Project 25 for Amateur Radio

The FM repeater era began nearly 40 years ago with hams "repurposing" commercial analog transceivers. Now they're doing it again, but this time it's digital!

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There is increasing interest in digital voice and data activities on the ham bands, particularly above 50 MHz. Many amateurs have probably heard of D-STAR, a digital voice and data system developed by the Japan Amateur Radio League in cooperation with ICOM. However, there is another approach that is attracting attention as well: APCO Project 25.

APCO Project 25 (P25) is a set of digital radio standards developed by various electronics manufacturers, along with input from local, state, and federal governments, and support from the Telecommunications Industry Association (TIA). P25 has been around since 1995, and provides guidance for building digital radio equipment for public safety users. P25 systems have proliferated among public service agencies. Chances are a police department, fire department or other public agency near you is using a P25 system right now.

Within the last several years hams have been acquiring commercial Project 25 mobile and handheld transceivers and converting them for amateur use, mostly on 2 meters and 70 cm. Because P25 is an open digital standard, it is perfectly legal for hams to use P25 on the air.

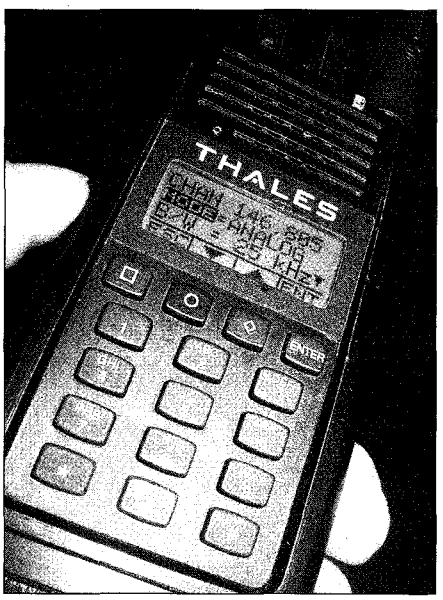
One common misconception about P25 is that all systems are trunked, where radios on the system are automatically directed to assigned frequencies by a central controller, as opposed to conventional systems where the users manually choose operating frequencies. In fact, P25 defines both trunked and conventional systems. While trunked systems aren't a real good fit for Amateur Radio for a variety of reasons, conventional P25 is much more useful.

The number of manufacturers making P25 equipment has greatly increased in the last eight years or so. In the 1990s Motorola and EF Johnson had a virtual monopoly, but now most major manufacturers of two-way radios for the public safety market have at least some kind of P25 offering. Modern scanners and communications receivers often have P25 decoding capability, adding to the number of P25 radios out there.

There are numerous amateur P25 repeaters around the US, so one might be closer than you think! The latest *ARRL Repeater Directory* identifies these repeaters, where known. Another source of information is on the Web **www.p25ham.com**.

P25 Features

With P25, voice and data share the same channel seamlessly and simultane-



The Thales 25 (formerly Racal 25) is a P25 digital radio covering the 136-174 MHz band. Notice that this one has been reprogrammed for use on the 2-meter ham band. It features a very intuitive user interface, which allows channel parameters to be quickly programmed or changed from the front panel.

To reprogram a Motorola Astro Saber, you need Motorola's programming software, a Radio Interface Box (RIB) and the appropriate cables. You can find the RIB and cables on eBay and other sites.

ously. Conventional P25 also supports data messages such as "digital DTMF" dialing packets, individual radio paging with acknowledgement, and even text messaging on some of the newer radios. P25 radios remain muted whenever data messages intended for other stations are received, so the user isn't annoyed by hearing data packets between voice transmissions.

The P25 standard supports *unit ID* numbers, which is another useful feature. This means that each transceiver is treated as a unique radio with its own digital ID. Many P25 radios have a unit ID alias list that can be programmed with text labels such as a name or call sign. You can configure the radio to display the alias whenever a particular person is talking.

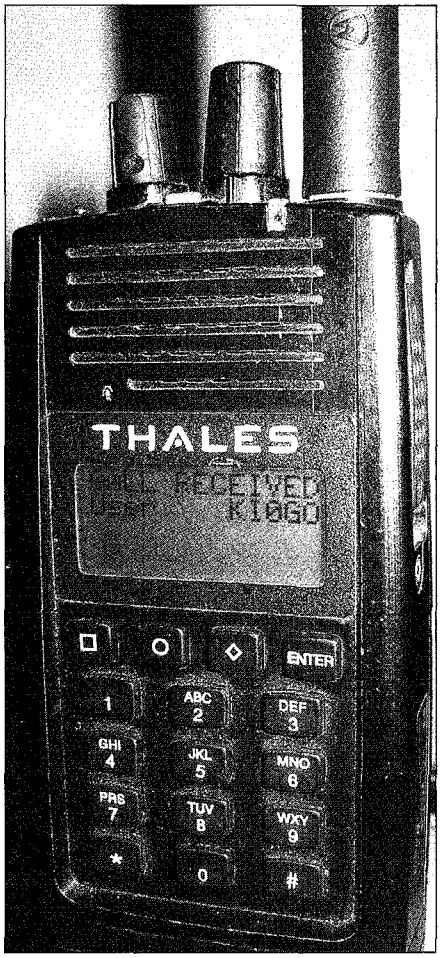
Like CTCSS tones on analog FM repeaters, P25 supports what are known as *Network Access Codes* (NAC) to allow radios or repeaters to ignore transmissions that are not intended for them. There are 4096 possible NAC values, which include the special reserved "hear all" value of F7E, and the "repeat all" F7F value.

