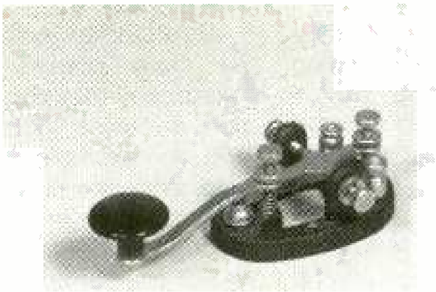
All About Amateur Communication Modes



From Morse code to the digital age, here's a look at the past and present communication methods used by radio amateurs.

BY KARL T. THURBER, JR.

Amateur radio is more exciting than ever, due largely to high-tech and digital operating modes and personal computers. But the vast number of communicating options available to hams today is only part of the story. Join us now for a look at the past, present, and future of amateur communications modes.

Classic Non-Digital Modes. One way to appreciate today's high-tech digital modes is to contrast the present with the pre-high tech days—say, the 1940s and 1950s. The radio and electronics world was different then; FM repeaters, packet radio and exotic digital modes, amateur satellite communications, and PCs didn't exist. The 1940s and 1950s were mostly an "analog world."

Amateurs could exchange messages by Morse telegraphy, voice (AM, FM, and SSB, or single-sideband); a few pioneering amateurs could even use TV. One classic digital mode, radioteletype (RTTY), was available, but it was more mechanical than digital. More sophisticated communication modes such as facsimile (fax), satellite, and packet weren't available.

The earliest radio amateur communications mode was that of spark, but it's been gone for about two-thirds of a century. Another simple mode, which is still in use today, is CW. That system consists of interrupting a "continuous wave" (CW) carrier in accordance with a code, such as International Morse (you could call it a digital mode if you wanted to).

Amplitude modulation, or AM, is an early form of voice communications. This relatively broad mode was the standard on the amateur bands until the 1950s, when a related mode became popular. That higher-tech mode was SSB (single-sideband).

SSB telephony makes use of a reduced or suppressed carrier and just one sideband, unlike AM, which transmits the full carrier and both sidebands. Either sideband can be used, but radio amateurs normally use lower sideband (LSB) below 10 MHz and the upper sideband (USB) above 10 MHz. SSB with little or no carrier isn't popular with broadcast-band and shortwave broadcasters because it can be difficult to tune.

Narrow-band frequency modulation (NBFM) is used widely on VHF and UHF, not just by amateurs but by many communications users—although AM still is standard on the VHF civilian and UHF military aircraft bands. FM is fairly immune to static.

Packet Radio. One form of "data by radio" in which the data is transported between PCs and radio transceivers is called packet radio. It's a high-speed, space-efficient

There's still room in this high-tech, digital amateur-radio world for a simpler mode: Morse Code, or CW. This MFJ electronic keyer combines built-in dot-dash memories, speaker, sidetone, and pushbutton mode selection with a classic paddle.

mode that lets you send, receive, store, and forward messages. It's similar to RTTY, but data are sent at a higher speed, and in a "connected" (telephone-like), nearly interference-free, error-checking mode.

Packet sends data in small bundles. Each contains the sending and receiving station callsigns and optional routing. The packets are sent one at a time; each is acknowledged when received. When a packet arrives error-free, the receiving station sends an "OK" (an ACK) and the next packet is transmitted. If a packet isn't received correctly, it's retransmitted.

Most packet is at a slow rate of 1200 bits per second (bps), although 9600 bps is becoming common. Some amateurs even experiment with higher rates. Even though the data transfer rates are relatively slow for the moment, packet provides low-cost, global connectivity, and it's still clear that higher speeds are on the way.

Packet radio seems to have three main advantages over simpler digital modes, such as RTTY. These are transparency, error correction, and automatic control.

First, transparency simply refers to the fact that a packet station's operation is transparent to you. Your Terminal Node Controller (TNC) automatically "packetizes" your message, keys the transmitter, and sends the packets. While receiving packets, the TNC automatically decodes them, checks for errors, and displays received messages. A packet TNC also can be used as a packet relay station, or digipeater.

Second, packet radio offers built-in error detection and correction. When you receive a packet, it's checked for errors and displayed only if correct. If the receiving station detects an error, it discards the faulty packet and does nothing. As mentioned earlier, after a while without an ACK from the receiving station, the transmitting station resends the packet. If the data can't be delivered intact, transmission is aborted.

Finally, there's automatic control. One advantage of packet is the ability for many users to use the same frequency simultaneously. With VHF/UHF packet, you can operate in an automatic control mode and leave your station (and its "mailbox") on at all times.

Some view packet as a tool to enhance their overall enjoyment of the hobby; others go further, using packet as their main means of on-the-air communication. With these thoughts in mind, let's detail the most popular applications of VHF/UHF packet today.

You can use packet radio to communicate directly with other amateurs, even over long distances using a packet radio network. Thus, you may find yourself chatting with an amateur in the same town, in the next state, or even halfway around the earth—without using HF.

Many packet operators communicate using BBS technology, which lets you transfer mail and bulletins over the network. Like telephone-line BBSs, PBBSs promote "time-shifting": you can transfer information between users who needn't be on the air and connected to the BBS at the same time. Besides mail and bulletins, many PBBSs also have a file section, and some PBBSs offer additional services.

