

Getting Started in Digital Communications - Part 1 - Introduction

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Getting Started in Digital Communications

Part 1—There's been a tremendous surge of interest in digital communications. Find out what's going on—and how you can get involved!

By Steve Ford, WB8IMY
Assistant Technical Editor

I have a friend—whose name and call shall remain anonymous—who refuses to have anything to do with digital communications. I've tried to gently nudge him into packet, but he dismisses my efforts with a smile and says, "Nah. You know I don't like that digital stuff." He'll be an analog man to his dying day and that's fine. (The beauty of Amateur Radio is that it offers something for everyone.) I still can't help but pity him, though. He'll never have the chance to experience the magic of the digital modes!

What are the Digital Modes?

Put this question to most hams and the first word to cross their lips will probably be *packet*. After some further thought they may add AMTOR and RTTY, but how many will remember to include CW?

Yes, you read that last sentence correctly. CW is the granddaddy of digital communications! If you're skeptical, consider the fact that CW meets all the criteria for being classified as a digital mode. The original information is converted to a standardized code (International Morse) for transmission. The CW signal is then decoded at the receiving end and the information is recovered. Like many other digital modes, CW is capable of high-speed communications and makes efficient use of the available spectrum.

Enter the Computer

With the advent of cheap personal computers in the '80s, hams suddenly discovered new ways to manipulate digital information faster and more efficiently than ever before. Old RTTY teleprinters were gradually replaced with monitor screens. Some hams abandoned their straight keys, bugs and paddles in favor of sending consistently perfect CW from their computer keyboards. The flexible processing capability of the personal computer also opened the door to AMTOR (an error-correcting form of RTTY) and packet. We'll discuss packet, RTTY and AMTOR



A modern, fully equipped station for digital communications.

individually in future installments of this series.

The Future Beckons

Even as you read this sentence, new digital modes are on the horizon. Someday the transmission of speech itself will become digitized, virtually eliminating interference and producing clear, high-fidelity audio. You don't believe it? Well, keep your eyes on digital audio broadcasting (DAB). The technology is available *now* and broadcasters are already talking to the FCC about DAB frequency allocations. With the trickle-down nature of technology, it's only a matter of time before digital speech transmissions become an Amateur Radio reality.

Future hams will probably look back on the last two decades of this century as the beginning of the Digital Era. The technological advancements in our time may seem as monumental as the transition from the spark gap to the vacuum tube. Like my dyed-in-the-wool analog friend, not everyone welcomes such radical changes. If

you've read this far, however, you're obviously not afraid to try something new. Let's take a look at the components you'll need to get started in digital communications!

HF Gear

If you favor the HF bands, you'll find that most modern transceivers are very accommodating to digital modes. If you're considering Mode-A ARQ AMTOR (that *chirp-chirp-chirp* sound you hear below the SSB subbands), check the specifications to determine if your rig can switch from transmit to receive very rapidly. (The same is true for amplifiers.) Mode-A AMTOR requires a transmit/receive turnaround time of 20 milliseconds or less. *QST* Product Reviews list these measurements.

If your interest lies in RTTY, you'll need a rig that can tolerate *high-duty-cycle* transmissions for extended periods of time. High duty cycle means that the transmitter is driven to its maximum rated output during the entire transmission. (CW and SSB are

low-duty-cycle modes since they cause the transmitter to produce full output for only brief intervals.) Many modern rigs are rated for high-duty-cycle use, but some must be operated at reduced output. Check the specifications *first* and abide by them.

Older rigs are often less tolerant of high-speed switching and high-duty-cycle transmissions. You may find, for example, that Mode-A AMTOR is impossible on many vintage radios. Most older SSB transmitters and transceivers should be RTTY compatible—although you'll have to be careful not to exceed their specifications for continuous output power! When in doubt, watch your output meter and reduce the maximum reading by 50% or more. If your rig still overheats, consider running less power and/or installing a fan to cool the final amplifier stage.

Received-signal filtering is another item to consider. Once again, most modern transceivers provide adequate filters for digital operation. Even older radios usually include fixed or variable audio filters. It isn't an absolute requirement, but if you're going to be operating in heavy QRM conditions (such as contests), or if you're chasing weak signals, audio filtering is a definite asset!

Finally, there is the issue of frequency stability. For HF digital communications you need a rig that is as stable as possible. This is particularly important for HF packet since most digital interfaces tolerate only a small amount of frequency drift. I've successfully operated HF packet with my 25-year-old Drake tube transceiver, but I have to let it "cook" for about 30 minutes before I begin. Even with a decent warm-up, it still drifts slightly. I have to watch my tuning indicator and make *very* careful VFO adjustments to stay on the correct frequency. RTTY is more forgiving, but a warm-up period is still a good idea.

Here's an easy rule of thumb for selecting an HF transceiver for digital applications: If you intend to operate packet or Mode-A AMTOR, buy a rig that was manufactured within the last five to ten years. If your only interest is RTTY, almost any good-quality radio made within the last 30 years will do the job.

VHF/UHF Radios

On VHF and UHF, packet is the king of digital communications. Since packet transmissions are relatively brief bursts, you generally don't have to be concerned about duty cycles and output-power ratings.

Although FM transceivers are designed to transmit and receive human speech, most models also function as packet radios without complaint. Among those transceivers that balk at the task of transmitting or receiving packet, the main problem involves audio frequency response. They're either incapable of transmitting the full range of audio frequencies that comprise a packet burst, or they have a limited fre-

Get Keyed Up!

TNCs and MCPs use solid-state switching for transmitter control—particularly when operating RTTY, AMTOR, ASCII and packet. (Some MCPs employ an internal relay for CW keying.) Solid-state switching is fast and efficient. It's perfect for modern transceivers, but it can cause problems when applied to older rigs (particularly tube radios).

Marrying today's technology to yesterday's equipment can be a challenge, but it's not impossible. One easy solution is to buy a small 12-V relay and wire it to the TNC or MCP as shown in Fig 1. The relay acts as

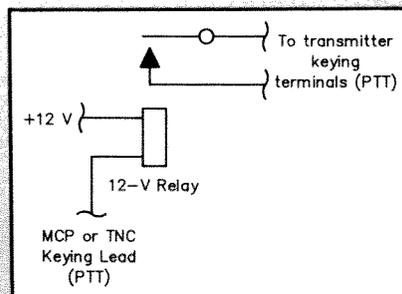


Fig 1—A small relay can be used to key older transceivers.

an isolator between the interface and the rig. The TNC or MCP keys the relay which, in turn, keys the radio. More elegant solutions are possible using solid-state devices. See "Cheap and Easy Control-Signal Level Converters" by James Galm, WB8WTS, in February 1990 *QST*, pages 24-27.

quency response for received signals. If you're unfortunate enough to own one of these rigs, the best approach is to consult the manufacturer for possible modifications to correct the condition.

Providing the proper audio level to the transceiver is also important for packet communications. FM transmitters modulate their signals by shifting, or *deviating*, their output frequency in response to changes in audio amplitude at the input. Perhaps you've heard someone on your local repeater complain that a transmitter is "over-deviating." This is another way of saying that the rig is being overmodulated, causing its frequency to shift beyond the passband of the repeater's receiver. For the sake of clarity, it's easiest to think of deviation in the same terms as audio level or loudness.

For packet communications, you'll want to find a happy medium between having a signal that's too loud or too weak. Over-deviation distorts your signal and causes data loss. Under-deviation is just as bad

because the receiving stations won't be able to hear your packets well enough to decode them. Most packet TNCs and multimode communications processors offer some form of audio-output adjustment. Borrow another receiver and compare the loudness of your packet bursts to others, or have other hams listen and offer their opinions. In most instances these simple tests will be sufficient. If you're concerned about having just the right deviation level, you'll have to find someone who has access to the proper test equipment to measure the exact deviation of your transmitter during packet operation.

The Computer

When the personal computer invasion began, a number of low-end models battled for market dominance. In the early '80s you could find amateur-oriented software and hardware for the Tandy Color Computer, the Atari, the Commodore 64 and several others. The Commodore 64s (and the 128s that followed) finally captured the

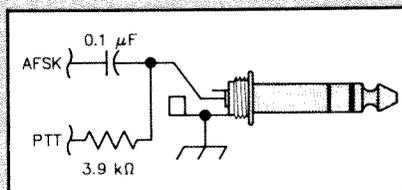


Fig 2—Keying schematic for ICAM hand-helds.

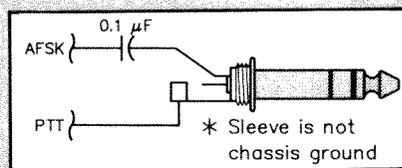


Fig 3—Keying schematic for Kenwood hand-helds. (Chassis ground is provided through the external-speaker jack.)

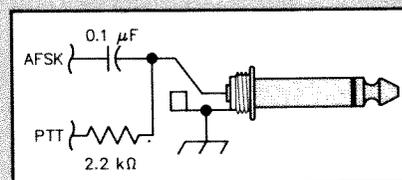
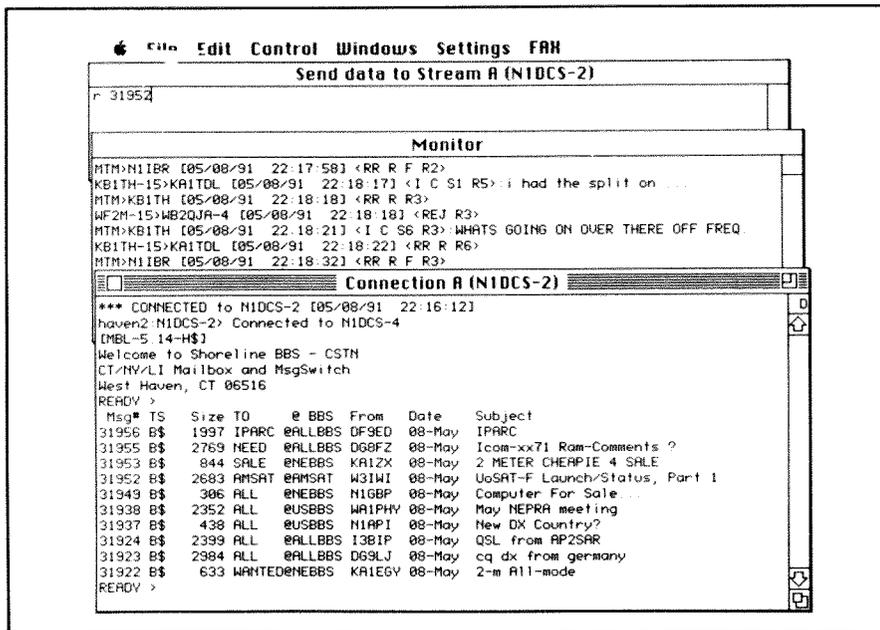


Fig 4—Keying schematic for Yaesu hand-helds



MacRATT is an example of an Amateur Radio digital communications software package written for the Apple Macintosh.

amateur spotlight by the middle of the decade, but IBM PCs and compatibles were gaining ground. Plummeting prices made PCs increasingly attractive to hams who wanted the speed, power and other features they offered.

With all due respect to owners of Apples, Commodores and other computer brands, it's fair to say that PCs have become the de facto standard in Amateur Radio today. This doesn't mean that other models are unusable for digital communications, though. If you have (or can get) a terminal-emulation program for your computer, you're halfway there. The second hurdle involves getting your computer to talk to your TNC or MCP. Most manufacturers of interfaces and communications processors provide information to assist you in wiring your computer to their devices. Until just a few months ago, for example, I did all of my packet operating with a Tandy Color Computer 3. A cheap terminal program allowed me to communicate with my packet TNC through the Color Computer's serial port.

Virtually any personal computer is sufficient to get you off and running. There are a few factors to consider before making your choice, however:

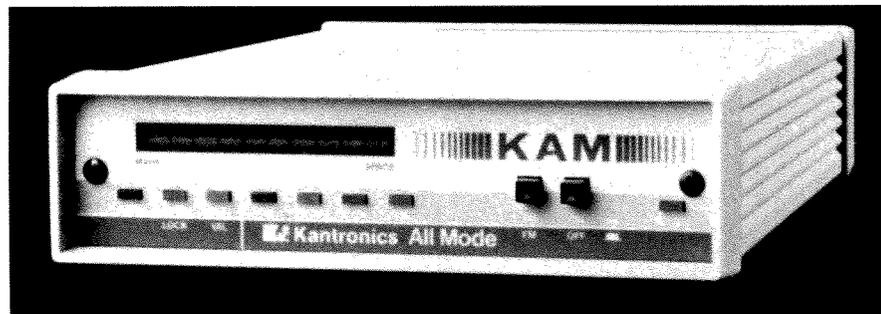
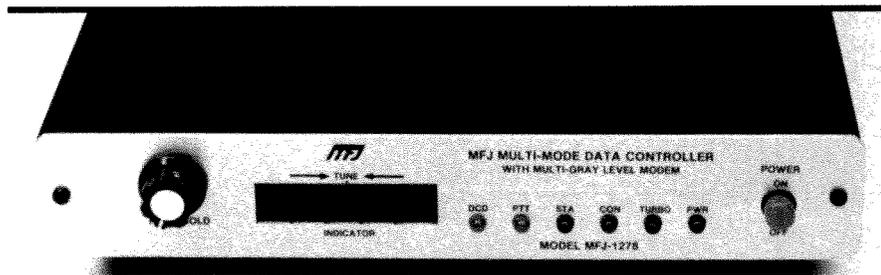
- **I/O (input/output):** Does the computer have a port to allow it to easily communicate with the outside world? Most digital interfaces require a standard RS-232-C *serial* connection to the computer—although some also accept a *TTL* (transistor-transistor logic) connection.

- **Software:** Is there a terminal-emulation program available for the computer? Can the computer run other types of Amateur Radio software?

- **Memory:** How much random-access memory (RAM) is available? Even though you may have located a terminal program and other software, you may be disappointed to find that their performance is limited by a lack of on-board RAM. When it comes to memory, the more the better.

- **Data storage:** Does the computer offer some form of reliable data storage (preferably floppy disks or a hard disk)?

- **Interference:** Does the computer bombard your receiver with RF of its own making? How does it respond to *your* signals? Ask any ham who's active in digital communications and you'll discover that mutual interference can be a major headache! (One of the shortcomings of my Color Computer was its ability to generate annoying signals on just about any band!) Before you surrender your hard-earned cash, ask other hams about their experiences with the model you have in mind. If you've already bought the computer, you may have to acquaint yourself with RF-suppression techniques!¹



If you want several digital modes at your fingertips, multimode communications processors (MCPs) are ideal. Shown from top to bottom are the MFJ-1278, the AEA PK-232MBX and the Kantronics KAM.

¹Notes appear on page 37.

• *Support:* If your computer suddenly becomes demented, is there anyone on the planet who remembers how to fix it? What about the availability of replacement parts and accessories?

The kind of computer that's best for you will ultimately depend on your budget and your goals. If you're a little unsure about digital communications, start small and work your way up. You can buy an older low-end computer and then upgrade to a modern model as you become more experienced. Commodores and Color Computers can be had for peanuts at hamfest flea markets. Even low-end IBM PC compatibles are selling for bargain prices.

If you want to jump in with both feet, consider stretching your funds to purchase the best computer you can afford. Your investment will pay off in convenience, speed and reliability. Chances are good that you'll be doing more than Amateur Radio work with your new machine, so choose a computer that's easy to upgrade as your needs change.

The Analog/Digital Interface

Having an affordable personal computer is one thing. Getting it to work with Amateur Radio equipment is another! Many modern transceivers provide the means for external computer *control* of their functions. This control capability is very convenient, but we need to use the

computer to *communicate!*

It's important to remember that a computer is strictly a digital device. It can only understand the presence or absence of small voltage levels at precise moments in time (data). Strict rules govern its operation and it's very unforgiving when those rules are violated. A transceiver, on the other hand, is analog in nature. It receives and transmits signals of varying amplitudes and frequencies. Its rules are few and it usually forgives all but the most abusive operators. Despite its flexibility, however, you can't feed computer data directly into its microphone, RTTY or CW jacks and expect to transmit a usable signal. By the same token, its analog audio output is totally incomprehensible from a computer's point of view.

So how do we get these two incompatible devices to work together in harmony? We need something to serve as a bridge between the digital and analog worlds—in other words, an *interface*. The interface must accept digital data from the computer and translate it into audio signals (or on/off keying) for the transceiver. The interface must also accept audio from the transceiver and convert it into digital data for the computer. This two-way function is basically an act of *modulating* and *demodulating*. Combine the italicized letters and what do you get? MODEM!

Just as we have modems to connect computers to telephone lines, we also have

modems to connect computers to Amateur Radio equipment. The first Amateur Radio modems were fairly simple devices dedicated to one or two modes (such as RTTY and CW). Packet modems (called Terminal Node Controllers or TNCs) arrived later. They were far more sophisticated with built-in microprocessors, memories and software. Although TNCs functioned as interfaces, they were smart devices—essentially computers themselves.

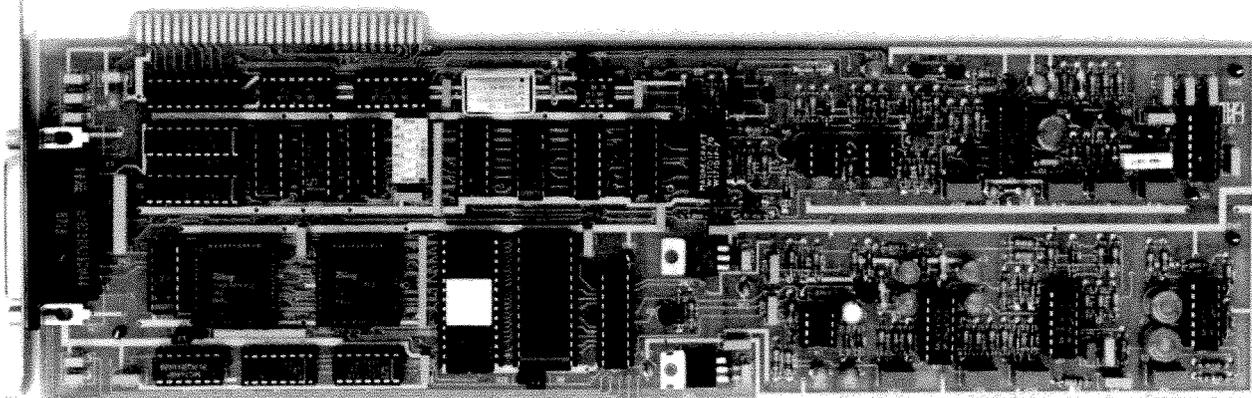
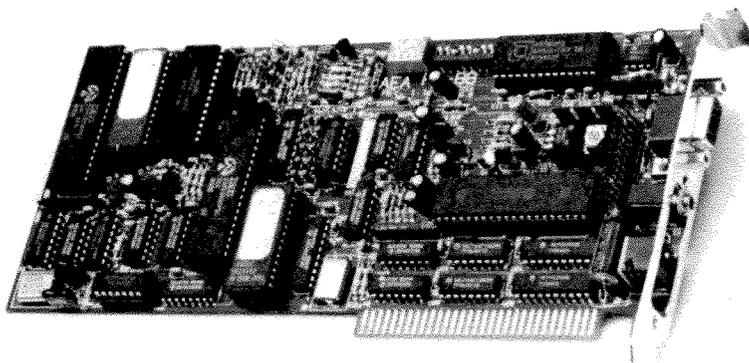
Multimode Communications Processors

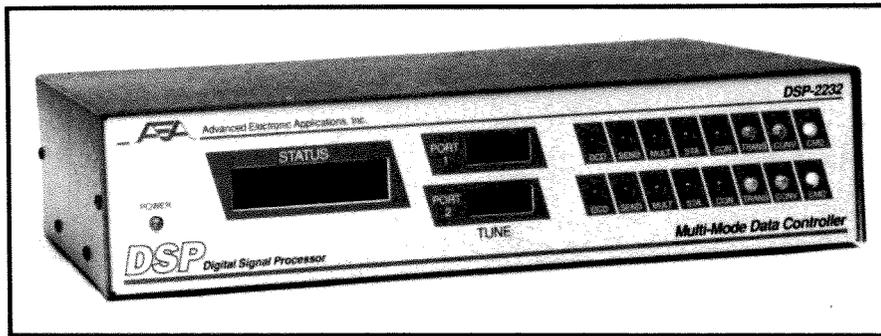
As digital technology evolved, it wasn't long before someone said, "Why should I have to use one interface for packet and another for RTTY? Why can't they all be together in one box?"

