COMMON MODES and MODULATION

Modulation is the process by which voice, music, and other "intelligence" is added to the radio waves produced by a transmitter. The different methods of modulating a radio signal are called **modes**. An unmodulated radio signal is known as a **carrier**. When you hear "dead air" between songs or announcements on a radio station, you're "hearing" the carrier. While a carrier contains no intelligence, you can tell it is being transmitted because of the way it quiets the background noise on your radio. The different modes of modulation have their advantages and disadvantages. Here is a summary:

Continuous Wave (CW) CW is the simplest form of modulation. The output of the transmitter is switched on and off, typically to form the characters of the Morse code. CW transmitters are simple and inexpensive, and the transmitted CW signal doesn't occupy much frequency space (usually less than 500 Hz). However, the CW signals will be difficult to hear on a normal receiver; you'll just hear the faint quieting of the background noise as the CW signals are transmitted. To overcome this problem, shortwave and ham radio receivers include a **beat frequency oscillator** (BFO) circuit. The BFO circuit produces an internally-generated second carrier that "beats" against the received CW signal, producing a tone that turns on and off in step with the received CW signal. This is how Morse code signals are received on shortwave.

Amplitude Modulation (AM) In amplitude modulation, the strength (amplitude) of the carrier from a transmitter is varied according to how a modulating signal varies. When you speak into the microphone of an AM transmitter, the microphone converts your voice into a varying voltage. This voltage is amplified and then used to vary the strength of the transmitter's output. Amplitude modulation adds power to the carrier, with the amount added depending on the strength of the modulating voltage. Amplitude modulation results in three separate frequencies being transmitted: the original carrier frequency, a **lower sideband** (LSB) below the carrier frequency, and an **upper sideband** (USB) above the carrier frequency. The sidebands are "mirror images" of each other and contain the same intelligence. When an AM signal is received, these frequencies are combined to produce the sounds you hear. Each sideband occupies as much frequency space as the highest audio frequency being transmitted. If the highest audio frequency being transmitted is 5 kHz, then the total frequency space occupied by an AM signal will be 10 kHz (the carrier occupies negligible frequency space). AM has the advantages of being easy to produce in a transmitter and AM receivers are simple in design. Its main disadvantage is its inefficiency. About two-thirds of an AM signal's power is concentrated in the carrier, which contains no intelligence. One-third of the power is in the sidebands, which contain the signal's intelligence. Since the sidebands contain the same intelligence, however, one is essentially "wasted." Of the total power output of an AM transmitter, only about one-sixth is actually productive, useful output! Other disadvantages of AM include the relatively wide amount of frequency space an AM signal occupies and its susceptibility to static and other forms of electrical noise. Despite this, AM is simple to tune on ordinary receivers, and that is why it is used for almost all shortwave broadcasting.

Single Sideband (SSB) Since so much power is wasted in AM, radio engineers devised a method to transmit just one sideband and put all of the transmitter's power into sending useful intelligence. This method is known as **single sideband** (SSB). In SSB transmitters, the carrier and one sideband are removed before the signal is amplified. Either the **upper sideband** (USB) or **lower sideband** (LSB) of the original AM signal can be transmitted. SSB is a much more efficient mode than AM since all of the transmitter's power goes into transmitting useful intelligence. A SSB signal also occupies only about half the frequency space of a comparable AM signal. However, SSB transmitters and receivers are far more complicated than those for AM. In fact, a SSB signal cannot be received intelligibly on an AM receiver; the SSB signal will have a badly distorted "Donald Duck" sound. This is because the carrier of an AM signal does play a major role in demodulating (that is, recovering the transmitted audio) the sidebands of an AM signal. To successfully demodulate a SSB signal, you need a "substitute carrier." A substitute carrier can be supplied by the beat frequency oscillator (BFO) circuit used when receiving CW signals. However, this means that a SSB signal must be carefully tuned to precise "beat" it against the replacement carrier from the BFO. For best performance, a SSB receiver needs more precise tuning and stability than an AM receiver, and it must be tuned more carefully than an AM receiver. Even when precisely tuned, the audio quality of a SSB signal is less than that of an AM signal. SSB is used mainly by ham radio operators, military services, maritime and aeronautical radio services, and other situations where skilled operators and quality receiving equipment are common. There have been a few experiments in using SSB for shortwave broadcasting, but AM remains the preferred mode for broadcasting because of its simplicity.