A recent refinement is the use of packet radio for "DX spotting" to announce the presence of "choice" DX stations they find on HF. DX spotting allows hundreds of contesters and DXers to be connected to the same system at the same time for DX reports.

Pavillion Software's DX-Cluster, formerly known as PacketCluster (R), lets multiple stations connect to the DX-Cluster station or node, or to connect to other nodes to form a network. It offers DX spotting and logging, real-time announcements, talk and mail, database access, and much more.

While packet radio isn't one of the more popular modes for awards-seekers, some packet operators do enjoy such pursuits. The ARRL, for example, issues packet-radio endorsements to the basic Worked All States (WAS) award, although it doesn't issue packet WAS as a separate award.

Two ARRL contests specifically include packet radio. One is Field Day, in which participants can earn bonus points for making packet contacts. A second is the ARRL RTTY Roundup, a "digital contest" for RTTY, AMTOR, and packet modes. The objective is to work as many digital stations as you can worldwide. So far, most HF digital contesting has focused on these modes; PacTOR, G-TOR, and CLOVER (to be discussed later) are not yet popular contest modes.

Packet radio lets you handle message traffic. By "traffic" we mean radiogram messages sent via the ARRL's National Traffic System (NTS). Amateur packet and other digital mode stations and PBBSs are well suited to exchanging traffic, and the NTS depends heavily on these modes to move vital messages. To find out more about traffic-handling, check into a local VHF/UHF voice network on an FM amateur repeater, or contact your ARRL Section Manger. The ARRL Operating Manual also contains information on procedures.

It's also possible to perform public service and emergency communications with packet radio. Many amateurs have their digital-mode stations ready for emergencies. The stations can become "digital lifelines," since transmissions don't depend on telephone lines. Packet, RTTY, and AMTOR can provide some security for messages while freeing voice channels for other uses. PBBSs also are used productively for these purposes.

Another high-tech use of packet radio is to monitor and communicate with amateur satellites. Many satellites are orbiting bulletin boards, relaying packet messages around the world. Others transmit images that you can display on your computer screen.

Finally, it's possible to transfer files between packet stations, using the TCP/IP protocol. Transfers are more satisfactory at higher bps transfer rates, but are still practical at 1200 bps (more on this later).

Packet Equipment. Now that we've discussed the main things you can do with packet, let's talk about how you can get in on the action. One special piece of equipment you'll need is a terminal node controller, or TNC. TNCs resemble phone modems that connect PCs and telephones to transmit computer data. But TNCs, or "radio modems," transmit data by radio rather than wire. TNCs usually contain the modem (used to interface with your radio) and a microprocessor or packet assembler and disassembler (PAD).

In transmitting, the TNC assembles packets from the data on the RS-232 serial line, computes an error check for the packet, modulates it at audio frequencies, and generates appropriate signals to transmit over the radio. On receiving, it reverses the process, translating the audio the radio receives into a data stream on the RS-232 line. Most TNCs use 1200 bps for local VHF and UHF packet, and 300 bps for HF communication. FCC regulations allow higher speeds on VHF and UHF, but not on HF.

You'll need a radio transceiver, too. For 1200 bps UHF/VHF packet, you can use commonly available FM transceivers. For HF packet, 300 bps data is transmitted using SSB. For high speed packet (greater than 1200 bps), modified radios may be required.

For packet transmissions, you can use a computer running a terminal-emulator program, a packet-specific program, or just a so-called "dumb terminal" as a user interface. Almost any modem communications program can be adapted for packet, but there are also custom packet programs.

There are three basic TNC operating modes: command, converse, and transparent. You use the command mode to configure and control the TNC; the converse and transparent modes are used to communicate with others. You use the converse mode for most communications, while the transparent mode sends special characters to another station without being interpreted as commands by your TNC.

Most VHF packet activity is on 2-meter FM. You'll also find packet on UHF, on 222 and 420 MHz. Packet is alive on 6 meters as well, with many opportunities for DX under the right ionospheric conditions.

Once you have all the basics, can you get your station up and running? Most TNCs connect to the transceiver microphone plug for push-to-talk and transmit audio connections, plus they need a connection to the audio output from the FM receiver. If you can plug an RS-232 cable into a modem, and wire the TNC to your radio, you have the technical savvy to get on packet.

The cost of setting up your station shouldn't hold you back either, especially since you might already have some of the components. TNCs are around $130 and up. MCPs cost $300 or more.

If you already own a PC, you already have the potentially most expensive part of a packet station. And, if you have an amateur FM transceiver (or HF SSB transceiver), then you're set. If not, you can purchase a used two-meter FM transceiver from $100-$250; new ones cost from about $300 up. An HF rig costs more.

MFJ offers TNCs for HF and VHF packet radio, several of which are based on classic TAPR designs. Thousands of units similar to this rugged basic model are used as digipeaters, nodes, and BBSs, and in commercial applications.

Packet Operation. A protocol is a standard stating how computer systems communicate with each other. One of the more popular protocols for amateur packet radio is known as AX.25.

The amateur AX.25 protocol standard was developed in the 1970s and accepted by the FCC and ARRL in the 1980s. It's based on the wired-network commercial protocol X.25, which was modified to suit amateur needs. One advantage of AX.25 is that every packet that's sent contains the sender's and recipient's callsign, thereby providing station identification.

