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Author: Gary Pearce, KN4AQ

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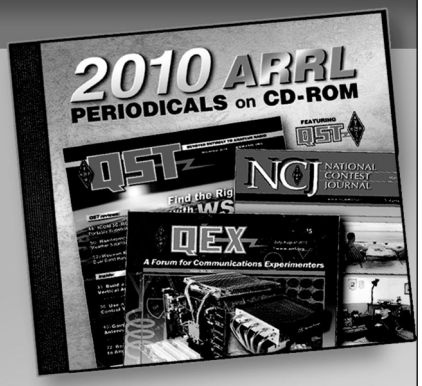

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Operating D-STAR

You've seen the ads, now find out how it works and what it does.

Gary Pearce, KN4AQ

ALL PHOTOS BY THE AUTHOR

Figure 1 — A complete system, an ICOM D-STAR repeater and controller, along with the ID-800 mobile and IC-91AD handheld, getting ready for operation on the K4ITL repeater system in Raleigh, North Carolina.

You've probably heard or read about D-STAR, the system for VHF/UHF digital voice and data being promoted by ICOM. At the very least you've seen the ads. But very few hams have actually used a D-STAR radio through a D-STAR repeater system. Since this could be the leading edge of "the future of Amateur Radio," you might be curious what that future sounds like and how it works.

Digital Telephony is Here to Stay

Out there in real life (that is, outside of Amateur Radio), the transition from analog to digital communications is happening all around us, though each industry has its own pace.

From the everyday user's perspective, cell phones are way out front. Try to buy an analog cell phone today — you're going to have to look hard. The cell phone industry had to embrace digital quickly, even though it had a huge analog infrastructure. Digital let cell systems more than quadruple the number of calls they could handle in a given amount of time and spectrum, two elements in very limited supply.

Digital *landline* telephony may seem in its infancy, but behind the scenes the good old phone company has been digital for years. The copper wire carrying your analog voice probably doesn't go more than a mile or two before the signal is converted to digital for transport to anywhere on the globe. Sykpe, Vonage and other VoIP phone systems are just the new kids on the block.

Digital audio and video on the Internet are booming. Just ask your kids. This is new stuff, with no old analog infrastructure to push out of the way, though it seems as if my computer is prodding me to install an update to one of the many media programs every few days.

Digital Voice over Radio

Broadcast television is teetering on the edge of its digital revolution. Almost every TV station now has a digital transmitter going, and most have at least some high-definition programming. In February 2009, just after the Super Bowl, all US analog TV transmitters get turned off for good. Public safety and business radio users sit poised to jump on the spectrum that will then open up in the 700 MHz band.

Broadcast radio, both AM and FM, are in their digital infancy. It's a troubled birth. I wouldn't blame you if you didn't know there *is* a digital AM and FM, even though there are more than a few stations broadcasting that way now and there have been a few fairly recent *QST* articles on the topic.[1,2] Digital AM yields "FM quality" sound, and digital FM is "CD quality." Some of the stations call themselves "High Definition Radio." They don't have the same pressure their TV siblings do, since digital radio is done "on-channel" along with the analog signal. It uses no extra spectrum, and there's no deadline looming for switching off the analog signals. Broadcast satellite radio is breathing down their necks, though, and they've been digital from the start (Sirius and XM Radio are the two satellite radio broadcasters in the US).

Business and public-safety two-way radio are slowly making the transition. They are required to reduce their channel space over the next few years, but they can do that with either analog or digital modes.

And then there's ham radio, where digital voice is still just a novelty. Hams are happily using voice modes that were developed in the first half of the previous century — AM, FM, SSB — and the equipment we use today is still compatible with the earliest products developed for those modes more than 50 years ago. For hams, the transition to digital is going to be bumpy, for many reasons. We have to spend our own money to upgrade and, except for the change from spark to CW, we've never been told we have to. SSTV, RTTY, packet, PACTOR and the other TORs, PSK and the newer, narrow text/data modes are niche modes that are fairly inexpensive add-ons to your existing HF and VHF radios. Even so, they have a relatively small (but enthusiastic) number of users. With few exceptions, digital voice is still an expensive and rare HF add-on.[3]

Enter D-STAR

Digital voice for VHF-UHF, such as with D-STAR, requires whole new, and fairly expensive radios. There have to be some big advantages to get us to go there. Will the D-STAR digital voice system provide the advantages that will spur a VHF/UHF version of the switch we saw from AM to SSB on HF in the '50s and '60s? It might. It offers clearer signals with less bandwidth than analog FM, and a more elegant and targeted form of networking than *IRLP* or *EchoLink* (amateur voice over the Internet with radio links) do today.

