EEE
Digital
Assignment
3

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Modulation and Demodulation – Amplitude and Frequency Modulation

Amplitude Modulation

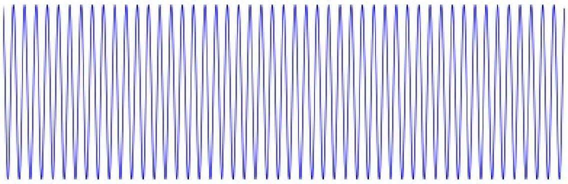
Amplitude modulation (AM) is a modulation technique used in electronic communication, most commonly for transmitting information via a radio carrier wave. In amplitude modulation, the amplitude (signal strength) of the carrier wave is varied in proportion to the waveform being transmitted. That waveform may, for instance, correspond to the sounds to be reproduced by a loudspeaker, or the light intensity of television pixels.

AM was the earliest modulation method used to transmit voice by radio. It was developed during the first two decades of the 20th century beginning with Roberto Landell De Moura and Reginald Fessenden's radiotelephone experiments in 1900.[1] It remains in use today in many forms of communication; for example it is used in portable two way radios, VHF aircraft radio, Citizen's Band Radio, and in computer modems. "AM" is often used to refer to medium wave AM radio broadcasting.

How it Works in latest technology?

Using modulation in radio communications is unavoidable. If, e.g., audio would be transmitted directly as a radio signal, then a single transmission would occupy the complete band, since all audio signals occupy about the same frequency range. Hence, nobody else would be able to transmit at the same time. Modulation moves the signal to (much) higher frequencies, and makes it possible to assign a different frequency to each transmitter. There is also the additional benefit that the size of an antenna is proportional to the wavelength of the signal, so that modulation enables the use of much smaller antennas.

The simplest modulation technique is *Amplitude Modulation* (*AM*), where the amplitude of a *carrier* is varied according to the *message* (e.g., a radio broadcast) that is to be transmitted. A carrier is a simple sinusoidal wave.



Carrier waves

In practice, a carrier such as this one would have a frequency of around 1 MHz for broadcast radio. How to transmit the following message signal by modulating the amplitude of the carrier wave?

Message

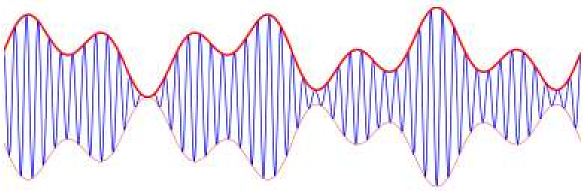
Mathematically, the modulation amounts to multiplying the carrier wave with the message. The carrier wave is defined as

$$c(t)=A\cos(2\pi f_c t),$$

with A the amplitude of the wave and fc the frequency. If the message is m(t), with |m(t)|≤1|, then the AM-modulated carrier is given by

$$c_{AM}(t)=(1+m(t))A\cos(2\pi f_c t).$$

Adding 11 to the message brings it to the range [0,2], so that the carrier vanishes at the smallest message values. The result is shown in Figure 3. The original message is the *envelope* of the modulated carrier.



AM Waves

In practice, the ratio between the frequency of the carrier and the frequencies that are present in the message is typically much larger than shown in this illustration. For broadcast radio, the frequency of the carrier is around 1 MHz, as mentioned before, while the frequencies in the audio signal are limited to about 10 kHz.

Although AM has been almost completely replaced by FM for radio broadcasting, it *is* still in use. It also has the added benefit of being the easiest of all modulation schemes to be explained.

Applications :

- ***Broadcast transmissions:*** AM is still widely used for broadcasting on the long, medium and short wave bands. It is simple to demodulate and this means that radio receivers capable of demodulating amplitude modulation are cheap and simple to manufacture. Nevertheless many people are moving to high quality forms of transmission like frequency modulation, FM or digital transmissions.
- ***Air band radio:*** VHF transmissions for many airborne applications still use AM. . It is used for ground to air radio communications as well as two way radio links for ground staff as well.
- ***Single sideband:*** Amplitude modulation in the form of single sideband is still used for HF radio links. Using a lower bandwidth and providing more effective use of the transmitted power this form of modulation is still used for many point to point HF links.

