Modulation Technique:

There are two basic families of continuous-wave modulation techniques:

1. Amplitude modulation, in which the amplitude of a sinusoidal carrier is varied in accordance with an incoming message signal.

2. Angle modulation, in which the instantaneous frequency or phase of the sinusoidal carriers varied in accordance with the message signal.

In basic signal-processing terms, in a communication system, the transmitter consists of a modulator and the receiver consists of a demodulator as

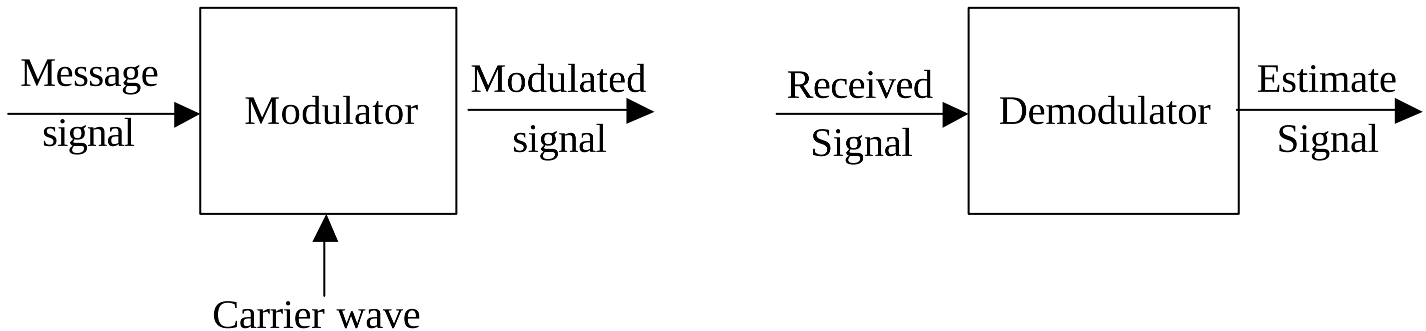

Fig. 1 Components of Modulation system

The degradation in receiver performance due to channel noise is determined by the type of modulation used.

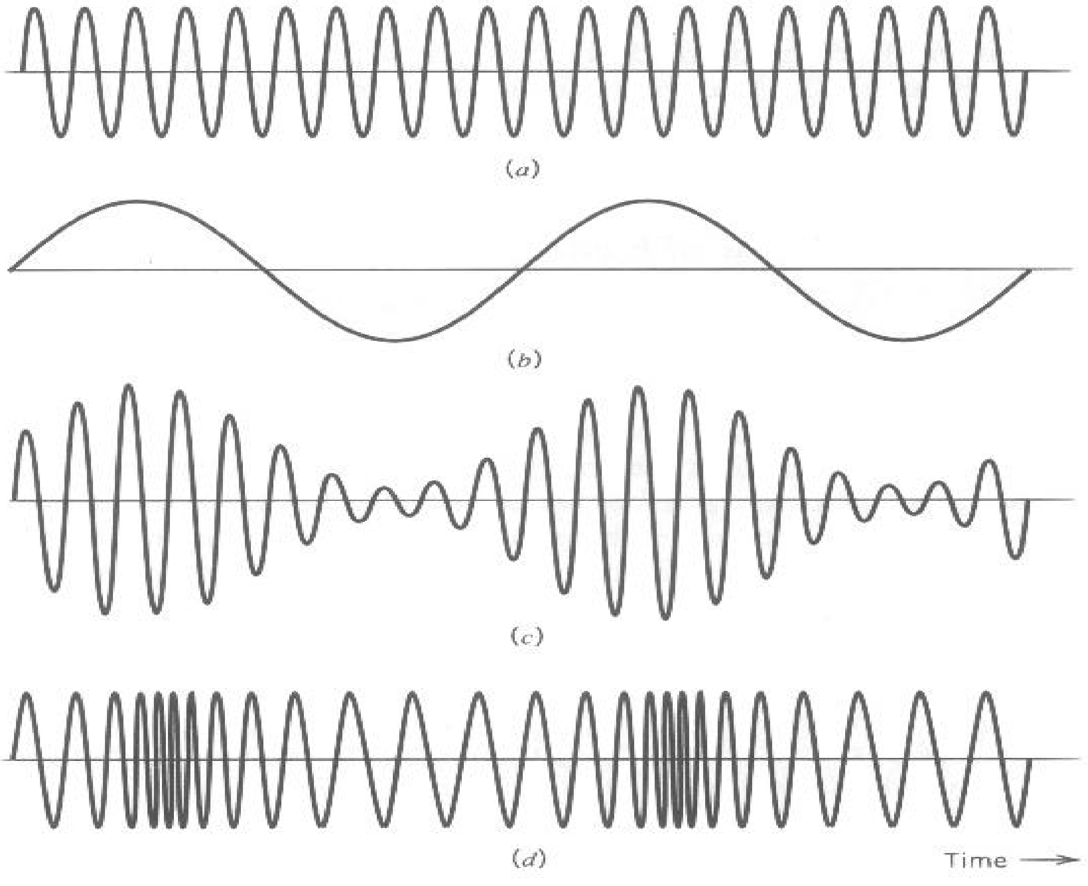

Fig. 2 AM and FM signals

Amplitude Modulation:

