Modulation: Changes in the Flow

Imagine a stream of water flowing through a forest. The stream channel is deep and unobstructed, so the water flows serenely along a straight path. If you tapped the surface of the water with your finger, you would change the flow, causing ripples or some other change. For our purposes, it can be said that you have *modulated* the water.

Radio communications is achieved by modulating a radio wave known as the *carrier*. This wave is steady, like the smooth, undisturbed stream in our example. Modulation involves applying a low-frequency *intelligence signal* — in ham radio, this is usually voice or tones — to that higher-frequency carrier signal. This intelligence is like the finger in our example. Just as the stream bears the marks of the finger's touch, the carrier wave bears the marks of the intelligence signal. The carrier has been changed, or modulated. It's carrying information that wasn't there before.

There are many methods of modulating a carrier, each with advantages and disadvantages. Here's an overview of the major types of modulation.

CW

The simplest technique for transmitting intelligence is to turn the carrier signal on and off in a predetermined pattern that the person on the receiving end can understand, which is what we do when sending Morse code. Samuel Morse invented Morse code to be used with the telegraph, and the code was easily adapted to radio by turning a continuous radio wave on and off. Hams often refer to Morse code as *CW* (for "continuous wave"), but Morse code is only the pattern used when turning the transmitter on and off — it is not truly modulation.

The tone we hear when listening to Morse code is created by *heterodyning*, a process where two higher-frequency signals are combined to produce a lower-frequency signal of a few hundred Hertz that, when applied to a speaker, is detectable by the human ear.

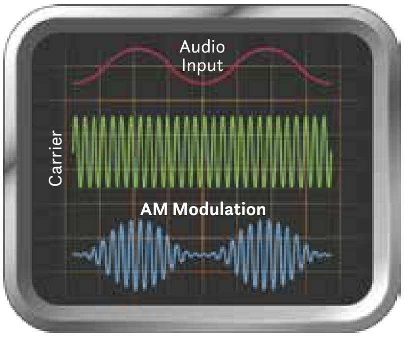
Voice, aka Phone

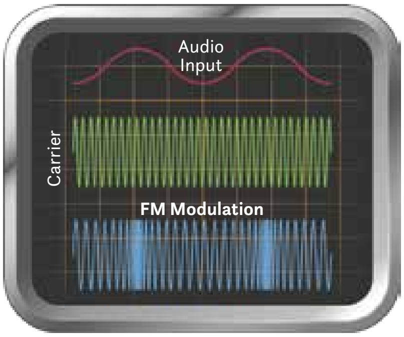
Two familiar methods of modulating a radio signal are *AM* (amplitude modulation), and *FM* (frequency modulation). Most people are familiar with AM and FM because of broadcast radio, and tend to think of AM and FM as frequency bands rather than forms of modulation.

AM — Amplitude Modulation (Including Single Sideband)

In voice radio communications, a microphone converts sound vibrations of a voice into an electrical current. This current, the *audio signal*, is directed through circuitry where it is amplified and embedded in the carrier wave.

If we were to look at an AM signal on a spectrum analyzer, we would see the carrier and two *sidebands*. A sideband is a band of frequencies produced in a modulator from the sum of — *upper sideband* (USB) — or difference between — *lower sideband* (LSB) — the carrier and the information signals. The sidebands are "upper" and "lower" relative to the center frequency of the carrier. All the intelligence is contained in the two sidebands, which are mirror images of each of each other. See the sidebar "Which Sideband Are You On?," on the next page, for more information. ➨





On the ham bands, a typical AM signal with carrier and sidebands is approximately 6 kHz wide. When the carrier is suppressed and one sideband is filtered out, we get a type of modulation known as *single sideband*, or *SSB*, which has a signal that's typically 3 kHz wide. Operating SSB dramatically reduces power consumption, because the transmitter doesn't have to continuously produce a carrier. While AM can deliver high-quality voice transmissions because of its wider bandwidth, the narrow bandwidth and power economy of SSB make it an efficient method for effectively communicating by voice over radio.

