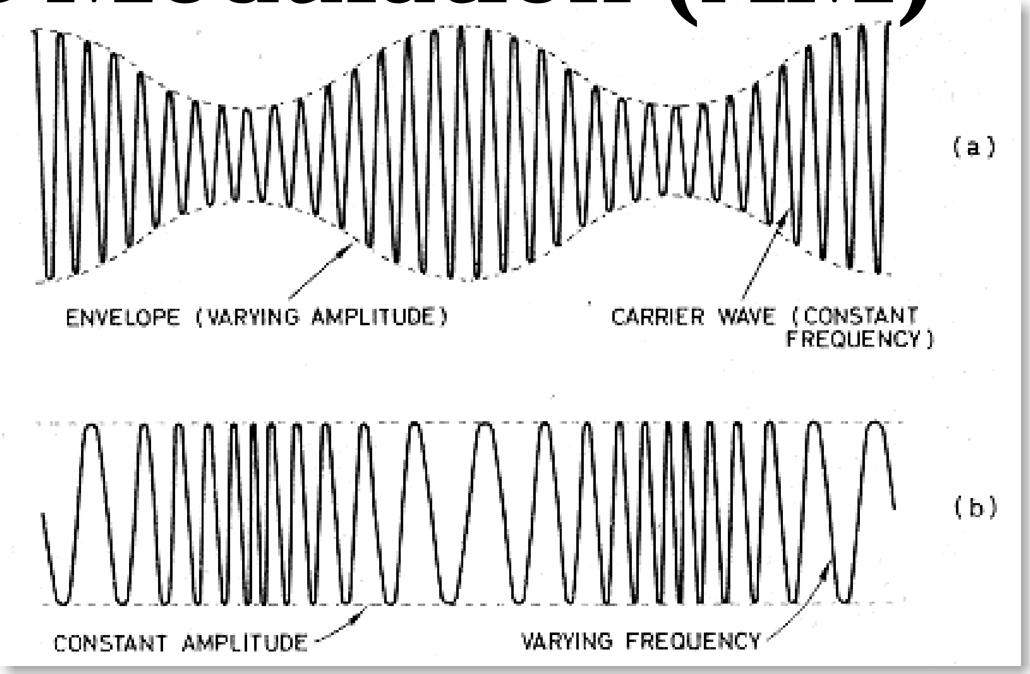
Amplitude Modulation (AM)



Contents

Modulation

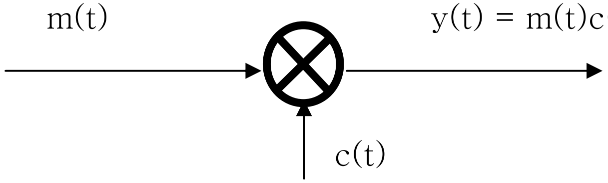
- Modulation is the process of converting a signal from its original form into another, "transmission ready" form
- Modulation → Transmit → Demodulation
- Why modulation?
  - Original signal is rarely in a form that is easy to tx
  - How far can human voice be tx in the air without assistance?
- Modulation is the process of causing some parameter of the carrier signal to vary in relation to the message signal

Amplitude Modulation

- The message signal is represented by variations in the amplitude of the carrier signal
- The amplitude of the message signal is recovered from the amplitude of the carrier
- The frequency of the message signal is recovered from the rate of change in the amplitude of the carrier signal
- AM radio, FDM multiplexers