Why not, indeed? Not only did manufacturers place packet and RTTY together in the same box, they added several other modes for good measure. The result was the *multimode communications processor* (or MCP)—probably one of the most popular pieces of equipment for the digital ham today.²

Like packet TNCs, MCPs incorporate microprocessor design and internal memory. By issuing a single command from the computer keyboard, you can switch the MCP from packet (HF or VHF), to AMTOR, to RTTY or even CW. Some models also add fax, ASCII, NAVTEX and SSTV to their list of modes.

Packet and RTTY/AMTOR/CW interfaces are also available on plug-in cards for your IBM PC or compatible. The models shown are the AEA PCB-88 (right) and the HAL Communications PCI-3000 (below).





Multimode communications processors with DSP (digital signal processing) are already available. The AEA model DSP-2232 is shown above.

Just about any terminal program can be used to communicate with your MCP. Most standard terminal programs, however, are designed to communicate over telephone lines and may be a bit awkward when used for Amateur Radio applications. If you plan to buy an MCP, consider purchasing terminal software specifically designed with hams in mind. Most MCP manufacturers offer software packages for their own devices, or you can buy third party software. The fourth edition of the *ARRL Operating Manual* offers a list of popular programs for several computers.³

To Multi or Not to Multi?

Few would argue with the claim that MCPs are versatile devices for digital communications. They've brought a smorgasbord of operating modes within the reach of average hams. I've spent many evenings tuning through the bands, switching my MCP from one digital mode to another as the spirit moved me. The sheer convenience of an MCP is highly addictive!

Even with all of the MCPs' advantages, you still need to pause and ask yourself, "Do I really need a full-featured multimode processor?" If you want the freedom to easily explore a variety of digital modes, the answer may be yes. On the other hand, if your interests are more focused (RTTY or packet only), you may be better off with a basic packet TNC or specialized RTTY/AMTOR equipment. As I said before, it all depends on your desires and your budget.

Digital Signal Processing

Now that I've given you the basics on MCPs and other digital communications equipment, it's time to tell you about an exciting new technology that has just arrived. It's called *digital signal processing* or DSP.

Before you throw up your hands in despair and confusion, be assured that today's digital communications equipment is perfectly useful and will remain so for many years to come. You can still buy that new multimode communications processor and enjoy a long, happy relationship.

As the term implies, digital signal

processing involves an entirely digital approach to decoding and encoding signals for various modes. The main advantage of DSP communications processors is their flexibility. Standard MCPs can also achieve a certain amount of flexibility, but they are ultimately limited by their internal hardware.

For example, you can add a new digital mode to a standard MCP by substituting an EPROM that has been programmed with new software. This approach works just fine as long as the hardware components (specialized ICs and other circuitry) can also support the new mode. But what if you want the processor to perform a task that's beyond the capability of its existing hardware?

Consider phase shift keying (PSK). It's the required mode for many packet satellites. None of the standard multimode communications processors on the market today contain the hardware necessary to generate a PSK signal. If you want to operate the Pacsats, you have to purchase a

separate PSK modem to convert the output of your MCP to PSK format.

With a DSP processor, you can add virtually *any* mode to the unit by simply adding new software. Unlike standard communications processors, DSP units use their software to directly encode and decode desired signals without depending on specialized hardware. The finer details are well beyond the scope of this article, but you'll be hearing a lot more about DSP in the months and years to come.

A few DSP multimode communications processors are already available. Buying a DSP unit will require a substantial cash investment, but this is normal for emerging technology. If you were around when packet TNCs made their debut, you'll remember how expensive they were at the time! DSP is more than just another clever product feature; Digital signal processing has the potential to revolutionize Amateur Radio communications.⁴

Next Month

Next month, we'll start talking about specific digital communication modes. The best place to begin is with the mode that has captured the interest of more amateurs than any other: packet!

Notes

- ¹*Radio Frequency Interference: How to Find It and Fix It*, is a valuable new reference available from the ARRL. See the ARRL Publications Catalog elsewhere in this issue for ordering information.
- ²Multimode communications processors are also commonly known as *multimode controllers*.
- ³The fourth edition of *The ARRL Operating Manual* provides a sampler of terminal-emulation software for a variety of computers. See page 10-2.
- ⁴B. Hale, "An Introduction to Digital Signal Processing," *QST*, Jul 1991, pp 35-37. □

Getting Started in Digital Communications - Part 2 - Packet

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Getting Started in Digital Communications

Part 2—Fire up your computer and get connected to one of the fastest growing modes in Amateur Radio—packet!

By Steve Ford, WB8IMY
Assistant Technical Editor

When I was living in Quincy, Illinois in 1986, I attended a meeting of the Western Illinois Amateur Radio Club and witnessed a live demonstration of packet radio. At first I was unimpressed. It was interesting to watch the operators exchange error-free text over a distance of several miles, but what else was packet good for?

After the demonstration was over, one of the packeteers stood at the podium and began to describe this mysterious mode in detail. I soon discovered that there was much more to packet than just sending messages across town. The sheer potential of this strange mode seemed almost limitless! I rushed home after the meeting and telephoned a ham friend back in my hometown. "You won't believe what I just heard!" I blurted. "It's this thing called packet radio..."

I've been a rabid packeteer ever since.

So What is Packet?

Without going knee-deep into technical jargon, packet is simply a form of computer networking that uses radio links rather than wires. CompuServe, Prodigy, GENIE and other large database systems are good examples of hard-wired computer networks. These systems communicate with their subscribers by sending information in small bundles of data, or *packets*. If a packet is received without error, an acknowledgment (an *ACK*) is sent to the originating computer and the next packet is transmitted. If an error occurs, the receiving computer rejects the packet and waits for a repeat. The data-exchange protocol used in many such systems is known as *X.25*.

Packet *radio* has been technologically possible for many years (commercial experiments were taking place in the 60s), but it took the invention of the personal computer to bring it within the grasp of the average ham. In the early 80s, amateur packet pioneers appropriated the *X.25* protocol and quickly adapted it for Amateur Radio use. The result was called *AX.25—Amateur X.25!* The computers still sent their information in packet bundles, but



The author's multimode communications processor (MCP), VHF-FM transceiver and power supply. Note the cable connecting the transceiver's microphone jack to the MCP.

now the network was *wireless*—connected by radio through smart interfacing devices known as terminal node controllers, or *TNCs*.

Over the past decade, packet has enjoyed a rate of growth that can only be described as explosive. As the cost of computers, TNCs and MCPs (multimode communications processors)¹ has declined, the number of packet-active hams has grown. Packet systems have also expanded, offering new features to their users.

What's In It for Me?

Before you dive head-first into unknown waters, it's reasonable to ask whether you have anything to gain by doing so! I prefer to think of packet as an *augmenting* mode. In other words, packet seems to function best when it's used to expand your enjoyment of Amateur Radio as a whole.

By connecting to your local packet bulletin board system (PBBS), for example, you can read bulletins from other amateurs concerning a wide range of topics. Perhaps you'll find something you can apply to your own situation. I built an HF-packet tuning indicator for my first TNC after reading a bulletin sent by a Canadian ham. His message described how to assemble a

simple tuning indicator for the Kantronics KPC-2 and he even included a rough schematic diagram. I tried his idea and it worked beautifully—all thanks to packet radio!

What if you need a rare tube for a transceiver you just bought at a flea market? Send a packet bulletin and ask if anyone knows where to find it! Have you discovered a strange problem with your antenna rotator? Maybe someone on the network knows the solution!

You'll also find propagation forecasts, Keplerian elements (for satellite tracking), special-event announcements and many other informative messages. The worldwide packet network also distributes bulletins containing personal commentaries on issues that affect Amateur Radio. Some of these editorials are quite controversial. Even if you don't agree with everything you read, at least they have a certain amount of entertainment value!

Do you have ham friends in another state or country? If they're packet-active, you can exchange mail through the network. I regularly swap mail with hams throughout the world and despite the fact that I'm using an *amateur* network, its reliability often rivals commercial systems. (I can usually send a packet message from Connecticut to my hometown of Dayton, Ohio, in under 12 hours. That sure beats regular

¹Notes appear on page 49.

US Mail!) You can also use packet to send messages to non-hams via the ARRL National Traffic System.

Are you a DXer? If so, try connecting to a DX PacketCluster! PacketClusters are regional networks devoted to DX hunting and contesting. By connecting to the cluster you can determine which stations are on the air and where they are operating. The cluster also provides a wealth of other useful information (more about that later).

Some packet networks offer specialized services such as weather nodes (get the latest conditions for your area), on-line call-sign directories and even magazine bibliographies that allow you to search for long-lost articles. Of course, not every network in the country has all of the latest packet innovations. As activity expands, however, many of these new features should begin to appear in your area.

Are Real-Time QSOs Possible on Packet?

Certainly! Live keyboard-to-keyboard chats are common on both VHF and HF packet. I've enjoyed a number of VHF QSOs and have managed to work a fair amount of packet DX on HF. There are some basic rules of etiquette to observe, though (see the sidebar, "Packet Etiquette").

Some networks and bulletin boards also support *conferencing*, where many amateurs can connect and exchange messages simultaneously. A well-attended conference is like a cocktail party on the air. Be forewarned! The comments may fly across your screen at a furious pace! Most TNCs and MCPs also support *stream switching* which

allows you to carry on several QSOs at once. Juggling multiple QSOs can be challenging, but it's fun, too.

Connecting Your Equipment

Most modern TNCs and MCPs provide a 25-pin *serial* port as the connection point for your computer. If your computer also offers a 25-pin serial port, you're on easy street! Just purchase a serial cable with matching DB25 connectors (male or female on either end, as required). Short, shielded cables help reduce the possibility of mutual interference between your computer, interface and radio.² If your computer or interface demands different plugs and wiring, you may have to construct a custom cable. Get out your soldering iron and consult your manuals.

Connections between TNCs/MCPs and radios vary from one manufacturer to another. Some models offer separate ports—one for your VHF FM transceiver and another for your HF SSB transceiver. Other models offer only one port, requiring you to purchase an external switchbox to select between your VHF and HF rigs. (Of course, you can also simply switch the cables by hand—the "armstrong" method!)

Most TNCs and MCPs include cable assemblies to link the units to your transceiver, but *you* have to supply the proper microphone plug for your rig. Be sure to read the instructions and wire the plug accordingly. If your transceiver is more than 10 years old (or if you are using a hand-held rig), the solid-state switching circuitry in the TNC or MCP may not be compatible. See the sidebar, "Get Keyed Up!" in

Part 1 of this series.

Don't forget that you also have to supply received audio to your interface. The external speaker jack of your transceiver is the most likely source. If your rig does not have an external speaker jack, you'll need to tap the audio at the speaker itself—possibly with a switch or a Y connector—and feed it to your TNC or MCP.

If you're operating VHF packet, it usually isn't necessary to hear the received audio. Your interface or computer software indicates when packet signals are being received. When operating HF packet, however, I've found it helpful to listen to the signal as I'm receiving it. Many TNCs and MCPs offer accurate tuning indicators, but using your own ears never hurts! By listening to the signal you may also hear fading and interference—something your tuning indicator may not tell you.

VHF Packet Operation

After all the wiring and soldering, you're probably more than eager to operate. Good! Turn on your rig and your TNC/MCP. Start your computer and load your terminal software.

If you're using software supplied by the manufacturer of your TNC or MCP, the data communications parameters (data rate, parity, stop bits and so on) may be preset to match the product. If not, or if you're using a different terminal program, you'll have to set the data communications parameters yourself. You'll know the settings are wrong if you see nothing but gibberish on the screen. The TNC/MCP is

Packet Etiquette

If Miss Manners ever gets her ham license, I'm sure she'll have quite a bit to say about packet etiquette. Minding your packet manners is more than a matter of decent behavior. . .

- If someone is using the local bulletin board, it's rude to start a QSO on the same frequency. (The reverse is also true.) You'll only be creating unnecessary interference and reducing network efficiency for everyone.

- If you have mail waiting at a PBBS, pick it up promptly and use the KM command to erase the message from the system after you've read it.

- Using more than two VHF nodes or digipeaters to connect to a bulletin board will render you persona non grata as far as your fellow hams are concerned. This practice is sometimes called *node hopping* and it can turn an otherwise efficient network into a morass. If you have a PBBS that you can reach through one or two nodes, you'll gain little by connecting to more distant systems. All regional bulletin boards receive essentially the same messages. In addition, conducting real-time QSOs through several nodes will have a similar effect on the network—and your reputation!

- Don't download large files (10 kbytes or greater) from a PBBS during prime-time hours (6 to 10 pm). Try to download the file when the frequency isn't as active.

- Avoid abusing your *beacon* function. A beacon is used to transmit station identifications, or to call CQ. If you have a personal packet mailbox built into your TNC or MCP, it's appropriate to identify its availability with a beacon transmission once every 30 minutes.

- When carrying on a live packet QSO (HF or VHF), many operators use *K* or *>>* to indicate when it's time for

the other station to reply. This is the packet equivalent of saying, "over." Don't begin sending your comments until you're sure the other station has finished. As you type, hit your **ENTER** or **RETURN** key well before you reach the end of an 80-character line.

- On HF, respect the informal agreements that exist between AMTOR, RTTY and packet operators. As you tune through the subbands, you'll notice that all three modes tend to congregate between certain frequencies. It's considered extremely rude, for example, to start a packet QSO in the middle of the AMTOR segment of the band.

- On HF, avoid frequencies used by automatic mail-forwarding systems. In addition to interfering with their communications, you might also be slowing the flow of your own mail!

- Unless you have a Special Temporary Authority (STA) issued by the FCC, it is *illegal* to operate an unattended packet mailbox or node on the HF bands.

- If you feel strongly about an issue, feel free to send a packet bulletin expressing your opinions. When you compose your message, however, keep it as short as possible and leave out slander, threats, rumor-mongering and such. *Think* before you reach for the keyboard. You'll have a much greater impact if you state your case clearly and intelligently. The use of proper grammar and spelling helps, too!

- If you must send a long bulletin or message, break it up into several separate messages. Label each message as "Part 1 of 4" or whatever. Shorter messages travel faster through the system and cause less congestion for others.—WB8IMY

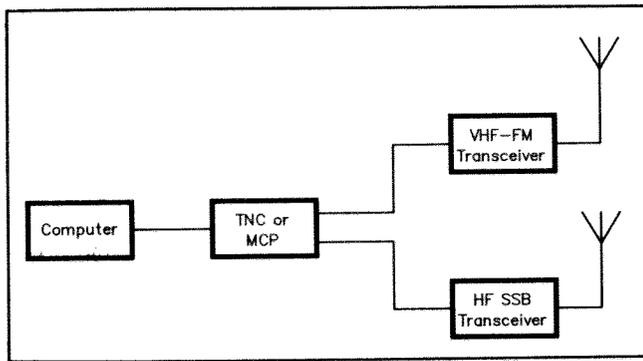


Fig 1—A typical packet station with HF and VHF capability.

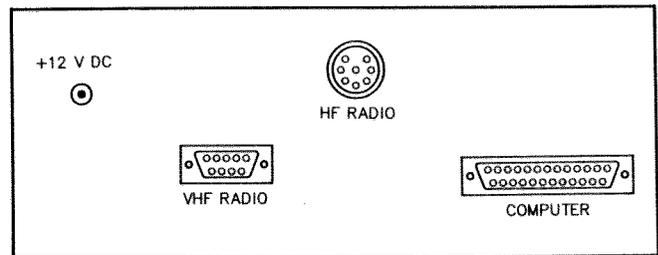


Fig 2—A full-featured TNC or MCP provides at least three ports on the rear panel: One for your computer, a second for your HF rig and a third for your VHF transceiver. The types of connectors used vary from one manufacturer to another.

trying to talk to your computer, but the information is getting lost in translation!

Read your software instructions as well as the TNC/MCP manual. Some TNCs and MCPs are shipped with preset (or switch-set) parameters and all you'll need to do is configure your terminal software to match them. Others use a technique known as *autobaud*. This means that the TNC or MCP sends a test message repeatedly at various speeds when it is activated for the first time. When you see the message appear in plain English, the TNC/MCP is communicating at your computer's speed setting. An autobaud routine looks something like this:

```
zxcvdfn23asvzmnxcvenfv9a09fv/ktmn34tnza4
PRESS (*) TO SET BAUD RATE
qqqqeoprwpowerowpoeirp2eoaca.,cmw-
pdo wojgpqwojrg
```

The trick is to *quickly* press the proper key the moment you see English text. Once you've pressed the key, you'll probably see a sign-on message followed by the *command* prompt:

cmd:

This means that the TNC or MCP is communicating with your computer and is awaiting your commands.

The first thing to do is enter your call sign. (Throughout this article, the symbol <CR> represents the **ENTER** or **RETURN** key on your computer.) We'll do this with the MYCALL command.³ For example:

cmd: MYCALL WB8IMY <CR>

MYCALL is just one of literally *dozens* of TNC/MCP parameters you can modify to match your operating conditions. With the exception of MYCALL and a few others, most of the parameters are preset at the factory (called *defaults*). This does not mean you have to leave them that way, however. For example, if your transceiver requires a longer interval between the time it is keyed and the time the packet signal is sent, you can lengthen the TXDELAY setting. I found this to be the case when I used my TNC with an older FM transceiver. I had difficulty connecting to other stations until I performed some tests and discovered that my TNC was keying the rig

and applying the packet audio too quickly. A slight adjustment of my TXDELAY solved the problem.

Before changing a parameter, it's always best to consult your manual. Some parameters are relatively harmless (such as BTEXT and CTEXT) and can be altered at will. Other parameters are very important and can cause a great deal of frustration if you tamper with them. Keep notes of whatever changes you make—the old settings and the new. You'll probably discover that the factory defaults are adequate to get you started. Once you have more experience with your system, you can begin tailoring your TNC or MCP to your particular operating habits.

Let's MONITOR!

The best way to get acquainted with packet is to *monitor* local VHF activity on various frequencies. See Table 1 for a list of common frequencies, or check the latest edition of the *ARRL Repeater Directory*.⁴ Make sure your TNC or MCP is in the

monitor mode by using the following command:

cmd: MON ON <CR>

This commands your TNC or MCP to begin monitoring for packet data. If you're satisfied with the data-rate setting between the interface and your computer (the higher the better), this may be a good time to use the PERM command. PERM is an *immediate* command. This means that the TNC or MCP takes an immediate, specific action when you use it. In the case of the PERM command, it immediately stores *all* current parameter settings in its permanent memory. When you turn on the TNC/MCP again, you won't need to reenter the data rate and other settings (including your call sign).

cmd:PERM <CR>

That's all there is to it. You can still make changes later and PERM them, too. Use PERM carefully and sparingly. If you have the MONITOR mode *OFF* when you

Table 1 Popular Packet Frequencies VHF

6 meters

Look for activity from 50.62 through 51.78 MHz. 51.70 MHz is the 6-meter packet calling frequency.