The Automatic Packet Reporting System (APRS) sends and receives station location or position information from various types of stations, including fixed and mobile stations, nodes, digipeaters, DX clusters, packet mailboxes, and the like. APRS graphically applies packet radio to real-time events by displaying information as a symbol on a map on your PC screen.

The position information includes, as a minimum, latitude, longitude, and station type. APRS is very useful in emergencies, exercises, weather nets, and other events that are most concerned with where things are and where they're going. Several firms, including PacComm, make equipment compatible with APRS and with GPS (Global Positioning System) satellite receivers.

Loosely related to packet operation is another VHF/UHF digital mode that's just getting off the ground: digital paging. The technology is being heavily promoted by Kantronics. Digital-paging transmission and reception formats adhere to the same Radiopaging Code No. 1 (POCSAG) signal format used by paging providers. Thus, most commercial pagers can be converted to amateur use.

If you're on packet, you already have much of the equipment needed; the Kantronics KPC-9612 TNC handles this mode. Kantronics offers pager crystals and will sell refurbished and "recrystalled" pagers for 2 meters and 70 cm. Pagers promise to be useful for amateur emergency communications.

Packet Networking and Gateways. If you're too far away from another station to make a direct connection, you can use the nodes, or switches, of a packet network. A wide variety of available networking schemes include digipeaters, KA-Nodes, TheNet, NET/ROM, ROSE, X1J, TPRS TexNet, FlexNet, and others.

Gateways offer access to another type of network, usually nonamateur. In the radio network world, you'll also see references to wormholes, amateur links that pass through nonamateur services, like the telephone system or the Internet.

Digipeaters made up the first packet networking schemes, but they're largely obsolete today. Digipeating, short for digital repeating, allows you to extend the range of your station by retransmitting packets addressed to the digipeater. But the links between digipeaters aren't 100-percent efficient, and they're dumb: they simply look at a packet, and if the callsign is in the digipeater field, they resend the packet.

Digipeating worked well with only a few people on the channel. However, as long-distance packet became more popular, digipeaters clogged the airwaves. Also, if a packet got lost by one of the digipeaters, the originating station had to retransmit the packet, forcing every digipeater to transmit again.

Kantronics improved on the digipeater concept with KA-Nodes. As with digipeaters, KA-Nodes repeat AX.25 frames. But a KA-Node acknowledges every transmission for each link instead of over the entire route; this allows for more reliable connections than digipeaters, because acknowledgments are only carried on one link. KA-Nodes are not true networks, and they don't offer automatic routing as do other schemes, like NET/ROM.

NET/ROM was one of the first networking schemes to address the problems with digipeaters. You connect to a NET/ROM station as if connecting to any other packet station. From there, you can send commands to instruct the station to connect to another local user or to another NET/ROM station. This scheme improved reliability considerably.

Another scheme is ROSE, which is an acronym within an acronym, standing for the "Radio Amateur Telecommunications Society (RATS) Open Systems Environment." A ROSE network includes a PBBS, an online callsign directory and database server, a bulletin broadcast controller, a message management system, a packet switch, and other features.

Now let's get back to gateways, which let you access other bands and operating modes. Gateways allow connectivity between two normally "non-connectable" communication technologies. For these reasons Gateways have become an integral part of most PBBS and digital networking schemes. They include crossband gateways,

TAPR, a nonprofit, scientific R&D corporation, is one of the cradles of amateur radio packet civilization. Various other high-tech and digital interests are supported on the TAPR home page, including spread spectrum, DSP, networks, the Internet, and other special interests. TAPR is found at http://www.tapr.org.

Internet/packet radio BBS gateways, and packet wormholes via the Internet.

You can participate in a variety of activities using an Internet-to-packet radio gateway. These include transferring files; "Telnetting," or accessing TCP/IP stations remotely through the gateway; and sending and receiving e-mail. Another activity is a "QSO bridge," a keyboard-to-keyboard QSO (contact) roundtable in which you enjoy real-time conversations.

TCP/IP and Packet Radio. Transmission Control Protocol/Internet Protocol, or TCP/IP, is a "suite" of protocols used over the Internet. Amateur TCP/IP nets, referred to collectively as AMPRNet, use an adaptation of Internet TCP/IP protocols. TCP/IP protocols provide a high level of flexible, intelligent packet networking that isn't possible with AX.25. Actually, TCP/IP software emulates many TNC functions so you aren't limited to the functions programmed into the TNC, which now can be programmed to do much more.

TCP/IP networks are mostly local and regional. But TCP/IP enthusiasts see a future when the entire country, and perhaps the world, will be linked by TCP/IP using microwave and satellites. Presently, most TCP/IP activity is on 2 meters and 70 cm.

What are some of the benefits of your using TCP/IP, in addition to its inherent ability to multitask (do several things simultaneously)? Let's take a brief look at some benefits:

With TCP/IP you can send mail reliably. You need only prepare the message and leave it in your own TCP/IP "mailbox." Your PC will attempt to make a connection and deliver the message directly—there are no PBBSs involved. The message packets travel through the net until they reach the other station. In the meantime, you can talk to, or receive mail from, the other station. If someone can't connect to you because you're not on the air, their PC holds the message and tries later.