My first experience with D-STAR came in Huntsville, Alabama last October at a D-STAR training seminar. Here several D-STAR pioneers gave talks to help the next wave of early adopters understand how this system works. These seminars are intended for repeater owners and the most dedicated users. You can get really deep into this stuff. It reminds me of both the enthusiasm and complexity that packet network sysops experienced in the mid '90s. Everyday users, you and I, won't need to get this deep into it. At the most basic level, we'll be able to operate digital voice through repeaters almost as easily as we use analog repeaters today — you'll need to enter your call sign in a menu in your radio before you use any repeaters. After that, just key up and talk. To go beyond that, to talk to a ham on a networked repeater in a distant town, the D-STAR system makes you poke and prod inside your radio's menus a bit to enter more call signs

[1]Notes appear on page 33.

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(your local repeater, the distant repeater, or the ham you want to talk to) and set options. If you are a ham who finds programming your radio for CTCSS (continuous tone coded squelch system) so you can use a tone access repeater too big a challenge, I'm afraid you might be left in the digital dust. At least for now.

But fear not — this change will happen slowly. That analog-only handheld you got for Christmas will have a place for a long, long time.

D-STAR Needs Repeaters, Too

D-STAR repeaters are special. Because of the narrower D-STAR bandwidth and special requirement to allow decoding of the modulating signals, D-STAR repeaters don't work between analog radios, nor can analog repeaters handle D-STAR signals.

Repeater coverage is reported to be just a little better with D-STAR than we're used to, thanks to the narrower bandwidth. I've heard numbers ranging from 10 to 25% better, although the same hams who make those reports also say that you might be able to copy a *very* weak, very noisy analog signal below the level that a D-STAR signal just disappears.

There are a few other things missing from your familiar repeater experience, at least with the current crop of repeater equipment and controllers being sold by ICOM. No squelch tails. No hang-time — just a quick burst of data from the repeater that you can see on your S-meter when you let go of your push-to-talk (PTT) switch. No courtesy beeps (though there is a beep of sorts generated by *your* radio that you hear at the end of a transmission sometimes). No autopatch. ICOM's controller has no provision for Morse tone (MCW) or voice identification announcements or other canned messages.

You hear a user's voice, or you hear nothing. You can *see* something, however. Whenever you receive a signal, you see the transmitting station's call sign on your radio display. You might also see a short text message, such as "Hello from Gary." And S-meters still work. When someone else is talking you can see how strong the repeater is, even if your ears aren't giving you any of the usual clues.

Otherwise, routine operation on a local repeater is, well, routine. You push-to-talk and release-to-listen. One exception — you have to program your call sign into the radio before you can talk through a repeater. You do that with the front-panel buttons and menus. Or you can do all the programming with a computer using optional software and an interface cable. (Everybody I've talked to recommends getting the software and cable.)

In theory, you don't ever have to speak your call sign. It's been sent as part of the data stream and appears on listeners' displays. In practice, D-STAR hams speak their call signs just as they do on analog FM, at least so far. (Maybe it's best not to lose that habit, if you also operate on analog repeaters.) You also have to have the repeater's call sign programmed in your radio, but that can be done automatically. Just make an initial transmission through to a repeater (that won't be repeated), and the repeater will send a bit of data with its call sign, which your receiver will pick up and store.

D-STAR Digital Voice — an Improvement?

What does D-STAR digital voice sound like? If you have a cell phone, you've probably heard lots of digital voice audio. My cell phone is one of the increasingly rare models that will do both digital and analog. When I'm in very rural areas (such as the middle of Death Valley, as I was recently when my phone surprised the heck out of me by ringing), I get only an analog signal, and I find the background noise and picket-fencing to be unusual, even though I'm used to hearing all that on ham repeaters. In digital mode, the cell phone audio is usually perfectly clear. When the signal gets *very* weak, the voice I'm listening to begins to garble a little. Syllables or whole words just disappear, but there is no noise. It's actually kind of irritating, because intelligibility begins to suffer before you know what's happening. You miss words, but you don't know you've missed them. With a noisy analog signal you know when you're losing pieces of a transmission.