2 meters

This is the most popular VHF packet band. You'll find activity at 144.91, 144.93, 144.95, 144.97, 144.99, 145.01, 145.03, 145.05, 145.07 and 145.09 MHz. Packet can also be found between 145.50 and 145.80 MHz.

222 MHz and up

Packet can be found on the 222, 420, 902 and 1240-MHz bands, but bulletin boards and live QSOs are somewhat sporadic. Most of the activity on the higher bands is in the form of *backbone* networks that pass packet traffic between bulletin boards and nodes. Avoid these backbones; they're not intended for individual user access.

HF

The hotbeds of HF packet activity are centered around the following frequencies:

```
3606, 3630, 3642 kHz
7093, 7097 kHz
10145 kHz
14101-14105 kHz
21099-21105 kHz
28099-28105 kHz
```

do a PERM, for example, your TNC or MCP will be as deaf as a doornail when you turn it on again. (It stored OFF as the normal, permanent MONITOR setting.) You'll have to activate the MONITOR mode manually and use PERM once again to ensure that the unit *boots up* with its ears open!

Before we're ready to monitor, we need to make a couple of adjustments to your transceiver. Follow the guidelines in your TNC/MCP manual. You'll probably find the optimum volume setting occurs when the knob is in the 9- or 10-o'clock position. With the audio output at the proper level, close your squelch—but not too tightly. If you apply too much squelch, you'll block some of the weaker packet signals.

Now sit back, relax and watch the screen. (I trust you're doing this during the early evening hours—prime time for packet activity.) If you don't see anything within five or ten minutes, you've either picked the wrong frequency, or everyone else is at the club meeting! For the moment, let's assume that you've picked an active frequency. Chances are you'll see a flurry of confusing messages. Maybe some of the lines will look like this:

```
KY1T-2 > ID
```

```
TheNet 1.0 (MERDN)
```

```
KY1T-4 > MAIL,KB1CQ-8,KY1T-2*,KF1ET  
Mail for: WD6EHR N1FIL KB2HND
```

What the heck is this stuff? Well, the first two lines represent a *node* sending an automatic identification. (We'll discuss nodes in more detail a little later.) The call sign of the node is KY1T-2 and it's telling you that it's using version 1.0 of a software system called *TheNet*.

MERDN is the *alias* of the node. No, the operator isn't a fugitive from the FCC! An alias is a convenient packet feature that provides an alternative means of identifying a station. Many aliases are abbreviations of towns or Amateur Radio clubs. When attempting to establish a connection to a node, your TNC or MCP will accept the full call sign *or* the alias. This is especially helpful when your memory is a little fuzzy. If you can't remember the call sign, you might recall the alias.

And why does the node have a -2 after its call sign? The -2 is known as a *Secondary Station Identifier* or *SSID*. If the same call sign is applied to more than one packet station (such as a node and bulletin board), the SSID keeps them separate. The node and bulletin board may be at the same location, or different locations.

As you can see, the KY1T-2 node is proudly announcing its existence and letting you know that its alias is MERDN. Can you guess what KY1T-4 is? It certainly looks like it has something to do with packet mail, doesn't it? If you guessed that KY1T-4 is a packet bulletin board system, you're right!

The KY1T-4 PBBS is letting you (and the rest of the network) know that it's available for use and has mail waiting for pick-

up. The second line of its announcement is pretty obvious. The first line, however, needs some explanation.

```
KY1T-4 > MAIL,KB1CQ-8,KY1T-2*,KF1ET
```

The bulletin board KY1T-4 is sending an announcement that it has *MAIL* ready for delivery. It is relaying this announcement through the KB1CQ-8, KY1T-2 and KF1ET nodes. An asterisk appears after KY1T-2 because that is the node that relayed the announcement to your station. Your receiver didn't hear the other nodes in the list, but what would you see on the screen if it did?

```
KY1T-4 > MAIL,KB1CQ-8*,KY1T-2,KF1ET  
Mail for: WD6EHR N1FIL KB2HND
```

```
KY1T-4 > MAIL,KB1CQ-8,KY1T-2*,KF1ET  
Mail for: WD6EHR N1FIL KB2HND
```

```
KY1T-4 > MAIL,K12CQ-8,KY1T-2,KF1ET*  
Mail for: WD6EHR N1FIL KB2HND
```

What a mess! Your TNC copied the announcement as it was relayed through KB1CQ-8, KF1ET *and* KY1T-2. This repeating text phenomenon is one of the most confusing sights for a packet newcomer. Whenever you see the same text repeated over and over, you're witnessing one of three things:

- Multiple node relays (as shown above)
- Retransmissions (due to data errors)
- Multiple *distribution* transmissions from a conference system or DX PacketCluster.

It may be of some comfort to know that when you finally make a connection you'll only see packets that are intended for you. Even if your station receives several transmissions of the same packet, you'll only see the one that finally makes it through unscathed. (If you enjoy confusion, your TNC or MCP will be more than happy to accommodate you. If you switch your MCON parameter ON, you'll see everything that is being sent on the frequency—even when you're connected to another station!)

Time to Get Connected

Okay, you're tired of monitoring. You've found a bulletin board and you're itching to give it a try. You can start by issuing a CONNECT command. This instructs your TNC or MCP to send packets to the target station to establish a connection. (We'll assume that you're using my call sign, WB8IMY, for the moment.)

```
cmd: CONNECT KY1T-4 <CR>
```

By the way, you can shorten most packet commands to just a few letters. Rather than typing CONNECT, CONN or even C works just as well.

```
Retry count exceeded  
***DISCONNECTED
```

What happened? It looks like you tried to make a connection to the KY1T-4 bulletin board and failed. The RETRY setting controls the number of times a packet will be sent without an acknowledgment.

Usually it is set to 10. In this case you sent 10 connect requests and didn't get an answer. Your TNC or MCP gave up!

Hmmm... what could be the problem? Maybe KY1T-4 is too far away and can't hear your signal. It looks like you need an intermediate station to act as a relay. That's where the nodes come in!

Those Versatile Nodes

A packet node is similar to a voice repeater. That is, it listens for signals and retransmits them over a wide area. There are a couple of major differences, though.

Voice repeaters listen on one frequency and retransmit *everything* they hear on another frequency, usually in real-time. In addition, only one station at a time can use a voice repeater.

Packet nodes listen and retransmit on the *same* frequency. (There are exceptions, such as nodes that relay to other nodes on UHF *backbone* links and *gateways* to HF frequencies, but that's a topic for another time.) Also, nodes relay only packets that are directed *specifically* to them, and more than one station can access a node simultaneously. Single-frequency operation works by time shifting; node stations receive and briefly store transmissions, then retransmit them to their destinations a few moments later.

In the early days of packet radio, nodes did not exist. The relaying was handled by *digipeaters*, which worked in much the same manner. The problem with digipeaters was that they weren't very intelligent. If you used a couple of digipeaters to connect to another station, all the digital information had to be relayed and acknowledged from one end of the route to the other. Under these conditions, reliable communication was often a matter of luck more than anything else! For example, if the receiving station sent an ACK and a digipeater failed to pass it along (due to interference, perhaps), the originating station would "assume" that the packet had never arrived and would send it again—dumping even more data into the swirling stream!

If packet stations communicated like human beings, a comedy of errors through a digipeater might look something like this:

```
STATION A TO DIGIPEATER: Here's  
packet #1.
```

```
DIGIPEATER TO STATION B: Hey, Sta-  
tion B! I'm relaying packet #1.
```

```
STATION B TO DIGIPEATER: Packet  
#1 looks fine. Here's my ACK.
```

(Interference blocks Station B's ACK transmission to the digipeater. The digipeater couldn't care less and does nothing.)

```
STATION A: I should have received an  
ACK from Station B by now. I guess he  
didn't get packet #1. I'd better send it  
again.
```

```
STATION A TO DIGIPEATER: Here's  
packet #1.
```

```
DIGIPEATER TO STATION B: Heads
```

Table 2
Common PBBS Commands

The following commands are available with version 10.11 of the WØRLI Mailbox public-domain software.

General commands:

B	Log off PBBS.		
Jx	Display call signs of stations recently heard or connected on TNC port x.	RH n	Read message numbered n with full message header displayed.
N x	Enter your name (x) in system (12 characters maximum).	RM	Read all messages addressed to you that you have not read.
NE	Toggle between short and extended command menu.	S x @ y	Send a message to station whose call sign is x at PBBS whose call sign is y.
NH x	Enter the call sign (x) of the PBBS where you normally send and receive mail.	S x	Send message to station whose call sign is x at this PBBS.
NQ x	Enter your location (x).	SB x	Send a bulletin message to x at this PBBS.
NZ n	Enter your ZIP Code (n).	SB x @ y	Send a bulletin message to x at PBBS whose call sign is y.
P x	Display information concerning station whose call sign is x.	SP x @ y	Send a private message to station whose call sign is x at PBBS whose call sign is y.
S	Display PBBS status.	SP x	Send a private message to station whose call sign is x at this PBBS.
T	Ring bell at the SYSOP's DTE for one minute.	SR	Send a message in response to a message you have just read.

Information commands:

? *	Display description of all PBBS commands.	ST x @ y	Send an NTS message to station whose call sign is x at PBBS whose call sign is y.
?	Display summary of all PBBS commands.	ST x	Send an NTS message to station whose call sign is x at this PBBS.
? x	Display summary of command x.		
H *	Display description of all PBBS commands.		
H	Display summary of all PBBS commands.		
H x	Display description of command x.		
I	Display information about PBBS.		
I x	Display information about station whose call sign is x.		
IL	Display list of local users of the PBBS.		
IZ n	List users at ZIP Code n.		
V	Display PBBS software version.		

File transfer commands:

Dx y	From directory named x, download file named y.
U x	Upload file named x.
W	List what directories are available.
Wx	List what files are available in directory named x.
Wx y	List files in directory named x whose file name matches y.

Port commands:

C x y	Via port x, send connect request to station whose call sign is y.
C x	Send data via port x.
CM x y	Send message numbered x to station whose call sign is y.
CM x y @ z	Send message numbered x to station whose call sign is y at PBBS whose call sign is z.
Mx	Monitor port x.

Roundtable commands:

RT	Initiate roundtable function.
<ESC> D x	Allows roundtable control station to disconnect station from roundtable whose call sign is x.
<ESC> H	Obtain assistance.
<ESC> P	Display ports available to roundtable.
<ESC> N x	Enter your name (x).
<ESC> Q x	Enter your location (x).
<ESC> U	Display list of stations in roundtable.

Message commands:

K n	Kill message numbered n.
KM	Kill all messages addressed to you that you have read.
KT n	Kill NTS traffic numbered n.
L	List all messages entered since you last logged on PBBS.
L n	List message numbered n and messages numbered higher than n.
L < x	List messages from station whose call sign is x.
L > x	List messages addressed to station whose call sign is x.
L @ x	List messages addressed for forwarding to PBBS whose call sign is x.
L n1 n2	List messages numbered n1 through n2.
LA n	List the first n messages stored on PBBS.
LB	List all bulletin messages.
LF	List all messages that have been forwarded.
LL n	List the last n messages stored on PBBS.
LM	List all messages addressed to you.
LT	List all NTS traffic.
R n	Read message numbered n.

up! Here's packet #1.

STATION B: What are you talking about? I was expecting packet #2. I already have packet #1!

With enough interference on the frequency, this conversation could drive both operators crazy in short order. Nodes handle the same exchange very differently. Like a digipeater, a node stores the packet and relays it to the target station. If the target station receives it error-free, however, the ACK only has to go back to the node. Let's take a look at a similar digi-

tal conversation using a node instead of a digipeater.

STATION A TO NODE: Here's packet #1.

NODE TO STATION A: I received it error-free. You can consider packet #1 acknowledged.

NODE TO STATION B: Here's packet #1.

STATION B TO NODE: Packet #1 looks fine. Here's my ACK.

(Interference blocks **STATION B's** ACK transmission to the node)

NODE: Hmm... I haven't heard an ACK

from **Station B** in a while. I guess I should retransmit packet #1.

NODE TO STATION B: Here's packet #1.

STATION B TO NODE: I already have packet #1.

NODE TO STATION B: Understood. Packet #2 has just arrived and here it is...

That certainly looks more efficient, doesn't it? All you have to do is get your packets to the node and the node assumes responsibility for relaying them to the next node or station! (Yes, you can use more

than one node to reach another station.)

The advantages of nodes over digipeaters were so obvious that nodes dominated the packet world in short order. You'll still find digipeaters here and there, but they're the exception, not the rule.

We know that KY1T-2 is a node. Why don't we use it to connect to the bulletin board?

```
cmd: CONNECT KY1T-2 <CR>
***CONNECTED to KY1T-2
```

Terrific! We now have a connection to a node. It's time to ask the node to connect to the bulletin board.

```
C KY1T-4 <CR>
```

(Notice that the cmd: prompt has disappeared. This means that your TNC or MCP automatically entered the CONVERSE mode once it established the connection with KY1T-2. Everything you enter is now interpreted as data to be sent, *not* commands for your interface.)

```
KY1T-2>Connected to KY1T-4
```

```
Welcome to Luck's PBBS
CT/MA Mailbox and MsgSwitch
Newington, CT 06111
```

```
Hi Steve! Active - 51, Last msg.# 57589
```

```
Type "?" or "H" for HELP with
COMMANDS
(B,D,DU,H,I,J,K,L,N,R,S,T,U,V,W,
X,Y,?)>
```

Looks like we made it to the KY1T-4 bulletin board with the help of the KY1T-2 node! Since I've checked into this PBBS before, it knows me by name. When you check into a board for the first time, don't be surprised if it requests your name, address and a few other details. This is a normal part of the *registration* process.

Once you've connected to a PBBS, you can use various commands to list messages (L), read messages (R), send mail (SP), send bulletins (SB), send NTS traffic (ST), download files (D) and so on. See Table 2 for a list of the most common PBBS commands. When you're ready to leave the PBBS, a simple *B* or *BYE* will disconnect you from the system.

The DX PacketCluster

As we discussed before, a DX PacketCluster is a network of specialized nodes developed for DX hunting and enhanced multiplier spotting during contests. Even if you only work DX occasionally, PacketClusters can be tremendous assets.

PacketCluster nodes permit many stations to connect simultaneously. Perhaps you've just found the frequency for the KC8PE node. Make a connection and watch what happens...

```
cmd: CONNECT KC8PE <CR>
***CONNECTED to KC8PE
```

```
Hi Steve!
Welcome to YCCC PacketCluster node -
Cheshire CT Cluster: 22 nodes, 9 local /
144 total users. Max users 367
```

```
WB8IMY de KC8PE 5-Dec-1991 0124Z
Type H or ? for help >
```

The cluster is waiting for your command. What would you like to see first? How about a list of the latest DX sightings (called *spots*)? Enter: **SHOW/DX <CR>**

```
7015.5 UL7MG 5-Dec-1991 0119Z <W3XU>
14029.3 UD6DF 5-Dec-1991 0106Z <K2LE>
14211.9 J68AJ 5-Dec-1991 0056Z <NE3F>
14002.6 4S7WP 5-Dec-1991 0054Z <K2LE>
14007.0 ZA1ED 5-Dec-1991 0048Z <K2LE>
WB8IMY de KC8PE 5-Dec 0124Z >
```

Now we have a list of the five most recent DX spots along with their frequencies and the times (in UTC) when they were heard. While you're tuning through the bands you may discover another DX station worthy of a spot on the cluster. Go ahead and make a contribution by posting it on the network. The simplest command format would be:

```
DX SV3AQR 21.250 <CR>
```

The PacketCluster will accept your information and will distribute it to all the other stations connected to the network. Thanks to your spot, anyone who needs Greece for their DXCC award will converge on 21.250 MHz! Don't worry about how long you are connected to the cluster. Unlike packet bulletin boards, you can remain connected to the cluster for *hours* while you search the bands for DX. (Just remember to disconnect when you're through!)

You can also use the PacketCluster to find the QSL manager for a DX station, determine the sunrise and sunset times for a particular location, post messages, read messages and many other useful features.⁵ If you're a VHF/UHF enthusiast, DX clusters are also excellent for tracking band openings. DX PacketClusters have become extremely popular and are spreading throughout the country. If there isn't one in your area, you may not have long to wait!

HF Packet

HF packet has many similarities to VHF packet. Bulletin boards are common and you can use them in much the same manner. (Many do not support mail forwarding, however.) Real-time QSOs are very popular and you will undoubtedly find many of these taking place.

You may also encounter seemingly endless streams of messages flowing back and forth between stations. This is automatic HF mail forwarding, one of the primary mechanisms for transferring packet mail over great distances. These are often unattended stations (usually part of larger VHF/UHF packet systems) that send mail to each other on a frequent basis. FCC rules forbid unattended third-party-traffic relaying on the HF bands, but these stations have been granted an STA—Special Temporary Authority—to perform their functions. Perhaps the FCC will make this type of operation a permanent part of

Amateur Radio in the near future.

Working HF packet takes a bit of skill and practice. Tuning is very critical and the margin for error is quite narrow. Watch for transmissions from bulletin boards or individual stations. Once you're on the correct frequency, you can issue a connect request just as you would on VHF.

```
cmd: CONNECT EA4GJT
```

If band conditions are favorable, you'll connect to EA4GJT and begin your QSO. HF packet transmissions, unfortunately, are easy targets for noise and other interference. It only takes a small amount of interference or fading to cause a data error. This means that both stations may have to send and resend their packets several times before they arrive in one piece. At 300 baud, this can become a frustrating experience! With enough patience, however, an HF packet exchange can be very enjoyable. Be sure to consult your TNC or MCP manuals for the proper settings for HF packet operation.

The Tip of the Iceberg

Although we've covered a lot of ground in this article, we've only nicked the tip of the packet iceberg. There is much more you can learn about bulletin boards, nodes, HF packet and new network systems such as ROSE, TCP/IP and TEXNET. I highly recommend that you pick up one or both of the following:

The ARRL Operating Manual, fourth edition. Available from your local dealer or direct from ARRL HQ. See the ARRL Publications Catalog elsewhere in this issue for ordering information.

Your Gateway to Packet Radio, by Stan Horzepa, W1LOU, second edition. Also available from your dealer or the ARRL.

Next Month

In Part 3 of our series, Bill Henry, K9GWT, will explore the fascinating mode of *radioteletype*, better known as RTTY!

Notes

¹Multimode communications processors are also commonly known as *multimode controllers*.

²If you find yourself grappling with an interference problem, consult *Radio Frequency Interference: How to Find it and Fix It*. It's available from your local dealer or direct from ARRL HQ. See the ARRL Publications Catalog elsewhere in this issue for ordering information.

³Some software systems may interact differently with your TNC or MCP. In this article, I illustrate *standard* software commands and prompts.

⁴The *ARRL Repeater Directory* is available from your local dealer or direct from ARRL HQ. See the ARRL Publications Catalog elsewhere in this issue for ordering information.

⁵A complete listing of PacketCluster commands appears in the fourth edition of the *ARRL Operating Manual*, page 10-22. 

