# Amplitude Modulation and Demodulation Basics
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## 1. MODULATION

Amplitude Modulation (AM) simply means changing the amplitude of some signal (usually called carrier in the context of radio transmission) with another signal(called message). It is the most common form of modulation of the radio signals (there are other exotic modulation methods but they are also AM modulation in essence).

Suppose we have a message signal $s(t)$ which could be an audio signal -in that case it is in the frequency range of 20 Hz to 20 kHz-, and we have a carrier signal $\cos(2\pi f_c t)$ at some frequency $f_c$.

The signal:

$$v_t = A[1 + s(t)] \cos(2\pi f_c t) \tag{1}$$

represent the amplitude modulation of the carrier by the signal $s(t)$. As you notice from this equation, $s(t)$ simply multiples the carrier signal (in addition to the carrier itself, think about the constant **1** inside the parentheses). However, it is easier to understand the AM modulation if we use a single frequency modulating signal instead of a complex signal such as audio signals. In other words we let $s(t) = \cos(2\pi f_s t)$. Here we assume our message is a single frequency ($f_s$) signal then the modulated signal becomes:

$$v_t = A[1 + m \cos(2\pi f_s t)] \cos(2\pi f_c t), \tag{2}$$

Here we have added another variable **m** which determines the amplitude of the signal and in general it is called *Modulation Depth*.

There are two major reasons for the modulation: First, if one wants to transmit a signal at a frequency $f$ efficiently, the antenna length must be on the order of the quarter wavelength of the signal ($\lambda = c/f$, where $c$ is the speed of the light). For a 1 kHz signal the wavelength is 300 km!, whereas for a 1 MHz signal it is 300 m. As one can imagine if one translates the signal into a higher frequency-that is modulating a high frequency carrier with it- it is possible to use a smaller antenna.

Second, by translating the signals to different carrier frequencies it is possible to use multiple transmitters without interfering with each other.

The figure below summaries the AM modulation process.