Most of the time the digital signal is preferable to a noisy analog signal. On D-STAR, it's the same. No noise. No picket-fencing. Above the minimum signal threshold, the voices you hear are crystal clear. They do have a digitized quality to them. I've heard it referred to as "metallic," or "robotic." This is a result of the vocoder (voice encoder) that the hams in the Japan Amateur Radio League (JARL), who developed the D-STAR protocols, chose to incorporate.

The vocoder is the software that digitizes your voice and compresses the data into a skinny serial stream that doesn't use much bandwidth. It's not as pleasant and full-bodied as some of the better analog FM signals we hear today. You don't hear as much of the unique timbre and qualities that distinguish one voice from another. People don't sound exactly alike, but they're not quite the individuals they are with a good analog signal. And frankly it's not something I'd be happy hearing over the long term, although hams have been happy enough with 2.1 kHz wide SSB, which

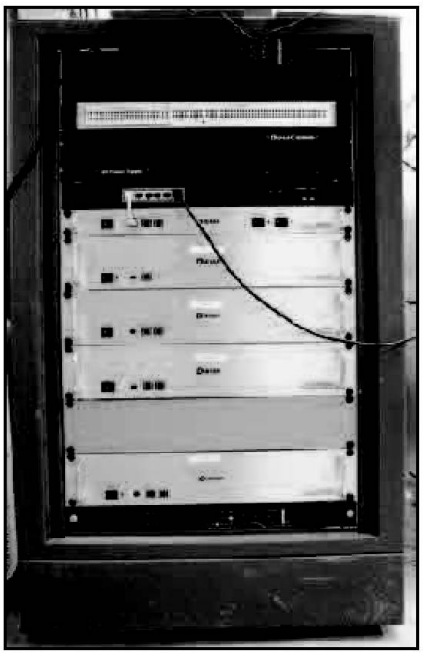

Figure 2 — The full stack of D-STAR equipment at the test bench of Jim McClellan, N5MIJ. From top to bottom, an IP-RP2C controller, an ID-RP2D 1.2 GHz data repeater, an ID-RP2V 1.2 GHz voice repeater, an ID-RP4000 440 MHz voice and data repeater, a blank panel and an ID-RP2000 146 MHz voice and data repeater.

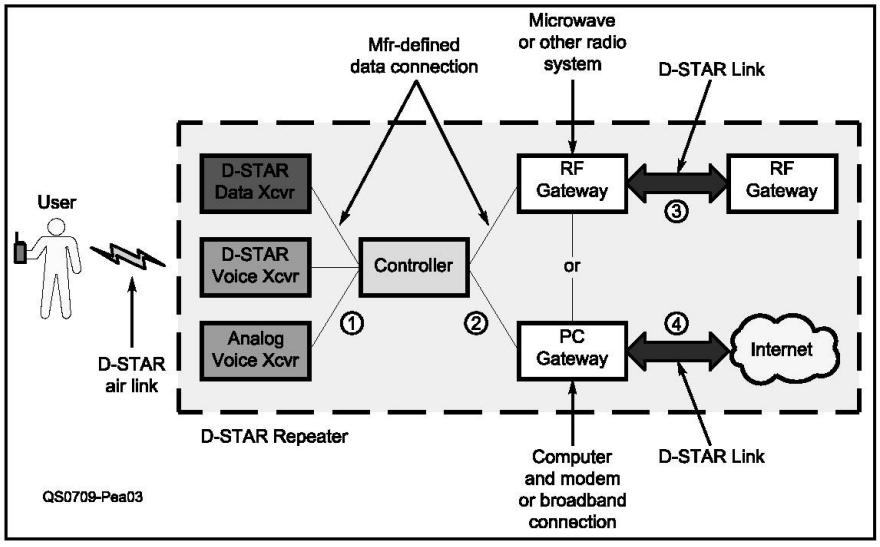

Figure 3 — Internal and external connections of a D-STAR repeater stack as in Figure 2.

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destroys a voice's personality as much or more than D-STAR does. I look forward to a day when we can stuff some fairly hi-fi audio on a narrow digital signal. It's much more pleasant to listen to on a long rag-chew.