Frequency Modulation (FM) In CW, AM, and SSB, the carrier of the signal will not change in a normally operating transmitter. However, it is possible to modulate a signal by changing its frequency in accordance with a modulating signal. This is the idea behind **frequency modulation** (FM). The unmodulated frequency of a FM signal is called its **center frequency**. When a modulating signal is applied, the FM transmitter's frequency will swing above and below the center frequency according to the modulating signal. The amount of "swing" in the transmitter's frequency in any direction above or below the center frequency is called its **deviation**. The total frequency space occupied by a FM signal is twice its deviation. As you might suspect, FM signals occupy a great deal of frequency space. The deviation of a FM broadcast station is 75 kHz, for a total frequency space of 150 kHz. Most other users of FM (police and fire departments, business radio services, etc.) use a deviation of 5 kHz, for a total frequency space occupied of 10 kHz. For these reasons, FM is mainly used on frequency above 30 MHz, where adequate frequency space is available. This is why most scanner radios can only receive FM signals, since most signals found above 30 MHz are FM. The big advantage of FM is its audio quality and immunity to noise. Most forms of static and electrical noise are naturally AM, and a FM receiver will not respond to AM signals. FM receivers also exhibit a characteristic known as the **capture effect**. If two or more FM signals are on the same frequency, the FM receiver will respond to the strongest of the signals and ignore the rest. The audio quality of a FM signal increases as its deviation increases, which is why FM broadcast stations use such large deviation. The main disadvantage of FM is the amount of frequency space a signal requires.

Digital Modes Digital modes can organize information into **packets** that contain address fields, information about the transmission protocol being used, error detection code, a few hundred bytes of data, and bits to indicate where each packet begins and ends. Instead of transmitting messages in continuous streams, packet modes break them into packets. At the receiving end, the different packets are re-assembled to form the original message. If a packet is missing or received with errors, the receiving station can request a retransmission of the packet. Packets can be received out of sequence or even from multiple sources (such as different relaying stations) and still be assembled into the original message by the receiving station. While packet modes have mainly been used to send text, any information that can be converted into digital form---sound, graphics, video, etc.---can be transmitted by digital modes. Another advantage of packet modes is that packets can be addressed to specific stations in the address field of each packet. Other stations will ignore packets not addressed to them. The big disadvantage of packet modes is the complexity of the necessary receiving and transmitting gear. The frequency space occupied is directly proportional to the speed at which messages are transmitted, and radio digital modes are very slow compared to their Internet equivalents. The slowest Web connection via the Internet is 14,400 baud (14.4K), while the maximum practical digital mode rate via radio is 9600 baud (9.6K). On frequencies below 30 MHz, it is even slower; rates are usually restricted to just 300 baud (0.3K)! As a result, digital modes via radio today deliver performance far short of their potential. Special receiving adapters for packet modes are available, and these usually work in conjunction with personal computers. Most offer FSK receiving capabilities as well. Another form of digital modulation is known as **spread spectrum**. Most other modulation methods pack all of the transmitter's output power into a bandwidth of only a few kHz. (Even in FM, the carrier doesn't occupy much bandwidth, although its frequency may be deviated over a wide range.) Spread spectrum literally "spreads" the carrier over a frequency range that may be as much as 10 kHz on frequencies below 30 MHz. (Spreading over 100 kHz or more is common on the VHF and UHF bands.) This spreading is usually done via a "spreading code" contained in an internal microcontroller chip. When heard on a conventional receiver, spread spectrum sounds like random noise or "gurgling" water. A receiver equipped with a microcontroller having the matching "spreading code" is necessary to properly receive the spread spectrum transmission. Advantages of spread spectrum include a high degree of privacy and freedom from interference, since the spread spectrum receiver will reject any signal not having the proper spreading code. Almost all users of spread spectrum below 30 MHz are various military and government services.