From Analog to D-STAR

D-STAR has come of age. Learn how to use its networking features and join in even if you don't yet have a D-STAR radio.

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Is D-STAR confusing? Difficult to master? Hams who know it well say "no," and hams who have yet to get over the learning hump say "yes." Let's see if I can smooth out that initial hill a little.

What is **D-STAR**?

D-STAR is system for ham radio digital voice and data communication for VHF/UHF. Think of it as an upgrade to the FM you've been using for years. As with FM, you push the PTT, talk into the microphone and listen to people on the speaker. You can talk to amateurs via simplex (on the same frequency) or through D-STAR repeaters. For repeaters you each transmit on one frequency and listen on another, so you have to both dial in a frequency and set an offset. Because it's all digital, there are some unique characteristics and added capabilities — especially networking.

D-STAR uses GMSK (Gaussian minimum shift keying). That's a complex frequencyshift keying technique that squeezes a lot of zeros and ones in a small amount of spectrum — about 4800 bits per second (bps) — into just 7 kHz of bandwidth. The D-STAR protocol organizes the bits into voice, control data, display data, some free form ASCII, forward error correction (FEC) and the usual overhead to run the show. Another form of D-STAR uses higher speed data — 128 kbps — but is only used on the 1200 MHz band.

Programming the Radio

You program a D-STAR radio the same way you'd program an FM radio - enter frequency, offset, channel step, mode (DV for D-STAR) and tone. Most D-STAR radios are full-up, high end analog radios too, so you'll put in all your favorite FM repeater and simplex channels. D-STAR adds even more programming (that's what this article is all about), but first, is there even a D-STAR repeater in your area? Not every urban area has one, and rural coverage is more miss than hit in most states. The ARRL Repeater Directory lists D-STAR machines, but since we're seeing fairly rapid growth, it's best to check some web resources including www. dstarusers.org and www.dstarinfo.com.1

Do some local research, too. The directories aren't perfect. You'll need that local info. Coordination groups have been shoehorning narrow D-STAR channels onto what may look like some unusual frequencies.

The Call Sign Fields

Now for the D-STAR specific programming. D-STAR is "controlled" by four call sign fields. They're named MY call, YOUR call, REPEATER 1 and REPEATER 2 (see Figure 1). The call signs you put in those fields somewhat correspond to the continuous tone

coded squelch system (CTCSS) and dual tone multifrequency (DTMF) tone functions you use in an FM radio.² They tell repeaters to do things such as key up or create a link. Some of the call signs have an extra letter or two that control specific functions.

The data field MY call is the simplest to understand. That's the call sign of the person doing the transmitting on the radio. I would say that it's "your call sign," but that really confuses the language because YOUR call means something else in the D-STAR world. This is best done in first-person English. I run my radio. I put in my call sign in the MY call field. Bad journalism, but good instruction manual.³

Is D-STAR difficult to master? Hams who know it well say "No."

I put my call sign in the MY call field of my radio using the display, the knobs and the keypad to navigate menus and enter digits (see Figure 2). It is tedious. I push buttons to get to the point at which a blinking cursor prompts me to enter the first letter. Next, I turn a knob and scroll to K (for KN4AQ). I press a button, the cursor jumps to the next position, and I scroll to N. Press, scroll, press, scroll, until my whole call sign is in there, plus four more characters at the end of the field that can be anything, so I add my name — GARY.



Figure 1 — The four D-STAR call sign fields are shown in the display of this ICOM IC-92AD handheld. Note that the RPT1 and RPT2 call signs have a port letter appended.

The information I put in MY call is seen on the screen of all the stations receiving my transmission. It's also used by the D-STAR network to find me, but I'm getting ahead of the story. You have to register that call sign before you can use the networking features. You usually do this on the website of your local D-STAR

repeater, and it's generally free.

More explanation is needed to cover YOUR call . It's the

key — the most useful, flexible field in the system. It's not complicated, but we'll deal with it last. You can talk on D-STAR repeaters just fine without programming YOUR call beyond the "placeholder" CQCQCQ.

The REPEATER 1 and REPEATER 2 fields both get my local repeater's call sign with an added character (see Figure 1). This is similar to using CTCSS on FM. It tells the repeater, "Hey, I'm talkin' to you."

