By Bob Witte,* KØNR

FM

FM/Repeaters—Inside Amateur Radio's "Utility" Mode

TRBO Hits the Amateur Bands

A new digital standard is gaining traction on the VHF and UHF amateur radio bands. This standard is called Digital Mobile Radio (DMR), sometimes called MOTOTRBO™, which is Motorola's implementation of the standard. Many hams just refer to this as "TRBO." DMR is another example of a land mobile radio standard finding its way onto the ham bands. There are over 90 DMR repeaters up and running in the U.S., with more planned.

DMR Standard

DMR originated as a European Telecommunications Standards Institute (ETSI) standard. The DMR Association is the industry body promoting adoption of the standard and includes these companies as members: Harris, Hytera, ICOM, JVC, Kenwood, Motorola, Tait Communications, Vertex Standard, and Zetron. While these are all known players in the land mobile radio industry, most radio amateurs may recognize only a few of them.

Like other digital radio standards, DMR converts the analog signal (usually from the microphone on the radio) to a stream of digital bits. These bits are used to modulate the radio-frequency carrier, which is decoded at the receiver and converted back into analog form. From a ham radio perspective, DMR takes a novel approach to spectral efficiency. The bandwidth of the radio signal is nominally 12.5 kHz with two signals sharing the channel via Time Division Multiple Access (TDMA); see figure 1. Simply put, two mobiles working through a DMR repeater share the channel by cycling their transmitters on and off in a synchronized manner. This is similar to how some cellular-phone systems handle multiple phones operating on the same channel. The cellular-phone base station controls the synchronization of the various phones so they do not interfere with each other. Similarly, with DMR the repeater has to synchronize the two mobiles using the same 12.5-kHz wide channel.

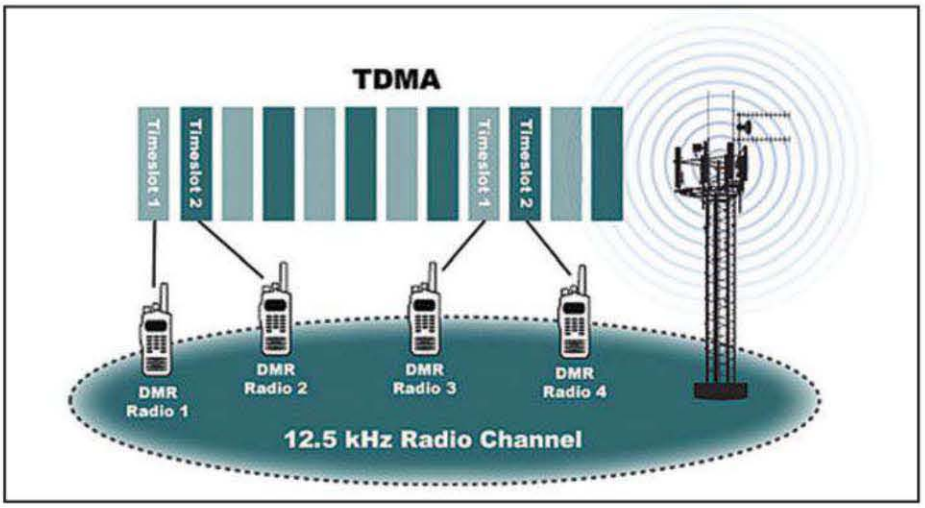

Figure 1. DMR uses Time Division Multiple Access to interleave two radio transmissions onto one 12.5-kHz-wide channel. (Figure courtesy of the DMR Association)

This two-for-one approach provides an effective spectral efficiency of 6.25 kHz per channel. The FCC is requiring most *commercial* users of the VHF and UHF spectrum to move to 12.5-kHz channel spacing by the start of 2013. This requirement *does not* apply to the Amateur Radio Service. The FCC is also anticipating a further shift to 6.25 kHz per channel sometime in the future, so the DMR standard is set up to achieve that efficiency. The DMR standard supports the mix and match of voice and data. That is, the digital bit stream can be used for data or to carry an analog voice signal. Both TDMA slots can be used for voice communication, or one can be used for voice and the other used for data, or both can be used for data.

