DMR mentor and for his help getting my first Mototrbo™ repeater working and online. Thanks to AA9VI and the DMR-MARC group for sparking my interest in amateur DMR at the Dayton Hamvention® in 2012, and lastly, special thanks to W1NGS and NO7RF for their assistance in learning to configure Super Groups on my c-Bridge™. Thanks to AA9VI, NE1B, NO7RF, K6BIV, W1NGS, WB8SCT and W9JW for reviewing this document. A special thanks to the Dayton Amateur Radio Association and all those involved with giving the rest of us the annual Mecca of Amateur Radio (aka The Dayton Hamvention®).

To the ARRL all I can say is good luck in your second hundred years. Thanks to AMSAT for getting the hobby off the planet, and the QCWA for reminding me I am getting old.

## What is DMR?

Digital Mobile Radio (DMR) was developed by the European Telecommunications Standards Institute (ETSI) and is used worldwide by professional mobile radio users. [<http://www.dmrassociation.org>]

DMR is divided into three tiers. Tier I is a single channel specification originally for the European unlicensed dPMR446 service. It is a single channel FDMA 6.25 kHz bandwidth; the standard supports peer-to-peer (mode 1), repeater (mode 2) and linked repeater (mode 3) configurations. The use of the Tier I standard has been expanded into radios for use in other than the unlicensed dPMR446 service. [<http://www.dpmr-mou.org>]

Tier II is 2-slot TDMA 12.5 kHz wide peer-to-peer and repeater mode specification, resulting in a spectrum efficiency of 6.25 kHz per channel. Each time slot can be either voice and/or data depending upon system needs. IP Site Connect (IPSC) for interconnecting repeaters over the Internet is vendor specific and is not part of the ETSI standards at this time. Most amateur radio implementations of DMR are using voice on both time slots.

Tier III builds upon Tier II, adding trunking operation involving multiple repeaters at a single site. Not all manufacturers' trunking implementation is Tier III compatible. Vendor specific protocols have expanded the trunking to multiple site operations.

It is Tier II that amateurs are implementing in their Mototrbo™ [<http://www.motorolasolutions.com>] and Hytera [<http://www.hytera.com>] infrastructure networks and the focus of this booklet. The IPSC protocols used by the different brand repeaters are not compatible; it is doubtful the equipment manufacturers will ever standardize for business reasons. Any brand DMR (Tier II) user radio will work on any Tier II system, although some manufacturers offer proprietary features.

The current implementation of DMR utilizes the DSVI AMBE+2™ vocoder by agreement of the manufactures; it is not specified in the ESTI standard. Most of the radio manufacturers have implemented the vocoder in licensed software. The forward error correction in the AMBE+2™ is an improvement of the voice quality of older vocoders such as used by D-Star™.

Amateur Mototrbo™ and Hytera DMR networks, from the end user standpoint, operate the same. Amateur Mototrbo™ networks are much larger, cover many more areas, and most are interconnected. I look forward to the day when the multiple vendor infrastructures can be

interconnected by the amateur community. Not all the amateur DMR repeaters are connected to the wide area networks; some are standalone either because they have yet to obtain an ISP connection at their repeater site or because they just want to use the repeater for local communications. Some standalones are operating in dual-mode (analog/digital). Mototrbo™ repeaters operating in dual-mode do not support interconnection via the Internet using IPSC.

Some hams have installed DMR repeaters in a vehicle, using 3G/4G cellular wireless services for Internet access. Others have implemented remote bases to interconnect to other networks or radios; it is important to remember that the wide area networks typically have policies prohibiting interconnected traffic, but what is implemented locally and stays local is acceptable. While some may consider network policies prohibiting interconnection to different types of networks political, these policies are really about keeping large networks functioning. Users sometimes don't realize the hours put in by network operators or the extent of their efforts that are required to keep a linked system running smoothly. There are sometimes issues of poor quality from interconnected technologies because of the vocoding process that would degrade the quality of the network. DMR-MARC has a sandbox available for persons interested in developing and experimenting that is separate from and off the main DMR-MARC network [<http://www.dmr-marc.net/sandbox.html>].

Back during the early era of amateur analog repeaters, most everyone used surplus commercial radios. Over time, equipment designed for and targeted to the radio amateur reached the amateur radio marketplace. Today in the DMR marketplace you can find used commercial gear, but new DMR radios are now available with street prices within the range of a typical ham budget. Some amateur DMR users are just using their commercial radios from work with a few extra channels programmed in.

Currently, no manufacturer is marketing an "Amateur" DMR radio; they are building DMR radios for the broader world market. Because of FCC Rules & Regulations for commercial users, DMR radios do not offer FPP (Front Panel Programming) as is the norm for other amateur radios. This is really not an issue because most DMR radios have enough channels to program all possible channels you may want to operate. Most of the DMR radios require a programming cable to program the radio using manufacturer software, while some radios support programming using BlueTooth and even over-the-air programming.