With FTP software and TCP/IP, you can pass binary files over the Internet to other stations. Under TCP/IP, you can send and receive mail or talk to others while the transfer is occurring.

Already amateurs and other hobbyists have constructed Internet Web pages and USENET newsgroups for a variety of purposes. You might want to check out some of these newsgroups:

alt.ham-radio.packet
alt.radio.digital
rec.radio.amateur.digital.misc
rec.radio.amateur.equipment
rec.radio.amateur.homebrew
rec.radio.amateur.misc
rec.radio.amateur.space
rec.radio.info
rec.radio.swap

But some amateurs also have constructed packet TCP/IP "radio Webs" with on-the-air, Internet-style Web page servers. Doing so effectively blends their several interests in amateur radio, computer communications, and networking.

As for hardware, all you really need is a computer; a 2-meter FM transceiver; and a "KISSable" TNC, one with KISS ("Keep It Simple Stupid") mode capability.

The heart of your TCP/IP setup probably will be the TCP/IP-based software written for the IBM PC by Phil Karn, KA9Q, called NOSNET, or simply "NOS." NOS, the Network Operating System, takes care of all TCP/IP functions, using your "KISSable" TNC. You'll find NOS software on CompuServe in the HamNet Forum, among other places on BBSs and the Internet.

When you place your TNC in KISS mode, you disable the AX.25 protocols and reduce it to a basic packet modem; the host PC must implement all high level protocols. Thus all of the incoming and outgoing data are processed directly by your PC and its software, not by your TNC. Most recent TNCs and MCPs have this feature.

You also need your own IP address, much like on the Internet. AMPRnet volunteer IP address coordinators issue the IP addresses; you have to contact the coordinator in your area for an address. But you don't need to memorize the addresses of TCP/IP-equipped stations; NOS keeps track of them. When you try to contact another station using TCP/IP, all network routing is performed automatically according to the TCP/IP address of the distant station. TCP/IP networks are transparent to most users.

Most amateur TCP/IP networks depend on dedicated switches to move data through the system. Like NET/ROM nodes, TCP/IP switches communicate with each other over high-speed backbone links on 222 MHz or 70 cm. Many TCP/IP users access local switches on 2 meters, at 1200 bps, while TCP/IP switches use backbone links to relay data at 9600 bps or higher.

HF Digital Communications Modes. Packet radio is one of amateur radio's most popular modes. But today's digital world is more than just packet, which isn't all that great a communications medium on HF. The packet goal of efficiently, rapidly, and reliably transmitting information between distant stations is still elusive: sending data via HF radio is downright tricky. Ionospheric conditions change rapidly, frequently causing distortion and errors in received data.

While you can generate each of the new and high-tech digital modes using a dedicated controller, the advent of one particular piece of hamshack equipment is largely responsible for amateurs being able to use a wide variety of digital modes. That device is called the Multimode Communications Processor, or MCP.

Today, the heart of many digitally-equipped hamshacks is an MCP that lets you use several digital modes with your transceivers. All modes may be handled by the same box, which like a TNC incorporates microprocessor design features and internal memory. With MCPs, you may be able to operate Packet, PacTOR, AMTOR, RTTY, SSTV, fax and WeatherFax (WeFax), CW, and several other high-tech modes.

Before we explore more sophisticated HF digital modes, let's discuss

RTTY (Radio TeleTYpe), a common HF communications protocol. RTTY is a half-duplex, non-error-correcting mode. It's primarily for single keyboard-to-keyboard contacts, and operating practices closely resembling those of Morse. RTTY still is king of digital DXing and contesting.

RTTY uses Baudot encoding, a five-bit code. These five bits allow only 32 possible combinations, not enough for a full alphanumeric character set. While ASCII coding can be used in RTTY, it's uncommon. Most RTTY is at a slow 45 bps (about 60 WPM, in Morse terms), as opposed to telephone modems which typically use 9600 to 28000 bps and VHF packet at 1200 bps or higher.

So just how efficient and effective is packet when used under real world, rough-and-tumble HF conditions? The AX.25 protocol isn't an efficient protocol for HF. Even using a good radio modem, you frequently get errors—with the AX.25 protocol, one bad bit makes an entire packet unusable. This is the main reason why AX.25 isn't good to use on the error-prone channels typically encountered on HF.

Presently, no better packet HF protocol is available. However, candidates for improved HF digital communications performance include PacTOR, G-TOR, and CLOVER. You can expect to see more exotic modes develop over the next few years.

Generally, to operate HF packet you need an MCP, a HF SSB transceiver, and a PC running an appropriate terminal software program. All MCPs today have HF packet capability; so do many packet-only TNCs. You probably already have the SSB transceiver, and likely have a PC. (Actually, it's possible to operate all HF digital modes except CLOVER without using a computer, using a simple data terminal.)

Operating on HF packet is different from VHF/UHF packet: interference and noise are anathema. Whereas you can use 1200, 9600, or even higher bps data rates on VHF and UHF, and lots of high-speed packet equipment is available, FCC regs place an upper limit on the maximum data rate on HF. This is 300 bps below 28 MHz, and 1200 bps on 10 meters.