Even though most P25 repeaters are set up to only repeat transmissions with a single NAC value, it's still possible to separate groups of users into *talkgroups*, if desired. As with the NAC, the talkgroup value is continuously sent throughout the P25 voice transmission. Any P25 radio can be programmed to operate with "Selective Squelch", where the radio will only unmute if both the NAC and talkgroup values match. This operation is very similar to having several groups of users on one frequency, but each using their own CTCSS tone. Imagine you and several friends carrying on your own "private" conversations while another group does the same — all on the same frequency.

P25 Repeaters

There are a few different ways repeaters can be set up to relay P25 signals. The simplest would be using a standard analog FM repeater set up for total carrier squelch operation (no CTCSS tones). If the audio response of the repeater is flat enough down to very low frequencies, P25 signals may pass through it sufficiently undistorted so that they can be demodulated on the output. Of course, this method provides no error correction of any kind to clean up the received signal, and has all the normal disadvantages of a carrier squelch repeater.

Another way to repeat P25 signals is to construct a repeater out of a couple of P25 radios, so that the audio from the receiver of one radio is routed to the transmitter of the other. A repeater constructed this way does at least provide a consistently clean P25 signal, but since the digital receive audio is converted to analog and then back to digital again, the quality suffers. This is known as "double vocoding." Another disadvantage to double vocoding repeaters is that the information continuously embedded in a P25 transmission doesn't pass through the repeater, so unit ID, talkgroups and data messages can't be used.



The Thales/Racal25 transceiver notifies the user of an incoming call with an audible alert and a display message. If the unit ID list in the radio is properly programmed, the radio displays the caller's name or call sign.

The best way to repeat a P25 signal is to use a repeater designed to do just that. These repeaters take the received digital signal, correct any errors to the maximum extent possible and send a totally regenerated P25 signal on the output. This permits the passing of all the embedded information like unit ID numbers, talkgroups, individual calls and even data messages, depending on the repeater.

Using P25

Getting a couple of P25 radios to communicate on simplex or through a repeater isn't all that much more difficult than doing the same with analog radios. The most important difference is to make sure the NACs are properly set in each radio.

One might be quick to conclude that the simplest way to do this would be to not use NACs at all, thinking it would be the equivalent of using no CTCSS tones. P25 doesn't work this way, as every frame in every transmission contains a NAC value, so something must be sent.

The default NAC value is 293 hexadecimal, and is the most commonly used value on amateur P25 repeaters. Most P25 radios require the NAC to be entered in hexadecimal format using the programming software, and some have the option to enter it in decimal format as well. Some of the P25 radios can be programmed from the front panel and in that situation the NAC must be entered in decimal. It's important to know which format your radio expects, so that you can convert it if necessary. Most scientific calculators make this hexadecimal/decimal conversion a snap.

Motorola P25 radios can be programmed for "Digital Carrier Squelch," where the radio will unmute on any P25 signal. However, this setting forces the transmitted NAC to 293, which may not always be what you want.

The P25 standard specifies NAC value F7E as a special "hear all" NAC that can be used in receivers to allow them to unmute on any NAC. Unfortunately, this wasn't specified until later in the life of the standard, so there are many P25 radios out there that don't treat F7E as a special NAC. A quick test for this is to try and program the value F7E into your radio as the *transmit* NAC. If the radio or programming software accepts this value, it probably doesn't treat F7E as the special value. Since F7E is a special NAC for receivers only, the standard states it isn't allowed to be transmitted. If a radio allows F7E to be transmitted, it was probably developed before F7E was declared a special reserved NAC, and would treat F7E just like any other value.

Once the NAC is properly programmed, that's pretty much it for basic operation. If coordinated with the other P25 users on the channel, talkgroups can be used if some users don't want to listen to all the channel activity. This involves selecting a talkgroup and reprogramming the squelch mode from "normal" to "selective," so the radio will require both the received NAC and talkgroup values to be correct to unmute. The highest conventional talkgroup, 65535 decimal, is designated by the P25 standard as the "all call" talkgroup and all radios will unmute on reception of this one, regardless of which talkgroup they're programmed to.

The programming software for some P25 radios has the ability to enable or disable talkgroup operation. Like the NAC, there's a slot for a talkgroup value in each standard

P25 voice frame, so something must be transmitted even if talkgroups are disabled. Most radios just send talkgroup 1 in this case, and unmute on reception of any talkgroup. Talkgroups are probably a little too complex for most amateur use, but the capability is there in all P25 radios.