In REPEATER 1, the added character will be an A, B or C, in the eighth position of the eight-character field. That's because a D-STAR site might have three repeaters, one each on 144, 440 and 1200 MHz. They all use the same call sign, so I differentiate between them by adding a port letter, which corresponds to the control port that each repeater module plugs into on the controller. By convention in most of the world, the 1200 MHz repeater plugs into the A port, the 440 MHz repeater goes into the B port and the 144 MHz deck plugs into the C port. That's now ingrained in D-STAR culture. Figure 1 shows my local UHF repeater's call sign entered as KR4RDU B. That's a blank space in the seventh position. Shorter call signs would have more blank spaces between the call sign and the port letter.

The same call sign goes into REPEATER 2, with a G in the eighth position. Doing that routes your signal to the gateway, a computer that accompanies the D-STAR repeater and controls the Internet connection. Always fill this field with the repeater's call sign plus a G, even for local contacts. I'll explain why later.

Your First Digital Contact

It's time for your first digital contact. You key up and announce yourself, the same as you would on FM. And you are greeted by a voice from Mars.

I exaggerate. The voice is human, but it's been digitized by a hard working voice encoder (vocoder) to fit in a small stream of zeros and ones. D-STAR has a unique timbre that colors voices to some extent. You can still recognize individuals. It's just that they've gone a little bit Claymation.

Notice the noise floor. It's dead quiet, far quieter than on FM. You can't tell how strong a D-STAR signal is by listening. Very weak signals can have some garble as the vocoder tries to reconstruct missing bits using FEC. Early D-STAR users dubbed this garble "R2D2," because it resembles the sound of that little Star Wars robot. The rest of your contact is routine. Press to talk, release to listen.

Gateway to Heaven

Time to learn all about YOUR call. D-STAR is designed to be networked. You can put up a stand-alone D-STAR repeater, but D-STAR comes alive when you connect it to the



Figure 2 — Programming the MY call field on an ICOM IC-2820H mobile. I've just finished dialing in the Q of KN4AQ. Below that are two call signs entered previously — KD4ACW and AC4ZO.

Internet by adding a gateway computer and an Internet connection to the repeater site. Then you join a worldwide community of hams, right on your handheld or mobile radio, through your repeater. Local activity will probably be light at first, but the gateway will keep your repeater busy. Drive down the road and be in a roundtable with hams in the US, Europe, Africa, Australia and Asia. Repeaters can be linked one to one, or can join reflectors that can tie dozens to hundreds of repeaters together.

FM repeaters have been using *EchoLink* and IRLP to link via the Internet for a decade. But D-STAR has some differences:

• The sound. D-STAR audio may start a bit more limited, but it stays the same from end to end — it doesn't degrade a bit (pun intended).

• D-STAR networking gets used a lot. A D-STAR reflector becomes a community of hams who talk to each other routinely as if they're all on the same local machine.

• No codes to remember. The control is in the call signs, and it's all stored in memory on your radio.

Using the Network

This is where the YOUR call field works its magic. There are two fundamentally different ways to use D-STAR over the network: *Call*

Sign Routing (the original system) and a newer overlay called *DPLUS*.

• Call Sign Routing. When I put a specific call sign in the YOUR call field of my radio (with my local repeater call signs in RPT1 and RPT2), I cause my signal to be routed through the Internet and appear on another D-STAR repeater. I can route to a specific ham or to a specific repeater.



Figure 3 — When I key up with AC4ZO in the YOUR call field, the D-STAR network will route my transmission to the repeater Jeff used most recently. And if he's using call sign squelch, his speaker will open for my signal.



Figure 4 — The YOUR call field is configured to send my transmission to the Charlotte 2 meter D-STAR repeater. The / tells the system that I want a repeater, not an individual ham. The C at the end tells the Charlotte system that I want is 2 meter machine.

To reach a specific ham, I put that ham's call sign in my radio's YOUR call field (see Figure 3). Since everyone is sending their call sign with every transmission, the D-STAR network knows where everyone is. I key up, and my local repeater's gateway checks YOUR call, and routes my signal through the Internet to the repeater that ham used most recently, all within a fraction of a second. If my friend is still listening there, he hears me. I don't even need to know what repeater he was on.