Consider the sinusoidal carrier wave c(t) defined as

$$c(t) = A_c \cdot \cos(2pf_c t)$$

A_c is the carrier amplitude and f_c is the carrier frequency. Let *m(t)* denote the baseband signal that carries the message. The modulated signal is as

$$s(t) = A_c \cdot [1 + k_a m(t)] \cdot \cos(2pf_c t)$$

Where k_a is a constant called the amplitude sensitivity, index of modulation, $0 < k_a < 1$.

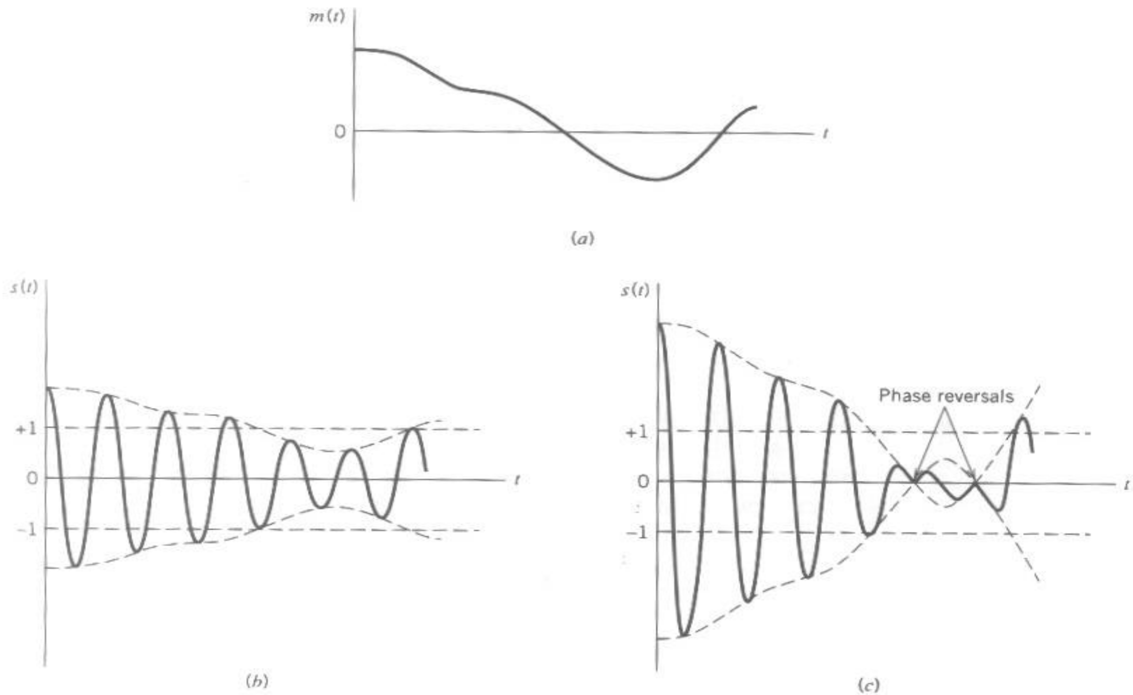

Fig. 3 AM wave with $|k_a m(t)| < 1$ and $|k_a m(t)| > 1$

According to spectrum analysis:

$$S(f)=\frac{A_c}{2}[d(f-f_c)+d(f+f_c)]+\frac{k_a\cdot A_c}{2}[M(f-f_c)+M(f+f_c)]$$

AM Example:

Consider the message $m(t) = A_m \times cos(2pf_m t)$. Find the corresponding AM wave and spectrum analysis.