Getting Started in Digital Communications - Part 3 - RTTY

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Part 1 (Introduction) appears in *QST* March 1992, pp. 33-37 (<http://www.arrl.org/tis/info/pdf/39233.pdf>)

Part 2 (Packet) appears in *QST* April 1992, pp. 44-49 (<http://www.arrl.org/tis/info/pdf/49244.pdf>)

Part 3 (RTTY) appears in *QST* May 1992, pp. 41-47 (<http://www.arrl.org/tis/info/pdf/59241.pdf>)

Part 4 (AMTOR) appears in *QST* June 1992, pp. 34-45 (<http://www.arrl.org/tis/info/pdf/69234.pdf>)

Getting Started in Digital Communications

Part 3—It's relaxing, informal and friendly. Its signals are music to the ears of those who've grown to love it. What are we talking about? RTTY, of course!

By Bill Henry, K9GWT
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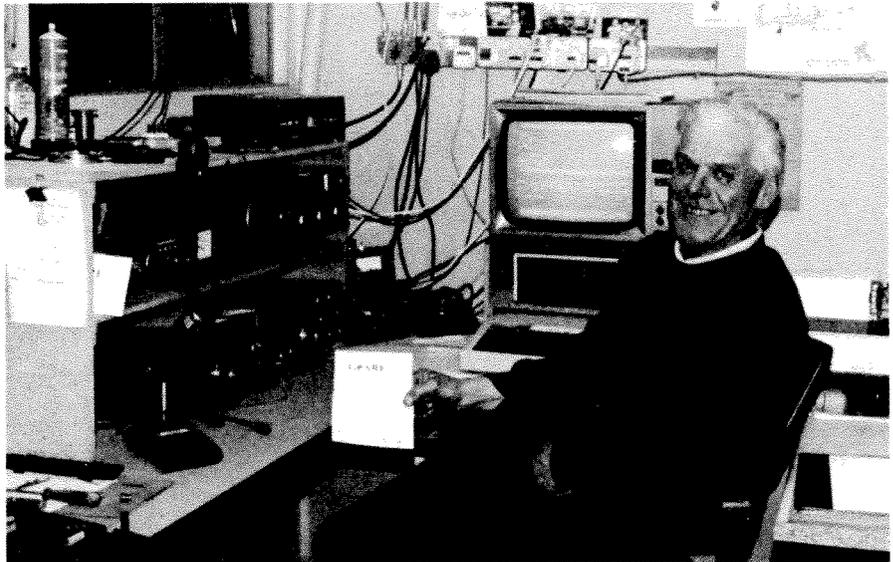
The beginnings of radioteletype (RTTY) date back to World War II when the military began connecting mechanical teletype machines to HF radios. At first they attempted to use simple on/off keying as a means of sending text, but the results were poor. After some further experimentation, the designers soon switched to *frequency shift keying (FSK)*. This scheme did the trick and RTTY was born!

RTTY is one of the most popular digital-communication modes on the amateur HF bands. Its error-correcting cousin, AMTOR, is steadily gaining ground, but RTTY has a special advantage: almost *any* SSB transceiver—no matter how old—can be used for RTTY. With a data terminal or computer and an RTTY modem or multi-mode communications processor (MCP),¹ you'll be up and running in no time. RTTY QSOs are loose and friendly, not the "weather here is..." variety. Opportunities for DX abound, too!

A Bit of Shifty Theory

The basics of RTTY reception are relatively simple. To decode the information, it's only necessary to detect the pulse state of the incoming signal. In RTTY jargon, we say *mark* for the *on* pulse and *space* for the *off* pulse. The difference between the mark and space frequencies is the *shift* of the FSK modulation. The shift almost all RTTY enthusiasts use today is 170 Hz.²

To decode RTTY signals, the tones must be converted back into logic levels—a "1" pulse for mark and a "0" pulse for space. This is accomplished by setting the receiver to the correct sideband (usually lower sideband) and tuning slowly until the tones correspond to the center frequencies of two audio filters in the RTTY demodulator. The output from each filter is then detected



Why is GØARF smiling? He just completed another successful ARRL RTTY Roundup despite gale-force winds and two power outages.

and amplified to produce the required mark and space pulses.

By tuning the receiver, we can produce practically any audio frequency for mark or space. However, the frequency difference between the mark and space tones *always* matches the shift used by the transmitting station. As you might guess, the exact center frequencies of your demodulator filters are not critical as long as their *difference* matches whatever shift is in use at the time.

When it comes to transmitting RTTY, most modern transceivers don't shift their carrier frequencies as a direct response to digital teletype signals. Instead, the teletype data signal shifts the frequency of an audio oscillator (the RTTY modulator). This is known as AFSK—for *audio* FSK. The oscillator generates one tone for mark and another for space.

Can you guess what happens when we apply these tones to an SSB transceiver operating on LSB? The 2125-Hz mark tone produces a signal that is 2125 Hz below the

suppressed carrier frequency. The 2295-Hz space tone creates a signal that is 2295 Hz below the suppressed carrier frequency. Both signals differ by 170 Hz—our RTTY shift! Although it's generated differently than true FSK, AFSK is basically the same. I prefer to call it "indirect FSK."

Fig 1 shows a comparison of "direct" FSK and "indirect" FSK techniques. These diagrams have been simplified for clarity. The carrier oscillator, balanced modulator, and LSB filter are usually at 455 kHz and then mixed with a VFO (and fixed oscillators) to the desired output frequency.

Many modern transceivers include FSK capability. However, a careful study of their schematics sometimes reveals that the so-called FSK mode includes an internal AFSK generator that's applied to the balanced modulator while the transmitter is operated on LSB!

Get Out Your Cables

RTTY theory takes you only so far. The real challenge is getting on the air and

¹Notes appear on page 47.

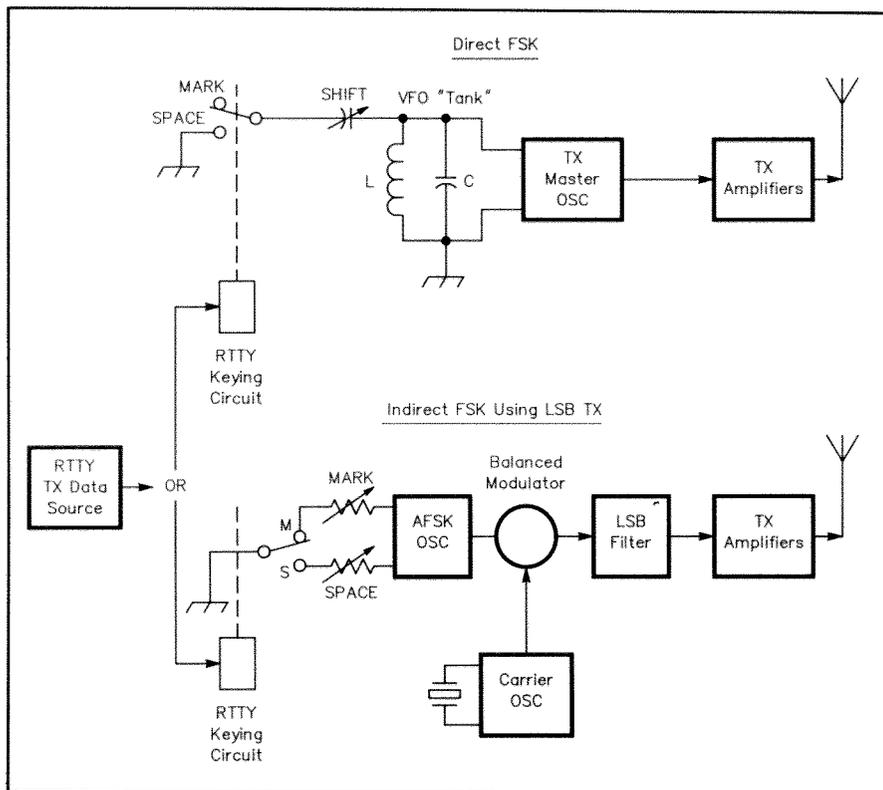


Fig 1—An illustration of *direct* versus *indirect* FSK.

working someone! Before you can do that, you have to assemble your station equipment.

As you begin installing your RTTY components, remember to establish good RF ground connections between each piece of equipment. RFI can be a major headache with solid-state RTTY devices. Computer “birdies” (unwanted signals), for example, can make reception miserable. By the same token, your transmitter can wreak havoc

with your computer. I’ve used ½-inch braid for my ground connections with good results. Many RFI experts now advocate using ½-inch wide copper straps. Regardless of the material you choose, make the ground connection your *first* priority and you’ll never regret it!

Keep all cables as short as possible. A 20-foot audio cable makes a marvelous antenna for RFI. Try to locate all equipment close together and limit all cables to

no more than six feet in length. Inexpensive audio cables will work just fine. However, their shielding leaves much to be desired. A piece of RG-58 with phono connectors has superior shielding. If you have an RFI problem, try improving the grounds and cable shielding first. Contrary to audio grounding techniques, ground the cable shields at *both ends*.

Setting Up for LSB Operation

Using an SSB transceiver in the LSB mode is the easiest way to get on RTTY. In most cases, all you have to do is make a few simple connections, adjust the transmitter and you’re on the air (see Fig 2). Even if your transceiver features an FSK mode (which many RTTY devotees prefer), it’s a good idea to get your feet wet using AFSK first—then switch to FSK as you become more experienced.

To operate in the AFSK mode, follow these steps:

- Set your transceiver to LSB.
- Connect the **TX Audio** leads from your RTTY modem or multimode communications processor to the phone patch or microphone input of your transceiver.
- Connect the modem/MCP push-to-talk (PTT) leads to the transmitter PTT terminals.
- Connect the modem/MCP **RX Audio** leads to the phone patch *output* or external speaker jack. Try to find a rear-panel connection that is *not* disabled when you plug in the headphones. (I often insert a “blank” plug in the headphone jack to quiet the *deedle-deedle* noise.) If your receiver has a 600-ohm line output, by all means use it.

A Handy Attenuator

The commercial standard for audio-frequency signals is a 0-dBm level (about 0.77 volts RMS) and 600 ohms impedance.

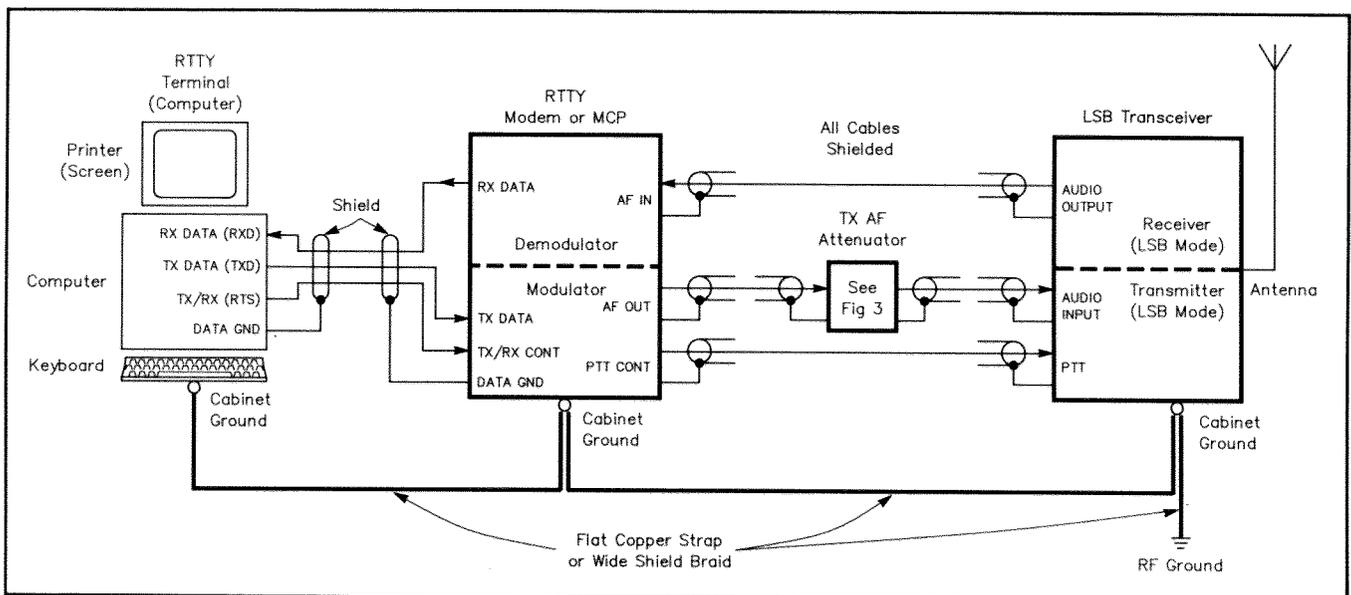


Fig 2—Computer, modem/MCP and transceiver configuration for AFSK RTTY on lower sideband.

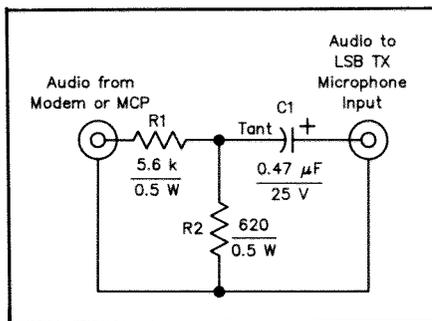


Fig 3—An audio attenuator for AFSK RTTY operating.

RTTY Standards

Here's a quick summary of the basic operating standards that most RTTY enthusiasts follow. You can usually implement these standards through your terminal software.

Tone frequencies: mark = 2125 Hz; space = 2295 Hz; shift = 170 Hz.

Polarity: Normal (mark = 2125 Hz; using AFSK or FSK mode).

Code and Speed: Baudot, 45 baud (60 WPM).

End-Of-Line (EOL) Designator: CR LF LTRS (CR LF for MARS).

Line Length: 72 Characters (69 for MARS).

Transmit Delay: 1-2 seconds (if available).

Terminal Mode: "ASR" (split-screen)

Other parameters can be set as well. In most cases, the default settings of your RTTY modem or multimode communications processor should be adequate.

Although most amateur equipment is designed primarily for voice transmissions, we rarely get 600-ohm, 0-dBm audio input (or receiver output) for RTTY.

Microphone inputs usually require 30 to 70 mV RMS (-20 to -30 dBm) for full RF output. This is 20 to 30 dB below the 0-dBm level. If you look at Fig 2, you'll notice an optional TX AF attenuator between the RTTY modem/MCP and the transceiver. The actual schematic is shown in Fig 3. The attenuator provides a 20-dB signal reduction between the RTTY modem or MCP output and the microphone input. If you experience difficulty matching your RTTY modem or MCP to your rig, this attenuator may provide the cure.

Make sure the attenuator is well-shielded (an aluminum minibox is ideal). Also, run shielded cables to and from the box. Place the attenuator close to the transmitter. Set the modem or MCP output level about 1/3 below its maximum setting and perform

transmitter power adjustments using the rig's mike-gain control. If you experience RFI, try adding 0.001 μF disc-ceramic capacitors between the center pins of the attenuator connectors and ground.

C1 in the attenuator may not be required with some equipment. An increasing number of transmitters place dc on the audio input terminal for powering an electret-capacitor microphone, microphone pre-amplifier or other active devices. C1 blocks dc, but passes the audio signal.

Setting up for FSK Operation

As mentioned earlier, many modern transceivers provide an FSK mode. Most radios with variable selectivity and/or narrow filters (intended primarily for CW) let you use these features in the FSK mode. In contrast, many rigs with such features—but without FSK—*don't* provide these capabilities in SSB modes.

Some amateurs assume that using the

FSK mode creates a *pure* RTTY transmission. This is doubtful. Yes, you can overdrive the transmitter in AFSK and produce an assortment of unwanted signals. When used properly, however, there is *no fundamental difference* between the RF output of either mode.

It's easy to set up for FSK operation (see Fig 4):

- Switch your rig to the FSK mode.
- Connect the your RTTY modem or MCP TX Data leads to the FSK IN or RTTY IN terminals. Use a rear panel connection if one is available.
- Connect the modem/MCP PTT output to your transceiver's PTT terminals. Once again, a rear-panel connection is highly desirable.
- Connect the modem/MCP RX Audio leads to the rig's phone-patch output or speaker terminals. Again, try to use a rear-panel connection that is *not* interrupted when you plug in the headphones.

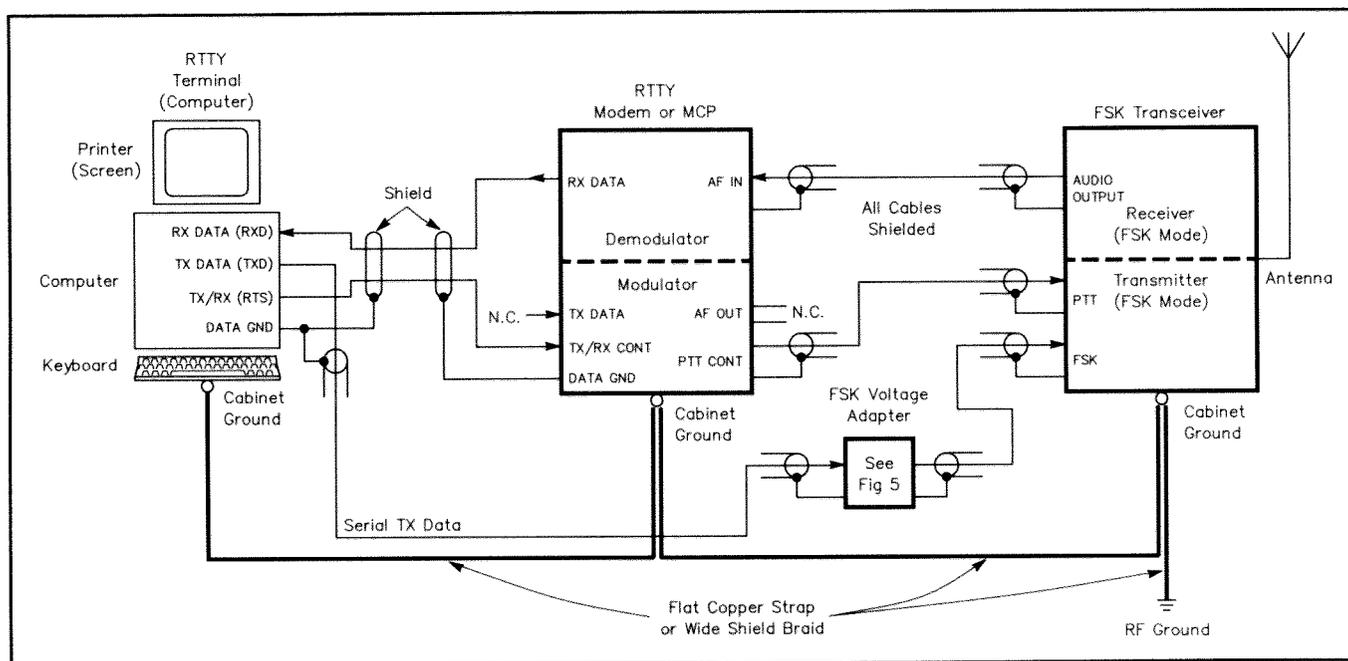


Fig 4—A typical RTTY set up for FSK operation.

The FSK Voltage/Polarity Problem

If wires and cables were all we had to worry about, FSK operating would be a snap! It may surprise you to know, however, that transceiver manufacturers have *not* established standards for FSK input polarities and voltage levels. Each rig has its own requirements, and it can be difficult to get your RTTY modem or MCP to produce the necessary signals.

All is not lost, though. Take a look at the FSK voltage adapters shown in Fig 5. Like our attenuator, these are optional. With any luck, you may not need them—especially if you own a Ten-Tec Corsair, Paragon, or Omni-V; a Kenwood TS-440S or any other rig that is fully EIA-232-D (also known as RS-232-C) compatible.