DSB-SC

Modulator mixes two signals



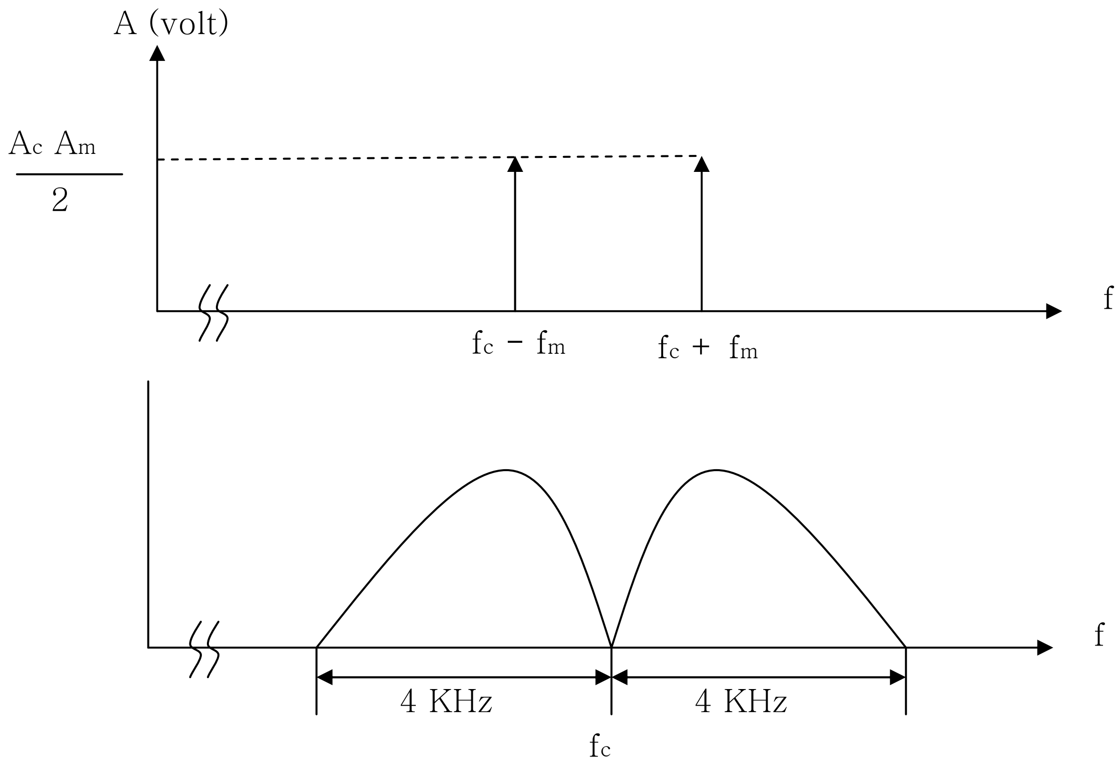
DSB-SC Modulator

$$y(t) = (A_m \cos w_m t)(A_c \cos w_c t)$$

$$= A_m A_c/2[\cos (w_c + w_m)t + \cos (w_c - w_m)t]$$

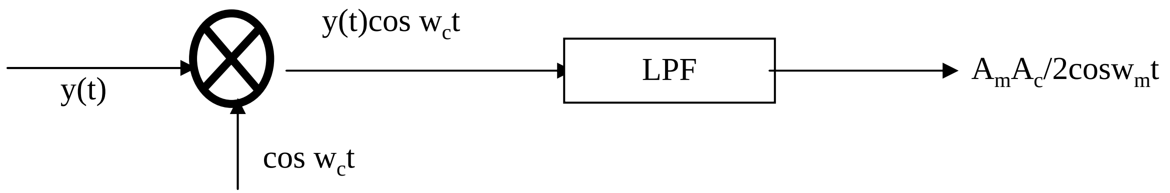
$$= A_m A_c/2[\cos 2\pi(f_c + f_m)t + \cos 2\pi(f_c - f_m)t]$$

