Digital Mode Overview

Gary Wescom – Update – October 5th, 2009

What It's All About

This is a short description of some of the major digital modes currently used on the HF and VHF ham bands. There are hundreds of different communications protocols and modulation methods available for our use. There are many computer programs that implement various combinations of them. In fact, there are simply so many that it would be impossible to cover all of them adequately in a short document. What is covered here are some that are commonly used today.

Ham digital communication may be broken down into two categories: keyboard-to-keyboard real time conversational and file transfer. File transfer consists of sending things such as digital image files or text message files. This discussion will concentrate primarily on the keyboard-to-keyboard modes. They are the easiest for beginners to work with.

Digital communication modes vary so widely in operating characteristics that quantities such as baud rate or bits per second are nearly meaningless. When comparing the various modes using different modulation methods and character encoding we generally use Words-Per-Minute (WPM). Even that description suffers some vagueness, as some modes use variable length character encoding so their speeds depends upon the exact text sent. Communications speeds for the different modes vary from a fraction of a word per minute to a thousand or more.

Digital communications via radio is legal on most of the ham bands. 60 meters is the current exception. VHF digital communications is gaining in popularity as hams are discovering that some of the digital modes can be heard farther and more accurately than either voice or CW. That is true for both SSB and FM transmissions. Operation on the HF ham bands even more popular but has more problems to deal with than VHF.

The communications modes used on the HF ham bands must handle problems not encountered in other environments. HF signal paths tend to be noisy and distorted in ways that make the digital modes used successfully in other environments fail badly. A common voice grade land-line telephone circuit will typically support 56 Kbits per second data rate. A HF SSB voice circuit can reliably support only a small fraction of that. In spite of that, speeds of 300 words per minute or more are possible.

Why Digital Modes?

Ham digital communications is fun. It is also an important part of amateur radio's communications capabilities. Modern digital techniques can provide performance not available with voice or even CW. It is not at all uncommon for successful digital communications to occur with signal levels so low that they are not heard by ear in radio speaker output. Some digital modes can provide error free copy with signals 10 to 15 dB below the noise level.

Digital modes are also great for operation from stations with modest antennas at relatively low transmit power levels. For instance, a typical digital station on the 20 meter band uses a dipole antenna and runs only 50 watts output or less. This makes digital operation good for hams living on residential city lots without much space for large antenna systems. The low transmit power minimizes overload problems in neighbor's electronic equipment. Plus, even if a neighbor's consumer electronic device can't handle a nearby transmitter, digital modulation is not easily recognized as ham radio activity.

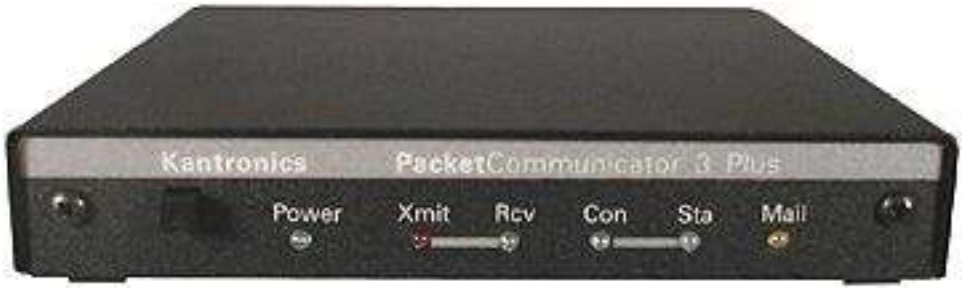
When considering emergency communications, digital communication provides the potential advantage of being able to transfer information error free. Ham support with tactical communications in emergencies and even health and welfare traffic sometimes involves moving lists of items or people's names. That kind of information is often difficult to transfer accurately by voice. Sending a text copy of the information, guaranteed to be accurate at the receiving end, is something that digital communications is good at.

Casual day to day operation using digital modes is popular. Your computer keyboard and screen are used instead of a microphone and speaker. Chatting, or rag chewing in ham parlance, is probably the most common use. As mentioned above, the performance of digital modes allows modestly equipped hams to communicate successfully with stations they would have difficulty reaching on voice.

There is another factor in digital mode popularity. That is the fun of tinkering with the various digital programs and modes. New software and modes are released almost daily, most of which is free to experimenters. Software developers are always asking for reports from users about possible problems or desired features. It is a real chance for the average ham to participate in the development of new communications technology.

Digital Mode Hardware

Early digital mode operation usually involved using surplus Teletype equipment. Just keeping some of those machinery marvels working properly added a degree of mechanical challenge to radio contacts. Eventually, dedicated computer terminals and personal computers running terminal programs replaced the noisy mechanical devices.