To reach a specific repeater, I put that repeater's call sign in YOUR call, preceded by a "/" slash bar to identify the call sign as a repeater, and followed by the port letter A, B or C in the eighth position. Remember that a D-STAR site may have three repeaters sharing one call sign, so I have to pick which one I want.

Let's take an example. I want to route my signal to the KI4WXS, Charlotte, VHF repeater (see Figure 4). I enter /KI4WXSC in the YOUR call field of my radio. I key up here in Raleigh on KR4RDU, and my voice is heard in Charlotte.

Call Sign Routing works, and it has some unique advantages, but most D-STAR users find it confusing and never master it. Some say the design is flawed, and some say it's elegant. Here are the facts:

The routing is done for every individual transmission. I'm not linking the repeaters. With each transmission, the gateway looks up the call sign, sees where my signal has to go, and sends it there. It does this in a fraction of a second. That's impressive, but it means that:

• The ham I'm calling can't just transmit back to me. That person has to enter either my call sign or my repeater's call sign (and the / and port letter) in their YOUR call field, so their signal is routed back to me. D-STAR radios have a button or menu function to do this quickly.

• Other hams on the repeaters at either end can hear all the traffic, but they can't join in unless they also enter the correct call sign in

their YOUR call field.

•Repeaters can't be linked for all-toall conversations, where everyone talks to everyone without configuring their own radios.

• Multiple repeaters can't be linked together. Any conversation has to be between two repeaters.

• DPLUS. DPLUS added the linking and conferencing capability that hams wanted in D-STAR. It's a utility program created by Robin Cutshaw, AA4RC, that runs on the gateway computer. Once the link is set up,

But, Is It Ham Radio?

We don't have any "all ham radio" system that can let us communicate worldwide with ease using VHF/UHF equipment. We can do that by using the Internet. Does that mean we shouldn't do it? Should we deny ourselves the fun of talking to hams in Hawaii and Australia while walking down a North Carolina street with a handheld transceiver?

Do be aware that in a disaster area, the Internet may not be available. So don't depend on it for EOC communication. It will be nice to have a few hundred miles of RF linking on D-STAR, but today that doesn't exist.

D-STAR's 1200 MHz "Ethernet" can be especially valuable in a disaster area. Tactical voice communication is good, but what most emergency management really wants these days is to keep their Internet and e-mail working. The low speed data and D-RATS on VHF and UHF will get things started, and it can hop radio to radio on simplex until it reaches a working Internet connection. The 1200 MHz 'ID1 can do the same at 128 kbps, especially if you can get the antennas up high.

nobody has to do anything special to their radio to communicate. Even stations that are not registered will pass through the network.

I command my local repeater to set up a link to another repeater or to a multirepeater "reflector" by putting call signs in my YOUR call field, with an extra character. For example, to set up a link from here in Raleigh to the Atlanta W4DOC UHF machine, I put W4DOC BL in my YOUR call field. I key up for a half second. If the Atlanta repeater is available and not already linked somewhere, a link is established and my repeater announces "remote system linked." Now I'll hear any traffic on the W4DOC machine, and they'll hear any traffic on the KR4RDU machine here. I set my YOUR call field back to CQCQCQ because I only have to issue the link command once. Note that the port letter - "B" for the W4DOC UHF machine moved to the seventh position in the field. The letter "L" in the eighth position tells DPLUS to create the link.

Reflectors don't have call signs, but Robin emulated them by giving reflectors six character designations: REF001, REF002 and on up. Each reflector has three "ports" — A, B and C — to make them similar to the repeater sites. A recent update has added extra ports to some reflectors for nonrepeater use. The three reflector ports are really separate reflectors sharing one Internet connection in a big data center somewhere. There are over 40 reflectors as I write this.

To connect my repeater to Reflector 1C, I put REF001CL in the YOUR call field and key up once (see Figure 6). Now all traffic on my local repeater appears on all the other repeaters on the reflector, and we hear all their traffic. To disconnect, I put a U in the eighth position of YOUR call and key up. Most D-STAR administrators allow registered users to control *DPLUS*.