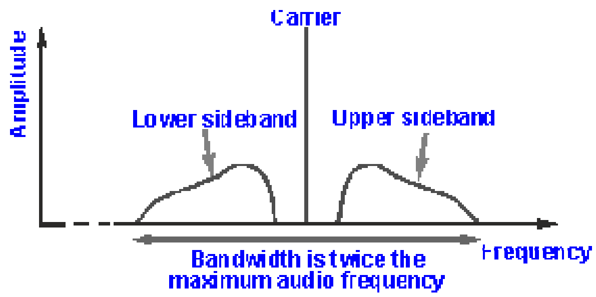
Amplitude Demodulation

The process of separating or extracting the modulation from a signal is called demodulation or detection. For amplitude modulation, the process of demodulation or detection can be accomplished very simply using a diode, or it may be achieved in other ways that provide more effective demodulation of the waveform. As amplitude modulation is still widely used as a result of its simplicity, receivers incorporating AM demodulators are manufactured in quantities of many millions each year. Within these radios a simple AM detector consisting of a diode is used.

How amplitude demodulation works?

In order to look at the amplitude demodulation process it is necessary to first look at the format of an AM signal.

An AM signal consists of a carrier which acts as the reference. Any modulation that is applied then appears as sidebands which stretch out either side of the signal - each sideband is a mirror image of the other.

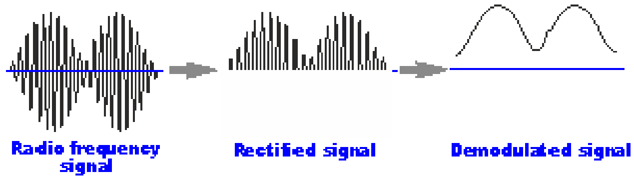


Within the overall AM signal the carrier possess the majority of the power - a fully modulated, i.e. 100% modulation - AM signal has sidebands which have 25% that of the main carrier.

When demodulating a signal, two basic steps may be considered:

- ***Create baseband signal:*** The main element of AM demodulation is to create the baseband signal. This can be achieved in a number of ways - one of the easiest is to use a simple diode and rectify the signal. This leaves elements of the original RF signal. When other forms of demodulation are used, they too leave some elements of an RF signal.
- ***Filter:*** The filtering removes any unwanted high frequency elements from the demodulation process. The audio can then be presented to further stages for audio amplification, etc.

The AM demodulation process is outlined in the diagram below. This particular example applies particularly to a diode detector.



Frequency Modulation

In telecommunications and signal processing, **frequency modulation** (**FM**) is the encoding of information in a carrier wave by varying the instantaneous frequency of the wave. This contrasts with amplitude modulation, in which the amplitude of the carrier wave varies, while the frequency remains constant.

In analog frequency modulation, such as FM radio broadcasting of an audio signal representing voice or music, the instantaneous frequency deviation, the difference between the frequency of the carrier and its center frequency, is proportional to the modulating signal.

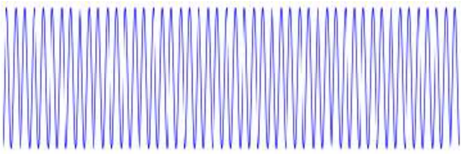
Digital data can be encoded and transmitted via FM by shifting the carrier's frequency among a predefined set of frequencies representing digits - for example one frequency can represent a binary 1 and a second can represent binary 0. This modulation technique is known as frequency-shift keying (FSK). FSK is widely used in modems and fax modems, and can also be used to send Morse code. Radio teletype also uses FSK.

Frequency modulation is widely used for FM radio broadcasting. It is also used in telemetry, radar, seismic prospecting, and monitoring newborns for seizures via EEG, two-way radio systems, music synthesis, magnetic tape-recording systems and some video-transmission systems. In radio transmission, an advantage of frequency modulation is that it has a larger signal-to-noise ratio and therefore rejects radio frequency interference better than an equal power amplitude modulation (AM) signal. For this reason, most music is broadcast over FM radio.

Frequency modulation has a close relationship with phase modulation; phase modulation is often used as an intermediate step to achieve frequency modulation. Mathematically both of these are considered a special case of quadrature amplitude modulation (QAM).

How does it work in the latest technology?