DSB-SC



$BW_{AM} = 2\ BW_{BB}$

Demodulation of DSB-SC



The original signal, cos w_ct is added at the demodulator

$y(t)\cos w_ct = m(t)\,c(t)\cos w_ct$

$= m(t)\,A_c\cos w_ct\cos w_ct$

$= m(t)\,A_c\cos^2 w_ct$

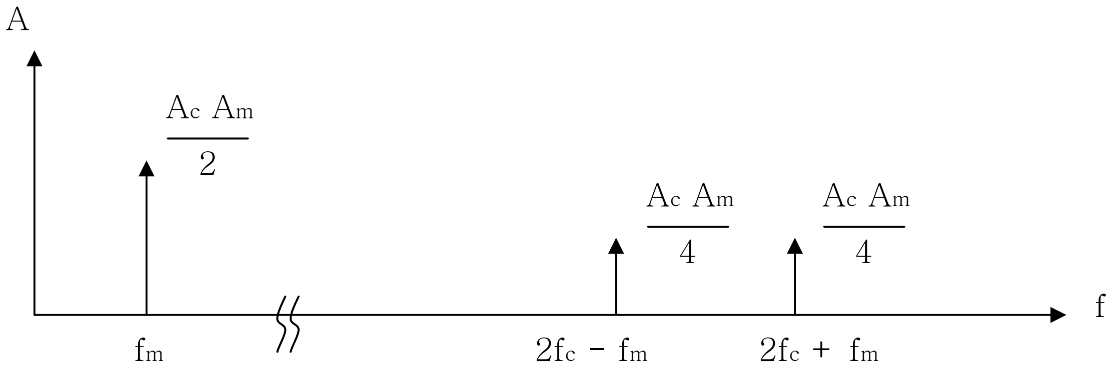
$= m(t)\,A_c\,[1 + \cos 2w_ct]/2$

$= (A_mA_c/2)\cos w_mt + (A_mA_c/2)\cos w_mt\cos 2w_ct$

$= (A_mA_c/2)\cos w_mt + (A_mA_c/4)\,[\cos(2w_c + w_m)t$

$+ \cos(2w_c - w_m)t]$

Demodulation of DSB-SC



After filtering, the same signal is obtained with which we started

DSB-SC technologies are often used for short-haul tx

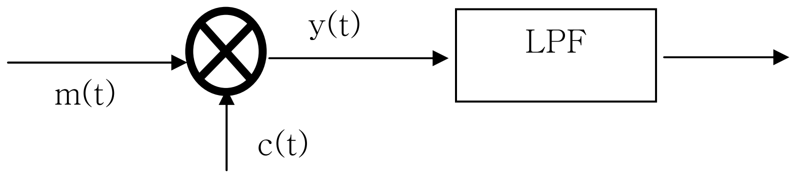
The modulator/demodulator are very simple and inexpensive

SSB

All the information of the original message signal appears in both sidebands

Since two sidebands of the DSB system are redundant, one can be filtered out without loosing any information

By passing the modulated signal y(t) = m(t)c(t) through a LPF before tx, the lower sideband is tx



SSB

(Advantages)

SSB uses half the power and half the BW of DSB

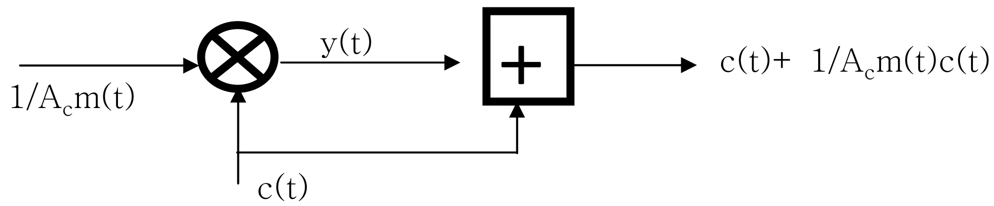
Often used for long-haul tx

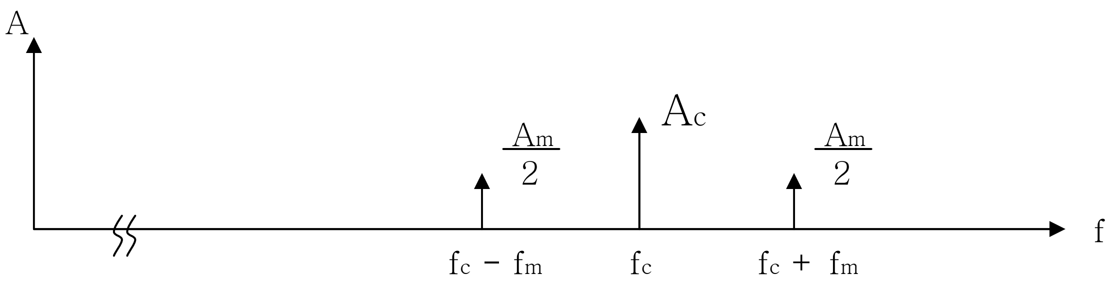
(Disadvantages)