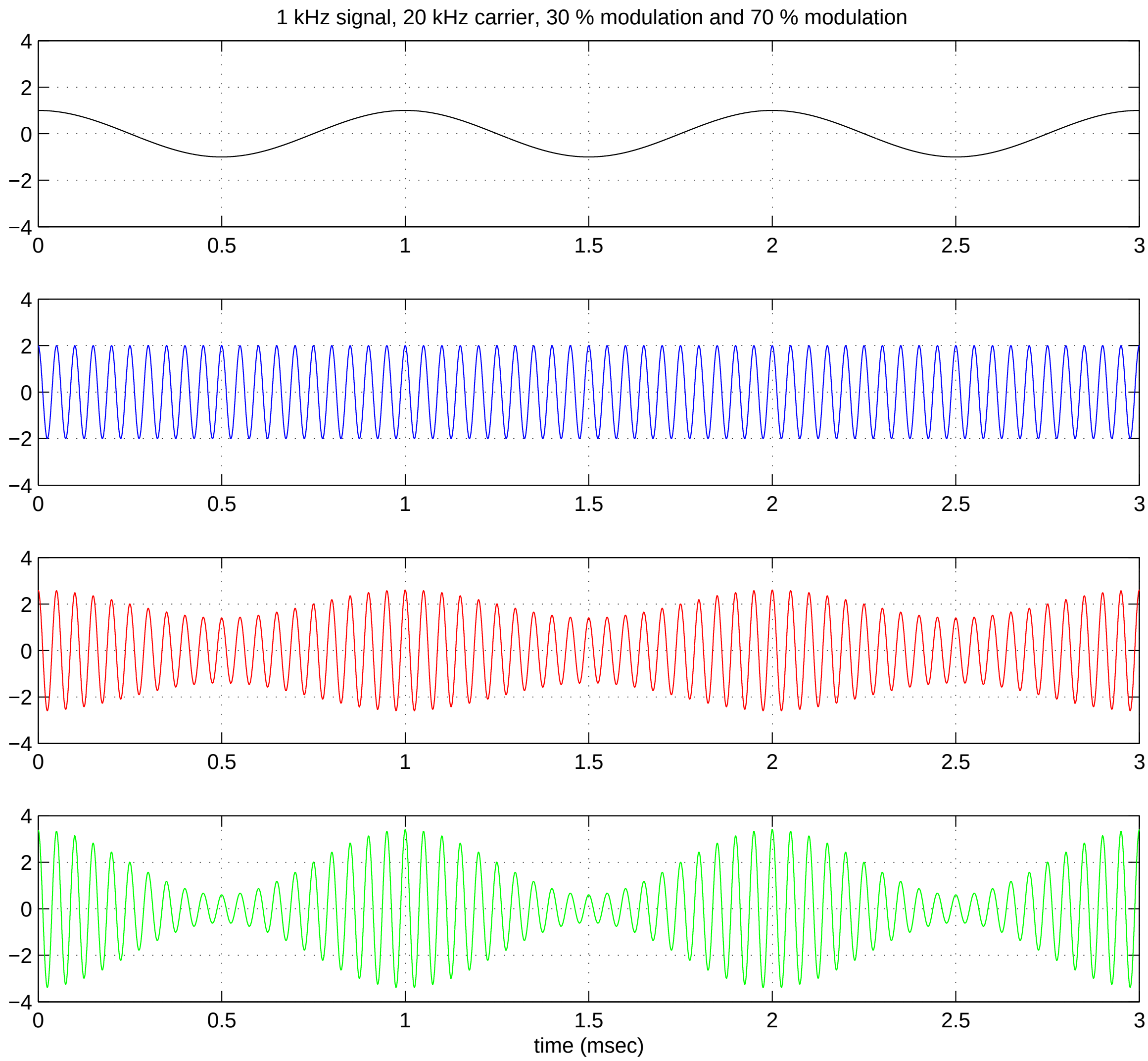


**Figure 1.** Top figure is the 1V amplitude, 1 kHz signal. The figure below that shows 2 V peak amplitude 20 kHz carrier signal. Third figure from the top (red) shows the amplitude modulation of the 20 kHz signal with the 1 kHz signal. Here the modulation index was chosen as 0.3. The last figure (green) shows the modulation for modulation index of 0.7. Modulated signal were obtained by using the Eq [2].

## 2. DEMODULATION

Once the modulated signal is received by the receiving antenna it has to be amplified by several orders of magnitude since the received signal amplitude is quite small usually, say on the order of $\mu V$.

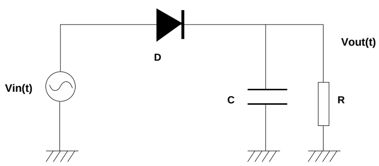


**Figure 2.** A generic AM demodulator. The RC time constant is chosen such that it is much larger than $1/f_c$ but it is much smaller than $1/f_s$, hence the high frequency variations will be smoothed out but the low frequency (signal) variations will remain on the output.

After the amplification, the received signal has to applied to AM demodulator (detector). The output of an ideal demodulator should contain only the signal and should be void of the carrier. The simplest demodulator is formed by a diode, a capacitor and a resistor as shown above. It is a half wave rectifier with a properly chosen resistor and capacitor values!

The figure below shows the input and output of a such demodulator in action:

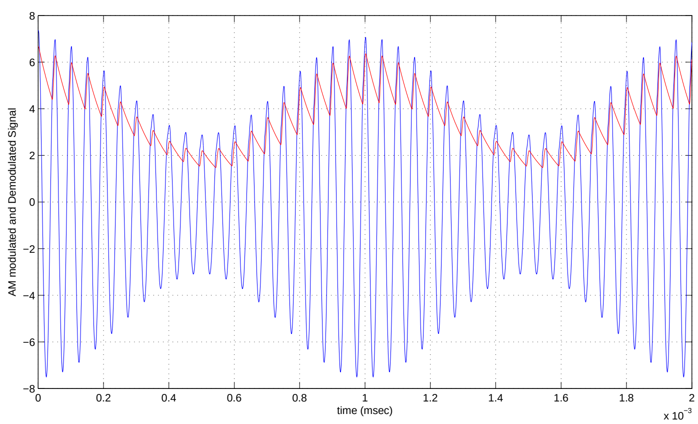


**Figure 3.** Here the blue curve shows a 20 kHz carrier amplitude modulated with a 1 kHz signal. Overimposed red curve is the output of the diode detector. Although not perfect the output curve is almost like the signal. The high frequency (20 kHz in this case) ripples on the signal would be absent if the carrier frequency was much higher. Here we selected the carrier frequency low enough to show the idea clearly.