After explaining how amplitude modulation works, the next step is *Frequency Modulation* (*FM*), which you might be more familiar with, since it is widely used for radio broadcasting.



Carrier wave

In practice, a carrier for FM broadcast radio would have a frequency of around 100 MHz (in most countries, the frequency range is 87.5 to 108 MHz). How to transmit the following message signal by modulating the frequency of the carrier wave?

Message wave

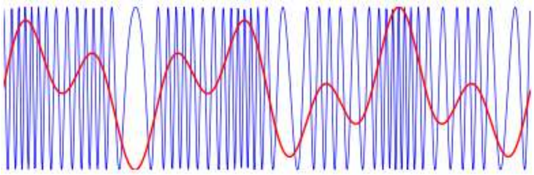
Mathematically, the modulation amounts to changing the frequency of the carrier wave proportionally with the amplitude of the message. The carrier wave is defined as

$$c(t)=A\cos(2\pi f_c t), c(t)=A\cos(2\pi f_c t),$$

with A the amplitude of the wave and fc the frequency. If the message is m(t), with |m(t)|≤1|, then the FM-modulated carrier is given by

$$c_{AM}(t)=A\cos(2\pi f_c t+2\pi f_D \int_0^t m(\tau)d\tau).$$

The parameter fDfD is the *frequency deviation*, which determines how far the frequency of the carrier is shifted away from the nominal frequency fcfc.
The result is shown in Figure 3. It is not possible to directly “see” the message in the modulated carrier, as it was for amplitude modulation, so I’ve drawn the two signals on top of each other. It is clear that the frequency of the carrier varies with the amplitude of the message. Also note that an FM-modulated carrier has a *constant envelope*.



FM Waves

As for AM, the ratio between the frequency of the carrier and the frequencies that are present in the message is typically much larger than shown in this illustration. For broadcast radio, the frequency of the carrier is around 100 MHz, as mentioned before, while the bandwidth of the transmitted message is around 50 kHz (for stereo audio) and this is the basic principle that underlies your FM radio.

Applications

- **Magnetic tape storage**

  FM is also used at intermediate frequencies by analog VCR systems (including VHS) to record the luminance (black and white) portions of the video signal. FM also keeps the tape at saturation level, acting as a form of noise reduction; a limiter can mask variations in playback output, and the FM capture effect removes print-through and pre-echo. A continuous pilot-tone, if added to the signal, can keep mechanical jitter under control and assist correction. These FM systems are unusual, in that they have a ratio of carrier to maximum modulation frequency of less than two; contrast this with FM audio broadcasting, where the ratio is around 10,000.

- **Sound**

  FM is also used at audio frequencies to synthesize sound. This technique, known as FM synthesis, was popularized by early digital synthesizers and became a standard feature in several generations of personal computer sound cards.

- **Radio**

  As the name implies, wideband FM (WFM) requires a wider signal bandwidth than amplitude modulation by an equivalent modulating signal; this also makes the signal more robust against noise and interference. Frequency modulation is also more robust against signal-amplitude-fading phenomena. As a result, FM was chosen as the modulation standard for high frequency, high fidelity radio transmission, hence the term "FM radio" (although for many years the BBC called it "VHF radio" because commercial FM broadcasting uses part of the VHF band—the FM broadcast band). FM receivers employ a special detector for FM signals and exhibit a phenomenon known as the *capture effect*, in which the tuner "captures" the stronger of two stations on the same frequency while rejecting the other (compare this with a similar situation on an AM receiver, where both stations can be heard simultaneously). However, frequency drift or a lack of selectivity may cause one station to be overtaken by another on an adjacent channel. Frequency drift was a problem in early (or inexpensive) receivers; inadequate selectivity may affect any tuner.

Frequency Demodulation

Many FM detector circuits exist. A common method for recovering the information signal is through a Foster-Seeley discriminator. A phase-locked loop can be used as an FM demodulator. *Slope detection* demodulates an FM signal by using a tuned circuit which has its resonant frequency slightly offset from the carrier. As the frequency rises and falls the tuned circuit provides changing amplitude of response, converting FM to AM. AM receivers may detect some FM transmissions by this means, although it does not provide an efficient means of detection for FM broadcasts.