Another difference is the way in which the packet-radio signals are generated. On VHF and UHF, we usually use audio frequency shift keying (AFSK), with audio tones being applied to the FM transceiver's mike input. On HF, we normally use the SSB signal to generate an FSK (frequency shift keying) signal. Most packet activity today is on 2-meter VHF, using FM AFSK.

AMateur Teleprinting Over Radio (AMTOR) was one of the earliest methods of bringing amateur HF digital communications into the computer age. It's an error-checking mode for HF text communication that minimizes interference (QRM), fading (QSB), and static (QRN), one that's suitable for casual keyboarding and contacting HF BBSs. Importantly, you often can maintain a usable connection during poor signal-to-noise (S/N) ratio conditions when a packet connection wouldn't hold.

In one sense AMTOR's a throwback to an earlier era, in that it uses the same character set as Baudot, encoded differently: each character has a constant mark to space ratio. This constant ratio is how errors are detected. Errors are corrected using either of two methods: ARQ (Automatic Retransmit reQuest), and FEC (Forward Error Correction). However, the five-level code makes binary data difficult to send, error correction is weak, and effective "throughput" is low.

In ARQ mode, two stations connect. The station with data to transmit sends three characters, then waits for the other to send an acknowledgment. This activity makes for the "chirp-chirp" sound of AMTOR ARQ signals, and it means that each station transceiver must switch from sending to receiving mode quickly. Each station also has to turn the link over to the other station at the end of each exchange.

Before you operate AMTOR ARQ mode, you have to choose a selective call identifier, or SELCAL, a series of letters of your choosing that you use to establish the link. Most amateurs use some combination of letters that match part of their callsign.

Unlike in ARQ mode, in FEC mode one station can communicate with many others at once, since there's no back-and-forth acknowledging of data. FEC gets its error-correction capability from time diversity, in which it sends characters twice. In FEC mode, you can call CQ to make contacts.

Both AMTOR and packet are popular on HF, but performance

Color Slow Scan for the Sound Blaster SSTV software from Harlan Technologies offers color SSTV send and receive using your PC and its sound card. Color and black-and-white, receive-only versions also are available. A typical received SSTV image is shown.

isn't optimum. Packet Teleprinting Over Radio (PacTOR), which appeared in 1990, is a robust, RTTY-like, error-correcting mode to overcome the shortcomings of packet and AMTOR on HF. PacTOR is like an enhanced AMTOR combining its best features with packet, for operation on noisy, fluctuating channels. There's about a fourfold increase in throughput over AMTOR. A new version, PacTOR II, is even more robust.

A popular DSP receiver enhancement device is the JPS NIR-12 Dual DSP Noise/Interference Reduction Unit. The NIR-12 provides "spectral subtraction" noise reduction in addition to dynamic peaking. The spectral subtraction mode is effective in reducing impulse noise.

This hybrid mode sends error-free data by using a handshaking system which requires that the receiving station send an ACK if data is received intact. PacTOR's most important feature is that of memory ARQ, which lets even noisy packets be restored: it tries to compensate for incomplete data by looking for missing data and filling the gaps. PacTOR also adjusts its speed automatically to changing band conditions.

PacTOR has built-in message storage and can hook up to most APLink systems; you can pass traffic interchangeably using PacTOR or AMTOR. There also are many PacTOR BBSs on the air.

CLOVER is a complex and very efficient HF digital communications waveform, system, and protocol, named after its clover-like oscilloscope wave pattern. The proprietary CLOVER properly recognizes that HF signal propagation may produce severe signal distortion, and so it takes measures to compensate for the distortion and maximize data throughput.

Developed jointly by Ray Petit, W7GHM, and HAL Communications president Bill Henry, K9GWT, it's a very popular HF mode, since CLOVER arguably offers the best overall HF digital performance. CLOVER also is very conserving of spectrum space: it requires only about 500 Hz, as compared with about 2 kHz for HF packet and 1 kHz for AMTOR.

CLOVER uses a four-tone modulation system; you can manually or automatically select any of ten modulation formats to adjust to different conditions. CLOVER incorporates ingenious adaptive modulation schemes: the more complex, high speed modulation formats are used when conditions allow them, while the slower, less error-prone modes are used otherwise.

To use CLOVER, you need a special HF digital modem, usually an IBM PC-compatible HAL Communications computer card, along with terminal software. But you won't need a separate interface since the PC card performs this function. And, while early cards were CLOVER-only, newer cards have multimode capability and offer RTTY (both Baudot and ASCII), AMTOR, and PacTOR.

First used in 1994, G-TOR is a high-throughput, narrow-bandwidth hybrid HF system developed by Kantronics Corp. G-TOR stands for Golay-coded Teleprinting Over Radio. It makes use of the error-correction system created by M.J.E. Golay used in space vehicle communications to ensure that data transmitted from the vehicle could be recovered despite serious errors caused by noise and interference. Like CLOVER, the system is very conserving of spectrum space and usually takes up 500 Hz or less.

Reliability and effective data rates generally are superior to both AMTOR and PacTOR modes; in fact, G-TOR sometimes even approaches CLOVER's efficiency. Operating using G-TOR is fairly simple and is similar to operating AMTOR or PacTOR.