Sharing a Channel with Analog Users

When using P25 or any other digital voice mode, care should taken to prevent interference to other users of the channel. Depending on how they're programmed, some P25 radios may not indicate when analog traffic is present, so it would be possible to unknowingly "double" with an analog user.

The best way to avoid this is to program every P25 channel in your radio as *mixed mode*, which allows the radio to receive both analog and digital traffic. Nearly every P25 radio supports some kind of mixed mode operation, so it's pretty easy to monitor the channel prior to transmitting. If you only want to listen to digital traffic on a channel, it's a good idea to program the channel as mixed mode anyway, but set the receive CTCSS/DCS value to one you wouldn't expect to be used. On most P25 radios that don't provide a busy indication for analog signals on a digital-only channel, setting the channel to mixed mode with a wrong receive CTCSS/DCS value will often provide some kind of busy indication.

Just about every P25 repeater can be configured for mixed mode operation, and repeat both analog and digital signals. This allows both analog and digital radios to use the machine, but it can create some problems, as well. Since the repeater can only repeat one mode at a time, it needs to be shared by users that may not be able to decode the opposite mode. Using CTCSS tones on the repeater output lets analog users with tone decode capability keep their radios muted while digital traffic is present. Of course, analog users without tone decode capability would just hear the unpleasant noise whenever digital traffic is there.

Any repeater owner or club considering replacing an existing analog-only repeater with a P25-capable one should carefully think about how it will be used by both analog and digital users. In many cases, replacing a heavily used analog repeater with a mixed mode repeater may cause too many problems. A better use of a P25 repeater may be to replace an existing repeater that doesn't see as much use. This may breathe new life into the machine, while not ruffling the feathers of too many analog-only users who may have been using it for years.

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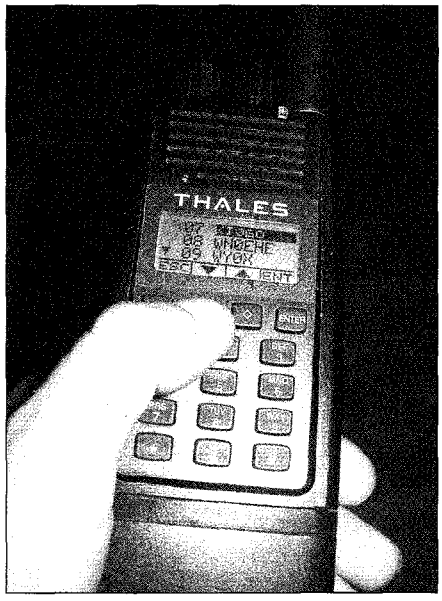

On the Thales/Racal25, accessing the unit ID list to make an individual call is as simple as pressing and holding the pound (#) key.

Finding P25 Rigs

So where do you get a P25 radio? Since these are mostly intended for the public safety and government markets, buying a brand new one may be surprisingly expensive or even difficult, depending on the manufacturer. Many manufacturers of P25 radios have an entry-level model with a list price in the $900-$1500 range, which is really steep compared to typical VHF/UHF analog ham gear. Full-featured radios can easily exceed $5000 list price, which would be out of the price range of most individuals.

Rather than buying new gear, most P25 hams look to the used/surplus market on auction Web sites (such as eBay) and radio web forums. Prices of P25 radios in this market typically range from $200 to $2000, depending on the radio. There are a quite a few used P25 radios in new or like-new condition.

There are several things to watch out for when shopping for a used/surplus P25 transceiver. The first is making sure the radio you're considering is really capable of P25 digital operation, and covers the desired frequency range. Many manufacturers sell their P25 models with digital voice as an *option*, so you need to ensure this option is actually enabled in the particular radio. This means that finding a P25 radio isn't as simple as searching for a model number.

Older Motorola radios, such as the Astro Saber and Astro Spectra may have an outdated proprietary *VSELP* digital voice option, which isn't compatible with P25. There is information available on the Internet detailing which firmware versions and flash code options are necessary for P25 operation. See **www.batlabs.com** to get started with the popular Motorola Astro radios.

Another very important thing to consider when purchasing a used/surplus P25 radio is where the radio came from. Ideally, the seller would have some kind of proof that the radio was obtained legally, as it isn't uncommon for these to disappear from public safety or government agencies. If the seller can't provide this information, or doesn't even know what band the radio operates on, it's probably best to move on.

Finally, before spending your hard earned cash on a P25 radio, you'll need to think about how to get it programmed. The PC programming software and the necessary cables are usually proprietary and can be quite expensive, depending on manufacturer. While some P25 radios like the Racal/Thales 25 and Relm/BK DPH are front-panel programmable, there are some initial settings that need to be set via the PC software.

Photos by the author.

Mike Kionka, KIØGO, received his BSEE from the University of Colorado at Boulder in 2001. He has been a ham since 1995 (originally licensed as KBØUCA). An ARRL Life Member, Mike currently works as a consultant designing and engineering two-way radio systems. You can contact him at 8735 W 67th Pl, Arvada, CO 80004; **kionka@colorado.edu.**

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