The modulator is more complex

DSB-TC

The carrier signal c(t) is added before tx





DSB-TC

Standard AM

Carrier as well as the sidebands are tx

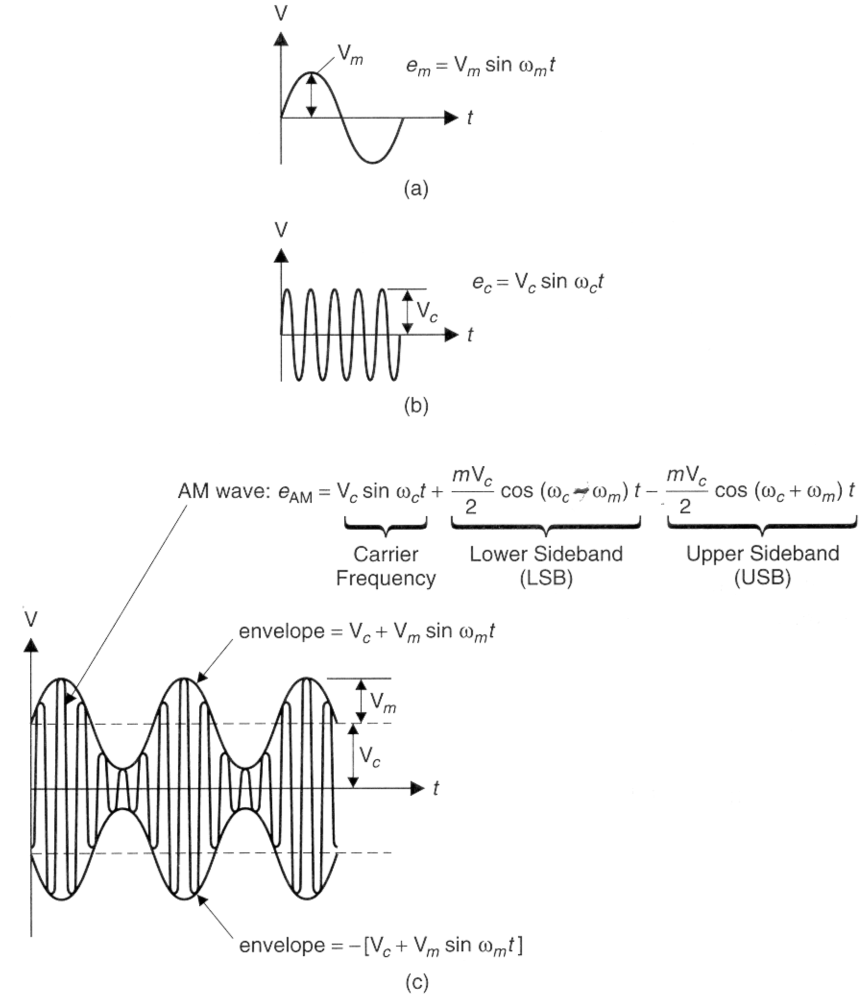
(Advantages)

- A very simple envelop detector (demodulator)
- Reduces Rx cost

(Disadvantages)

- DSB-TC uses more power and more complex Tx
- Increases Tx cost

DSB-TC



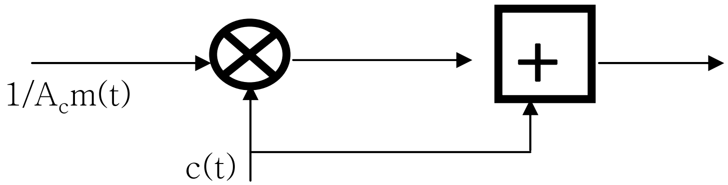
The AM waveform with sine wave modulation shown in the time domain: (a) modulating voltage; (b) carrier frequency; (c) resulting AM waveform