Adapter A is suitable for rigs that demand reverse-polarity RS-232-C and TTL levels. Adapter B is used with transceivers that require standard RS-232-C polarity and TTL (0 or +5 V) voltage levels.

I must caution that Fig 4 illustrates typical connections between a computer, RTTY modem and transceiver for FSK operation. This diagram assumes that you are using a standard RTTY demodulator (HAL ST-6, ST-5000, ST-6000, etc) and *not* a multimode communications processor (MCP). Many of the multimode devices include their own TTL or RS-232-C data outputs that may be somewhat more flexible when used to drive your transceiver's FSK input. Read your MCP manual carefully before trying your hand at FSK.

If you're using a HAL PCI-3000 RTTY/AMTOR modem, a separate FSK output is included and circuit board jumpers are provided to set the voltage polarity and level. See Tables APC.1 and APC.2 (page A-14) in the *PCI-3000 Reference Manual*.

Frequency Displays Never Lie—Do They?

The amateur standard for specifying a RTTY frequency is to specify the frequency of the mark signal. While this is a logical approach, the mark frequency can be *different* from what your rig's fancy multi-digit display tells you it is!³

If you're using your transceiver in the LSB mode, your digital display indicates the *suppressed carrier frequency*. In most cases you can subtract 2125 kHz to determine your mark frequency. On the other hand, if you're in the FSK mode, you'll discover that calculating the exact frequency is *not* a matter of simple subtraction! It all depends on what rig you're using.

Some radios (ICOM and Ten-Tec units, for example) show the mark frequency. Others indicate the space frequency (TS-930S and TS-940S in particular). Others show the *suppressed carrier frequency* (just like LSB operation). And still others show f_0 —the imaginary center frequency between mark and space. (MARS stations specify f_0 .) If in doubt, read your manuals.

It's also important to note that digital frequency displays are *not* frequency meters! Usually, three or four oscillator stages, in addition to the VFO, determine the rig's output frequency. If a frequency error occurs anywhere other than the VFO, it may *not* be evident in the display. Your display reading can easily be several hundred or even a few thousand hertz off! Buying the "high stability option" (if available) will improve the frequency stability of your transceiver, but it usually won't correct your display calibration. (WWV has been "off-frequency" on my radio for years!) If you really want to know your exact RTTY frequency, buy a frequency counter, attach a short wire antenna and measure your mark signal frequency while sending continuous mark pulses. This technique works on *all* radios.

It's important to know your operating frequency for two reasons:

- To maintain your signal within the legal band limits according to your license class.
- To set your transceiver to the correct frequency for bulletin boards or autostart operation.

Receiving RTTY

Before you even touch your power switch, read your modem/MCP and terminal software manuals thoroughly. Make sure you understand the control keys that govern transmission, reception and special program features. Some programs offer a huge variety of features that can easily overwhelm a beginner. A little light reading pays off in the long run!

When you're ready, turn on your computer and load your terminal software. Switch your transceiver to LSB or FSK—whichever mode you've decided to use. Set

the modem or MCP data polarity to **NORMAL** and the shift to 170 Hz at 45 baud. Most RTTY modems and MCPs default to the receive mode when you turn them on. If not, switch to **RECEIVE** now.

Tune slowly through the RTTY subbands and search for signals. As soon as you find one, stop and eavesdrop for a while. It's always a thrill to listen to the pulsating tones and watch them become *words* on your monitor screen! Tuning and listening will give you valuable practice in proper RTTY receiving techniques. I suggest trying 14.080 to 14.100 MHz. You'll also want to check 3.60-3.65, 7.05-7.10, 21.075-21.100 and 28.075-28.125 MHz.

Be patient when using your modem or MCP tuning indicator. Keep practicing until you understand what it's trying to tell you. Every tuning indicator is a bit different, but it all boils down to knowing when you have the mark and space tones perfectly centered. Take some time to experiment with various filters and pass-band settings, if possible. A 500-Hz filter is ideal, but it's not essential for normal RTTY reception. I prefer to hunt for contacts using the wider SSB filter and then switch to a 500-Hz filter if I encounter interference.

It Sounds Like RTTY, But...

As you're searching for RTTY signals, you may discover a few oddballs. Your tuning indicator will tell you that everything is as it should be, but you're seeing gibberish on your screen—or nothing at all.

As I've said before, 45 baud/170 Hz shift is the most common amateur RTTY mode, but that doesn't mean everyone uses it. If you can't print the signal, try changing the shift or speed setting. Also check to see if the signal is *inverted* (mark and space fre-

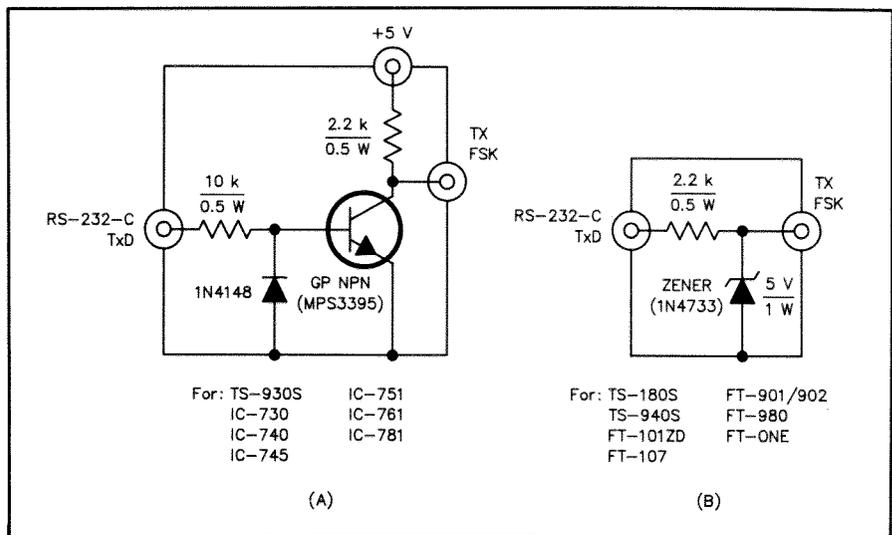


Fig 5—Voltage and polarity adapters for FSK RTTY operation. Adapter (A) is designed for rigs requiring reverse polarity RS-232-C and TTL levels. Adapter (B) provides standard RS-232-C polarity and TTL levels. Recommended transceiver models are shown below each adapter diagram.

quencies reversed).

There's also the possibility that you've picked up an AMTOR Mode B FEC signal. You probably thought AMTOR signals only made that funny *chirp-chirp* sound, didn't you? Well, they do—most of the time. When an AMTOR station is calling CQ, however, the transmission is sent in Mode B so that any AMTOR station can copy the text. Mode B signals sound like very rapid RTTY and often confuse first-time operators. If your RTTY modem or MCP has AMTOR capability, switch to the *listen* mode and you should be able to copy the CQ message.

Transmitting RTTY

If you're comfortable receiving RTTY signals, it's time to adjust your transceiver in preparation for your first RTTY QSO. Connect your transceiver to a dummy antenna and set your output power to minimum. Type several lines of text and then place the RTTY modem or MCP in the transmit mode.

While watching your RF power meter, slowly increase output until it is *half* of your maximum CW or phone output. If you're using FSK, increase your output to the maximum level recommended in your manual for FSK operation. Note this setting as your *maximum* RTTY power setting.

As you're transmitting, use a second receiver (without an antenna) to monitor your signal. Tune above and below your RTTY frequency by at least 20 kHz, listening for "extra" (spurious) signals and distorted modulation. It often helps to have another nearby station listen to your signal, too. If you hear spurious signals or distortion, all is not well! Try decreasing transmitter power to alleviate the problem. If you're using AFSK, check the input signal to make sure you're not overdriving the transmitter. A hum or buzz on your transmitted signal is almost always caused by poor shielding and/or grounding.

A Word about Power

A few comments are in order concerning RTTY output power. I have suggested that you adjust your transmitter for an output power level that is *half* of what you might normally use. This is admittedly conservative. On most modern transceivers, it means that your "normal" RTTY output will be about 50 watts—when you could get 100 watts or more if you ran "full bore."

It's important to remember that RTTY is a 100%-duty-cycle mode—meaning that the transmitter is keyed *continuously* during each transmission. In contrast, CW typically has a 50% duty cycle; SSB is even less. In other words, 50 watts during a RTTY transmission produces at least as much heat as 100 watts of phone or CW. You know what prolonged, excessive heat does to electronic components. Since transmitter parts are expensive, why risk them?⁴

Keep output power in perspective: 50 watts is only 3 dB less than 100 watts. That's *half* an S-unit on the other guy's receiver. Bear in mind that transmitters generally exhibit more distortion at full power, too. On voice, the result is splatter. On AFSK RTTY, the result can be spurious signals that could earn you a citation from the FCC! By running higher power you also increase the risk of interference to your digital equipment. If you're having computer problems at 50 watts, imagine what might happen at 100 watts!

If you believe that you need more than 50 watts to communicate, it's best to consider using a linear amplifier and running it well below full output. In RTTY service, the amplifier rule of thumb is: "The bigger and heavier, the better!"

RTTY on the Air

After all of the reading, wiring and adjustments, we've finally reached the moment of truth. It's time for your first RTTY QSO!

The easiest approach is to tune around and find another station calling CQ. Make note of his call as soon as you copy it. When he signs K, it's your chance to answer. Keep the call short. Assuming that I (K9GWT) am answering W6IWO, I prefer this format:

```
[switch your modem or MCP to transmit]
[send a blank line]
W6IWO W6IWO W6IWO DE K9GWT
K9GWT K9GWT W6IWO DE K9GWT
K9GWT K9GWT IN URBANA, IL K
[send another blank line]
[switch back to receive]
```

Note the blank lines above. The first blank line assures that the other station's equipment prints your response on a new line on the screen or printer. The second blank line gives you the same advantage when you receive his response.

If the station doesn't answer, try again two or three times. It's *much* better to make several short calls than to make one long call. If you want to call CQ yourself, try this format:

```
[switch your modem or MCP to transmit]
[send a blank line]
CQ CQ CQ DE K9GWT K9GWT K9GWT
CQ CQ CQ DE K9GWT K9GWT K9GWT
CQ CQ CQ DE K9GWT K9GWT K9GWT,
BILL IN URBANA IL K
[send a blank line]
[switch back to receive]
```

Whatever you do, avoid the temptation to start your CQ with "RYRYRY..." or, worse, "THE QUICK BROWN FOX..." messages. Such preambles were helpful to operators 30 or 40 years ago, but they are frowned upon today. Yes, you'll see other operators sending RYs without end, but imitating their bad habits won't win you any friends. Also, your RTTY modem or MCP probably has the ability to send

date/time messages automatically along with your text. These date/time groups may be required for MARS and other traffic handling operations, but there's no point in sending them on initial calls.

To improve your chances of getting an answer to your CQs, stick to a quick, clean transmission. Don't resort to fancy or cute CQs. They may look neat on your screen, but most of us lose patience with fancy formats and keep tuning for someone who'll keep calls short and to the point. The most important part of any RTTY transmission is *your call sign*. Send enough CQs so that it's clear what you're after, then send your call several times. After all, no one can answer you if they don't know who you are.

Assuming that you've established communications with another RTTY ham, the rest is quite simple. RTTY is by nature a *simplex* or *half-duplex* mode. That is, you and the other station take turns transmitting. For those of us who are not good typists (me in particular), this gives us a chance to get a running start on our next transmission while the other fellow is sending.

How can we do this? Through the magic of software! Virtually all modern terminal programs include a split-screen transmit and receiver buffer (storage) option—frequently called "ASR mode" in honor of tape systems we used on the old Model 19 and 28 Teletype machines. (See the sidebar, "An RTTY-Speak Glossary.")

When you've finished your first transmission and the other station starts sending to you, disable the transmit buffer output and start typing your reply. Begin by inserting a blank line and call sign exchange (W6IWO DE K9GWT). Use **ENTER** or **RETURN** to start another new line and begin typing your comments or answers as you read the other station's text. Also, look at the screen and fix those annoying typos that always seem to appear.

When the other station finishes his transmission, switch your station to transmit and your computer will start sending the text you've already typed. Until the buffer empties its contents and catches up to your *real-time* typing, all text is transmitted at full "machine speed." As far as the other station is concerned, your transmission looks like the fast, smooth output of a newsroom wire service or a W1AW bulletin! With practice, you'll soon reach the point where your entire response is pre-typed. Your transmission will look great on the other guy's screen and you'll waste little time sending the information. That's the relaxing part of RTTY. Just sit back and watch your computer send your reply for you!

Identification

The FCC rules say we must identify our stations at least once every 10 minutes during a QSO. I prefer to ID more often and

An RTTY-Speak Glossary

AFSK: Audio frequency-shift keying. The modulation method used for VHF RTTY operation on AM and FM radios. Also used to refer to the practice of applying audio tones to the input of an HF SSB transmitter to produce an FSK RTTY signal (see *Indirect FSK*).

ALC: Automatic level control (or automatic load control). A feed-back voltage in the transmitter's output amplifier used to prevent amplifier overload.

AMTOR: Amateur teleprinting over radio. An error-correcting form of RTTY.

ASCII: American national standard code for information interchange. The standard 8-bit code used for computer-to-computer communications. Also used for HF RTTY.

ASR: Automatic send-receive. An RTTY terminal mode that allows the operator to compose a response while receiving text from the other station. ASR was originally used by the Teletype Corporation to denote mechanical machines in which paper tape could be punched while receiving. Modern usage applies to split-screen CRT terminals and computer terminal software with separate transmit and receive character buffers.

Asynchronous: A data format that includes start and stop bits, permitting the receiving printer or terminal to maintain synchronization with each character received.

Baud: A measure of the data rate (or speed) of a RTTY signal.

Baudot: The standard 5-bit teletype code used for HF RTTY.

Bit: The shortest data pulse used to make a RTTY character. The Baudot code uses 5 data bits. ASCII code uses 8 bits (7 data plus one parity bit).

Code: Baudot is the standard HF RTTY code. ASCII may also be used.

CR: Carriage return. The control character that places the print carriage or screen cursor at the beginning of a line.

Demodulator: The portion of a modem or MCP that converts received RTTY tones into mark or space data pulses.

EOL: End-of-line control-character sequence. For Baudot code, the amateur standard is to send CR, LF, and LTRS in sequence at the end of each transmitted text line (MARS uses CR LF, no LTRS). The ASCII EOL is CR LF for HF use and CR only for computer-to-computer communications.

FIGS: A Baudot control character that signals the printer to shift to the FIGURE5 case.

FSK: Frequency-shift keying. Modulating the transmitter by using the RTTY data signal to shift the carrier frequency.

HDX: Half-duplex. A communications system in which stations take turns transmitting and receiving.

Indirect FSK: The practice of using audio tones to drive the input of an HF SSB transmitter to produce an FSK RTTY signal output (sometimes referred to as AFSK).

KSR: Keyboard send-receive. A RTTY terminal mode in which the operator may either type characters to be sent or receive characters from another station. KSR was originally used by Teletype Corporation to distinguish between simple teletype machines and those including Automatic Send-Receive paper tape equipment (see ASR).

LF: Line feed. The control character that advances the paper or screen cursor position to the next text line.

LSB: Lower sideband. The mode used for most amateur RTTY transmissions.

LTRS: A Baudot control character that signals printer to shift to the letters case.

Mark: The ON or "resting" pulse state of a RTTY data signal. Also the "1" digital logic state.

Mark frequency: The RF or audio frequency corresponding to the mark data signal. 2125 Hz is the standard audio RTTY mark frequency.

MCP: Multimode communications processor. A modem device that includes digital processing to decode and process RTTY and other data modes. Also known as a multimode data controller.

Modem: A MODulator-DEMulator device that translates digital RTTY data pulses to and from audio tone frequencies.

Modulator: That portion of a MODEM that converts RTTY data pulses into mark or space audio tone frequencies for transmission.

PTT: Push-to-talk. The transmit/receive control line of a transceiver or separate transmitter and receiver system.

Polarity: The order of RTTY data pulses and tones. The RTTY standard is mark = 2125 Hz, space = 2295 Hz; RS-232-C data mark = -V, space = +V.

RATT: A nickname for radio teletype

RS-232-C: A data voltage and load protocol used by most computer devices for data pulses. An RS-232-C mark pulse has a negative voltage between -3 and -25 volts. A space pulse is positive between +3 and +25 volts.

RTTY: Radio teletype. Often pronounced "ritty."

RTTY delay: The delay between the moment a transmitter is keyed and the actual transmission of RTTY data. Also, the delay between the end of a RTTY transmission and the return to a receive-ready state. An adequate time delay prevents data loss that might occur if transmit/receive switching is slow. Recommended delay times for HF radios are 1 to 2 seconds.

RX data: Received RTTY data pulses from the demodulator.

Shift: The frequency difference between the mark and space pulses. The standard RTTY shift is 170 Hz.

Space: The off or "open-loop" pulse state of a RTTY data signal. Also known as the "0" digital logic state.

Space frequency: The RF or audio tone frequency corresponding to the space data signal. 2295 Hz is the standard audio RTTY space frequency.

Speed: 45 bauds is standard RTTY data rate (speed = 60 WPM). 50 bauds (66 WPM), 57 bauds (75 WPM), and 75 bauds (100 WPM) may also be used with Baudot code. 110 baud is the common data rate for HF ASCII RTTY.

Split-frequency: Using a different frequency for transmitting and receiving.

Start bit: The first bit sent in an asynchronous data transmission. The START bit is always a space with a time duration equal to one data bit. HF Baudot RTTY always uses one start bit.

Stop bit: The last data bit sent in an asynchronous data transmission. The stop bit is always a mark pulse. In Baudot, the stop bit may be 1.41, 1.5, or 2 times the length of a data bit. In HF ASCII, the stop bit is two times the length of a data bit. At ASCII data rates greater than 110 baud, the stop bit is generally the same length as the data bit.

Synchronous: A data format that does *not* include start and stop bits. Receiving devices are synchronized by special sequences of data bits at the beginning of each transmission. HF RTTY does not use synchronous data, but AMTOR and packet do.

TX data: Transmit RTTY data pulses from the RTTY terminal or computer (TxD).

identify *both* stations when I do. My preference is to identify at the start and end of each transmission. For example:

W6IWO DE K9GWT

A "one-by-one" ID is sufficient. Once again, turn off your automatic date/time generator. Most RTTY operators don't care what time your computer may think it is! If you make a 1- or 2-line short-break transmission, one ID at the start or end is enough. RTTY operators are a close-knit, fun group. There are often a lot of us listening in. If we see a familiar call sign, or a topic about which we want to comment, we will often break in and turn the QSO into a 3-way, 4-way and so on.

Speaking of break-in, it works very well in modern RTTY. For this reason, "drag your feet" a few seconds after the other station's transmitter stops transmitting to see if you have any breakers. It becomes an automatic reflex after a while.

Contest Techniques

RTTY contests are loads of fun. That's when all the RTTY DX stations come out of the woodwork! On a good contest weekend, you can earn your RTTY DXCC if you stay at it. During a contest, you'll hear many short CQs as you tune up and down the band. A DX station usually stays near the same frequency, quickly making one contact after another. If you don't copy his call sign the first time, *don't* get on the air and send "QRZ DE K9GWT." Instead, *listen*—the station will eventually send CQ again, or will identify itself as it answers another call.

When you do call a DX station, *keep your call short*. As I mentioned earlier, a one-line call is enough. In fact, you may want to modify that approach to two repeats of his call and *four* of yours. He

knows his own call, but he *doesn't* know yours!