When D-STAR signals are weak you hear more garble, for a longer period of time, than you do on a cell phone. Cell phone systems suppress the weak, garbled signal. D-STAR doesn't. So if the signal you're listening to sits at the threshold for a long time, you hear something that sounds like speech with a bunch of random musical tones thrown in. You can pick a word out here and there, but you can't really understand anything. Just a little change in signal strength, though, and you're back to 100% again — or down to nothing.

D-STAR Does Data

D-STAR also includes data capability that starts with packet-like text and expands to moderate-speed Web browsing.[4] Basic connectivity starts with 2 meter and 70 cm transceivers and their repeaters that can feed combined voice and data at a respectable 9.6 kbps into network controllers. Transceivers at 23 cm work into separate repeater types dedicated to either voice or data at 128 kbps — perfect for data concentration nodes or heavy data hub connectivity. A full stack of D-STAR equipment at N5MIJ is shown in Figure 2.

The power of D-STAR data connectivity, and its usefulness as an emergency communication data backbone, is shown in Figure 3. Here we see the repeater interconnections expanding into potentially worldwide networks that can interoperate with other systems through internetworking.

Networking is Power

Networking is where D-STAR gets more complex and really adds value. D-STAR repeaters can operate as stand-alone systems. Or they can be interconnected into networks using either other D-STAR RF links or by plugging into the Internet. The connection to a network is called a gateway. A repeater with a gateway gives users instant access to other networked D-STAR repeaters. Here's where it gets cool, if a little complicated.

To communicate through a network to another station or group of stations, you program call signs into your radio. If you want to reach a specific individual on any repeater on the network your local machine is connected to, you program his or her call sign. If you want to talk to anyone and everyone on a specific repeater on that network, you program that repeater's call sign. If you want to talk to everyone on a *group* of repeaters or on the whole network — you can't. At least not yet. It seems the Japanese D-STAR developers did not plan for multiple repeater linking, in which everyone talks to everyone over a group of linked repeaters, so they didn't design that into the system. It'll come. (At this time, there is only one "network" of D-STAR repeaters, and each repeater owner with a gateway has joined that one network. There can, and probably will someday, be multiple networks. With the current gateway software, a repeater owner would have to make a choice — the repeater can't join more than one network.)

The ability to target an individual ham by call sign might be the most interesting feature of D-STAR. Once you've been "registered" on a gateway repeater (by talking to the sysop and to have your call sign plugged into the repeater database) your call is propagated to every other D-STAR repeater on that network. They all know *who* you are, and they all know *where* you are. That is, they know what repeater you keyed up last. So when you travel, say from your home in San Francisco to Washington, DC, you make a transmission on a D-STAR repeater when you arrive, and that repeater tells the network you are now on a specific repeater in Washington. A friend back in California may not even know you've left town, but when he plugs your call sign into his radio and calls you, his audio is routed to the Washington repeater and out your speaker. You reply. (There is some delay, up to 24 hours, in getting your position propagated across the network. But if you call back to your local repeater right away, that repeater updates your location immediately. System gurus are working on speeding up the general call sign propagation.)

The audio your friend hears is exactly the same as if you were still local. In fact, nothing tells him that you are on a distant repeater. No repeater calls, no beeps, clicks, crackles or sputters. Unless he looks at his display. Then he can see that there are a couple of repeaters involved in the QSO.

Figure 4 — Part of the extensive menu system on the IC-91AD handheld. It takes a minute to get used to what YOUR call sign and MY call sign mean. To talk to anyone, you program CQCQCQ in the YOUR field. If you wanted to talk to a specific station, you'd program that station's call sign in the YOUR field. If you want to use specific linked repeaters, you use the RPT1 and RPT2 fields. This is one radio you can't operate without some quality time in the manual.

You, though, need to do something on your end before you reply. You need to program your friend's call sign into your radio, so the network can route your signal back to him. You can set your radio to do this automatically when it receives a call directed to you.

This scenario does point to a combined technical and human consideration with D-STAR. If your friend does not know you are out of town, how likely is it that he's programmed your call sign into his radio? That depends. If you guys operate D-STAR mostly like a conventional repeater, where you just listen for any voice calls on the local machine, then it's not likely he'll program your call sign into his radio to make this call. It is a little cumbersome to program call signs into the proper menus. It is *not* something you want to do while driving. And he's expecting you to be listening, so he just calls.