There are police and fire departments, local/state governments and many businesses using DMR Tier II and Tier III; any Tier III capable radio will



also work on Tier II systems but neither will work on Tier I. If you have a DMR radio for work, you may be able to program it to also work on amateur repeaters (make sure you have permission) and you will need to contact DMR-MARC about a usable subscriber ID that will work on both networks.

## **Digital vs. Analog**

If you are use to operating on analog FM repeaters, you will have noticed that the audio quality degrades as a station's signal into the repeater (uplink) gets weaker; you start hearing an increase in noise bursts intermixed with the audio until the signal gets so weak that the station can no long access the repeater or you can not understand the audio because of noise. As you move further from the repeater you will start hearing the same noise bursts into your receiver as the repeater's signal gets weaker (downlink) until you can no longer hear the repeater. A combination of a station's weak signal into a repeater and a repeater's weak signal to the listener can make the usability degrade faster.

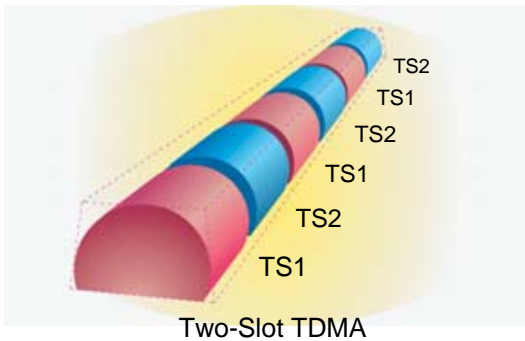
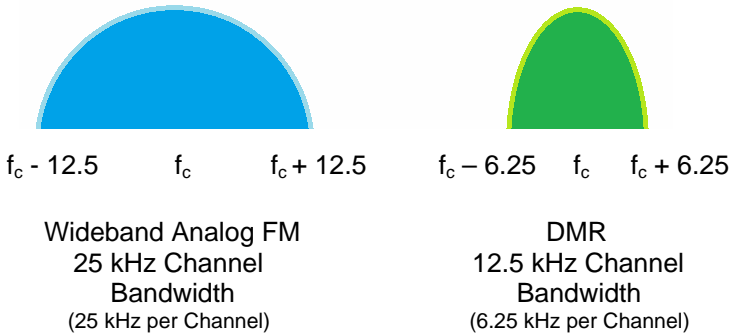
The basic difference with digital repeaters is that the audio quality remains the same on the uplink and downlink until the very end of the coverage range; then the audio starts sounding broken (missing portions of the speech) on DMR systems caused by lost packets. The Internet can also drop the UDP packets used for moving traffic between repeaters and bridges, causing the same broken audio affect. Analog static is a thing of the past using DMR.

DMR has Forward Error Correction (FEC) which can correct small bit errors, slightly extending the usable range and improving communication quality.

Better quality receivers can operate at a lower noise floor, higher power transmitters, and higher gain antenna systems will also extend coverage of both analog and digital systems.

## **Two-Slot TDMA**

DMR Tier II/Tier III occupies a 12.5 kHz bandwidth that two channels share using Time-Division Multiple Access (TDMA). This results in spectrum efficiency of 6.25 kHz per channel. Comparing the spectrum efficiency of DMR to a wideband analog FM, DMR only uses 25% of the bandwidth per talk channel. Each channel can carry either voice and/or data depending on system design. The two time slots are called Time Slot 1 (TS1) and Time Slot 2 (TS2).



For the amateur, this means one repeater allows two separate channels at the same time. Currently most amateur DMR repeater system implementations utilize both channels for voice and some limited text messaging. Typically one channel (time slot) is used for wide-area and the second is local and regional Talk Groups.

For repeater operators, a single two-slot TDMA repeater offers a significant savings over two standalone repeaters to obtain two separate communication channels as only one repeater, one duplexer, and one antenna system is required.

The utilization of TDMA offers about a 40% battery savings on transmit, extending talking time over non-TDMA and analog transmissions for portable users.

The two-slot TDMA implemented in DMR uplinks (portable/mobile to repeater) uses a 30-ms window for each time slot, the 30-ms is further divided into a 27.5-ms frame and a 2.5-ms gap. This means when transmitting, your transmitter is only turned on for 27.5ms every 60ms, resulting in extended battery life for portables. The DMR repeater (downlink) transmits a continuous data stream even if only one timeslot is being used; the 2.5-ms uplink gap is replaced with a CACH burst

(Common Announcement Channel) that is used for channel management and low speed signaling.

The 27.5-ms frame consists of a total of 264-bits; 108-bit payload, 48-bit SYNC or embedded signaling, and a second 108-bit payload for a total of 216-bits of payload per frame. The vocoder must compress 60-ms of audio with FEC (forward error correction) into 216-bits of data for transmission. The 2.5ms-gap is used for guard time to allow PA ramping and propagation delay.

## Talk Groups

Talk Groups (TG) are a way for groups of users to share a time slot (one-to-many) without distracting and disrupting other users of the time slot. It should be noted that only one Talk Group can be using a time slot at a time. If your radio is not programmed to listen to a Talk Group, you will not hear that Talk Group's traffic.