A DX station is often called by many RTTY stations—a true RTTY pileup! Under these conditions it can take a long time for the DX station to tune through the signals and find one he can copy. Be patient! If it's a country you need for DXCC or a new multiplier—and you don't snag him after three or four calls—note his frequency and tune around. You can often work several more stations on other frequencies and return to him later.

RTTY demodulators *cannot* sort out multiple signals when they are all sending on the same frequency. In extreme cases, only the strongest first and last stations calling have a chance to be recognized—and this is the first or last strong station *at the DX QTH*. He is no doubt hearing a completely different set of signals than you are!

An SSB contest practice finally being adopted by RTTY enthusiasts is split-frequency operation. In this case, a DX station will often call CQ, including a note saying "LISTENING UP 5-10" or just "U 5-10." This means that he is listening for replies at frequencies 5 to 10 kHz higher than his transmit frequency. Obey his instructions. If you attempt to call him on his transmitting frequency, you'll only make yourself highly unpopular. Rather, you need to place your transceiver in the split-frequency mode so that your transmit frequency is, in this case, 5 to 10 kHz higher than your receive frequency.

When you finally get that cherished call from the DX station you've been hunting, be considerate and avoid starting a long-winded QSO. After all, this is a contest! Since speed is essential, it's hardly the time to send lengthy descriptions of your station equipment, or a long print-out of a RTTY QSL card!

Next Month

AMTOR is a relative newcomer to Amateur Radio, but the proliferation of inexpensive personal computers has made it one of the fastest growing HF digital-communications modes. In Part 4 of this series we'll explore the mysteries of AMTOR.

Notes

¹Multimode communications processors, or MCPs, are also commonly known as multimode data controllers.

²Some multimode devices use a 200 Hz shift for RTTY operation (mark = 2110 Hz, space = 2310 Hz). These tones are used for HF packet radio as well. To some extent they are compatible with standard 170-Hz shift tones (2125/2295 Hz) since the center frequency (2210 Hz) is the same. However, in weak signal conditions, using a 200-Hz shift places you at a disadvantage. Both you and the other station (possibly using 170-Hz shift) must resort to *straddle tuning* to achieve true transceive operation. This is tricky at best and often results in less than optimum performance. Operators who are truly serious about obtaining optimum RTTY performance retune their MCP receive filters and transmitter tones to match the 2125/2295 Hz standard. While this technique offers a noticeable improvement, you should *not* attempt the adjustment unless you are thoroughly familiar with your MCP and possess all the necessary test equipment. A botched realignment will probably void your MCP warranty.

³D. Newkirk, "What Your Frequency Display Really Tells You," *QST*, Aug 1991, pp 28-32 (Part 1) and Sep 1991, pp 26-31 (Part 2).

⁴If you are using a transmitter with tubes in the final amplifier stages, *never* exceed half of your rig's maximum power. Replacement tubes are sometimes hard to find. At the very least, consider installing a fan to cool the tubes.

Licensed in 1956, Bill Henry is the President and Chief Engineer of the HAL Communications Corporation. He is a Life Member of the ARRL and QCWA. Bill obtained his MSEE from the University of Illinois where he played a key role in their ionospheric research program from 1964 through 1975.

QST

Getting Started in Digital Communications - Part 4 - AMTOR

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Part 4 (AMTOR) appears in *QST* June 1992, pp. 34-45 (<http://www.arrl.org/tis/info/pdf/69234.pdf>)

Getting Started in Digital Communications

Part 4—AMTOR...and Beyond!

By Bill Henry, K9GWT

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AMTOR is mysterious to many hams. The uninitiated may know it only as odd, cricket-like signals they hear below the HF phone subbands. What do these chirping signals mean? Why do they make those peculiar sounds? If you've asked these questions yourself, you're not alone!

What is AMTOR?

AMTOR is one of the fastest-growing HF digital communications modes in Amateur Radio. It has much in common with RTTY, but includes an error-correcting system similar to packet. Like CW, AMTOR has the ability to maintain communications under marginal conditions. I've seen clean text appearing on my screen when I could barely hear the signal from the other station!

AMTOR is based on an existing radio-teleprinter system designed for maritime communications. The commercial version is often called TOR (Teleprinting Over Radio) or SITOR (Simplex Teleprinting Over Radio). The technical details of AMTOR, TOR, and SITOR can be found in CCIR 476 and CCIR 625.¹ Peter Martinez, G3PLX, is the father of AMTOR as we know it today.² He adapted the CCIR definitions for Amateur Radio use and coined the term "AMTOR."

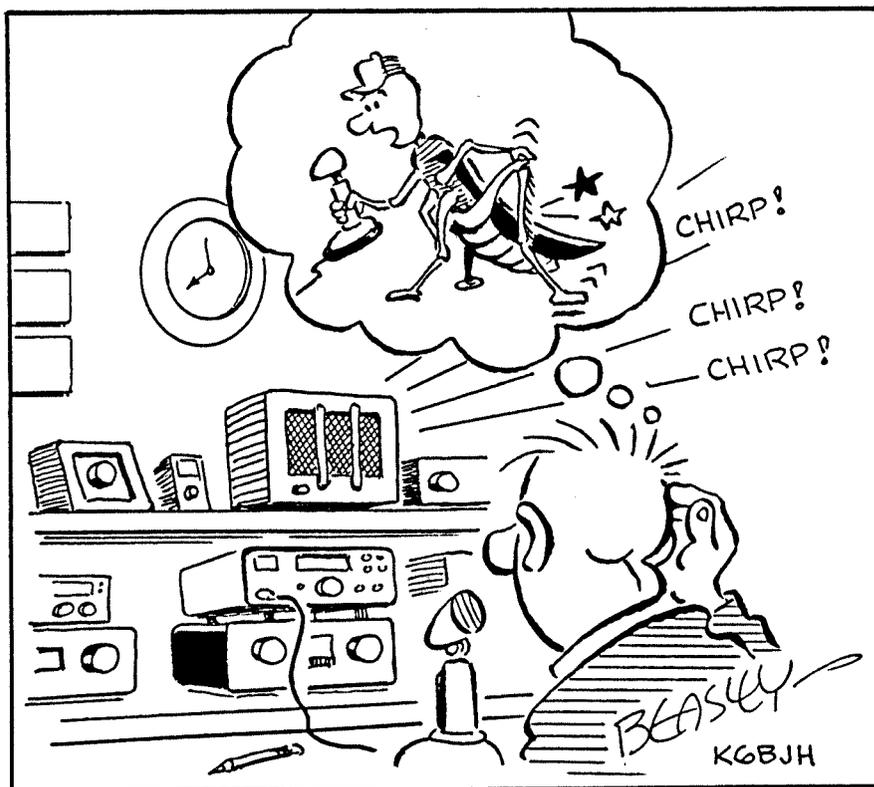
AMTOR has two primary modes—*ARQ* (or Mode A) and *FEC* (or Mode B). ARQ produces the familiar cricket signals. FEC, on the other hand, sounds like high-speed RTTY.

Like RTTY, AMTOR uses FSK (frequency-shift keying) and a 170-Hz shift. (See Part 3 of this series for more information concerning frequency-shift keying.)³ Lower sideband (LSB) is preferred for amateur transmissions. Commercial SITOR stations commonly use upper sideband (USB).

Setting Up for AMTOR

When it comes to connecting your equipment, there is no difference between AMTOR and RTTY. You can use either

¹Notes appear on page 45.



AFSK or direct FSK depending on your rig and AMTOR modem or multimode communications processor (MCP). To my knowledge, all AMTOR modems and MCPs include RTTY as well. I strongly suggest that you follow the setup and operating details in Part 3 of this series and become familiar with RTTY *before* you try AMTOR.

AMTOR and Radios

The first question I always hear from newcomers to AMTOR is, "Won't the high-speed transmit/receive switching ruin my rig?" No! I've used AMTOR for ten years with almost every radio I could get my hands on. I have yet to see a modern transceiver that was damaged by frequent AMTOR operating. It's true that some radios work better on AMTOR than others, but it shouldn't damage (or wear out) the equipment.

Caution! The same may *not* be true for linear amplifiers! Unless your amplifier is expressly rated for fast on/off switching (QSK), don't risk it! Besides, 50 or 100

watts of RF output is usually more than enough for AMTOR.

The major concern with using any transceiver on AMTOR is *transmit/receive turnaround time*. Most HF transceivers made in the last 6 to 8 years switch fast enough for AMTOR ARQ operation. However, some of the older-generation equipment may be pretty slow when changing from transmit to receive and back again. This is not always the case, though. I know several fellows who use 20-year-old tube equipment on AMTOR. In addition, many radios can be modified to increase their switching speeds. Radio manufacturers and active AMTOR operators are your best source of data concerning modification of older rigs.

If you have the equipment and like to tinker, Fig 1 shows how to use a triggered-sweep oscilloscope to measure your transceiver's transmit/receive time delay. The shorter the delay, the better. Ten to 20 milliseconds (ms) is good; up to 30 ms is usable.

If you don't have access to the proper

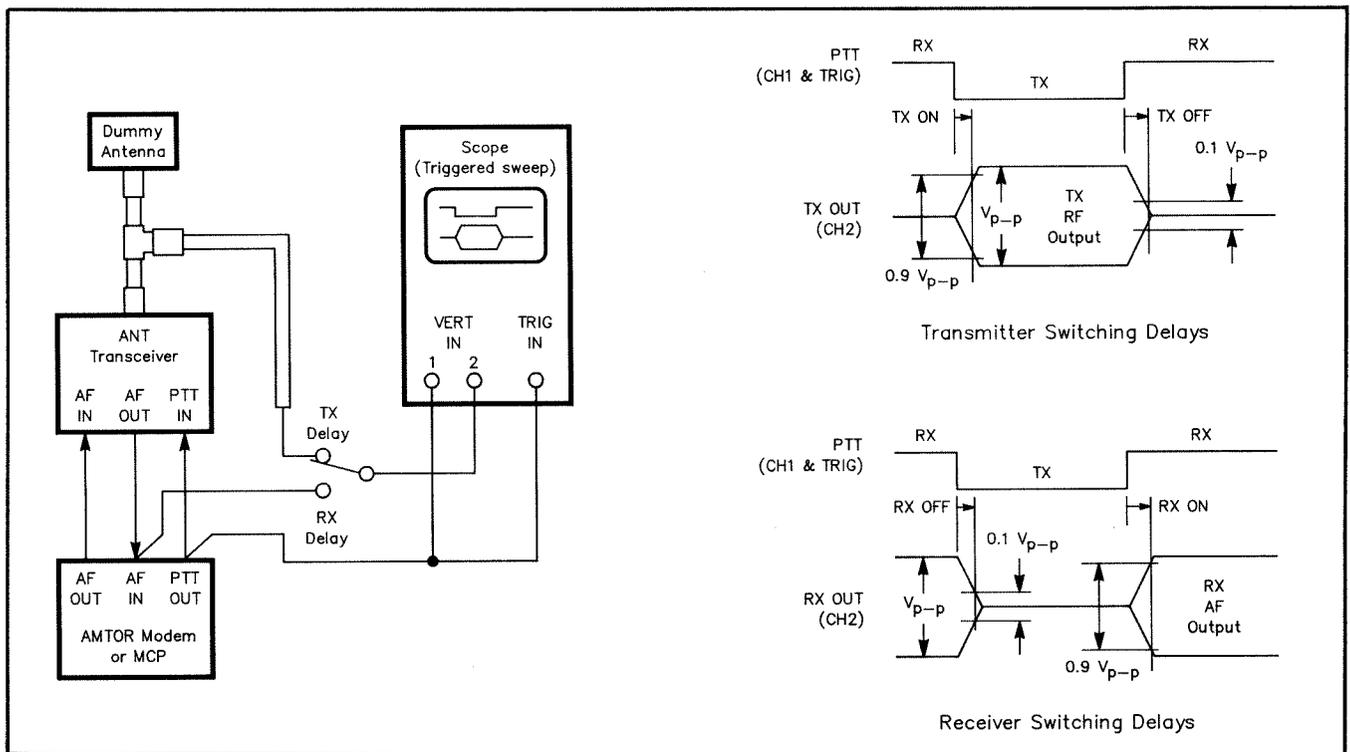


Fig 1—An oscilloscope triggered by the push-to-talk line of your AMTOR modem or MCP can be used to measure transceiver switching delays. Set your transceiver to LSB, switch on your modem/MCP calibrator and tune for the mark signal. Now adjust your transceiver output to a typical operating level. (Be sure to use a 10:1 scope probe when sampling RF at the T connector.) Place your modem/MCP in the ARQ mode and begin calling. Adjust your oscilloscope trigger to produce the display shown above. Adjust your transmitter output and receiver volume as well. Use delayed sweep if available. When you see a display similar to the one shown above, carefully measure the time delays.

measuring equipment, don't worry. Give AMTOR a try anyway. If your rig won't switch fast enough, you'll know right away because you won't be able to connect with other stations. Even then, don't give up hope completely. There are probably a couple of programmable delays in your AMTOR controller or MCP that you can use to skew the odds in your favor. We'll talk about them a little later.

AMTOR Theory and Modes

As we discussed earlier, AMTOR and RTTY have a great deal in common. Unlike RTTY, however, AMTOR has the ability to check for data errors. AMTOR uses a special 7-bit code for each character. There are 4 *mark* and 3 *space* bits in each character sent. The AMTOR receiving modem (or MCP) checks each received character for this 4:3 bit ratio. If the ratio is different, it's assumed that at least one bit of the character was received incorrectly.

ARQ Mode

The primary mode used in AMTOR today is ARQ. ARQ is a generic data term that means *automatic repeat request*. In ARQ mode, the *information sending station* (ISS) sends three characters and then turns its transmitter off. The *information-receiving station* (IRS) checks each character for the 4:3 ratio and then transmits a

single control character. The control character means "Acknowledged. Send the next three," (ACK) or, "Not acknowledged. Repeat the last three" (NAK). The character group is repeated over and over until it's copied error-free. It's this rapid transmission/acknowledgment cycle that creates the *chirp-chirp* signal that's the hallmark of ARQ.

ARQ Timing

AMTOR ARQ is precisely timed so that both stations know exactly when one is transmitting and the other is listening. As you can probably guess, this timing is *very* critical, and it's one of the reasons why an AMTOR controller is more complicated than a RTTY system. It's also the reason why high-speed transmit/receive switching is important. A slow radio may still be switching when it should be listening or transmitting!

A typical ARQ transmission/acknowledgment sequence is illustrated in Fig 2. The example may seem complicated, but bear with me. The concept is far simpler than the diagram!

The ARQ cycle starts when the ARQ link is established. The sending station (ISS) sends three AMTOR characters, which takes 210 ms. After receiving and checking the characters, the receiving station sends its ACK/NAK control signal (CS). The ISS has a 240-ms receive *window*. The

CS character must arrive at the ISS before the window "closes," or the ARQ link will eventually fail.

The IRS requires 70 ms to send the CS character. That leaves 170 ms to spare (240 ms - 70 ms = 170 ms). Sounds like we've beaten the clock so far, doesn't it? The catch, however, is that we haven't considered all the possible delays that can take place. After all, even radio waves aren't instantaneous. They travel at the speed of light. The delay they induce is called the *propagation delay*. The propagation delay depends on the distance between the two stations.

Keep in mind that our goal is to communicate over varying distances. The distance may vary from "zero" (two stations a short distance apart) to half-way around the world—about 6300 miles or 10,000 km. (I use 6900 miles [11,000 km] to account for extra travel due to multiple hops). Taking the speed of radio waves into account, it takes about .037 seconds (37 ms) for a signal to travel halfway around the world. Since the ARQ signals must pass *both ways* within each cycle (ISS to IRS and IRS to ISS), we need *twice* that time for the total propagation delay (74 ms). If you subtract 74 ms from 170 ms, we still have 96 ms remaining. That's plenty of time—or is it?

Don't forget that equipment delays take a significant bite out of our spare time. The modems at each station add a *1 bit period*

delay. That's 10 ms for each modem, or 20 ms total. If slow-switching (60 ms) transceivers are used at both stations, an additional 120 ms is added to the delay ($60 \text{ ms} \times 2 = 120 \text{ ms}$). Add the 20 ms modem delays and our total equipment delay has now reached 140 ms. We've used all of our spare time with an extra 44 ms for good measure. ($96 \text{ ms} - 140 \text{ ms} = -44 \text{ ms}$) This AMTOR link is doomed to failure!

If both stations have fast-switching transceivers (30 ms), the total equipment delay can be reduced to 80 ms (60 ms for the rigs and 20 ms for the modems). That leaves sufficient time to spare in our previous example. ($96 \text{ ms} - 80 \text{ ms} = 16 \text{ ms}$) Fig 3 shows the cumulative effect of equipment and propagation delays.

Now let's look at the opposite extreme. Consider two AMTOR stations side by side. The propagation delay is effectively zero. Let's also assume that the IRS sends its ACK/NAK control character immediately after receiving the ISS data pulse. If the transmit/receive switching delays at the ISS are too long, ISS equipment will still be switching when it should be receiving the control character. As a consequence, it will never hear the control-character transmissions.

Programmable Delays

The solution to the timing problem is the control delay (CD). This is the delay between the time the IRS receives a data pulse and the time it sends its ACK/NAK character. If both stations are extremely close to each other, the IRS station must

lengthen its control delay to allow the ISS station sufficient time to switch back to the receive mode.

Some hams have argued that AMTOR can't be used over short distances—no matter what adjustments are made. Baloney! It can work over zero propagation distance if the IRS control delay is set properly. The total delay is dependent upon the equipment used at both stations. What works for one pair of stations may *not* work for a different pair of stations. With these thoughts in mind, I'd like to suggest several guidelines for setting your control delay:

- There is no universal setting that works for all distances and all stations.
- If you're working a nearby station (2500 miles or less), set your control delay in the range of 30 to 50 ms.
- If you're working a distant station (more than 2500 miles), set your delay to a lower value (10 to 20 ms).
- If you call a station and the station can't seem to maintain the link, try adjusting *your* control delay.
- If another station calls you and *you* can't maintain the link, the calling station must adjust his or her delay.
- There *is* a maximum distance for AMTOR communications that varies with the equipment and delay settings at both ends. With proper adjustments, however, you should be able to work most earth-based stations.

Not all AMTOR modems and multi-mode communications processors will allow you to adjust the control delay. If this

is the case with your equipment, don't let it stop you from trying AMTOR. There are some stations you won't be able to contact, but there are many other stations you *will* be able to contact—depending on propagation and equipment delays.

There is another programmable delay in most AMTOR controllers and MCPs: the *transmit delay* (TD). Take another look at Fig 3. You'll note that the transmitters don't reach full output instantly. Since this is the case, the transmit delay tells the AMTOR controller or MCP to hesitate before sending the data. I find that practically all HF transmitters work correctly if you set TD to 10 ms. If you're in doubt, measure your transmitter delay using an oscilloscope triggered by the push-to-talk line from your AMTOR modem or MCP. After you've determined your transmitter delay, set your TD to match it. This parameter can remain fixed since it will be valid for all AMTOR contacts. Of course, remember that your transmit delay—and the transmit delay used by the other station—will increase the total time delay in the ARQ link.