Kantronics KPC-3 PacketCommunicator ($220)

In years past, digital modes were implemented using dedicated electronic hardware encoders and decoders. This equipment was typically called a Terminal Unit (TU) or Terminal Node Controller (TNC). Prices for this equipment varied from about one hundred dollars to over a thousand. Packet TNCs are still in use and available commercially.

Personal Computers have evolved in power and flexibility so that now, for the most part, the complex functions performed by a dedicated TU or TNC have been replaced by software in your PC. Some sort of connection between your transceiver and your computer is necessary of course but there a number of choices available as to how that is implemented.

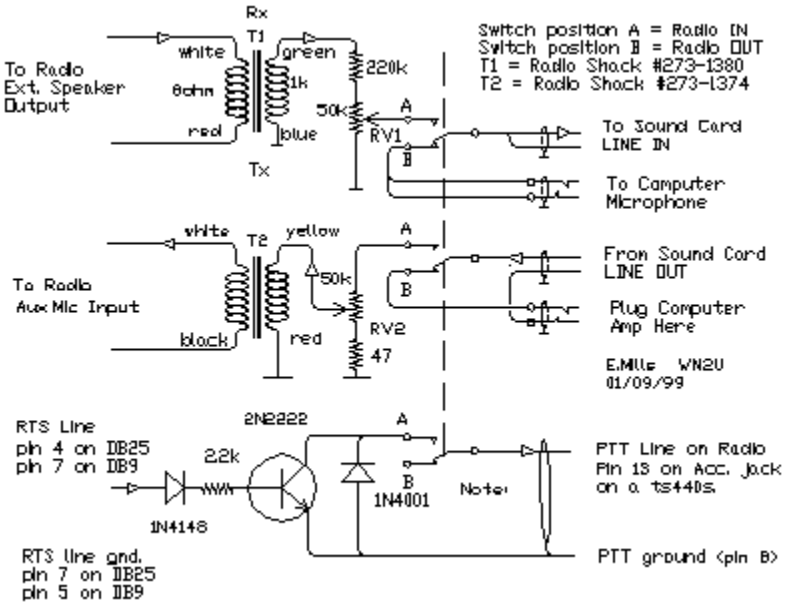
In general, your HF or VHF transceiver's microphone input and receiver audio lines are connected to your computer's sound card. Software decodes the receiver audio and generates transmitted audio. As you might imagine, there are many ways that can be done.

On VHF FM some hams simply hold their microphone next to the computer speaker to transmit their digital signal and place their computer's microphone near the radio speaker. What this method lacks in sophistication it definitely makes up for in simplicity. A more solid connection between your radio and your computer will provide better performance and more convenience but keep this method in mind for emergency situations.

The next step up in an interface between your radio and computer is to run cables between them to carry transmit and receive audio, and operate the push-to-talk line. Making the proper connections to the radio can be tricky since essentially every brand

and model of radio requires a different wiring scheme. Fortunately, instructions for doing this are available in the operator manuals most newer transceivers and is available on the web for older models.

Here is the schematic of a full feature interface box:



Note that the connection between the radio and the sound card in the previous schematic is shown as using the speaker output. If a fixed level auxiliary audio port is available at the back of the radio, change T1 to the same type as T2 and eliminate the 220K resistor between that transformer and the 50K pot.

The above interface is available from several manufacturers. While the West Mountain Radio RIGblaster is best known, there are several other products from other manufacturers. Prices run from $70 to $400 for these units. All of them appear to work equally well with differences primarily in the flexibility and features.

West Mountain Radio RIGblaster plus ($160)

A third choice is available now which most hams find is a better way to make the radio to computer connections. These are interface boxes with built in sound cards. The only connection made to the computer is via a single USB cable. Connection to the radio is usually a single cable also. Prices range from $90 to $400 with the higher end units including additional features such as computer control of your radio.

Tigertronics SignaLink USB ($100)

MicroHAM USB Interface III ($225)
(Includes rig control, direct FSK, etc.)

Regardless of which digital interface model you choose, remember that it will require cables made to operate with your specific radio. Be sure to order the correct cable or cables for your radio.

Yet another kind of hardware is available. That is PACTOR modems. These are used for a variety of messaging and remote email networks. They are used for some emergency communications networks and for email service for private sailing vessels at sea. This option is not particularly popular with the general ham community because of the high cost of the hardware.

SCS PACTOR modem ($1500)

Digital Software

Software for ham digital operation is available in a bewildering variety. Once digital communications migrated to PC soundcard operation, new digital modes and software to support them began popping up on what seems to be a daily basis. Just attempting to keep track of new developments in digital communications became a hobby in itself for some hams. Their efforts provide us with web sites with long listings of software that can be downloaded and used for free.