The DMR-MARC Mototrbo™ network supports a number of Talk Groups on TS1 including World Wide (TG1, PTT), North America (TG3), and World Wide English (TG13). TS2 is for local, state, and regional Talk Groups. The DCI/TRBO network uses TG3163 for North America and TG3161 for World Wide, and TG3 for World Wide English on TS2.

**Check with your local repeater operator to find out what Talk Groups/Time Slots are available on a repeater.**

The DMR standard also supports private calls (one-to-one), encryption, and data. Private calls are not allowed by most of the amateur networks and many consider private calls not amateur friendly; private calls tie up a large number of repeater time slots across the network. Encryption is not legal on amateur radio in the USA but is allowed in Canada! Data and text messaging is supported on some networks.

For simplex traffic, the accepted standard in the amateur community is to use TG99 on TS1 with CC1.

When programming your DMR radio, you may find it easier to program multiple Talk Groups for receive. I have two RX Group lists programmed in my radios, one for TS1 and one for TS2; this allows my radio to listen to all the possible Talk Groups used on a time slot when I have my radio set to any channel.

There are Talk Groups implemented for individual states and regional on many networks. Some Talk Groups are available all the time, while others only at preprogrammed times. Some Talk Groups require a local

user to PTT on the Talk Group to activate it for a period of time. Since only one Talk Group can be active at a time on a time slot, many systems will disable other Talk Groups when a local user is active on a different Talk Group on the time slot. Be ham friendly and try to use Talk Groups that tie up the fewest number of repeaters if you are going to have a long QSO. Further information about specific Talk Groups can be found on the DMR-MARC, DCI, and regional group websites.

<http://www.dmr-marc.net>

<http://www.trbo.org>

## Zones

User DMR radios support Zones. A Zone is just a grouping of individual channels. Some model radios may limit the number of channels per Zone and the number of Zones allowed.

You could program Zones for local channels (DMR or analog), another Zone for a neighboring state, and a Zone for business and government channels. If you do program non-amateur channels in your radio, make sure they are RX only unless you are licensed or authorized to use them as per FCC 90.427(b); otherwise you will be in violation of FCC R&Rs and enforcement action could be taken against you. If you have a VHF model, you could program a Zone for all the possible NWS Weather Channels (again, make sure you program the channels as receive only). Zones are just a way to manage large number of channels, much like file folders or directories on your computer.

## Color Codes

DMR repeaters use Color Codes (CC) much like analog repeaters use CTCSS (PL) or DCS. To access a repeater you must program your radio to use the same CC as the repeater. There are 16 different CCs (CC0-CC15). The use of Color Codes is not optional on DMR systems. If your Color Code is not set correctly, you will not be able to access the repeater. The only real purpose of using different Color Codes is when multiple repeaters operating on the same frequency have overlapping coverage areas.

## Code Plugs

A code plug is simply a radio's configuration file. Using a manufacturer's programming software you configure the channels and operating parameters of a radio. This file is uploaded to the radio and typically should also be saved on your computer as a backup. You can also download the code plug from a radio to modify it. Building a code

plug can take many hours, especially if you want to program hundreds of channels. The code plug can also contain a Contact List of Radio IDs, call signs, and names to be displayed. You can find copies of configured code plugs on the web for different models of radio; check out the different Yahoo DMR groups. All DMR radios support a limited number of entries in the Contact List; you can download Code Plugs with the Contact List populated using a generator on the DMR-MARC home page.

## Scanning

All DMR radios allow you to configure scanning of channels. Remember, you will only hear traffic on the frequency, time slot, and groups you have programmed on a channel. I typically scan both time slots on my local repeater and a simplex channel I use; you can also scan analog channels mixed with the digital channels. Scanning will decrease the battery life on your radio.

## Roaming

Roaming is not supported on all DMR radios. Check your owner's manual or manufacturer website to see if roaming is supported. In some radios it may be an additional cost option.

Roaming is NOT scanning. Roaming is similar but different. Roaming is designed to have your radio automatically select the best channel if your current channel's Receive Signal Strength Indicator (RSSI) falls below a defined level as you move throughout the coverage area of a group of repeaters that carry the same Talk Groups on the same time slots. You should select channels that have the same time slot and receive groups configured; if you do not, roaming may not work correctly. Repeaters can be configured to transmit beacons at predefined intervals of inactivity so roamers will be on the correct channel. Without the repeater beacons, roaming will still work, but the radio will only change channels if it hears a repeater on the air.

Roaming would be really great if all the DMR repeaters were on the same set of repeater pairs across the country, but it is too much to expect the Repeater Councils to work together for a unified rebanding of existing coordinations. It would also help if the different DMR networks could agree on which time slots were used by which Talk Groups. Wouldn't it be really nice to be able to program a dozen different frequencies, with a variety of common Talk Groups, on the same time slots in your radio and be able to travel across North America and be able to access all DMR repeaters?