FEC Mode

AMTOR FEC (forward error correction) does *not* rely on rapid on/off transmitter switching. Instead, the ISS turns its transmitter on, sends the complete text, and then turns its transmitter off. FEC also includes error correction, but not by repeated chirps. FEC sends each character twice, with the repeats delayed by four characters (280 ms). Using the 4:3 ratio test, the FEC

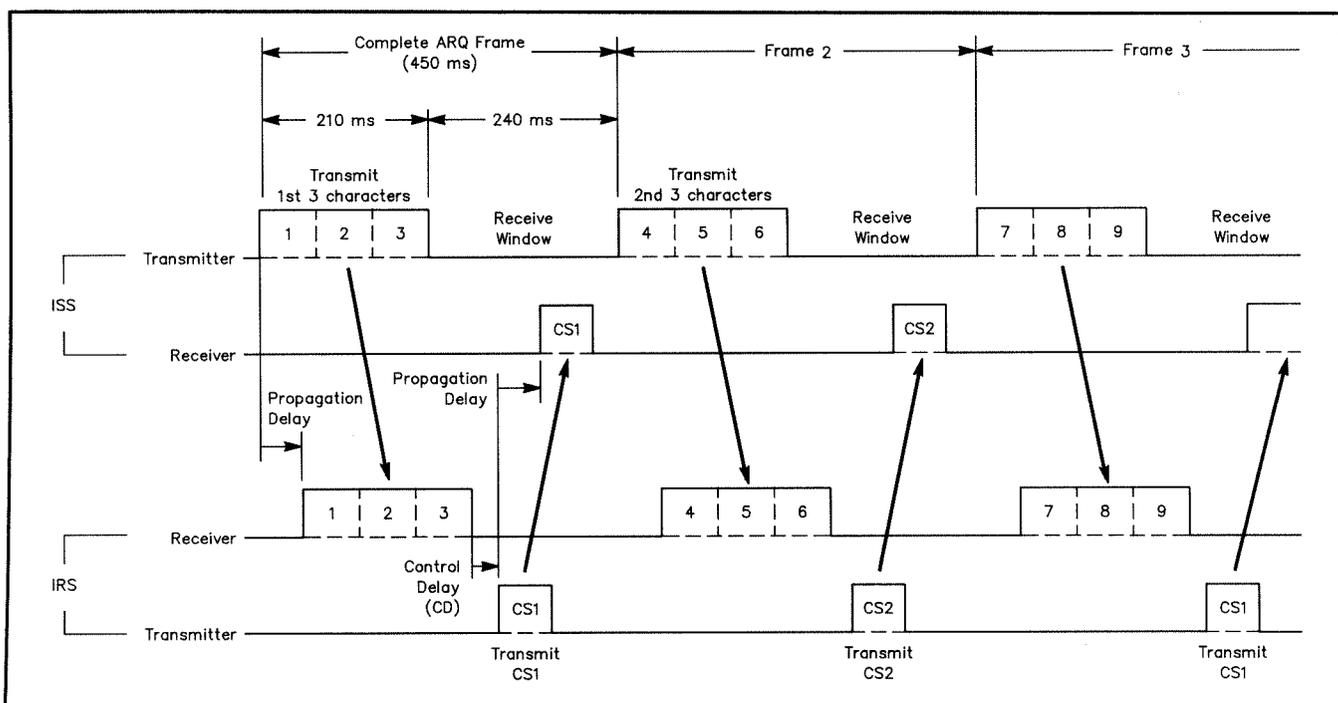


Fig 2—A typical AMTOR timing cycle. The dark arrows indicate the signal path from the transmitting station (ISS) to the receiving station (IRS) and vice versa. Notice how transmitted data does not reach the receiving station instantaneously. This is caused by propagation delays.

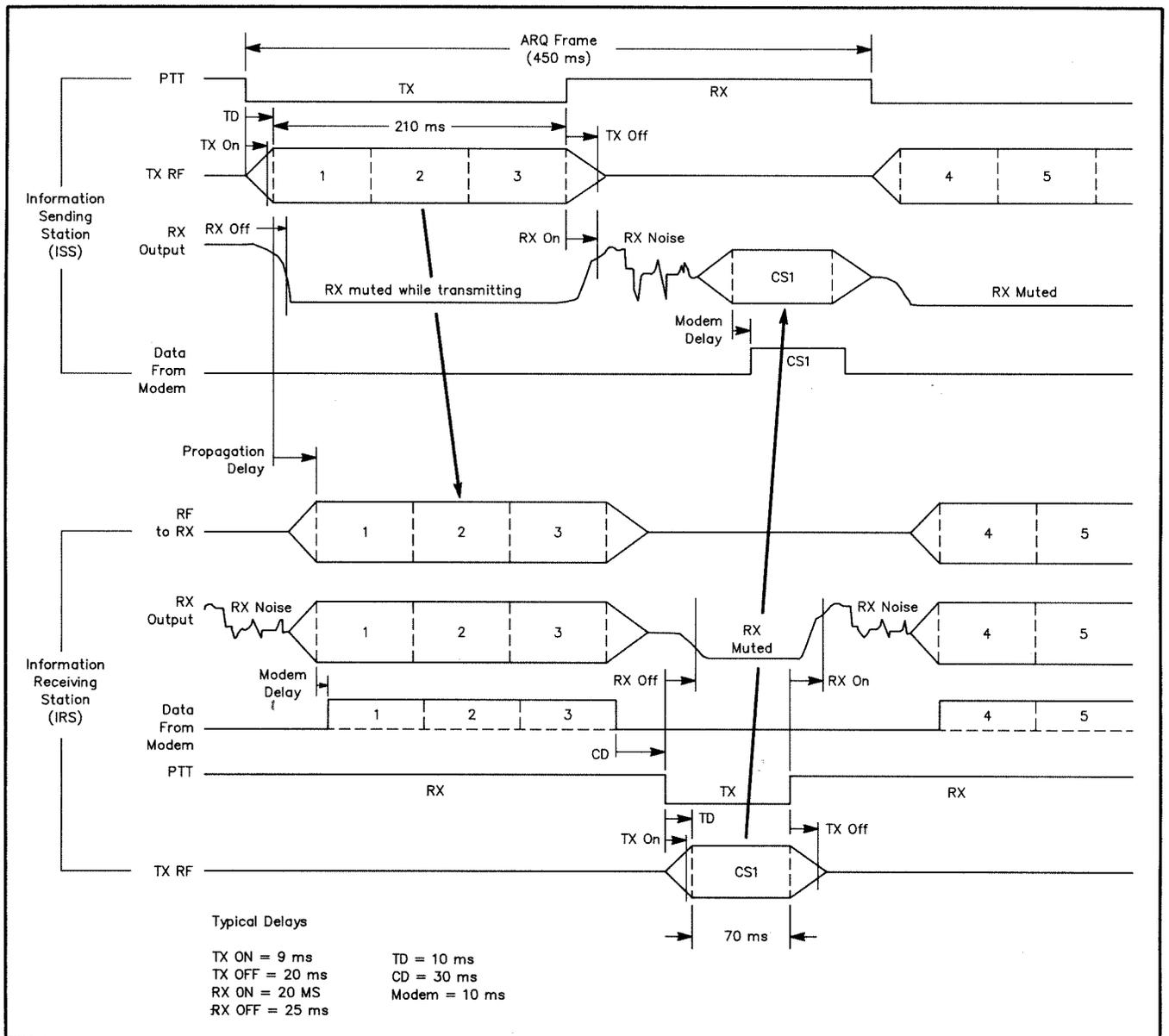


Fig 3—One ARQ cycle with all delays—equipment and propagation—included. The ISS sends a 210-ms burst of data after its TD expires. After a propagation delay, the signal arrives at the IRS and is decoded, with the modem adding its own delay to the process. By the time the IRS control character (CS1) is transmitted and received at the ISS, the ISS receive window (RX) is about to close!

receiving station checks the first reception of each character and prints it if it's correct. If the first test fails, the second transmission is examined. If both transmissions fail the test, a blank space or underline character is printed (this varies with AMTOR controllers and MCPs).

In commercial SITOR operation, FEC is used to send broadcast messages from one station to several others (weather bulletins to ships, for example). Commercial FEC is also called Collective Broadcast Mode.

Amateurs use FEC primarily to call CQ, but it's also used for round-table QSOs with more than two stations. FEC is used by W1AW to send bulletins via AMTOR.

SELFEC Mode

Selective FEC (SELFEC) is used com-

mercially to make limited broadcast transmissions to a specific group of stations (from company headquarters to company-owned ships, for example). SELFEC has its own group call (GC) code that all stations must recognize before they can copy the message. While SELFEC is a valid AMTOR mode—and it is included in some AMTOR controllers and MCPs—few amateurs use it.

Listen Mode

Listen mode is unique to AMTOR and is usually not included in commercial SITOR controllers. Listen mode allows AMTOR stations to tune to an ARQ QSO in progress and print the text *without* being part of the link. You need a bit of patience when using listen mode since it doesn't include the error-correcting feature you get

when stations are linked. You'll no doubt see some errors, and it may take a while for the controller to synchronize to the signal.

Listen mode also works differently depending on the AMTOR controller or MCP you're using. The listen mode in some controllers automatically senses and switches to ARQ, FEC or SELFEC mode, copying any signals that match these modes. Other units monitor only ARQ transmissions in the listen mode and must be manually switched to the standby mode to monitor FEC or SELFEC signals.

Standby Mode

Most AMTOR controllers have a standby mode. (In some MCPs, entering the ARQ mode places the unit in the standby state.) If your controller is in standby mode

and you tune in an FEC signal, it automatically switches to FEC and prints the received signal. Also, if a station calls you in ARQ mode (using your SELCAL code), the controller will automatically switch to ARQ and attempt to establish a link.

Tuning AMTOR Signals

Tuning AMTOR takes practice. If you're a long-time RTTY operator (as I am), it may be difficult to break some old habits. RTTY operators tend to tweak the knob while they're receiving, watching both the indicator and the printed output. While this technique is fine for RTTY, it can be deadly to AMTOR!

When tuning AMTOR, keep your eyes on the modem or MCP tuning indicator. Tune slowly until your indicator tells you that the signal is tuned correctly. Once you've got the signal locked in, don't touch the tuning knob! Even a slight frequency change can disrupt the link. Also, do not expect characters to instantly appear on the screen. An AMTOR controller must receive several ARQ characters, or as much as one FEC line, before it can synchronize to the received signal. Have faith and believe your indicator!

Eavesdropping on AMTOR

Set your receiver to LSB and your AMTOR controller or MCP to the *listen* or *monitor* mode. Now hunt for a chirping ARQ signal. I suggest that you look for a strong signal between 14.070 and 14.080 MHz. (Twenty meters isn't the only band with AMTOR activity, but it's one of the most popular.) When you've tuned the signal correctly, you should see characters within 15 to 20 seconds. If not, try another signal. On some controllers, you may have to reset the listen mode to restart the synchronizing process. With practice, you should be able to copy an ARQ signal with ease. The listen mode drops out of sync at times, especially when one station ends its transmission and switches from ISS to IRS. This is normal since the listen mode can only synchronize to one station at a time.

Now, find an FEC signal. At first, FEC may be hard to differentiate from RTTY. Set the controller to the standby mode and tune-in the FEC signal. An FEC transmission includes special synchronizing characters, but the CCIR specifications only require that they be sent once per line of text. It can take 10 seconds or more to receive these synchronizing characters—longer if you miss them or get a noise burst when they're sent. Some AMTOR modems and MCPs send extra FEC synchronizing signals and these signals will be easier to receive. Practice tuning FEC before you attempt your first AMTOR QSO.

Loading Your SELCAL

To use the ARQ mode, you must first load your own selective call identifier, or SELCAL. When AMTOR stations wish to communicate in ARQ, this is the code that

must be used to establish the link. The SELCAL code uses *only* letters, and we choose letters that match at least part of our call signs. Some examples are:

Call Sign	CCIR-476	CCIR-625
	SELCAL	SELCAL
K9GWT	KGWT	KIGWXXX
W6IWO	WIWO	WFIWOXX
KS9I	KKSI	KSIIXXX
WA9YLB	WYLB	WAIYLBX
W1AW	WWAW	WAAWXXX
WB8IMY	WIMY	WBHIMYX

SELCAL codes for both CCIR-476 and CCIR-625 are shown above. Most amateurs use only the CCIR-476 configuration. Also, the letter combinations shown for CCIR-625 are strictly my own choice—you can use others. In our QSO examples, we'll use only CCIR-476 SELCAL codes.

But What is CCIR-625?

CCIR-625 is the new AMTOR/SITOR international standard. It was devised to address two problems: (1) the four-character CCIR-476 code was too limited to provide different SELCALs to all stations, and (2) under some circumstances, a CCIR-476 station could re-link with an incorrect station if the original link failed. CCIR-625 allows *seven* characters in its SELCAL, automatically identifies both stations at link-up, and also tightens the specifications for FEC synchronization.

Newer AMTOR controllers include both modes, but CCIR-476 is compatible with both new and old equipment. A discussion of the differences between the two modes requires more space than this article permits. You may want to do a bit of reading and research on your own.⁴ It would be time well spent! In a few years, CCIR-625 may become the dominant Amateur Radio AMTOR format.

Let's Call CQ!

Switch your controller/MCP to the FEC mode to call CQ. (Some controllers and MCPs permit you to send FEC while in the ARQ mode.) An AMTOR CQ should include both your call sign *and* your SELCAL code. The format I prefer is:

```
[Transmitter ON]
[blank line]
CQ CQ CQ DE K9GWT K9GWT K9GWT (KGWT
KGWT KGWT)
CQ CQ CQ DE K9GWT K9GWT K9GWT (KGWT
KGWT KGWT)
CQ CQ CQ DE K9GWT K9GWT K9GWT (KGWT
KGWT KGWT) K
```

[Return to standby mode]

The last step is *very* important! Your AMTOR controller must return to standby to be ready to receive an ARQ call. Most AMTOR controllers have two different ways to end an FEC transmission; one command returns the controller to the standby mode and another returns to the FEC mode. Be sure to check your manual!

If someone copied your FEC CQ, they'll call you in ARQ mode using the SELCAL code specified (KGWT in our example). If you don't get an answer, try another call. Keep your calls short—don't get fancy or long-winded!

Under no circumstances should you ever start an FEC transmission with the "RYRYRY..." sequence. In FEC AMTOR, the "RYRYRY..." string thoroughly confuses the other fellow's controller, preventing it from synchronizing to your transmission. Using "RYRYRY..." in FEC is a good way to guarantee that your CQ will *not* be answered!

More AMTOR-Speak

Before we go further, we need to learn some more AMTOR terminology, or "AMTOR-speak." For example, the calling station sets-up the ARQ link. For the duration of the QSO, this station is the *master* and the station called is the *slave*. All timing for the ARQ QSO is set by the master station; the slave synchronizes its timing to the master. This has *nothing* to do with which station is sending or receiving (ISS or IRS). When a station responds to your FEC CQ, it's the calling station and therefore becomes the master; your station is the slave.

Over Commands

The *over* command allows the stations to trade places from ISS to IRS. When you finish typing your comments, for example, you must turn the link over so that the other station can reply.

There are two over commands that can be used. The normal procedure is to type +? at the end of your transmission. (Depending on the terminal software and the AMTOR modem or MCP you're using, the +? can be sent by tapping a single key.) This automatically sends a control code that says, "Let's turn the link around. You're the ISS now." When the link switches, you'll hear the difference immediately.

Recognizing that there are times when the IRS operator (receiving station) would like to immediately break in and make a comment, most AMTOR controllers also include a *forced over* command. A forced over causes an immediate link reversal, even if the ISS operator is still typing or has text in his transmit buffer. The exact command used to cause a forced over varies between controllers. Again, read your manual. Use the forced over sparingly; it's rarely needed, but very handy at times.

End Command

An ARQ link will continue indefinitely unless one station or the other sends the *end* command. Again, the code used to send the command varies with the controller or MCP. With HAL units, for example, you'd type ZZZZ when you wanted to *down the link*.

An Anatomy of an AMTOR QSO

Let's take a look at a typical AMTOR QSO. Notice how each command is used.

[My station in FEC mode]:
[K9GWT transmitter ON]

CQ CQ CQ DE K9GWT K9GWT K9GWT (KGWT
KGWT KGWT)

CQ CQ CQ DE K9GWT K9GWT K9GWT (KGWT
KGWT KGWT)

CQ CQ CQ DE K9GWT K9GWT K9GWT (KGWT
KGWT KGWT) K

ZZZZ

[K9GWT returns to the standby mode]
[W6IWO loads "KGWT" into his controller and answers in ARQ Mode]

KGWT KGWT KGWT [W6IWO sends my SELCAL code. This not printed.]

[The ARQ link is established; W6IWO is master and ISS]

K9GWT DE W6IWO GOOD AFTERNOON OM. NAME HERE IS DALE, QTH IS FOUNTAIN VALLEY, CA. YOU ARE 10 OVER NINE. IT'S SUNNY AND 75 DEGREES HERE. HOW COPY? +? [W6IWO sends the *over* command]

[K9GWT becomes ISS, W6IWO changes to IRS]

W6IWO DE K9GWT

GOOD AFTERNOON TO YOU DALE. MY NAME IS BILL AND QTH IS URBANA, IL. YOU ARE REALLY BOOMING-IN AT 20 OVER! I ENVY YOUR WX. SNOW IS A FOOT DEEP AND STILL FALLING. IT SURE IS NICE TO BE INSIDE. I'M TRYING A NEW RIG HERE. HOW'S IT SOUND TO YOU? +?

[K9GWT sends the *over* command]

[W6IWO becomes ISS, K9GWT changes to IRS]

The QSO continues between W6IWO and K9GWT. We discuss all kinds of important things and solve most of the world's problems. Eventually, the QSO ends:

[K9GWT is ISS, W6IWO is IRS]

W6IWO DE K9GWT

FINE DALE. IT'S BEEN NICE TALKING WITH YOU. SNOW HAS STOPPED FALLING AND I'D BETTER GO FIND A SHOVEL. 73 FOR NOW. +?

[K9GWT sends the *over* command]

[W6IWO is ISS, K9GWT is IRS]

K9GWT DE W6IWO OK BILL. HAVE FUN IN THE SNOW AND DON'T OVERDO IT. 73. ZZZZ

[W6IWO sends the *end* command and ARQ link is broken]

Answering an AMTOR CQ

As you can see from the example, W6IWO heard my FEC CQ and then called me in ARQ. To answer an FEC CQ, we must first load the *other station's* SELCAL code. Be careful not to change your own SELCAL code in the process! Obviously, there are two SELCAL codes involved: your SELCAL and the SELCAL of the other station. To help keep this straight, AMTOR controllers and MCPs label your SELCAL as *MYCALL*, *MYA*, *MYSEL* or *LOCAL CALL* (LC).

When you want to answer a CQ in the ARQ mode, most controllers will prompt you to enter the SELCAL of the other station:

SELCAL?

Other controllers (such as the HAL PCI-3000) include a call directory that lists several calls in a menu format. Still other controllers label the SELCAL to be sent as the *remote call* (RC), or sometimes *HISCALL*. Consult your manual to determine the correct label and the proper procedure to enter the other station's SELCAL.

WRU Answer-Back

Most AMTOR controllers and all commercial SITOR controllers include an automatic station identification feature called "Who Are You" (WRU). This feature dates back to mechanical Teletype machines. The concept involves another station sending a special character code that triggers an automatic response from your station—usually your call sign. If the station doesn't know your call sign, it's literally asking, "Who are you?" AMTOR WRU works like this:

- My WRU feature is on and I have text in my *ANSWERBACK* storage (my call sign).