Many digital software packages are simply slight variations on others while others are the programs that digital communications protocol designers used for testing their ideas. In general though, there is a manageably small list that we need to pay attention to. That list includes some impressive programs.

Though the list is manageable, it is still fairly long. There is enough variety that finding one that matches your operating preferences is not hard. This description will not attempt to describe any more than a small sampling of the good software packages available. In general, the user interface for the various kinds of sound card digital software is similar enough that once you have become familiar with one, you should be able to rapidly learn another. Here are some you might consider as a starting point in learning digital modes and software:

RTTY:

- MMTTY – Very reliable radio teletype program, easy to get started with, and great performance but somewhat advanced in its features. This program and several other interesting free products are available on the following web site: http://mmhamsoft.amateur-radio.ca/

PSK31:

- DIGIPAN – Probably the best known program for PSK31. It is a good beginners program and performs as well as any. DIGIPAN was the program that set the standard for digital program user interface. It was the first popular program to use the waterfall display with point-and-click signal tuning. http://www.digipan.net/

MULTIMODE:

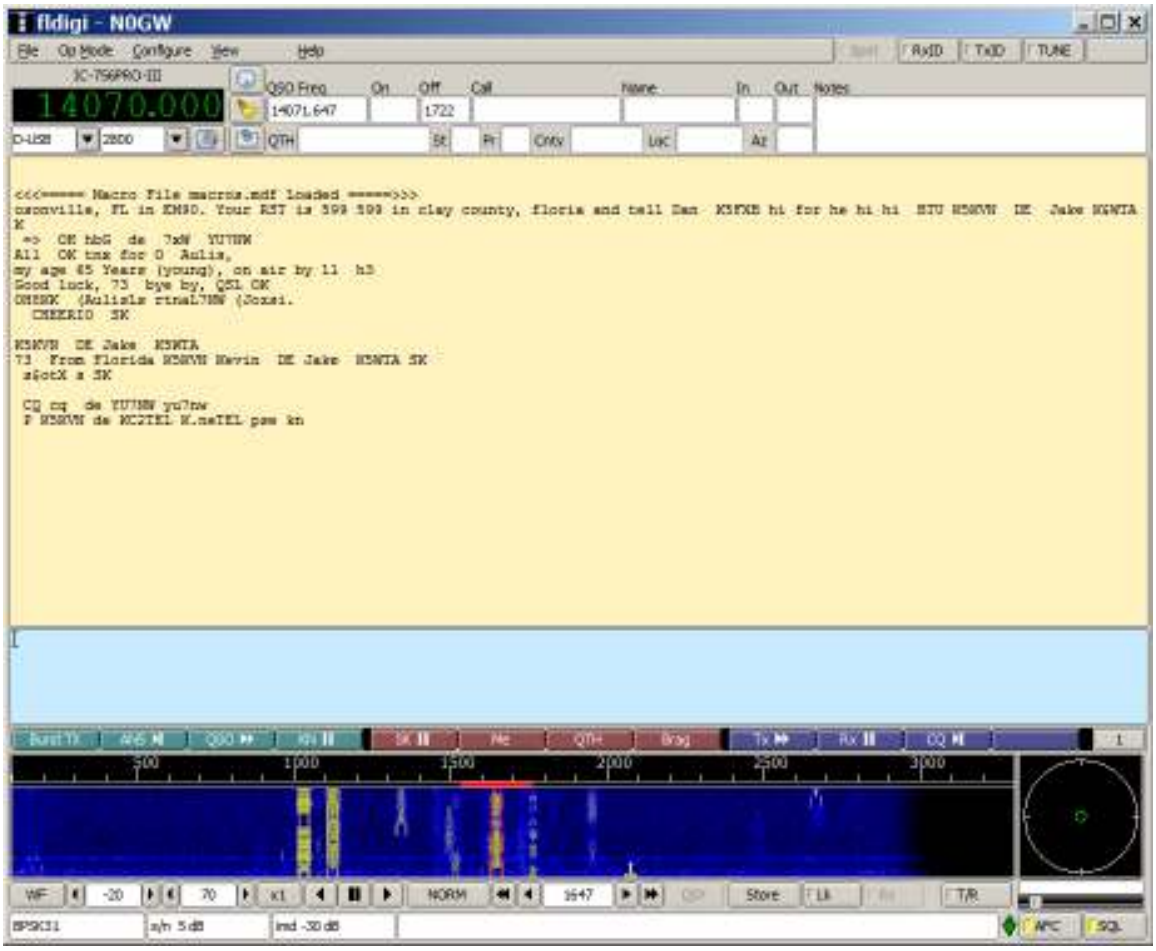
- FLDIGI – This is a relatively new entry into the ham digital software world. It does have a large and active development team who are constantly upgrading this product. Its real claim to fame is its sibling FLARQ. That program interacts with FLDIGI to provide simple to use automatic repeat functionality so error free message passing is possible. That capability is essential for passing messages in a disaster. It supports essentially all the popular digital modes in use today. http://www.w1hkj.com/