## Simplex

On the professional side of DMR, *Talk-Around* refers to operating simplex on a repeater output channel. This allows a direct communication while still being able to hear the repeater. This allows users to directly contact other users listening on the repeater output frequency. Amateurs typically use dedicated simplex channels so as not to interfere with repeaters. The amateur DMR community has published a list of recommended simplex frequencies to be used instead of operating simplex on repeater outputs:

UHF 1) 441.000 2) 446.500 3) 446.075 4) 433.450

VHF 1) 145.790 2) 145.510

[Use TG99 / CC1 / TS1 / Admit Criteria: Always / In Call Criteria: TX or Always]

Do not use 146.520 or 446.000; they are the national analog simplex channels and operating DMR on these common analog use frequencies will just cause disharmony within the amateur community. Also, avoid repeater inputs and outputs, locally used non-DMR simplex channels, satellite sub-bands, and any other frequencies that could disrupt other amateur communications.

## Admit Criteria

The Admit Criteria determines when your radio is allowed to transmit. The recommended setting for repeater channels is ***Color Code Free***; this configures your radio to be polite to your own digital system. You should configure your In Call Criteria to ***Follow Admit Criteria***. Simplex channels should be configured as ***Always*** for both Admit Criteria and ***Always*** or ***Follow TX*** for In Call Criteria.

## Accessing a DMR Repeater

When you want to access a DMR repeater, you must have the frequency, Color Code, and Talk Group set correctly. When you key your transceiver, you send a signal to the repeater and the repeater responds back to you to acknowledge you can transmit your message. If you do not receive the repeater's acknowledgement, your radio will stop transmitting and you will hear a negative confirmation tone. This is one of the advantages of TDMA: allowing bidirectional communications between user and the repeater when transmitting. The repeater can also signal your radio to stop transmitting if there is contention on the network because more than one station is transmitting at a time.

Not all DMR repeaters are interconnected on the Internet. Internet connectivity may not be available at the repeater site, or not available at a reasonable cost. Some repeater operators may just prefer to keep their repeater for local usage only, or maybe only want it connected to a small local/regional network, without connecting to the larger world wide networks.

## IPSC and Bridges

IP Site Connect (IPSC) is a vendor specific repeater feature offered by some manufacturers. Note that Mototrbo™ repeaters will only interconnect over the Internet with other Mototrbo™ repeaters because it is not part of the ETSI specifications and the manufacturers don't want to interconnect their infrastructures.

Motorola Solutions Mototrbo™ IPSC implementation allows up to 15 Mototrbo™ repeaters operating in DMR mode to be connected on a fully meshed IP network, with one of the repeaters (or a c-Bridge™) serving as a Master and all of the others are Peers. Any traffic originating on one of the interconnected repeaters is relayed over the IP network to each of the other repeaters. The Peers will first establish a connection with the Master and obtain the database of the other Peers along with their IP and port addresses.

The more repeaters in this fully meshed IPSC network, the more IP network bandwidth required for each repeater. A single Peer connected to a Master requires 15 kbps for each time slot participating in the IPSC network, 6 kbps for link management, and 55 kbps for RDAC (Remote Diagnostics and Control) traffic; if both time slots are participating in IPSC, 91 kbps bandwidth is required; each additional Peer requires 36 kbps bandwidth. The Master requires an additional 3 kbps bandwidth for each Peer in the network. The *Mototrbo™ System Planner* has full details about calculating necessary bandwidth for repeater operators.

To expand beyond the limits of basic IPSC network requires the utilization of a bridge to interconnect the different IPSC networks. Rayfield Communications c-Bridge™ [<http://rayfield.net>] is the current preference in North America. In the European market, SmartPTT [<http://smartptt.com>] is common. BridgeCom Systems MV-IPSC™ [<http://www.bridgecomsystems.com>] is also compatible with the c-Bridge™ as both are products of RavenNet. These bridges require static IP addresses and larger IP network bandwidths than individual repeaters.

The c-Bridge™ supports individual managers for each repeater (micro-segmentation), which is an improvement over having the c-Bridge™ manager connected to a network of repeaters; this gives the ability to reduce bandwidth requirements and customize Talk Group availability for individual repeaters. The c-Bridge™ manager can serve as either a Master or Peer on an IPSC network.

The c-Bridge™ allows for network connections to other IPSC networks, and other c-Bridges™ utilizing Control Center (CC) connections. The c-Bridge™ allows for the management of Talk Groups on an always-on, scheduled, or on-demand (PTT) basis. Models (upgradeable) are available to support 5, 15, 30, and 50 repeaters and they also support 100 CC connections between c-Bridges™.

The c-Bridge™ also supports the interconnection of non-DMR audio sources utilizing an optional USB analog dongle and vocoder module.

Remember, someone is paying for all of the infrastructure and monthly operating costs. If a club is operating your local DMR repeater, join and support the operation. If an individual is operating the local repeater, donate to support his ongoing expenses. Repeater operators should also be supporting their bridge operators. Besides the cost of the infrastructure equipment, there are also recurring monthly expenses for rent, utilities (power and Internet), insurance, and maintenance.