By the way, *DPLUS* is the reason you need to keep the RPT2 field filled with the repeater's

call sign and the G. *DPLUS* runs on the gateway, and that G routes your signal to the gateway where *DPLUS* can hear it. No gateway, no network.

Data and More Data

There's more to D-STAR than flapping your yap. Non-voice data comes in two flavors: low speed data that's included in every voice transmission, and (relatively) high speed data available on the ICOM ID-1 1200 MHz radio.

Low speed data. Each D-STAR voice signal is sending 4800 bits of data per second. 2400 bits are used for voice. 1200 bits are used for forward error correction that's applied to the voice signal (that's a lot of FEC, but it's needed to keep you intelligible when your signal gets weak and what would be noisy on FM). Most of the remaining 1200 bits are available for you to use as ASCII data — anything you want to do with it --- through a serial port on the radio. A few programs have been written to format the ASCII into something more useful. The most popular is D-RATS. Dan Smith, KK7DS, wrote D-RATS as a messaging program, but he's expanded it to handle all kinds of traffic. It can populate forms, and put you on a map. You can send small files and pictures in a few seconds.

■ *GPS*. D-STAR can send location data on its low-speed data channel. ICOM's IC-2820H mobile and IC-80, IC-92 and ID-31 handhelds can display a compass rose with bearing and distance to another station sending GPS data (see Figure 7). The handhelds need a fairly expensive GPS/speaker mic to do this. Note that this isn't APRS. You can't put a D-STAR radio on 144.39 and use the APRS system. But there is a one way bridge between D-STAR and the APRS network via the Internet. A gateway program called *DPRS* takes your GPS information and forwards it to the APRS IS network. The **Find-U** and **aprs. fi** websites will show you on their maps, along



Figure 5 — Robin Cutshaw, AA4RC, speaking at a D-STAR forum at the Dayton Hamvention.[®] Robin reverse engineered the D-STAR protocol, then wrote the *DPLUS* utility program for gateways and was co-creator of the DVDongle and DVAP devices.

with all the other APRS stations in your area.

High(er) speed data. On 1200 MHz, the one radio available — the IC-ID1 (the original D-STAR radio) — has a separate data function with a higher bandwidth of 128 kbps. It's not cable or DSL, but it's faster than dial-up, and way faster than the zero bps available when disaster knocks out the lines. It appears as an Ethernet port on the back of the 'ID1



Figure 6 — The YOUR call field is set up to initiate a link to Reflector 1C. This reflector has become a popular worldwide repeater, with hams checking in from everywhere. Everyone speaks English on REF 1C. Other reflectors are used regionally with local languages.



Figure 7 — This display shows that the station I'm listening to is 12.5 miles north-northeast of my location, and it gives me their coordinates. It updates in real time as long as the signal is still transmitting.

radio, and can talk to a computer through a browser window. At the repeater site, a data module (not really a repeater) can pipe the Internet out to the users. So you can drive around with an 'ID1 and a laptop, and use the Internet mobile. You won't be downloading *YouTube* videos, but websites that aren't too graphics intensive work fine.

Other Ways to Do D-STAR

ICOM is currently the only company making off the shelf radios, but there are some other ways to do D-STAR. Robin Cutshaw, AA4RC, the ham who developed *DPLUS*, also collaborated on two devices for using D-STAR without a local repeater.

The first is the DVDongle (see Figure 8). It's a little slab of plastic that plugs into your computer via USB. It contains the vocoder chip, and it lets you use your computer's audio system to communicate through D-STAR repeaters and reflectors directly via the Internet. I reviewed it in the February 2009 issue of *QST*.⁴

Next is the DVAP Dongle, or DV Access Point. It looks like the DVDongle, but instead of a vocoder, it has a little 2 meter transceiver with a 10 mW transmitter and an antenna. You need a computer with Internet and a D-STAR radio (usually a handheld) to use

it, and like the DVDongle, it lets you connect to D-STAR repeaters and reflectors. Note that it does not convert an FM signal to D-STAR. Both devices are available from ham retailers. The websites for info are www.dvdongle.com and www.dyapdongle.com.