Spread Spectrum. Spread spectrum isn't a discrete modulation scheme. Rather, it tries to get around the twin obstacles to sending greater and greater amounts of information: frequency congestion and bandwidth. It involves "slicing" a whole band of frequencies into various frequency ranges that it uses almost simultaneously. A signal is present only on one frequency at a time, but the overall effect is like being able to operate on a whole band of frequencies.

First allowed by the FCC in amateur radio in 1980, spread spectrum is still an experimental mode that's limited to certain frequencies and implementation methods. It requires sophisticated equipment that few amateurs have, and it also suffers from the objections of amateurs who don't like its basic (and arguably inefficient) premise of using whole bands of frequencies. But it has potential advantages in being able to resist interference and share frequency bands with other users.

Image Communication Modes. Many amateurs effectively extend the PC and home-video revolutions to amateur radio. They send and receive images by graphical modes such as fax (facsimile), FSTV (fast scan television), and SSTV (slow-scan television)—sometimes the latter two modes are lumped together as amateur TV, or ATV.

SSTV and fax can be handled by multimode hardware interfaces and appropriate PC software. The more advanced MCPs offer a sort of "one-stop communications center" for various on-the-air modes including CW, RTTY, PacTOR, AMTOR, fax, SSTV, and more.

Fax is the oldest amateur image mode. Offering higher image resolution than SSTV or even FSTV, fax sends a high-resolution photocopy of a two-dimensional image of a piece of paper or a still photograph.

Today, amateur faxes usually are sent using PCs equipped with special software. The images sent may be in any one of several different formats that may be displayed as received or saved to a disk file for later viewing. Color fax also is possible, though the ups-and-downs of HF transmission generally limit its successful use to VHF and UHF.

Many amateurs and SWLs also enjoy receiving government WeatherFax (WeFax) broadcasts, which often originate from weather satellites, to obtain a graphical depiction of the weather. The bulk of this activity lies below the amateur 2-meter band, in the 137-138 MHz range using AM video subcarriers, and at 1691 MHz using FM transmission formats.

You can use SSTV to transmit black-and-white or color still pictures on HF, using relatively narrow bandwidths comparable to those used by SSB stations. Conventional SSB rigs generally are used to transmit and receive SSTV signals.

Recent years have witnessed the availability of inexpensive MCPs and PC-based scan converters. You can use an MCP for SSTV, or you can use a dedicated SSTV adapter. Several firms offer dedicated SSTV hardware and or software, including Absolute Value Systems and Harlan Technologies.

Getting on FSTV isn't a great deal different from voice modes, except that you also hook up your camcorder to provide the signal input to your transmitter, and use your TV set to receive the picture. A special radio isn't required. Amateurs typically show their radio hamshacks, home videos, construction projects, and computer graphics, or they repeat SSTV video and audio. Some even transmit local radio club meetings for shut-ins.

A FSTV signal looks like a commercial TV signal; you won't find FSTV on HF. Rather, it's on UHF, mostly on the 70-cm band because of the spectrum space required, and there also are many UHF FSTV repeaters across the country. Some FSTV buffs equip themselves with professional equipment, including special-effects devices to manipulate and control video images. A full range of FSTV equipment is offered by P.C. Electronics and several others.

Satellite and Space Communications. Since 1961, when the first

SUGGESTED READING

Books

Baker, Keith, KB1SF. *How to Use the Amateur Radio Satellites, Third Edition.* Washington, DC: The Radio Amateur Satellite Corporation, 1992.

Crisler, M. *The PACSAT Beginner's Guide.* Washington, DC: The Radio Amateur Satellite Corporation, 1991.

Curtis, Anthony R., K3RXK. *HamSat Handbook.* Lake Geneva, WI: Tiare Publications, 1993.

Curtis, Anthony R., K3RXK. *Outer Space Frequency Directory.* Lake Geneva, WI: Tiare Publications, 1994.

Davidoff, Martin, K2UBC. *The Satellite Experimenter's Handbook, Second Edition.* Newington, CT: The American Radio Relay League, Inc., 1990.

Ford, Steve, WB8IMY, ed. *The ARRL Operating Manual, Fifth Edition.* Newington, CT: The American Radio Relay League, Inc., 1995.

Ford, Steve, WB8IMY. *Your HF Digital Companion.* Newington, CT: The American Radio Relay League, Inc., 1995.

Hedtke, John, KD7WS. *Using Computer Bulletin Boards, Third Edition.* New York: MIS Press/Henry Holt & Co, 1995.

Horzepa, Stan, WA1LOU. *Practical Packet Radio.* Newington, CT: The American Radio Relay League, Inc., 1995.

Mayo, Jonathan, L., KR3T. *The Radio Amateur's Digital Communications Handbook.* Blue Ridge Summit, PA: TAB Books, 1992.

Schetgen, Robert, KU7G, ed. *The ARRL Handbook for Radio Amateurs, Seventy-Third Edition (1996).* Newington, CT: The American Radio Relay League, Inc., 1995.

Taggart, Ralph, WB8DQT. *Weather Satellite Handbook, Fifth Edition.* Newington, CT: The American Radio Relay League, Inc., 1994.

Articles

Anderson, Phil, W0XI. "Ham Radio Paging: Putting 'POCSAG' on Packet." *CQ VHF*, July 1996.

