

1. What is meant by each of the following terms: modulation, modulating signal, carrier signal, modulated signal, and demodulation? Explain the following types of signal modulation giving an application for each case: AM, FM, PM, PWM, PFM. How could the sign of the modulating signal be accounted for during demodulation in each of these types of modulation? Explain, in your own words, how AM modulation and demodulation works. When and why the demodulation process can fail?

Modulation:

According to the textbook, “modulation” refers to signals of which its properties (such as amplitude or frequency) have been varied. According to WikiBooks, modulation is a process of mixing a signal with a sinusoid to produce a new signal.

Modulating Signal:

Modulating Signal is also known as the data signal or the message signal. It is used to vary a property of a carrier signal.

Carrier Signal:

Carrier Signal is used for subsequent handling. The carrier signal is the sinusoidal signal that is used in the modulation.

Modulated Signal: Modulated signal is the combination of the carrier signal and the data signal, which is used for subsequent handling.

Demodulation: Demodulation is the process to recover the data signal from the modulated signal by removing the carrier signal.

AM: Amplitude Modulation.

This is a type of signal modulation in which the amplitude of the carrier signal is modulated in proportion to the message signal while the frequency and phase are kept constant. AM is used in AM radio (long distance radio transmission)

FM: Frequency Modulation

This is a type of signal modulation in which the frequency of the carrier signal is modulated in proportion to the message signal while the amplitude and phase are kept constant. FM is used in FM radio transmission (shorter distance radio transmission with higher quality due to its higher bandwidth).

PM: Phase Modulation

This is a type of signal modulation in which the phase of the carrier signal is varied according to the low frequency of the message signal. PM is used in digital transmission coding schemes that underlie a wide range of technologies like WiFi, GSM and satellite television.

PWM: Pulse Width Modulation

This is a type of signal modulation in which the carrier signal is a pulse sequence of constant amplitude. The pulse width is changed in proportion to the amplitude of the data signal while keeping the pulse

spacing constant. PWM signals are extensively used for controlling electric motors and other mechanical devices such as valves and machine tools.

PFM: Pulse frequency modulation

This is a type of signal modulation in which the carrier signal is a pulse sequence of constant amplitude. In this method, it is the frequency of the pulses that is changed in proportion to the value of the data signal, while keeping the pulse width constant. PFM can also be used in controlling motors, with better response because it is less susceptible to noise.

Accounting the sign:

In PCM (Pulse Code Modulation): an extra sign bit is added to represent the sign of the transmitted data sample.

In AM and FM: a phase-sensitive demodulator is used to extract the original signal with the correct algebraic sign.

In PWM and PFM: A sign change in the modulating signal can be represented by changing the sign of the pulses.

AM in depth:

AM is achieved by multiplying the data signal by a high-frequency (periodic) carrier signal.

$$x_a(t) = x(t)x_c(t)$$

The carrier could be any periodic signal such as harmonic (sinusoidal), square wave, or triangular. The main requirement is that the fundamental frequency of the carrier signal be significantly large (by a factor of 5 or 10) than the highest frequency of interest (bandwidth) of the data signal.

Assuming that the carrier signal is a cosine wave, the modulated signal is:

$$\tilde{x}(t) = \frac{2}{a_c} x_a(t) \cos 2\pi f_c t$$

Taking the Fourier Transform, the spectrum of the modulated signal can be recovered as:

$$\tilde{X}(f) = X(f) + \frac{1}{2} X(f - 2f_c) + \frac{1}{2} X(f + 2f_c)$$

Where the spectrum of the modulated signal is represented as  $X(f)$ , and this can be recovered by using a low pass filter to the modulated signal.

Demodulation failure:

As discussed previously, the spectrum of the modulated signal can be obtained by applying a low pass filter to only recover  $X(f)$ . However, if the frequency band of  $1/2X(f - 2f_c)$  overlaps the spectrum of the data signal, the signal recovered would not consist of purely the data signal, which results in failure.