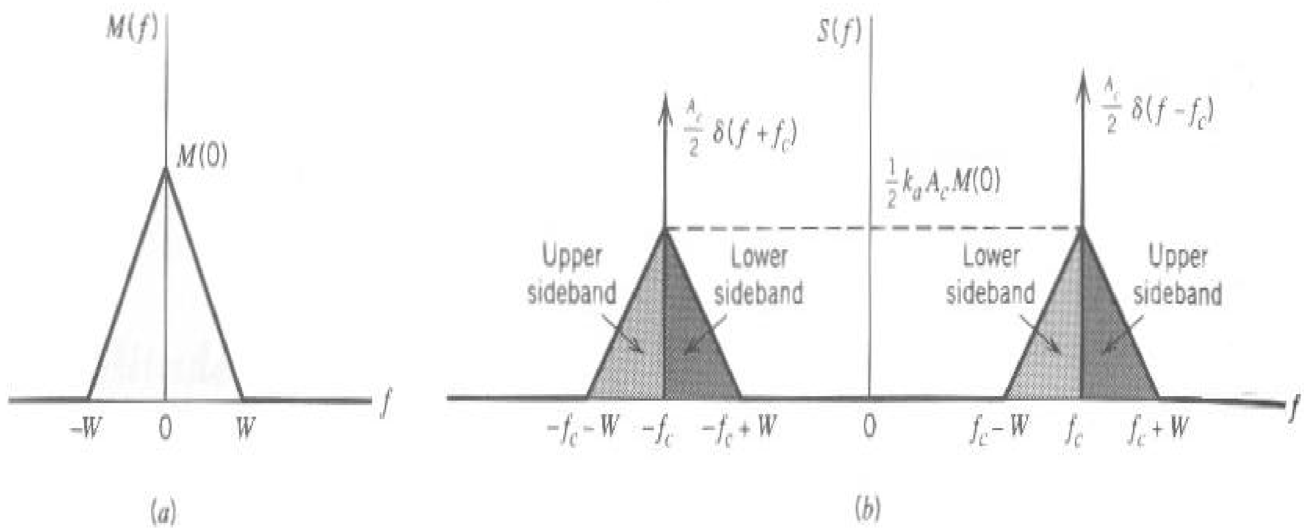

Fig. 4 Spectrum analysis of message signal and AM wave

DSB-AM (Double Side Band AM):

Consider the carrier wave is

$$c(t) = A_c \cdot \cos(2pf_c t)$$

The message signal is *m(t)*. Then, the modulated signal is

$$s(t) = A_c \cdot m(t) \cdot \cos(2pf_c t)$$

The representation of DSB-AM signal in frequency domain is

$$S(f) = \frac{A_c}{2} M(f - f_c) + \frac{A_c}{2} M(f + f_c)$$

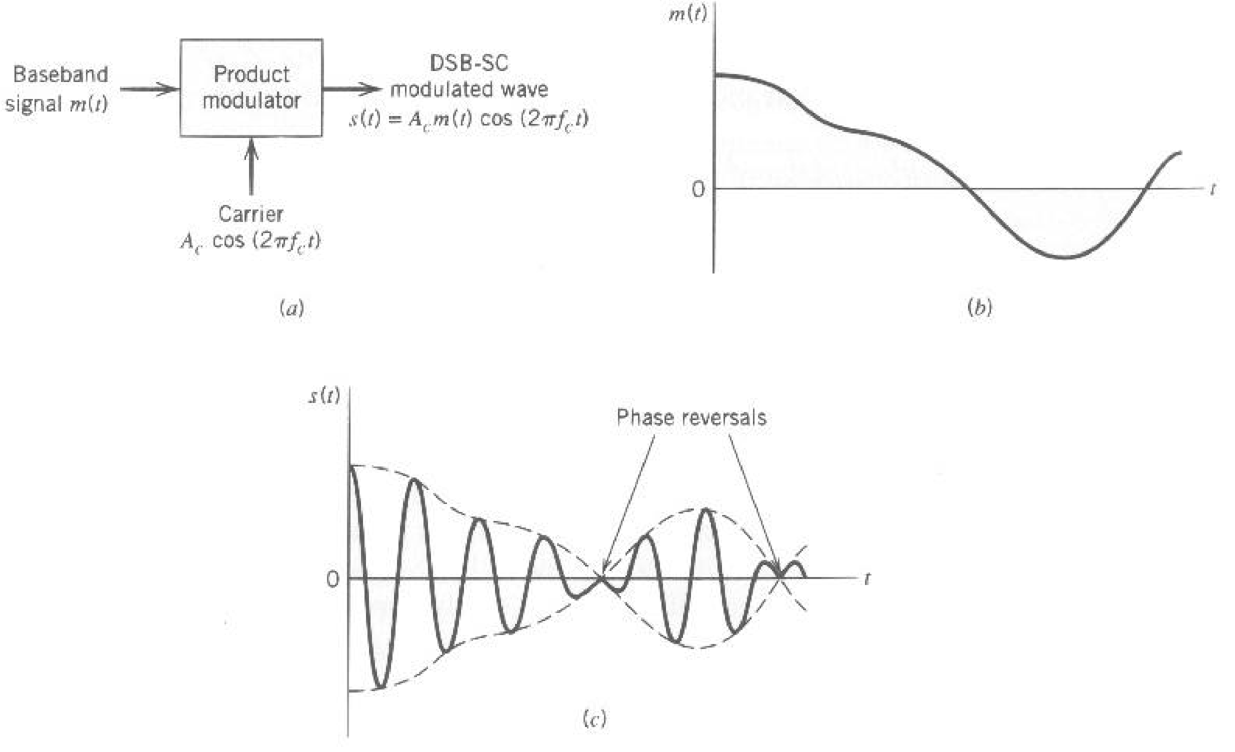
Baseband signal $m(t)$
Product modulator
DSB-SC modulated wave $s(t) = A_c m(t) \cos(2\pi f_c t)$
Carrier $A_c \cos(2\pi f_c t)$
(a)
$m(t)$
0
t
(b)
$s(t)$
Phase reversals
0
t
(c)