## **User Radios**

There are many sources of new and used DMR radios. As of this date, you can't walk into an amateur radio store and buy a DMR radio, but that may soon change. Presently all DMR radios are professional (commercial) radios marketed primarily to commercial radio users. If you want to purchase a new DMR radio for ham use, you can easily find a dealer, and some dealers are "ham friendly" and will offer reasonable discounts to hams. Check with other DMR users or on DMR related websites for further information.

You can also search on eBay™ and other online flea markets for both new and used radios. Larger hamfests may also have DMR dealers or sellers in their flea markets. Here are a few things you need to know before buying a DMR radio:

New or Used. For used DMR radios, it is buyer beware! Just remember that you will not be able to repair a non-working DMR radio unless you have the technical skills and necessary test equipment, and that test equipment can cost hundreds of times the cost of the radio. The street price for new DMR radios is ~\$200-\$800. Arguably higher quality,



name brand radios, such as those bearing the name Motorola, typically sell for more used than brand new radios cost from newer entrants into the DMR market. You typically get what you pay for; higher priced radios usually have more features, are better constructed and can handle more abuse than less expensive radios.

VHF, UHF, or 900MHz. UHF is the most commonly used DMR band in the US and world wide, but because of military radar in some US areas, as well as different UHF public service frequency allocations in Canada, only VHF repeaters may be used in certain areas. In most areas, however, DMR activity may be found on VHF and UHF bands. As of April 2014, there are only two amateur 902-928MHz DMR repeaters in the US. If you are purchasing UHF equipment, make sure it covers the amateur band (420-450 MHz) from the factory. No one currently manufactures a multi-band DMR radio; there is little, if any, professional demand for such a radio and the amateur market is too small, at this time, to incentivize manufacturers to build one.

Programming Software. Some manufactures supply Programming software free. Motorola Solutions charges ~\$260 for a three year subscription (which covers all their models within a region) to their software and updates. DMR radios, because they are professional radios, typically do not allow keyboard programming. If a vendor charges for the programming software, do not ask another ham to bootleg a copy for you. If you have a legal copy, you may program radios for others, but you cannot legally distribute the software. Software piracy is illegal, and if caught, it could cost you greatly in the end.

Programming Cable. Some radios use standard USB cables for programming, and some use cables that can cost upward of \$80.

Number of Channels. Some radios have as few as 16 channels while others have as many as 1,000 channels. You will need a channel for each frequency, Color Code and Talk Group combination. You can easily use 3 to 10 memory channels for each DMR repeater you program into your radio.

Display or Non-Display. Some radios have only a channel selector knob, while others have displays (monochrome or color) that will show Talk Group and ID information. Some displays only show channel number.

Visually Impaired Operators. Consideration must be given to the channel selection knob on the radios. Most of the non-display models have channel selection knobs that have fixed stops instead of 360° degree continuous rotation to allow the operator to find channel one. Some LCD display models also have fixed stops on the channel selector knob; these

include some Hytera and CSI radios. Some models offer programmable voice announcements.

DTMF Keypad. Some radios have a 12-button DTMF keypad while others do not. Mototrbo™ repeaters support a proprietary autopatch feature (Digital Telephone Interconnect, requiring an entitlement key costing ~\$550). This feature may not work with non-Mototrbo™ radios.

GPS. GPS is available on some models, but DMR does not support APRS (Amateur Packet Reporting System). On professional networks, one of the time slots is typically allocated for location reporting and is interconnected to server based dispatch applications. GPS will shorten battery life if it is enabled.

Bluetooth. Some higher end radios have Bluetooth built in for wireless headsets. I find this a great feature at work and home so I can listen without bothering others. Some radios with Bluetooth support data and programming via the Bluetooth wireless connection to the radio. Some models have Bluetooth adapters optionally available. Bluetooth will shorten battery life if enabled.

Analog. The Mototrbo™ SL75xx models don't support analog FM. If analog FM is supported, it needs to be wideband FM because wideband FM is used on most legacy amateur repeaters. Current FCC rules require narrowband for most commercial/government services. For DMR radios from some manufacturers, this requires a programming entitlement key or a different version of the programming software.

Warning. Some DMR capable radios are available as analog only in their base configuration. The user may later add DMR for an additional license fee. This is because some manufacturers are discontinuing their analog non-DMR radios, while offering the DMR radios at a reduced MSRP if the digital mode is not enabled. On these radios, the customer later can upgrade the radio to operate DMR if their needs change, for an additional fee.

External Antenna on Portable. Not all portable radios support the connection of an external antenna, except for testing and alignment purposes. Using an adapter to connect an external antenna can place undue stress on the portable antenna connector which may result in premature equipment failure and expensive repair. If you are going to use an external antenna adapter, I recommend an adapter cable that uses RG-174 size cable to reduce stress on the radio's connector. Some Mototrbo™ models, such as the XPR6000 series, support an external microphone with an antenna mounted on the top.

Portable or Mobile. Portables are available in the 2-5 watt range; mobiles are available with a maximum of 10-45 watts. I recommend that your first DMR radio be a handheld type unless you live beyond the handheld coverage of your local DMR repeater. If you spend significant time in your vehicle commuting, you will find a mobile a good investment. Mobiles can also be used as a base station with the addition of an external power supply.