MULTIPSK – This is an advanced program that covers even more digital modes than FLDIG and has some very advanced capabilities. With all that capability, MultiPsk's user interface is quite busy so expect to spend a few days getting used to it.
http://f6cte.free.fr/

For a much more complete list see the following web site:
http://www.muenster.de/~welp/sb.htm

Digital User Interface

The screen capture below of the FLDIGI user interface is a good example of what you will encounter. Some programs will be simpler, some can be much more cluttered and complex.



Fldigi screen capture

On the screen above, you will find (from top to bottom) familiar windows buttons, an area for monitoring and controlling your radio, an area for logging your digital contacts, a large (pink) text are where incoming text is displayed, a smaller (light green) area used for typing your transmitted characters, and a row of macro buttons to allow you to send preset text (name, address, age, etc.) and control the digital program.

Below the macro buttons, is an area found on almost all digital programs today. It is called the waterfall display. That area is the key to much of modern digital operation. It is a spectrum representation of the audio pass band (100 Hz to 3300Hz in this example). The spectrum scrolls downward slowly to show you what has been happening over time. Signal strength is indicated by the brightness of the signal. The signals shown in the above waterfall are in the PSK31 mode. Each signal is only about 30 or 40 Hz wide so what you are seeing is actually several digital text conversations in progress between hams in various places in the world. The standard way of choosing which one to monitor is to place your mouse cursor over the waterfall trace and click. The automatic frequency control feature of the program then locks in and starts decoding the signal onto the receive (pink) text box above.

Digital Modes – The Basics

As mentioned above, there are many different digital modes. It is difficult to keep track of them all. Fortunately, they break down into a relatively small number of different types. The most common types are:

On/Off keying

On/Off keying is familiar to us as CW. Morse Code is sent by turning a transmitter's output on and off. This is about a simple as it gets for modulating a transmitter but is not very reliable for computer decoding because of the difficulty differentiating noise spikes from the desired signal. There are other uses for On/Off keying though:

- **CW** – Yes, computers can be used to send and receive CW. It works but receiving is not terribly reliable in the presence of noise, interference, or when signals are weak. *(5 – 60 WPM, -10 dB S/N with experience operator)*
- **HELL** – Nope, not that hot place with the sulfurous odor. This is a communications mode invented in 1929 by a German whose last name happened to be Hell. There are variations of this mode but the most commonly used is FELD HELL that used simple On/Off keying to form visible characters by marking dots on a paper tape. PC programs simulate the paper strip as bands on the monitor screen. The PC program does not attempt to decode the characters as they are received. It merely makes light and dark marks on the simulated paper strip. It is up to the operator to make sense of what is shown. If you hear something like high speed CW that you can't make sense of, it is probably FELD HELL. *(25 WPM, -10 dB S/N)*

Frequency Shift Keying (FSK)

FSK overcomes the decoding problem of CW by transmitting a continuous carrier and shifting its frequency for indicating On/Off conditions, known as Mark/Space in FSK terms. This allows the decoder active redundant information to work with so is more reliably decoded.

- **RTTY** – This is the granddaddy of ham digital modes. Current practice is to use 170 Hz shift of the RF signal frequency with the higher frequency being the Mark

and lower Space. The most common data rate used is 45.45 Baud. RTTY is typically used at high power: 100 watts to 1500 watts. *(67 WPM upper case only, -5 dB S/N)*

- **AMTOR** – This is the ham version of a commercial protocol based upon standard RTTY. It uses an automatic retransmission request protocol to achieve reliable communications. It uses 200 Hz shift at 100 baud. There is also a Forward Error Correction (FEC) mode. AMTOR is normally used with hardware modems. *(0 – 67 WPM, -5 dB S/N)*
- **PACKET** – Designed by hams in 1978 through 1984. It is used extensively on VHF, especially for APRS. HF Packet runs 200 Hz shift at 300 baud. It performs poorly on HF but is still used for automated messaging services. It operates in a dedicated connection mode that allows continuous transmission repeats until a message is finally delivered. It also has an unconnected mode that is used for general broadcast transmissions as with APRS position reports. *(330 WPM, +20 dB S/N)*

Phase Shift Keying (PSK)
Instead of shifting the carrier frequency as in FSK, PSK shifts the carrier's phase, typically by 90 or 180 degrees. PSK modulation has proven to perform quite well on the HF bands, providing acceptable copy under conditions that would be difficult for FSK. PSK is considered a QRP mode. It is commonly used at low power (5 to 50 watts) and with modest antennas, even by DX operators.