Clearly, synchronizing the time interleaving of two radio transmitters is not trivial. However, once you handle the complexity of on/off timing of the mobile radios, two-slot TDMA has a lot of advantages. For the repeater technical crew, a DMR installation looks a lot like a normal repeater system but with the benefit of two channels built in.

The TDMA time slots (called the TDMA Burst) are 30 msec in duration, one slot per mobile radio, with a total time of 60 msec (called the TDMA Frame). In the 30 msec slot, the transmitter is required to ramp up to full power in 1.5 msec, send data for 27 msec, then power down in 1.5 msec. While the two mobiles on the repeater input are switching on and off, the repeater transmitter stays on continuously while either mobile is active.

For simplex operation, there is no repeater available to coordinate the timing of the two TDMA slots, so simplex operation basically uses the entire 12.5-kHz channel. The DRM standard does include the concept of a *Reverse Channel*, which allows the open timeslot to be used as a "back channel," allowing other transmitters to insert upstream information onto the channel. (This is not implemented on MOTOTRBO today.)

The voice modulation is digitized and compressed using a proprietary AMBE+2 vocoder from DVSI. This is one generation newer than the AMBE+ technology used in D-STAR. Actually, the DMR specification does not specify the vocoder technology, but AMBE+2 is the vocoder that the manufacturers have adopted.

The modulation technique for DMR is

*21060 Capella Drive, Monument, CO 80132
e-mail: <bob@k0nr.com>

4FSK Encoding		
Frequency Shift	**Bit 1**	**Bit 0**
+1.944 kHz	0	1
+0.648 kHz	0	0
–0.648 kHz	1	0
–1.944 kHz	1	1

Table 1. DMR uses 4FSK modulation, which is Frequency Shift Keying (FSK) with four distinct frequency shifts. Two logical bits are encoded onto each frequency shift.

a four-level frequency-shift-keying (4FSK) method. Many of us are familiar with conventional RTTY, which is a two-level frequency shift technique. A logical 1 is commonly indicated by 2125 Hz (relative to the carrier frequency) and shifting the frequency by 170 Hz (to 2295 Hz) indicates a logical 0. We shift back and forth between these two frequencies according to the bit stream we are sending. The 4FSK approach extends that idea to use four different frequencies (or "levels"). Table 1 shows how this is defined by the DMR specification. Instead of just flipping between two states (1 and 0), the 4FSK approach has four different frequency shifts signifying two bits of data. This essentially crams twice as many bits onto each time slot associated with a frequency shift.

It is common to call each one of the

Photo A. The Motorola XPR 6550 is a popular DMR portable radio, available in VHF and UHF models.

Line-up of Popular VHF/UHF Digital Radio Standards

The use of digital voice technology is becoming fragmented on the amateur radio VHF and higher bands. There are three incompatible technologies that have a significant presence.

D-STAR: Digital Smart Technologies for Amateur Radio is an open standard digital communication protocol established by the Japan Amateur Radio League (JARL). This protocol was designed for the Amateur Radio Service and ICOM is currently the only major equipment manufacturer making D-STAR gear. See "D-STAR, Digital Voice for VHF/ UHF," *CQ VHF* magazine, Winter 2006.

APCO 25: The Project 25 radio standard was developed by the Association of Public-Safety Communications Officials-International (APCO) primarily for the Public Safety Spectrum. A primary goal of this standard is to enable intercommunication between multiple public safety organizations (e.g., fire, police, medical).

DMR: Digital Mobile Radio standard was developed by the European Telecommuni cations Standards Institute (ETSI). This standard uses TDMA to allow two communication links simultaneously on a single 12.5-kHz channel.

states a *symbol,* rather than a bit, since a symbol can represent more than one bit. The DMR spec calls for 4800 symbols/ second. Since there are two bits per symbol, this gives us a data rate of 9600 bits/second.

The DMR protocol includes Forward Error Correction (FEC) to mitigate the presence of errors in the bit stream. This means that the audio quality stays intact as the signal level drops off, creating errors in the bits. FEC can correct for a relatively small number of bit errors, but when the error rate increases, the audio signal falls apart.