FM — Frequency Modulation

Like voice amplitude modulation, frequency modulation for voice communication begins by using a microphone to convert a voice into an electrical current. Instead of varying the intensity of the carrier signal, as AM does, in FM the audio signal is used to deviate the frequency of the carrier. Because ham radio transmissions are used for communication, FCC regulations require hams to use narrowband FM instead of the wider signals that FM broadcast stations use (broadcasting music requires higher fidelity).

Because the amplitude of an FM radio signal is constant, amplitude limiter circuits can be used to eliminate background noise caused by atmospheric conditions and other electrical sources. This gives FM a big advantage over AM, making frequency modulation the most widely used modulation technique in wireless communication. In an FM signal, all power is useful.

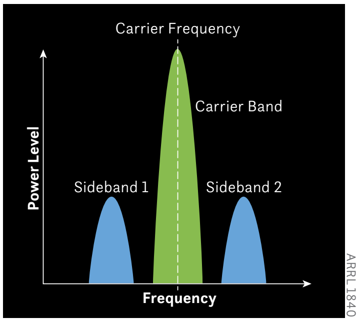
Another advantage of FM is the *capture effect*. When two FM signals are present on the same channel, the receiver will capture the stronger of the two, eliminating the competing signal. All these advantages of FM outweigh what some may consider disadvantages, such as wider bandwidth, an infinite number of sidebands, and complex circuit designs not required for AM.

Tools for Catching a Wave

Two laboratory instruments are used to visually display and analyze waveforms, the oscilloscope and the spectrum analyzer.

Oscilloscopes (at left) display the change of an electrical signal over time. The voltage is the Y (vertical) axis, and time is the X (horizontal) axis. Oscilloscopes allow us to analyze a waveform's properties, such as amplitude, frequency, distortion, and others.

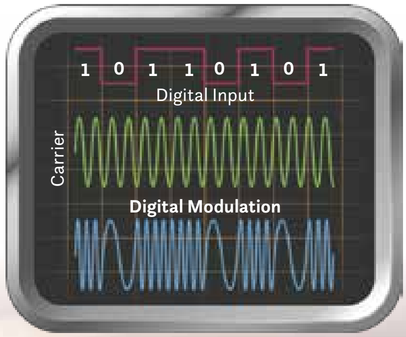
A *spectrum analyzer* (at right) measures the magnitude of an input signal versus its frequency so we can examine things like dominant frequency, power, distortion, harmonics, bandwidth, and other spectral components of a signal.



Which Sideband Are You On?

Sidebands are mirror images of each other, so it doesn't matter which sideband is used for communicating, provided the receiver is operating on the same sideband. Hams use lower sideband (LSB) on some frequencies and upper sideband (USB) on others as a matter of tradition. Early radio designs used a 9 MHz intermediate frequency (IF) circuit that made it easier and less expensive to use LSB for frequencies 7 MHz and below, and USB on frequencies 14 MHz and above. Advances in technology have made this unnecessary. Today most commercial, maritime, and military communication systems that use SSB use USB only.

