3.17.1.5: Transmission

Electronic signals may be transmitted as current flows in wires, pulses of light in fiber optic cables and by electromagnetic waves. There are three basic formats in which to send the information; amplitude modulation (AM), frequency modulation (FM), and phase modulation (digital).

As we saw earlier, a radio wave is emitted from an antenna when charge in the antenna is up and down as shown in the simulation of radio waves in Chapter 5. We can change the frequency of the emitted wave by changing the rate at which we move the charge in the antenna back and forth. The amplitude of the wave can be changed how far the charge moves up and down. Suppose you want to send a sine wave signal to the receiving antenna. The easiest way would be to simply move the charge in the antenna with the same frequency and amplitude as the sine wave you want to send. So far so good, the receiving antenna and amplification system can be tuned to that frequency. The problem comes when you want to send a different frequency. Then the receiving system has to tune to a new frequency. We know from Fourier analysis that sound (and therefor the electrical signal carrying it) can be thought of as a combination of many sine waves, each with a different amplitude and frequency. This causes a difficulty for the receiving antenna system because it can only be tuned to one frequency at a time.

In ***amplitude modulation*** (AM) a carrier wave with a constant frequency has its amplitude changed to encode the signal. The changing envelope of the carrier wave represents the signal being sent. The receiving antenna is tuned to the carrier frequency but the electronics on the receiving end decodes the amplitude as the signal and ignores the carrier frequency.

In ***frequency modulation*** (FM) the carrier's frequency is adjusted slightly up or down to indicate the signal being sent. The electronics on the receiving end interpret the slight variation in frequency as changes in the signal being transmitted. A simulation of both is shown below.

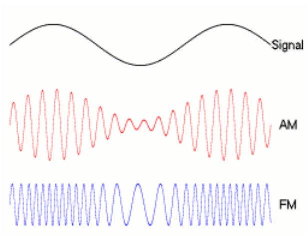

Figure $3.17.1.5.1$

There are advantages and disadvantages to both AM and FM. The AM carrier signal uses longer wavelengths and these waves will reflect off a charged region in the upper atmosphere called the ionosphere. FM, which has shorter carrier wavelengths, does not. As a result, an FM station has to be in direct line of sight in order for the waves to be received. Cell phone and TV signals are also shorter wavelengths than AM and have the same problem; you have to be within sight of a cell tower or a TV tower to receive a signal. AM signals, on the other hand, because of their longer wavelengths (lower frequencies), will reflect off the ionosphere and can be received at long distances from their source, as seen in the diagram below. Shortwave radio and ham (amateur) radio use wavelengths only slightly shorter (wavelengths between AM and FM) than broadcast AM and can be transmitted around the world. Because the ionosphere is higher at night due to temperature changes and the effect of the sun on the layer, the range of AM, ham and shortwave reception improves at night.

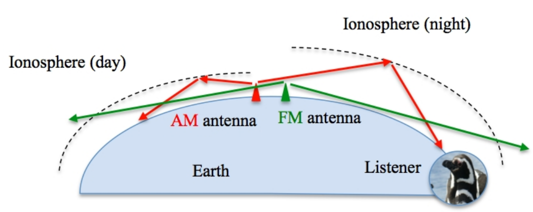

Figure $3.17.1.5.2$

An advantage of FM over AM is that FM can transmit a higher quality signal. If a signal varies too rapidly the signal amplitude might vary faster than the carrier frequency for AM. This does not happen with FM because the carrier wave has a higher frequency. The fact that the amplitude remains constant for FM also means the strength of the signal does not vary whereas a weak AM source might be lost at points where the signal amplitude is low.

A final difference in the quality of AM versus FM signals has to do with the effect of static from other sources such as lightning, car spark plugs and other random noise. Random electromagnetic noise will change the amplitude of both AM and FM carrier signals. But because the information resides in changes to the frequency of the carrier for FM, the quality of the signal is not as affected by changes in amplitude due to static noise.

Digital signals such as WiFi and Bluetooth involve sending a signal where the phase of the carrier wave is shifted relative to a reference wave. A code or key is set up in advance so that a particular shift in phase indicates a predetermined binary number. The phase shift is measured using a device called a lock-in amplifier that compares the arriving signal to a local reference frequency. Some digital signals involve sending several phase shifted frequencies at the same time at different carrier frequencies and there are several different ways to set up the key that matches the phase to a binary number. Digital signals typically use carrier waves of much higher frequencies than FM or AM so that information can be transmitted at a higher rate. As a result of the higher frequencies, however they suffer some of the same limitations of FM; the antennas must be in direct line of sight in order to communicate. Digital WiFi signals are also sent at much lower power than radio transmission and so are of short range, typically 30 m indoors and up to 100 m outdoors.

Summary

Recording generally starts with sound waves that are analog in nature. A microphone converts the vibrations in the air into an analog electrical signal; the amplitude and frequency of the electrical signal matches the sound amplitude and frequency. Vinyl and tape are analog recordings of the sound; the amplitude and frequency of the groove vibrations or the amplitude and frequency of the magnetic fields in the tape vary the same way as those of the sound source. For digital recordings the analog signal from the microphone is converted to a binary digital signal which is recorded as ones and zeros on a CD, DVD or disk drive. Electronic instruments create digital signals directly (MIDI) which can be recorded or manipulated with a computer. Digital signals are converted into analog signals, amplified and then sent to a speaker to convert them from electrical analog signals to sound vibrations. Here is a schematic of electronic recording and transmission.