Bible, Steve, N7HPR. "Spread Spectrum: It's Not Just for Breakfast Any More!" In the *Digital Communications* column, *QEX*, June 1995.

Bible, Steven, N7HPR, and Greg Pool, WH6DT. "Amateur Radio on the World Wide Web." *QST*, June and July 1995.

Ford, Steve, WB8IMY. "Exploring the Internet." *QST*, September through December 1994.

Ford, Steve, WB8IMY. "Gateways: Amateur Radio Meets the Internet." *QST*, January 1995.

Ford, Steve, WB8IMY. "KISSes, POPs, and Pings." *QST*, June 1995.

Hershberger, Dave, W9GR. "DSP—an Intuitive Approach." *QST*, February 1996.

Kleinschmidt, Kirk, NT0Z. "Go Digital!" *QST*, September 1994.

"Packet Bulletin Boards—Ham Radio's 'General Store.'" In the *Basics* column (no author stated), *CQ VHF*, June 1996.

Rotolo, Don, N2IRZ. "A Packet Networking Primer." *CQ VHF*, June 1996.

Townsend, Jay, WS7I. "CQ Reviews: The HAL Communications P38 HF Radio DSP Modem." *CQ*, October 1995.

NAMES AND ADDRESSES

Absolute Value Systems
115 Stedman St.
Chelmsford, MA 01824-1823

Advanced Electronic Applications (AEA)
P.O. Box C2160
Lynnwood, WA 98036

Amateur Radio Research and Development Corp.
P.O. Drawer 6148
McLean, VA 22106-6148

Amateur Television Quarterly
3 North Court St.
Crown Point, IN 46307

American Radio Relay League, Inc.
225 Main St.
Newington, CT 06111-1494

International Digital Radio Association
P.O. Box 2550
Goldenrod, FL 32733-2550

HAL Communications Corp.
1201 West Kenyon Road
PO Box 365
Urbana, IL 61801-0365

Harlan Technologies
5931 Alma Dr.
Rockford, IL 61108

JPS Communications, Inc.
P.O. Box 97757
Raleigh, NC 27624-7757

Kantronics
1202 East 23rd St.
Lawrence, KS 66046-5099

MFJ Enterprises, Inc.
P.O. Box 494
Mississippi State, MS 39762

MIS Press
A division of Henry Holt & Co.
115 West 18th St.
New York, NY 10011

P.C. Electronics
2522 Paxson Lane
Arcadia, CA 91007-8537

PacComm Packet Radio Systems, Inc.
4413 N. Hesperides St.
Tampa, FL 66614-7618

Pavillion Software
c/o XX Towers, Inc.
814 Hurricane Road
Mason, NH 03048

Radio Amateur Satellite Corp.
P.O. Box 27
Washington, DC 20044

Radio Amateur Telecommunications Society (RATS)
P.O. Box 93
Park Ridge, NJ 07656-0093

Tab Books
A division of McGraw-Hill, Inc.
P.O. Box 5445
Blacklick, OH 43004-0545

Texas Packet Radio Society
P.O. Box 50238
Denton, TX 76206-0238

Tiare Publications
P.O. Box 493
Lake Geneva, WI 53147

Tucson Amateur Packet Radio Corporation
8987-309 E. Tanque Verde Rd. #337
Tucson, AZ 85749-9399

Orbiting Satellite Carrying Amateur Radio (OSCAR) was launched, amateurs have communicated via satellite over thousands of miles using VHF and UHF frequencies that normally are used for short distance communications.

Many amateur satellites contain microcomputers that provide specialized information and communications. Some have onboard cameras that let you download images of the earth and the stars. Others provide "store-and-forward" packet mailboxes for message transfers. Some satellites use the AX.25 protocol; others use special packet protocols developed for satellite communications.

Since 1984, when OSCAR 10 was used as a repeater to connect packet stations on the two coasts, packet radio TNCs and related gear has been carried aboard amateur satellites. This has enabled packet communications either of a real-time or "store-and-forward" (PBBS-like) nature—the latter is more common. There are some amateur satellites in orbit that are dedicated to packet radio (called "PACSATs"). These are PBBS-like and help distribute packet traffic around the world.

You'll find PACSAT operation to be fairly similar to conventional, earth-bound packet, and the same AX.25 protocol is used. But the PACSATs use a variety of data rates and signal modulation schemes and formats. Special modems must be used with your TNC to communicate with the 1200-bps phase shift keying (PSK) satellites (PacComm makes dedicated "satellite modems" to support both modes). You also need a 2-meter FM transmitter to send data and a 70-cm SSB rig to receive downlink transmissions.

Several satellites are 1200 bps PACSATs; these are OSCAR 16, OSCAR 19, and OSCAR 26. OSCAR 22, OSCAR 23, and OSCAR 25 are 9600-bps PACSATs. The 9600-bps birds have become popular—their 9600-bps capability is excellent for a satellite that may be "in view" for but short periods. Unfortunately, the PACSATs can serve only so many stations at one time.

Several packet-radio based Shuttle Amateur Radio Experiments (SAREX) have been conducted by amateur astronauts. Usually special "robot software" is used that enables stations to make contact with the Shuttle. This onboard software recognizes connect requests, sends sequential contact numbers to the station, disconnects, and logs the contact. The Shuttle also carries a beacon which transmits lists of successful contacts. Most of the experiments are digital-based, but ATV operators have successfully transmitted 70-cm FSTV signals to the Shuttle.