Upper-/Lowercase AMTOR

AMTOR evolved from commercial TOR and SITOR, which in turn evolved from Baudot radioteletype. One of the handicaps of this evolution was that AMTOR could only send uppercase letters and limited punctuation. Peter Martinez, G3PLX, and Victor Poor, W5SMM, have recently created an extension of AMTOR, using the *null* code as an upper-/lowercase shift signal for receiving stations. The null code was assigned in CCIR-476 and CCIR-625, but was previously unused.

By using upper-/lowercase AMTOR, additional punctuation symbols can be transmitted as well. In fact, the W5SMM version of APLink includes all of the standard punctuation symbols. For this reason, some operators refer to mixed-case AMTOR as *ASCII AMTOR*. It really isn't full ASCII, but it's close. When an APLink BBS uses this modified software, there is no discernible difference between the received text passed via AMTOR or packet.

At the time this article went to press, only the AEA PK-232 and the HAL PCI-3000 and AMT series controllers supported upper-/lowercase AMTOR. No doubt other manufacturers will incorporate this modification as it becomes more popular. Stations using upper-/lowercase AMTOR—including APLink BBSs—are fully compatible with uppercase-only users.—K9GWT

- Your station is the ISS and you send the WRU code.

- My AMTOR controller responds with a *forced over*.

- My station then sends the preprogrammed ANSWERBACK text.

- Finally, my station sends *over* (+?).

Note that it should be the station called (mine in this example) that forces the first *over*. If your controller or MCP doesn't handle the exchange in this manner, using your WRU feature can create some *very* confusing situations! For this reason, you may not care to use the WRU function unless you are also using APLink.

APLink

APLink is a BBS program designed by Vic Poor, W5SMM, to provide message store-and-forward capability for AMTOR users. APLink allows stored messages to be shared between two computer ports—one port for an HF AMTOR controller and another for a VHF packet TNC. Messages can be read or stored by an AMTOR station on HF, or by a packet station on VHF. As a result, APLink provides a connection (no pun intended!) between AMTOR operators and the VHF packet network.

The use of APLink has renewed interest in AMTOR. Prior to the advent of APLink, there were a few hundred dedicated AMTOR operators in the US. Since APLink became popular, that number has swelled to over 5000!

APLink uses the WRU function if it's available. Just make sure your ANSWERBACK message is in the expected format.

The APLink Scanning BBS

Frequency-scanning AMTOR BBS stations first appeared in Europe as the brainchild of G3PLX. They're now common in the United States and they are spreading worldwide.

A scanning APLink BBS uses the programmable memories and scanning options of newer HF transceivers. When the BBS is not in use, its receiver continuously scans the programmed frequencies. A BBS station often scans four or five bands and two or three different frequencies within each band. A complete scan can take 15 to 30 seconds.

The scan pauses for 2 to 5 seconds on each frequency. If the BBS station hears its own SELCAL being sent by a potential user, scanning ceases and an ARQ link is established. If the frequency is busy, or the BBS SELCAL is not heard, the BBS resumes scanning.

This frequency-scanning technique allows one BBS to serve stations at varying distances—regardless of propagation conditions. If you can't connect to an APLink BBS on 20 meters, for example, try again on another band. Eventually you'll find a band that offers a good path between you and the APLink BBS. It's a very clever way to make the best use of our

The AMTOR-Speak Dictionary

ACK (Acknowledge): the ARQ mode **IRS** response that tells the **ISS**, "The last three characters were received correctly, please send next three characters."

AMTOR: AMateur Teleprinting Over Radio. An adaptation of commercial ship-to-shore **SITOR** (CCIR-476) by Peter Martinez, G3PLX.

ANSWERBACK: The programmable message that responds when **WRU** is enabled and the **IRS** receives the **WRU** signal.

APLink: A radio bulletin board station (BBS) program created by Vic Poor, W5SMM. Messages and files may be accessed by either HF **AMTOR** or VHF packet-radio stations.

ARQ: Automatic repeat request. This is the error correcting mode of **AMTOR**. **ARQ** signals are easily recognized by their *chirp-chirp* sound. An **ARQ** link can be established only between two stations.

CCIR-476: The international recommendation that gives the technical specifications for **AMTOR** and **SITOR**.

CCIR-625: The newer international definition for **AMTOR** and **SITOR**. Compared to **CCIR-476**, **CCIR-625** expands the **ARQ SELCAL**, clarifies **ARQ** mode re-linking and defines **FEC** mode synchronization. **CCIR-625** controllers are compatible with **CCIR-476** operation.

CD: Control delay. A programmable **AMTOR** controller time delay inserted by the **slave IRS** between the end of its reception of the **ISS** data "chirp" and the transmission of its control signal.

CLOVER: A new modulation and data protocol created by Ray Petit, W7GHH. **CLOVER** uses **PSK** and **ASK** modulation on a pulsed tone sequence. **CLOVER** modulation levels are adaptive and data may be sent at throughput rates 10 to 100 times faster than HF **AMTOR** or HF packet radio. The **CLOVER** signal bandwidth (500 Hz at -50 dB) requires half the equivalent spectrum of **AMTOR** and a quarter that of HF packet radio.

Control Signal: The single character sent by the **IRS** to acknowledge (**ACK**) or not-acknowledge (**NAK**) the data sent by the **ISS**. The **ISS** repeats characters when a **NAK** (or no response) is received from the **IRS**.

Down the link: Terminating an **AMTOR** **QSO** by sending the end command. As in, "I'll let you down the link."

DSP: Digital signal processing. A technique that uses specialized, high-speed microprocessors to process signals.

End: The control command sent by an **AMTOR** station to end an **ARQ** link.

FEC: Forward error correction. An **AMTOR** mode that may be used to send a message to more than one receiving station. Each character is sent twice to provide error correction. **FEC** is also called "Collective Broadcast" mode in commercial usage.

Forced Over: An over command that can be initiated by the **IRS** to force a change in the channel direction (**IRS** to **ISS** and vice-versa). The command used to cause a forced over varies with the **AMTOR** controller or **MCP**.

GC: Group call. The special letter (or number) sequence sent at the beginning of an **AMTOR SELFEC** transmission. The transmission will be printed only by stations who have programmed the same **GC** in their controllers.

ISS: Information-sending station. The station that is sending information on the **ARQ** link. The **ISS** may be either the **master** or **slave** station.

IRS: Information-receiving station. The station that is receiving information on the **ARQ** link. The **IRS** may be either the **master** or **slave** station.

Listen: The mode of an **AMTOR** controller that allows it to monitor ongoing **ARQ** (and **FEC** and **SELCAL**) transmissions. Listen mode does not include error correction when receiving an **ARQ** **QSO**. Listen mode is generally not included in commercial **SITOR** controllers.

Master: The station that establishes the **ARQ** link. The master station designation remains fixed for the duration of the **ARQ** **QSO**, regardless of which station is sending information. The

master station sets the timing for both stations in an **ARQ** link.

NAK: Not-acknowledge. The **IRS** response that tells the **ISS** station, "The last three characters were not received correctly, please repeat last three characters."

Over: The control command that switches the roles of the two **ARQ** stations—**IRS** becomes **ISS** and **ISS** becomes **IRS**. **Over** is signaled by typing + ?.

PACTOR: A modification of **AMTOR** and packet radio developed by DL6MAA and DF4KV. **PACTOR** uses the **ASCII** character code and adaptive data speed control to provide two to four times faster data throughput than HF **AMTOR** or HF packet radio.

RX Off: The delay between switching the push-to-talk (**PTT**) line from receive to transmit and the receiver audio falling to 10% of its full output.

RX On: The delay between switching the push-to-talk (**PTT**) line from transmit to receive and the receiver audio reaching 90% of its selected output.

SELCAL: Selective call. The special letter (or number) sequence sent at the beginning of an **AMTOR** call in **ARQ** mode. An **ARQ** link will be established only when the transmitted **SELCAL** letters match those programmed at the desired station.

Amateurs create a **SELCAL** code as a contraction of their amateur call signs; commercial **ARQ** stations are assigned numerical codes. **CCIR-476** provides a four-letter **SELCAL** code and **CCIR-625** provides seven letters. **FCC** Amateur Rules and Regulations (Part 97) do not define how amateur **SELCAL** codes are constructed.

SELFEC: Selective **FEC**. An **AMTOR** mode that may be used to send a message to multiple selected stations. It is an **FEC** mode that includes a group call (**GC**) that all receiving stations must use. **SELFEC** is also called "Selective Broadcast" in commercial usage. **SELFEC** is permitted for US Amateur use.

SITOR: Simplex Teleprinting Over Radio. A commercial name for **CCIR-476** **ARQ** ship-to-shore communications.

Slave: The **ARQ** station that is called in an **ARQ** link. The slave designation remains fixed for the duration of the **ARQ** **QSO**. The slave always synchronizes its timing to that of the **master** station.

Standby: The resting state of an **AMTOR** controller. When the programmed **SELCAL** is received, the **AMTOR** controller automatically switches to **ARQ** mode and establishes the link. When called in **FEC** mode, the controller automatically switches to **FEC** mode and prints the message.

Switching Delays: The delays associated with changing a transceiver or transmitter/receiver system from transmit to receive and back again. These delays are usually called **TX On**, **TX Off**, **RX On**, and **RX Off**.

TD: Transmit delay. A programmable **AMTOR** controller time delay that blocks data transmission until the transmitter **RF** envelope has reached full power.

Throughput: A measure of the effectiveness of a data system. The throughput rate is the number of data elements per unit time (characters, bytes, or bits) that can be passed from one station to another without error. The throughput of **AMTOR** under ideal conditions is 6.67 characters per second (cps).

TOR: Teleprinting over radio. A commercial name for **CCIR-476** **ARQ** ship-to-shore communications.

TX Off: The time delay between switching the push-to-talk (**PTT**) line from transmit to receive and the time it takes for the transmitted **RF** envelope to fall to 10% of full output.

TX ON: The time delay between switching the push-to-talk (**PTT**) line from receive to transmit and the time it takes for the transmitted **RF** envelope to reach 90% of full output.

WRU: Who Are You? A signaling system that lets one **AMTOR** controller automatically obtain identification from the other station. When enabled, reception of the **FIGS-D** (\$) **AMTOR** code reverses the channel direction (over), sends text stored in the Answerback message, and restores channel direction (second over). **WRU** is often used by **APLink**.

Table 1
APLink Operating Summary

Here's a brief operating summary for APLink. It provides only a quick reference to APLink operation. You are strongly encouraged to obtain a user's manual from your APLink SYSOP.

There are a few points to keep in mind when using APLink.

- Commands to APLink on its AMTOR port should always be on a new line and end with a carriage return.
- The user should avoid transmitting the "+?" sequence. APLink knows when it is its turn to send. APLink will change the link direction, as needed.
- Arguments shown in square brackets [like this] are optional. Arguments shown in point brackets <like this> are not optional and must be included.

A—Abort the current output; GA +? prompt
 CANCEL <num>—Cancels message <num> if originated by you
 F—Abort the current msg; GA +? prompt
 LOGIN <call>—Logs you in if you are registered
 LOGOFF—Same as LOGOUT
 LOGON <call>—Same as LOGIN
 LOGOUT—Logs you off
 H—Send the help file
 L—List all non-bulletin, non-private messages
 L [number]—List all non-bulletin, non-private messages equal to or greater than (number)
 LTO or LM—List all messages to you
 LTO [call]—List all messages to <call>
 LFM—List all messages from you
 LFM [call]—List all messages from <call>

LB—List new general interest bulletins
 LB [number]—List general interest bulletins from [number] and higher
 LT—List all NTS messages
 NTS—List all unforwarded NTS messages (may be restricted)
 LU—List all registered users
 LR—List all stations that have logged on during last 24 hours
 RN or RM—Read all new messages addressed to you
 R [number]—Read message [number]
 RH [number]—Read message [number] including routing headers
 RI—Read the Intercept File (for forwarding to home BBS)
 RF— Read the Auto-Fwd File (to see how AMTOR routing is done)
 SP <call>—Send a private message to <call>, end with NNNN
 SP <call1> AT <call2>—Send a private message to <call1> to be forwarded by packet to BBS with call sign of <call2>
 ST <zip> AT NTS <st>—Enter (Send) an NTS message
 SB [name]—Enter (Send) a bulletin to "name"; End with NNNN
 SB [name1] AT [name2]—Enter a bulletin to be forwarded; End with NNNN
 T—Talk to the SYSOP
 V—Read version number
 /// Anywhere on a command line cancels the command

available HF spectrum and propagation!

If you want to connect to a scanning APLink BBS, you must: (1) know the exact frequencies the BBS is scanning, and (2) be able to accurately set your transmitter to those frequencies. My comments in Part 3 of this series concerning dial readings and what they mean for RTTY (and AMTOR) are especially important in this case. Scanning BBS stations have files that list the exact frequencies they monitor. When you first connect to an APLink BBS, download its frequency list so you'll know where to find it the next time.

Before attempting to use an APLink station, I suggest you listen to several of the listed frequencies and see if you can hear the BBS communicating with other stations. This will tell you whether the BBS is busy (calling it will do no good if it is), and the quality of the BBS station's signal at your QTH. When you finally call the BBS, choose a frequency where its signal is strong and stable.

Most APLink operating commands will be familiar to packet users. As is the case with many packet BBS systems these days, APLink stations have disabled their command list response. This means that you may only see GA +? when you initially establish the link.

Sending a private message via APLink is very similar to packet, but AT is used in place of @. For example, on an APLink BBS you'd enter: SP WB8ISZ AT WA8ZWJ

rather than SP WB8ISZ @ WA8ZWJ. (Even this is changing with the advent of upper/lower-case AMTOR. These APLink stations *do* use @ in their message format—just like packet.) See Table 1 for a list of common APLink commands.

Future Digital Modes

There are two new digital modes about to hit the HF bands—*PACTOR* and *CLOVER*. Our series wouldn't be complete without a few words about each one.

PACTOR

PACTOR was designed by Peter Helfert, DL6MAA, and Ulrich Strate, DF4KV.⁵ At this writing, a few PACTOR units are on the air and the final details are being worked out. PACTOR addresses two major limitations of AMTOR: (1) AMTOR uses a limited Baudot-type character set rather than ASCII; (2) AMTOR is basically a *slow* mode, even when propagation is superb.

PACTOR includes an adaptive scheme that doubles the data rate from 100 to 200 baud when link conditions are very good. If you are sending text only, PACTOR features a data-compression mode that can double the speed again to nearly 400 baud. PACTOR promises to double—or even quadruple—the data rate currently employed by AMTOR. Like all other data modes previously described, PACTOR uses FSK modulation.

CLOVER

CLOVER was invented by Ray Petit, W7GHM, and is under development in a cooperative effort with HAL Communications.⁶ CLOVER uses a form of modulation that is completely different from any data mode yet described. CLOVER modulation utilizes phase-shift keying (PSK) and amplitude-shift keying (ASK). CLOVER also sends a sequence of *four* tone pulses rather than two (as used in packet, RTTY and AMTOR).

The time-versus-amplitude shape of each CLOVER tone pulse is carefully controlled to reduce bandwidth. The total bandwidth of a CLOVER signal (at -50 dB) is just 500 Hz. This compares very favorably to the bandwidth required for AMTOR (as much as 1 kHz) or HF packet (as much as 2 kHz).

When operating in the ARQ mode, CLOVER includes an error-correction code which allows the receiving station to fix errors *without* requesting repeat transmissions. This greatly enhances the efficiency of HF digital communications. Like PACTOR, CLOVER ARQ is adaptive. CLOVER can chose from a total of 128 different modulation, code, and block formats to automatically select the optimum parameters to match existing propagation conditions.

(continued on page 45)

Getting Started in Digital Communications

(continued from page 41)

CLOVER is still under development, but recent tests have proven that CLOVER modems pass HF data at least ten times faster than AMTOR or HF packet under typical band conditions. When conditions are especially good, CLOVER can be even faster! CLOVER uses digital signal processing (DSP) technology to achieve this level of performance.

Food for Thought

AMTOR is really not as hard to use or understand as it may appear. In fact, it takes longer to read this article than it takes to get on AMTOR and work someone! By taking the plunge into AMTOR, you'll enjoy one of the most fascinating HF digital modes available—and you'll be taking your first steps into the future of Amateur Radio!

Within the next few years, technological innovations like CLOVER will allow us to communicate with ever-increasing speed on the HF bands. Similar advances will offer ultra-high-speed amateur communications on VHF and UHF as well. As Steve Ford, WB8IMY, suggested in the first part of our series, it won't be long before hams begin to digitize speech itself. The data will be sent through high-speed modems and processed by specialized software at the receiving stations. Noise and interference will be discarded, resulting in clear, natural-sounding voices. Commercial telephone companies and the military are far ahead of us in this area, but their systems are extremely complicated and expensive. It's up to hams to find a way to make it cheaper and simpler!

Just as spark yielded to CW in recognition of its inherent superiority, I believe analog communications must eventually yield to digital. As amateurs we have an obligation to explore every possible avenue that may lead to an improvement in our ability to communicate. Digital technology is a tool we can use to make a gigantic leap forward!

I hope you've enjoyed our digital communications series, and I strongly encourage you to try packet, RTTY or AMTOR. No matter how old you may be, these modes will rekindle your child-like sense of awe and wonder. Put aside your microphone or key this weekend and try something different. There's no better time than now to "think digital!"

Notes

¹CCIR Recommendation 476-4 (1986), "Direct-Printing Telegraph Equipment in the Maritime Mobile Service", *Recommendations and Reports of the CCIR, 1986*, Volume VIII-2, Maritime Mobile Service, Geneva; International Telecommunications Union, pp 60-69.

CCIR Recommendation 625 (1986), "Direct-Printing Telegraph Equipment Employing Automatic Identification in the Maritime Mobile Service", *Recommendations and Reports of the CCIR, 1986*, Volume VIII-2, Maritime Mobile Service, Geneva; International Telecommunications Union, pp 5-59.

²P. Martinez, "AMTOR, an Improved Error-Free RTTY System," *QST*, Jun 1981, pp 25-27. For more information about AMTOR, also see: P. Newland, "An Introduction to AMTOR," *QST*, Jul 1983, pp 11-13, and P. Newland, "A User's Guide to AMTOR," *QST*, Oct 1985, pp 31-34.

³B. Henry, "Getting Started in Digital Communications—Part 3," *QST*, May 1992, pp 41-47.

⁴B. Henry, "New AMTOR Mode," *CQ*, Nov 1989, pp 36-40.

⁵H. P. Helfert and U. Strate, "FACTOR—Radioteletype with Memory ARQ and Data Compression," *QEX*, Oct 1991, pp 3-6.

⁶R. Petit, "CLOVER-II: A Technical Overview," *ARRL Amateur Radio 10th Computer Networking Conference Proceedings (1991)*, (Newington: ARRL, 1991), pp 125-129. 

Feedback

□ Bill Henry, K9GWT, discovered an error in his article, "Getting Started in Digital Communications—Part 4," *QST*, Jun 1992, p 35. In paragraph 2, column 3, half of the total circumference of the Earth is given as 6,300 miles or 10,000 km. The propagation time for a signal to travel this distance is given as 37 ms.

Half the total circumference of the Earth is actually 12,451 miles or 20,038 km. The time required for a signal to travel this distance is approximately 66.79 ms. Therefore, the total propagation delay between two stations is about 134 ms (assuming a two-way path), *not* 70 ms as stated in the article. While these new figures change the math used in the ARQ timing discussion on pages 35 and 36, the conclusions and recommendations are still valid. AMTOR ARQ can be used for communication over long distances *if* equipment delays are minimized. To communicate over a 12,000 mile path, for example, both transceivers must be capable of switching from transmit to receive very rapidly (approximately 15 ms or less).—*WB8IMY*