If you're deeper into the D-STAR capabilities, though, he might expect you to be using something like "call sign squelch." With that, you can set your radio to be quiet unless someone calls you with *your* call programmed into *their* radio. It's like your own personal CTCSS code, only more obvious because it's your call sign, not just a tone frequency. And if your radio is on but you're not immediately available, it can send an automatic reply in data or voice to say you got the call. If you and your friends are D-STAR power users, you'll be ready for anything and you'll work the system like pros.

The Bells and Whistles

D-STAR is full of features like that, each more or less complex. Will hams take advantage of them? So far, most hams have shown little interest in much beyond push-to-talk. Figures 4 and 5 provide a view into programming features into an IC-91AD handheld transceiver.

Well, D-STAR call sign squelch is a more elegant next level compared to analog paging. You want to call me? You don't have to remember that I'm *256 and you're *847. You just plug in KN4AQ and you're done. Hams who have been using D-STAR for a while quickly realized that they could use the radio's extensive memory system to program common routing and call sign addresses, so they don't have to fumble with the keypad and display as much as they would have had to with analog equipment.

D-STAR's feature set goes well beyond voice and command data. The VHF and UHF radios can be used for 1200 bps text and data *while simultaneously being used for voice.* The 1200 MHz radios can be used for 128 kbps data, fast enough for Internet browsing and file transfer. ICOM's 1200 MHz D-STAR radios have Ethernet ports and appear to your computer as just another network. Hams are busy writing applications to adapt D-STAR to messaging, database,

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APRS and other networking operations.

But How Will D-STAR Fit?

Beyond user operation, D-STAR has introduced some new challenges to the world of VHF and UHF repeaters. The US and other countries with significant V/UHF operation have band plans in place developed for our current analog technology — 15 or 20 kHz channel steps on 2 meters, and 25 kHz channel steps on 70 cm. In all but the most rural areas, the 2 meter band is fully allocated. There's little or no room for additional repeaters. In our bigger metro areas, the 70 cm band is also full. Where do we put new D-STAR repeaters? How do we accommodate this new mode, and take advantage of its more efficient use of spectrum (D-STAR repeaters work fine with 10 kHz channel steps, whereas analog FM repeaters work better with 20 kHz steps). Frequency coordinators and repeater councils are struggling with this question now. There are no easy answers.

The hams who want to run D-STAR repeaters now won't be contained. Some are taking down analog repeaters and replacing them with digital machines, for the time being wasting some spectrum. And some are squeezing into areas of 2 meters where repeater operation is prohibited (144.1-144.5 and 145.5-145.8) based on an exchange of correspondence with the FCC's William Cross, in which he expressed the opinion that if D-STAR is as described — more like a store-and-forward packet system than a voice repeater — it isn't really a repeater and is not subject to repeater rules. This opinion, and the logic behind it, doesn't hold water with many frequency coordinators, but there are some repeaters on the air now in regions of the spectrum generally considered not to be repeater segments.

As D-STAR grows, analog radio users, who will be in the majority for a long time to come, will begin to have problems with digital and analog signals mixed in the same spectrum. A D-STAR transmission heard on an analog receiver sounds like the rush of open squelch. Except you can't just turn up the squelch control and make it go away. Almost every repeater today has several neighbors on the same channel 100 to 200 miles away, and almost every repeater user hears one or more of their co-channel neighbors during band openings. If one of those neighbors goes digital, they will hear, instead of voices, that rush of noise. This won't make analog users happy, and the solution offered — have the analog users turn on CTCSS to block the unwanted signals — has never been popular.

Not the Only Game in Town

While this article is about D-STAR, I should point out that D-STAR isn't the only digital mode on VHF-UHF Amateur Radio. Alinco was actually first to market with a similar type of digital VHF Amateur Radio system but one not compatible with D-STAR.