- **PSK31** – The most popular keyboard-to-keyboard modes for new digital operators. PSK31 uses 180-degree phase shifts at 31.25 baud with carefully controlled waveforms to produce a very narrow transmitted signal. It is not unusual to see a dozen or more QSOs in progress in a 2 KHz chunk of radio spectrum. A variable length coding for characters is used with the most commonly used characters having shorter codes. Lower case letters are shorter than upper case letters. There are several variation with higher baud rates and some with FEC. *(50 WPM lower case, 37 upper case, -11.5 dB S/N)*
- **PACTOR** –This is a proprietary set of protocols that perform quite well but are protected from general implementation by patents. Dedicated TNC's are needed for PACTOR operation. The current price is about $1500 for a Pactor III modem. *(Performance is very good but it should be for the price)*

Multi-Frequency Shift Keying (MFSK)
MFSK differs from FSK in how it shifts the carrier frequency. FSK shifts between two tones. MFSK shifts between more than two, with 4 to 32 being common.

The advantage of MFSK over simple FSK is that each frequency shift can signal more than one bit of information. As a simplistic MFSK example, consider a four tone scheme. No shift could indicate a sequence of two zeros, or '00'. The second tone could indicate zero followed by a one, or '01', the third, '10', and the fourth, '11'. Each shift would transmit two data bits. Our theoretical 4 tone MFSK signal could shift its tones at half the

speed as a two tone FSK signal for the same transmitted data rate. This gives a decoder twice as long to detect each tone, improving its reliability by a factor of two or better.

The current popular MFSK modes use sophisticated bit coding schemes to produce performance that is quite amazing in weak signal HF communications. The coding schemes are particularly good at ignoring lightning static. Most even manage to do a good job of ignoring non-MFSK signals such as CW on top of the MFSK signal.

- **MFSK16** – This mode has been in use for only about 8 years now. It was the first successful ham implementation of MFSK. It uses 16 tones, spaced 15.625 Hz, at 15.625 baud. It works quite well as a QRP mode, occupying only about 350 Hz bandwidth. There is a version, MFSK8, which operates at 7.8125 baud for better weak signal performance but at half the typing speed. MFSK32 and MFSK64 have been introduced and are becoming popular *(MFSK16: 42 WPM, -13.5 dB S/N)*
- **OLIVIA** – This is a newer mode that expands upon concepts implemented in MFSK16. It has 40 sub-modes that are combinations of 4 to 32 tones and with bandwidth ranging from 250 Hz to 2 KHz. The most commonly used are 32 or 16 tones, 1 KHz wide for DX contacts, 8 or 16 tones, 500 Hz wide for domestic contacts. *(Varies with number of tones and bandwidth: 20 WPM @ -14 dB S/N, 39 WPM @ -10 dB S/N)*
- **DominoEX** – This mode is still experimental but is becoming popular. Its claim to fame is that it is narrow, 140 Hz to 388 Hz, and that it uses a scheme that allows a wide tuning latitude of 60 Hz or more. That is a big plus as most modes require 3 or 4 Hz tuning accuracy. In its current form, it does not seem to handle QRN and QRM as well as OLIVIA. *(Varies with speed, 27 WPM @ -14.5 dB S/N, 154 WPM @ -9 dB S/N)*

Starting Out On Digital

Now, with all this information bubbling in your brain, how do you start with digital communications? You will need a PC with a sound card and a cable to connect your transceiver's receive audio to the microphone input. If you don't want to be troubled with that much work, you can simply place your transceiver's speaker next to your PC's microphone.

That simple receive audio connection will allow you to use essentially all PC based digital software in receive mode. This is a great way to become familiar with software packages and see what is going on in ham digital operation. The best place to start is to tune your transceiver to 14.070 MHz in USB. That is the PSK31 waterhole for the whole planet. Depending upon the time of day, you may see signals from all over the world.

Once you become serious about trying digital operation, borrow, buy, or steal a digital interface unit designed for your radio and computer. The newer USB based interface boxes with built in sound cards are the easiest way to start. With your transceiver and computer connected, getting on the air is as simple as tuning to the right frequency and clicking a button.