You won't get far on 10 mW. You can create a bigger pool of coverage by connecting an analog FM radio that has a 9600 bps packet port to a device called the D-STAR HotSpot. This isn't quite the finished product that the DVAP and DVDongle are, but you can find kits or finished boards, software and firmware on the Internet (Google "D-STAR HotSpot"). Though it uses an FM radio as the RF deck, it also does not convert FM to D-STAR.

But there is a device that does make an FM radio work on D-STAR — the DV Adapter (Google "D-STAR DV Adapter"). It's an outboard box that has the buttons and display you need to program all the functionality this article describes for ICOM radios. It might be a little kludgey in a mobile, but would work well in the shack. I'm being vague on the HotSpot and DVAdapter because they're not really polished commercial products yet, and I've never used them. So you'll need to do some research.

The Dongles and HotSpot all reach across the Internet and tap into the *DPLUS* program running on Gateways and Reflectors. Radio users who do not have the gateway in RPT2 will not be able to talk to Dongle users, so that's why everyone now keeps the gateway in RPT2.

In Conclusion

Figure 8 — The DVDongle plugs into your

computer and lets you talk through D-STAR

repeaters and reflectors over the Internet

without using a radio.

D-STAR advantages — high signal-to-noise (and no "noise" until the signal is just about gone), narrow RF footprint, designed for networking, including call sign routing to find hams anywhere, voice+data on the same signal, features such as call sign squelch. devices like the DVDongle, DVAP and Hot Spot to extend the network beyond local repeaters.

Disadvantages — single source for radios, some complexity and learning curve, repeater

availability/coverage limited (but growing), no RF networking (yet), small user base (so far), equipment cost (20 to 50% more than analog).

A few years ago, if someone asked me if they should get D-STAR equipment I'd

tell them to consider it only if they were willing to risk being out there on the edge and

having that edge break off from under them. That's not the case anymore. While it would be nice to have a second or third source of radios, ICOM has proven its commitment to D-STAR by developing new models and incorporating D-STAR into new radios including the adapter available for their IC-9100.

There are enough repeaters running that I don't think the mode is going away any time soon. D-STAR could use more participation just about everywhere, but the reflectors, dongles, DVAPS and such ensure you that you'll be able to play with your D-STAR equipment as much as you want, every day. D-RATS will give you something to experiment with. If you're in the market for a new radio, and a new experience, consider D-STAR.



Figure 9 — The AMBE 2020 Vocoder in this IC-91AD handheld does the analog to digital encoding and decoding. It is the only proprietary component of the D-STAR system.

This Just In

Yaesu's Dennis Motschenbacher, K7BV, told me at the Orlando HamCation that Yaesu will introduce their own digital voice mobiles, handhelds and repeaters at the Dayton Hamvention.[®] He would not reveal what digital protocol the radios would be other than *not D-STAR*. (See the interview at **www.HamRadioNow.TV**, Episode 2.)

The good news — a second line confirms digital voice's place in Amateur Radio's future. The bad news — a different protocol, whatever it might be, might dilute the pool of D-STAR users that has become strong worldwide, but remains thin locally for many repeaters. This was going to happen sooner or later. D-STAR is over 10 years old. That's an infant in the hardware-intensive world of Amateur Radio, but an antique in the fast moving world of digital communication.

Notes

- ¹The ARRL Repeater Directory, 2011-2012 Edition. Available from your ARRL dealer or the ARRL Bookstore, ARRL in either desktop-sized edition, order no. 0861, or pocket-sized edition, order no. 1769. Telephone 860-594-0355, or toll-free in the US 888-277-5289; www.arrl.org/shop/; pubsales@arrl.org.
- ²S. Ford, WB8IMY, "Low Tones in High Places," QST, Jul 2007, p 52.
- ³G. Pearce, KN4AQ, "Operating D-STAR," QST, Sep 2007, pp 30-33.
 ⁴G. Pearce, KN4AQ, "Product Review — DV
- ⁴G. Pearce, KN4AQ, "Product Review DV Dongle D-STAR Adapter," QST, Feb 2009, pp 47-49.

Photos by the author.

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