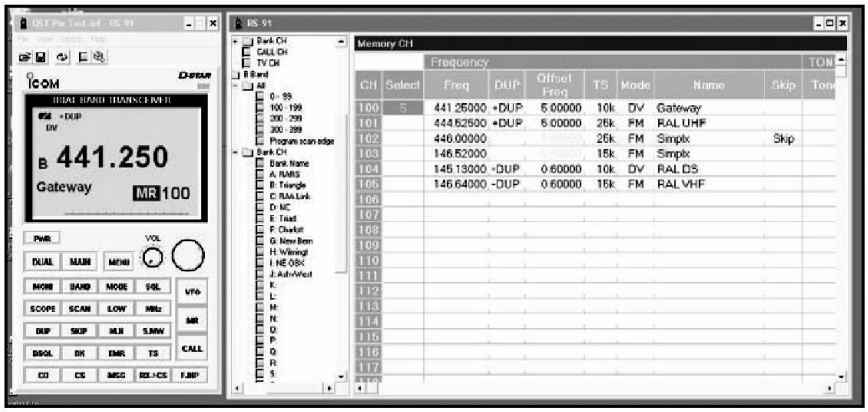

Figure 5 — Screenshot of a small part of the extensive RS-91 programming software for the IC-91AD. Each model radio needs its own software and interface cable, sold as individual options by ICOM.

They offer radios that can be upgraded to digital operation, but have not announced the repeaters and other networking hardware needed to make complete systems, as are available for D-STAR. The AOR digital models that some are using on HF can be used on any type of voice system, including VHF and UHF FM.[5] They offer the option of working with the existing repeater infrastructure.

A few hams have also acquired surplus commercial radios and have built repeaters using the APCO (Association of Public-Safety Communications Officials) P-25 digital standard used by public safety networks (also not compatible with D-STAR). Nobody's making P-25 equipment specifically for the amateur market. To use P-25 you have to convert commercial radios. For the moment, ICOM is the only manufacturer making D-STAR equipment, though it's not proprietary and others are expected to announce D-STAR equipment. All of ICOM's D-STAR equipment is dual-mode and works fine in the analog world. Nothing says that D-STAR will be *the* digital mode for V/UHF Amateur Radio in the future, though ICOM and D-STAR have a head start with a fairly deep line of mobile, handheld and repeater radios and systems already on the air.

Where Will it Lead?

In this article I've just scratched the surface of D-STAR. A deep scratch, perhaps, but there's still a lot more out there. I recommend two Web sites to begin learning more: ICOM America's site (**icomamerica.com/amateur/dstar**), and the Texas Interconnect Team, K5TIT, site (**k5tit.org**). Both sites feature forums from which you can review past discussions and ask your own questions. Beyond that there are many more Web sites and Yahoo forums dedicated to digital ham radio and D-STAR. I've talked to many D-STAR system operators while researching this article, and I'd like to thank them all for their contributions.

My ever-fuzzy crystal ball says that VHF digital does have the operational advantages to slowly gain popularity and eventually overtake — perhaps replace — analog operation. The questions are how fast, and how messy, the process will be. My guess is "not fast" because of the vast analog infrastructure we have now, and pretty messy because of the straitjacket of that infrastructure and the band plans that accommodate it. But it will grow. D-STAR repeaters are popping up around the country (with Alabama taking the lead, thanks to a statewide push to improve ham radio networking there following hurricane Katrina). The question for you today is whether you want to get in on the ground floor, or wait a while to see how it matures. Either option suits the future of ham radio just fine.

Notes

[1]R. Lindquist, N1RL, "FCC News: FCC Adopts Digital Broadcasting Standard," *QST*, Jul 2005, p 70.

[2]S. Ford, WB8IMY, "Digital Broadcasting Has Arrived — the Story of WOR," *QST*, Mar 2003, pp 31-33.

[3]*WinDRM* is an exception — see S. Ford, WB8IMY, "Life Could be a DReaM," *QST*, Apr 2007, pp 38-40.

[4]W. Silver, NØAX, "D-STAR Digital Voice and Data — An Overview," *QST*, Jun 2005, pp 67-69.

[5]J. Hallas, W1ZR, "Product Review — AOR ARD9800 Digital HF Voice Modem," *QST*, Feb 2004, pp 80-81.

Gary Pearce, KN4AQ, has been involved with FM and repeaters since the late 1960s. He is the former editor of the Repeater Journal, *the magazine of the SouthEastern Repeater Association — SERA — and is a former FM columnist for* CQ VHF *magazine. He is currently launching a video production company aimed at producing programs for and about Amateur Radio called ARVN, Amateur Radio//Video News. The ARVN Web site is* **www.ARVidNews.com**. *You can reach Gary at 508 Spencer Crest Ct, Cary, NC 27513 or* **kn4aq@arrl.net**.

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