Envelope of AM waveform

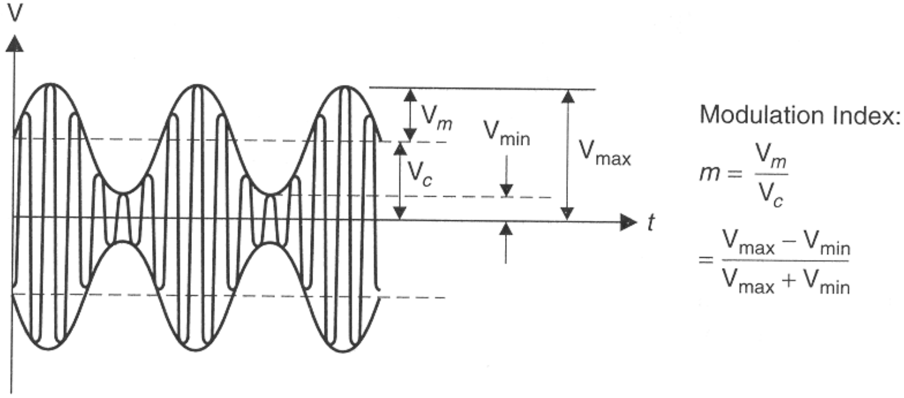
$$A_c + m(t) = A_c + A_m \cos w_m t$$

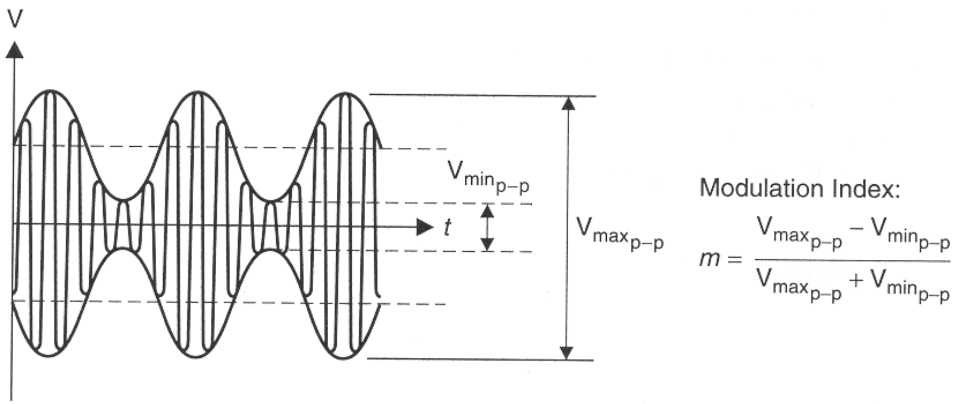
$$= A_c (1 + \beta \cos w_m t)\text{: positive envelope}$$

$$- A_c (1 + \beta \cos w_m t)\text{: negative envelope}$$



Envelope of AM waveform





Measuring modulation index, m, using: (a) peak values, (b) peak-to-peak values

AM waveform from the Envelope

$y(t) = A_c\ (1 + (A_m/A_c) \cos w_m t)\ \mathbf{\cos w_c t}$

$0 \leq (A_m/A_c) \leq 1$: modulation index

$$\beta = \frac{A_m}{A_c} = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$$: in terms of peak voltage

General Signal Equation of DSB-TC

$$y(t) = (1 + (kA_m/A_c)\cos 2\pi f_m t)\,(A_c \cos 2\pi f_c t)$$
$$= A_c \cos 2\pi\, f_c t + (kA_m/2)\cos 2\pi(f_c + f_m)t$$
$$+ (kA_m/2)\cos 2\pi(f_c - f_m)t$$

kA_m/A_c: modulation index

k is a function of the characteristic of the modulator