External Amplifier. Many external amplifiers will not work with DMR radios unless they are specifically designed to meet the fast switching requirements of TDMA on DMR. If you need more output power than a handheld DMR radio provides, purchase a mobile DMR radio.

### Suppliers of DMR Radios

The following brands of user radios are currently available or will hopefully soon be available in the US. There are a number of other manufacturers making DMR radios overseas that do not have distribution channels in the US. Motorola Solutions and Hytera also offer repeaters with their respective proprietary IPSCs. Vertex Standard repeaters do not support Internet connectivity. Many manufacturers offer a variety of DMR radio models, including portables and mobiles. Currently there are no fixed base DMR radios available; typically a mobile is used with an AC power supply in fixed base configurations. Some manufacturers of DMR radios may never make them available in the US market because of the cost of obtaining FCC approval.

Motorola Solutions \$\$-\$\$\$\$

<http://www.motorolasolutions.com>

Hytera \$\$-\$\$\$\$

<http://www.hytera.com>

Vertex Standard \$\$-\$\$\$

<http://www.vertexstandard.com/lmr/Digital>

Connect Systems \$

<http://www.connectsystems.com/>

Select CS-700 (UHF) or CS-701 (VHF)

CS-800 and CS-7000 are new models not yet available as of this publication date.

BaoFeng Telecom Technologies (BFDX) \$\$-\$\$\$

<http://www.bfdx.com/en/products.php?listid=60>

Kirisun \$\$-\$\$\$

<http://en.kirisun.com/>

Lisheng \$\$-\$\$\$

<http://www.cnlisheng.com/aspx/EN/index.aspx>

Kenwood \$\$-\$\$\$ (best guess)

<http://www.kenwoodcommunications.co.uk/kenwood-dmr/>

Note: Kenwood has already released DMR radios in other parts of the world, when they will arrive in the US market has not yet been announced.

**Batteries and Chargers.** Battery operated radios need a charger. Most radios come with at least a wall type charger. Some have desk chargers included or available for optional purchase. Some models have gang chargers available. You may want to consider a mobile charger or 12v battery adapter. The SL75x0 series can be charged using a USB cable, just like many cell phones. I always recommend having at least one spare battery and rotating them. You should follow manufacturer instructions for initial charging for maximum battery life. Remember to properly dispose of old batteries. Lithium ion batteries should not be thrown into the trash!

**Warranty and Service Contracts.** If you buy an expensive new radio, you may want to consider the warranty and possibly purchase an extended service contact. Few amateurs have the technology or skills to work on these radios.

## Programming your Radio

When you get your new radio, it must be programmed before first use. Check the DMR-MARC website for basic parameters that need to be configured to get your radio working correctly on the network.

First, you need a subscriber ID. The DMR-MARC website [<http://www.dmr-marc.net>] handles issuance of all subscriber IDs for amateur users and repeaters. Click on *Contact Us* in the top right corner of their page and then follow the instructions. IDs are assigned based upon your geographic location (Country/State). You should have your subscriber ID within a few hours of requesting it. If you have ordered your radio, request your subscriber ID and have it ready when your new DMR radio arrives. If you use an unauthorized subscriber ID, you may find that you can't access repeaters or the wide area network.

If you have multiple radios that will be on the air at the same time, you will need a subscriber ID for each. If you have a mobile and portable and are going to be only transmitting on one at a time, they can share subscriber IDs. Some brands of radios (including Mototrbo™) will not listen to traffic from another radio with the same subscriber ID. It can be an advantage if both your mobile and handheld both use the same subscriber ID, as it eliminates issues of audio feedback.

DMR radios have a code plug which contains configuration parameters, including channel information and a contact list with a limited number of subscriber IDs and call signs/names. Your radio only transmits your subscriber ID and not your call sign or name. You can download code plugs populated with some subscriber IDs already in the database. The complete database is many times larger than any of the radios will support, so you want to limit your code plug to regional users and others you may commonly communicate with.

In the DMR world, repeaters are identified by frequency and by a parameter called a Color Code. There are 16 possible Color Codes (CC0-CC15). You need to have the correct Color Code programmed in order to access a repeater. The repeater database available at the DMR-MARC website lists the frequencies, offsets, and Color Codes for DMR repeaters. You will need to contact another local user or repeater operator to find out which Talk Groups are available on a repeater.

When you press your PTT button, your radio sends a data packet to the repeater, and if it is successfully received by an available repeater, the repeater will send back an acknowledgement signal to your radio, and your radio will generate an audible signal telling you to continue to transmit. If you do not receive an acknowledgement back from the repeater, your radio will signal you that your request was not successful. The use of this hand shaking between your radio and the repeater will give you confirmation that you are making it into the repeater, although you could still be in a fringe coverage area and have too high of packet loss to be understandable. If you are communicating across the IPSC network, wait a second or two for your first transmission to signal all the receiving radios to wake up, as they may be scanning or in a power saving mode.