Russian cosmonauts have conducted live packet QSOs using amateur radio aboard the Russian Mir Space Station. It uses standard, 1200-bps AFSK packet. The station includes a PBBS-style mailbox for communicating with the cosmonauts.

While Mir is fairly simple to work, and no special equipment is needed, the problem with actually working it is its erratic schedule, caused by the cosmonauts' scrambling to find the time to operate. They're sometimes forced to turn off their amateur equipment altogether to avoid interference to other systems during critical duties and tests.

The Phase 3D international satellite project is a replacement for the amateur workhorse satellite, OSCAR 13, which soon will plunge into the atmosphere and be destroyed. But it's more, being aimed squarely at reducing the cost and complexity of ground-based, satellite-capable amateur stations. It adds several new frequency and data format choices, including digital-mode capabilities.

The new satellite will have powerful transmitters, receivers, and antennas for frequencies from 21 MHz to 24 GHz. The new satellite also will be easy to find, since its orbit will place the satellite at the same position above your horizon every 48 hours.

Communications with manned spacecraft and satellites are not the only amateur digital comms in the "outer space" realm. For several years, amateurs have experimented using "natural space objects" for packet radio communication. They long have used packet radio in meteor scatter communication, bouncing packets off the ionized trails of meteors that enter the earth's atmosphere, allowing much greater than line-of-site between VHF and UHF packet stations.

Amateurs also have used earth-moon-earth (EME), or "moon-bounce" communications, to bounce their own beacon signals off the moon and listen to them on the rebound. Two-way moon-bounce is a little more difficult, however, as EME signals typically are very weak and fluttery.

DSP: Digital Magic. A promising technology that can dramatically enhance your hobby enjoyment is digital signal processing (DSP). DSP represents a highly flexible, entirely digital approach to decoding, encoding, modulating, demodulating, and filtering signals for various operating modes.

Unlike regular analog communications processors, DSP units use software to encode and decode signals, so they aren't dependent on specialized hardware. In DSP systems, the incoming audio is converted into digital data for very effective, thorough processing by the DSP software, which rejects noise and interference according to the specified bandwidth. The result of this processing is converted back into audio for your MCP.

Most applications have focused on receiver filtering, where DSP-based CW filters add narrow, razor-sharp selectivity to receivers that lack it. Since DSP filters are virtual, existing only in microprocessors, they also can offer "adaptive filtering" to react to changing conditions, automatically reduce noise or hiss on weak signals, and notch out interference.

DSP filters are being used to perform more and more functions. Besides receiver filtering, we're seeing DSP-based filters in transceivers, MCPs, TNCs, and radio modems to do such things as generate SSB, process speech, generate and detect FSK and FM signals, and more. Best of all, with a DSP processor it's possible to add practically any mode to your MCP by adding new software.

PCs in the Radio Hamshack. Do you use a PC in your radio shack? If so, great, since you have to have one for at least some of the digital modes. Microcomputers perform valuable tasks in the radio hamshack and listening post, from doing calculations to cutting down on record-keeping time to beaming in on other stations.

While computers other than the IBM PC and compatibles can be used in the hamshack, the IBM PC has pretty much become standard. But any computer for which you can obtain terminal-emulation software will work in digital communications, except for CLOVER, which requires a CLOVER board installed in an IBM PC.

Hamshack PC software used to be quite limited, and it focused on QSO and contest logging. But amateur software has come a long way since it first appeared in the late 1970s. Today, hamshack software lets you use your PC for much more, including at least a dozen-and-a-half distinct classes of hamshack software applications.

These applications include Morse Code and radio-theory practice, instruction, and testing; computer-based radio and station control; logging, contesting, and awards tracking; automated QSL card processing; directional-antenna aiming; radio propagation prediction; antenna design and modeling; satellite tracking and antenna control; CW and RTTY reception and transmission; and support for packet radio and other digital communications modes.

Other hamshack computer applications you may enjoy include support for image communications such as fax, WeFax, SSTV, and FSTV; electronic circuit design and performance calculation; CD-ROM based callsign lookup; and online communications. ■

BUILD A LIGHTING SYSTEM

(Continued from page 44)

conduction angle. Use Table 1 to set your Lighting System for light levels that mimic 75-, 60-, 50-, 40-, and 25-watt lamps.

With the potentiometer set, you can complete the Lighting System by mounting it in a plastic electrical box with an AC receptacle cover. You can also modify a small project box. No matter what enclosure you use, however, *never touch any of the components while the circuit is plugged in and turned on!*

If the glow of the lamp seems to waver, check that other appliances on the circuit are in good condition. Also check that all outlets have the proper polarity (house-wiring testers are available for this purpose); appliances with reverse polarity can adversely affect the circuit. ■

Communication models can sometimes encourage traditional thinking and stereotyping but can also omit some major aspects of human communication. Methods and channels of communication to be used and the purpose of communication, must be considered before choosing a specific communication model. Models are used by business companies and other firms to foster their communication, explore their options and to evaluate their own situations. It is also used to understand how the receivers will interpret the message. Types of Communication Model. There are three general types of communication models i