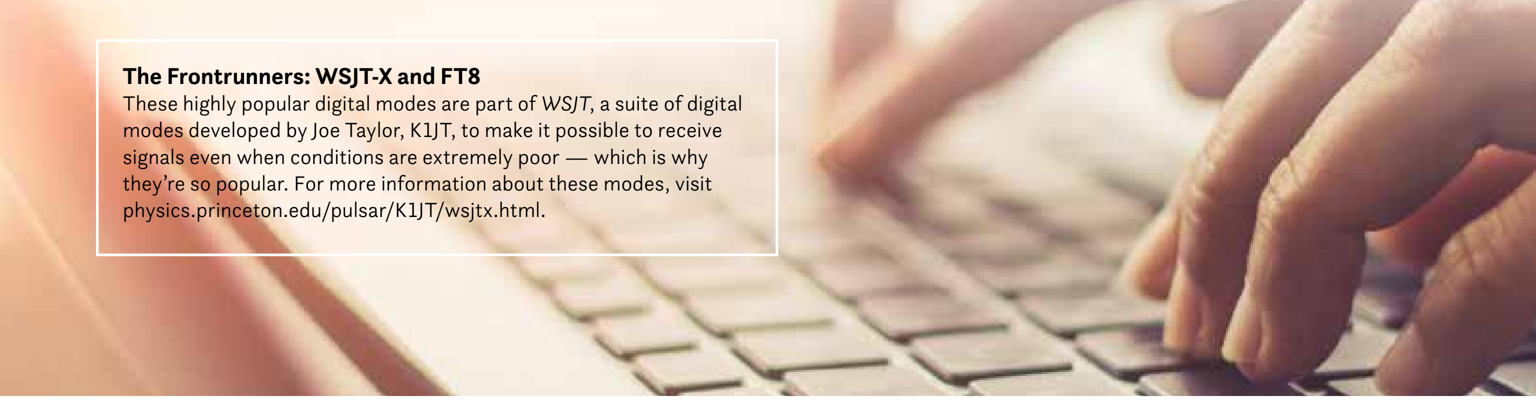
Digital



Many of the numerous digital techniques used in ham radio require messages to be typed on a computer keyboard. This is called *keyboard-to-keyboard communication*. Most digital techniques use *Audio Frequency-Shift Keying* (AFSK).

Although hams refer to these as *digital modes*, AFSK is a modulation technique where a computer converts data into audio tones of varying audio frequency or pitch. The tones are injected into the audio circuits of the transmitter to be sent over the air. The receiver *demodulates* the tones — removes them from the high-frequency carrier — and software decodes them.

The audio tones are transmitted using using LSB or USB, depending on the agreed-upon protocol for the digital technique being used. Because AFSK uses single sideband, that makes it another variation of amplitude modulation.



The Frontrunners: WSJT-X and FT8
These highly popular digital modes are part of *WSJT*, a suite of digital modes developed by Joe Taylor, K1JT, to make it possible to receive signals even when conditions are extremely poor — which is why they're so popular. For more information about these modes, visit physics.princeton.edu/pulsar/K1JT/wsjtx.html.

Radio Teletype (RTTY)

At one time, RTTY (pronounced "ritty") was accomplished using mechanical typewriting machines that responded to codes sent via radio. Computers replaced those machines long ago, but the Baudot (pronounced "baw-DOH") code used for RTTY is still very popular. The five-character Baudot codes can be sent two ways, the most popular being from a computer sound card generating AFSK modulation. The other method is *Frequency-Shift Keying*, where the computer toggles the transmitter output in a way that shifts the frequency ever so slightly to create tones that correspond to the codes being sent. This is a form of FM.

Regardless of which modulation technique is used, two stations can easily communicate using RTTY, even if one station is operating FSK and the other AFSK. You can easily recognize a RTTY signal on the bands by its distinctive "deedle-deedle" sound.

RTTY can be reliable for communicating especially when using high power and gain antenna systems, however, several error-correcting AFSK modes will do a better job, especially in noisy or less-than-desirable propagation conditions.

SSTV — Slow-Scan TV

SSTV is an AFSK technique used to transmit and receive still pictures. The term *slow scan* is a reference to the days when television used scanning electron beams. For television to be able to transmit and receive seamless motion video, the electron beam had to scan very fast (FSTV). Slow scanning beams, on the other hand, could only exchange still pictures. At one time, this mode required complex equipment, but today it's all accomplished with a computer and software. Most ham radio digital mode software packages are in the public domain, and SSTV is just one component of a software bundle.

Find Your Modes

Your amateur radio license allows you to use all sorts of modulation schemes to communicate. It's easy to locate the more popular operating modes like SSB, CW, AM, and and RTTY on the bands. You can search the internet and Facebook for user groups of these and other operating modes. Find some like-minded hams, ask some questions, and give a new mode a try.