Your radio may stop transmitting while you are talking because of contention on the network or because you have travelled beyond the repeater's range. Your radio is receiving control information from the repeater when you are talking. Network contention occurs when more than one station is transmitting at the same time on the same Talk Group.

## **Operating on DMR**

When you make an initial transmission to announce your availability, to place a call to another station, or to make a general call, you should also announce what Talk Group you are on because some users may be scanning or have radios without a display. Please avoid calling CQ; DMR is not HF and operating DMR over the network is not DXing.

When you are talking on one of the wide area Talk Groups, hundreds of repeaters will be tied up. If you are unable to move to a more localized Talk Group, be considerate of the other users on the network. Talk Groups share time slots. When one Talk Group is active; other Talk Groups on the same time slot will be blocked. Leave space between transmissions so others can break in. Remember that emergency traffic always has priority over all other traffic.

Examples of good operating practice for initial calls on the DMR networks include:

***“This is W2XAB monitoring Southeast Regional.”***

***“N5ITU this is W9JW on North America.”***

***“This is WB8VYS for a radio check on Local.”***

***“WB8FXJ this is WB8SCT on Ohio State.”***

A quick reminder of the Amateur’s Code by Paul M. Segal, W9EEA (1928) may be helpful to remember.

*The Radio Amateur is:*

***Considerate – never knowingly operating in such a way as to lessen the pleasure of others.***

***Loyal – offering loyalty, encouragement and support to other amateurs, local clubs and the American Radio Relay League, through which Amateur Radio in the United States is represented nationally and internationally.***

***Progressive – with knowledge abreast of science, a well built and efficient station, and operation beyond reproach.***

***Friendly – with slow and patient operation when requested, friendly advice and counsel to the beginner, kindly assistance, co-operation and consideration for the interest of others. These are the hallmarks of the amateur spirit.***

***Balanced – radio is an avocation, never interfering with duties owed to family, job, school or community.***

***Patriotic – with station and skills always ready for service to country and community.***

Spend most of your time listening, not talking. Be a good neighbor and don’t hog the network. Don’t over ID! Help new users develop good operating practices. Be polite when informing other users about their poor operating practices or audio levels.

You must identify your transmissions in accordance with the governmental rules and regulations of your country. In the United

States, you need to be sure you are in compliance with the FCC Rules & Regulations. If you are a foreign licensed station operating within the jurisdiction of the FCC under Part 97.107, you must comply with Part 97.119g and append a radio district prefix before the call sign such as W8/DH6KQ and identify your location (city/state) at least once during each communication. If you are going to use a phonetic alphabet when you ID, make sure you use standard ITU phonetics.

Canadian licensees operating in the US should append the radio district prefix after their call sign, such as VE3BNI/W2. DMR does not automatically identify for you. US licensees operating in Canada should append the Canadian call district after their US call sign, such as W2XAB/VE3.

Further information about foreign licensees operating in the US and US licensees operating in foreign countries, on the high seas aboard ships and in aircraft can be found on the American Radio Relay League's website [<http://www.arrl.org>].

Note that Mototrbo™ DMR repeaters identify in analog mode, during which time the repeater will not accept DMR input. If you have an RSSI (signal strength) indicator on your radio, it will tell you if the repeater is transmitting, but not whether a Time Slot is being used, or if the repeater is IDing in analog mode.

## **Buying a Repeater**

While DMR is an international standard, the networking capability of repeaters is vendor specific. If you want to be able to connect your repeater to a Mototrbo™ network such as DMR-MARC, you must use a Motorola Solutions Mototrbo™ brand repeater. If you want to connect to a Hytera network, you must use a Hytera repeater. Talk to other repeater owner/operators before purchasing any repeater equipment.

If you want better DMR coverage, consider becoming a repeater owner/operator or talking your local club into converting an under utilized analog repeater into DMR. If you have an existing repeater, just purchase a DMR repeater to replace it and keep your duplexers and antenna system. You can operate the repeater in analog mode, digital (DMR) mode, or dynamic mixed mode (DMM). Mototrbo™ repeaters require an entitlement key (~\$550 extra) for DMM mode; DMM and analog will not work with Mototrbo™ IPSC.

To use the IPSC, you will need a connection to the Internet. A static IPv4 address is preferred, but only required if the repeater is a Master on the IPSC network. DSL and cable modems will work. WiFi, (802.11)

Wireless 3G, 4G, and WiMax (802.16) broadband connections are usable, especially if you want to operate the repeater mobile or portable. VSAT is a possibility but delay (latency) times can be an issue.

In a metro area, it may even be a good idea to have a DMR repeater that is not connected to a network for local usage only. Wide coverage area, high profile repeater sites can be difficult to obtain. A network of interconnected lower profile DMR repeaters can provide equivalent coverage as a high profile mega site.

Used DMR repeaters can sometimes be found on eBay™ or other websites. Some “ham friendly” dealers offer good prices. There is not a great difference between used and new street prices, especially when you consider the warranty with the new equipment.