It is very apparent that the DMR Standard was created by a standards body that is used to completely specifying a complex radio standard. The documentation available on the web is very complete and detailed. Compare this level of documentation to what is available on D-STAR and you'll see that the D-STAR spec is relatively thin.

MOTOTRBO

No surprise, most of the repeaters showing up on the ham bands are MOTOTRBO, Motorola's implementation of DMR. MOTOTRBO offers some features over and above what is defined in the standard, while maintaining compatibility with the standard. The DMR industry is motivated to maintain compatibility across manufacturers, else the whole "standard" concept falls apart.

For backward compatibility, MOTOTRBO repeaters and user radios can operate in analog FM mode, both narrowband (12.5 kHz) and wideband (25 kHz). The wideband FM mode is important to radio hams for operating on existing FM repeaters.

MOTOTRBO radios include the concept of Radio ID, where each radio on a system is assigned a number between 1 and 16776415. Each radio stores a list of aliases that translate these numbers to name, location, or assignment. For ham use, the alias feature will often be used for name and amateur callsign. Alternatively, it could be used to indicate a fixed location such as an Emergency Operations Center (EOC). MOTOTRBO has a robust text-messaging system built into it. Most, but not all, radios have a GPS receiver built in to enable location-based features. Motorola is releasing new software for both the repeaters and the user radios, so the specific features will improve over time.

In photo A is a popular MOTOTRBO UHF handheld radio (Motorola XPR 6550) that covers 403 to 470 MHz. I received several quotes for this model of radio new from dealers in the range of $700–750. On the used market they can be picked up for less than $500. This is significantly higher than other ham radio equipment but actually not that expensive for commercial-quality digital gear.

DMR equipment is available from several land mobile radio companies. Also, earlier this year Yaesu published a paper that argued for the use of DMR and APCO 25 technology in the amateur radio market. The rumors persist that they will have something to show at the Dayton Hamvention® this year. This means an amateur radio manufacturer is adopting DMR or APCO 25 specifically for amateur use. (Recall that Yaesu is now a separate company from Vertex/ Motorola.) This could get interesting.

Is It Legal?

In early 2011 the issue was raised as to the legality of DMR/MOTOTRBO for use under FCC Part 97. Motorola had classified MOTOTRBO as emission types 7K60FXD (data-only mode) and 7K60FXE (data and voice mode). A careful reading of Part 97.305 led many to conclude that these emission types are not allowed in the Amateur Radio Service. This, of course, was hotly debated in the amateur radio community.

The ARRL petitioned the FCC to revise the rules to clarify the situation and allow DMR on the ham bands. In March 2011, the FCC opened RM-11625 and asked for public comments. While over a year later the FCC has not taken action, Motorola filed with the FCC to add new emissions designators to the MOTOTRBO equipment. The modes of interest to amateur radio are 7K60F7W for the repeater stations and 7K60F1W for the user radios. These emission types are specifically allowed in Part 97. Since there have been no public enforcement actions on the part of the FCC, we have to conclude that they don't see a problem. Stay tuned to see if the FCC takes action on RM-11625.

More Information

If you want to dig deeper into the technical details of DMR, take a look at the DMR Association website or the MOTOTRBO website (both listed in the references section). To find TRBO activity, check out the online TRBO repeater database or visit the DMR-MARC website. DMR-MARC is a worldwide network of TRBO repeaters.

Thanks for taking the time to read another one of my columns on the *Utility Mode*. I always enjoy hearing from readers, so stop by my blog at <http://www. k0nr.com/blog> or drop me an e-mail. 73, Bob KØNR

References

Digital Mobile Radio Association: <http:// www.dmrassociation.org>

ETSI Digital Mobile Radio page: <http:// www.etsi.org/WebSite/Technologies/DigitalMobileRadio.aspx>

MOTOTRBO website: <http://www. motorola.com/mototrbo>

Digital Voice Systems, Inc.: <http:// www.dvsinc.com>

Yaesu "A Digital Communications Guide for Amateur Radio Operators": <http://www. yaesu.com>

DMR-MARC Worldwide Network: <http://dmr-marc.net/>

TRBO Repeater Database: <http:// www.n6dva.org/trbo-database/trbo_ repeatersview.php>