Fig. 5 DSB- AM

Assignment:

SSB-AM (Single Side Band AM):

Angle Modulation:

Let $q_i(t)$ denote the angle of a modulated sinusoidal carrier, assumed nto be a function of the message signal. Express the angle modulated wave is

$$s(t) = A_c \cdot \cos[q_i(t)]$$

where A_c is the carrier amplitude. A complete oscillation occurs whenever $q_i(t)$ changes by 2π radians.

$q_i(t)$ may be varied in some manner with the message signal. There are two commonly used methods, as **Phase modulation** and **Frequency modulation**.

Phase Modulation (PM):

$$q_i(t) = 2pf_c t + k_p m(t)$$

The Phase modulated signal s(t) is

$$s(t) = A_c \cdot \cos[2pf_c t + k_p m(t)]$$

Frequency Modulation (FM):

$$q_i(t) = 2p[f_c t + k_f \cdot \int_0^t m(t)dt]$$

The Phase modulated signal s(t) is

$$s(t) = A_c \cdot \cos[2pf_c t + 2pk_f \int_0^t m(t)dt]$$

FM Example:

Consider the message $m(t) = A_m \cdot cos(2pf_m t)$. Find the corresponding FM wave.

Narrow –Band FM:

Consider the FM signal s(t)

$$s(t) = A_c \cdot \cos[2pf_c t + \mathbf{b} \sin(2pf_m t)]$$

$$= A_c \cos(2pf_c t) \cdot \cos[\mathbf{b} \sin(2pf_m t)] - A_c \sin(2pf_c t) \cdot \sin[\mathbf{b} \sin(2pf_m t)]$$

Assume β is small,

$$\cos[\mathbf{b} \sin(2pf_m t)] \cong 1$$

$$\sin[\mathbf{b} \sin(2pf_m t)] \cong \mathbf{b} \sin(2pf_m t)$$

Hence,

$$s(t) \cong A_c \cos(2pf_c t) - A_c \cdot \mathbf{b} \sin(2pf_c t) \cdot \sin(2pf_m t)$$

Assignment: Wide-Band FM

Bandwidth of FM signal:

An approximation for the transmission bandwidth of an FM signal generated by a single-tone message signal of frequency f_m is as

$$B_T \cong 2\Delta f + 2 f_m = 2\Delta f\,(1+\frac{1}{b})$$

where $\Delta f = k_f A_m$.

Another definition is called deviation ratio D, defined as the frequency deviation Δf to the highest modulation frequency W. The deviation ratio D plays the same role for non-sinusoidal modulation and β plays the sinusoidal modulation,

$$B_T = 2(D+1)\cdot f_m$$

Example:

A 20MHz carrier is frequency modulated by a sinusoidal signal such that the peak frequency deviation is 100 KHz. Determine the modulation index and approximate bandwidth of the FM signal if the message signal is (a) 1KHz, (b) 50KHz, (c) 500 KHz.

The given condition: Δf =100K, f_c=20M

For sinusoidal modulation $\beta = \Delta f / f_m$

(a) With f_m=1000 Hz, β = 100K/1000 = 100

$$B_T = 2\Delta f + 2 f_m$$
$$= 2\Delta f \cdot (1 + \frac{1}{b})$$
$$= 2 f_m (1 + b)$$
$$= 202 KHz$$

(b) With f_m=50K Hz, β=2

$$B_T = 300 KHz$$

(c) With f_m=500K Hz, β=0.2

$$B_T \approx 2 f_m = 1 MHz$$

Example,

In North America, the maximum value of frequency deviation Δf is fixed at 75KHz for commercial FM broadcasting by radio. If the modulation frequency W=15KHz, which is the maximum radio frequency of interest in FM transmission?

Corresponding deviation ratio D

$$D = \frac{75K}{15K} = 5$$

The transmission bandwidth of the FM signal is

$$B_T = 2 \cdot (D+1) \cdot 15K = 180KHz$$