If this is your first endeavor into owning or operating a repeater, be aware that there are many steps needed beyond buying the repeater. To make your new repeater fully operational, you will need to purchase duplexers, possibly band-pass filters, lightning protection, feedline, antennas, antenna mounts, mounting rack, battery backup, site (tower or commercial site), insurance (most commercial sights require it), antenna/feedline installation, electricity, internet connection (at commercial or remote sites residential service may not be available), and repeater coordination. Before you take the plunge into repeater ownership, talk to other amateur repeater owners/operators.

Mototrbo™ repeaters also support remote receiver and digital voting, digital telephone interconnect (autopatch), DMM and remote programming, all at additional cost.

Motorola Solutions makes a series of DMR capable repeaters available, including the XPR8300 (discontinued), XPR8400, and MTR3000 models that cover either the amateur 144-148 MHz or the 420-450 MHz bands. There is also a model XPR8380 for 800/900 MHz that some hams are using on the 902-928 MHz band. The XPR8300 model is an older version of the XPR 8400 and does not support some advanced repeater options such as digital voting and remote programming. Hytera has RD62x, RD96x, and RD98x repeaters; these will not inter-connect with the Mototrbo™ networks. Vertex-Standard has two repeater models (they look exactly like the XPR8300 and XPR8400) but they do not support IPSC, so I would not recommend them. If you want to connect to a Mototrbo™ network such as DMR-MARC, you must use a Mototrbo™ repeater.

The number one thing you need is time and really deep pockets or a very supportive club structure!



## The End of the Beginning

The most important thing about the hobby of Amateur Radio is to enjoy learning new technologies, experimentation, meeting new friends, public service, and to leave the hobby better than when you entered.

The spark gap transmitter gave way to frequency selective transmitters and receivers using CW; CW gave way to AM; AM was largely pushed aside by SSB; FM became the mode of choice for most on the VHF and shorter wavelengths. The digital ham started at the same humble beginning, CW over spark gap. Over the years, the digital ham's interests may have included CW, RTTY, then Packet (AX.25), and a whole host of mainstream and experimental digital modes, and even WiFi (802.11). With the advent of faster computer processors and vocoder technology, analog voice moved into the digital age, both on the HF bands and on VHF and higher bands. Vocoder technology merged with packet technology and D-Star™ took the VHF and UHF bands by storm with the help of a single vendor and the JARL (Japan Amateur Radio League). Yaesu has enter the arena with their proprietary System Fusion™.

Traditional professional analog FM two-way users are all migrating to digital formats, including TETRA, P25 (Phase 1 and Phase 2), NXDN, and DMR (Tier II and Tier III). Hams have already adopted the professional P25 (Phase 1), NXDN, and DMR (Tier II) technologies. DMR is the clear winner based upon number of amateur systems and users currently using the technology.

D-Star™ is not going away overnight; it has a strong base. But with the expansion of DMR and the entry of low cost DMR radios into the marketplace from multiple vendors, lower cost per channel, better audio quality, and international standards, DMR is going to be the technology of choice for digital repeaters systems in the foreseeable future. DMR is not the final answer; it is only one small step along the path to the future of our hobby. Someday DMR will be replaced by something better. When that happens, hams as early adopters of emerging technology will be in the forefront of the technology change.

***If you build it, hams will use it!***

## For Further Information about DMR

**DMR-MARC (Motorola Amateur Radio Club)**

<http://www.dmr-marc.net>

**DMR-MARC Canada**

<http://www.va3xpr.net/dmr-marc-canada/>

**DMRUK.net (United Kingdom)**

<http://www.dmr.uk.net>

**Digital Communications Interconnect Group (DCI)**

<http://www.trbo.org>

**DMR Core Talkgroup Server Project (NATS)**

<http://dmr-na.com>

**Digital Mobile Radio Association (Professional DMRA)**

<http://www.dmrassociation.org>

## Regional DMR Groups

**Central Michigan Emergency Network (CMEN MI5)**

<http://w8cmn.net>

**K0USY Group (Kansas)**

<http://k0usy.strikingly.com>

**NC-PRN (VA/NC/SC/TN)**

<http://www.ncprn.net>

**New England Digital Emergency Communication Network (NEDECN)**

<http://nedecn.org>

**NJ-TRBO Network (NJ/NY)**

<http://www.n2jti.net>

**NOCO DMR Group (CO/UT)**

<http://www.w0dmr.org>

**CALDMR (California)**

<http://www.caldmr.org>

**Massachusetts Interconnect Team (MIT)**

<http://www.mitcom.com>

**Rocky Mountain Ham Radio**

<http://www.rmham.org>

## For Further Information about Amateur Radio



**American Radio Relay League (ARRL)**

<http://www.arrl.org>



**Quarter Century Wireless Association (QCWA)**

<http://www.qcwa.org>



**Radio Amateur Satellite Corporation (AMSAT)**

<http://www.amsat.org>



**Tucson Amateur Packet Radio Association (TAPR)**

<http://www.tapr.org>



**Radio Amateurs of Canada (RAC)**

<http://www.rac.ca>



**Radio Society of Great Britain**

Advancing amateur radio since 1913

**Radio Society of Great Britain (RSGB)**

<http://www.rsgb.org>



## Ham On DMR!

