CHAPTER 5

Amplitude Modulation

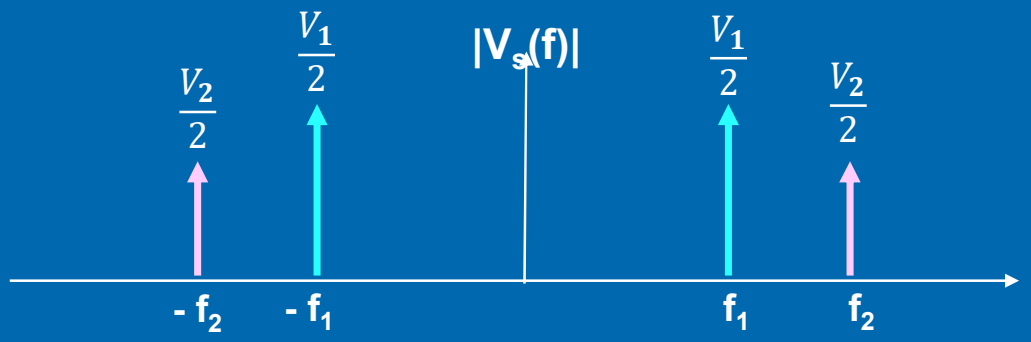
(Part 3 of 4)

5.2 Multi-tone AM signals

- Modulating signal is usually a complex signal known as **Multi-tone** modulating signals.
- An AM signal modulated by a multi-tone modulating signal is known as **multi-tone AM signal.**
- Consider a multi-tone modulating signal

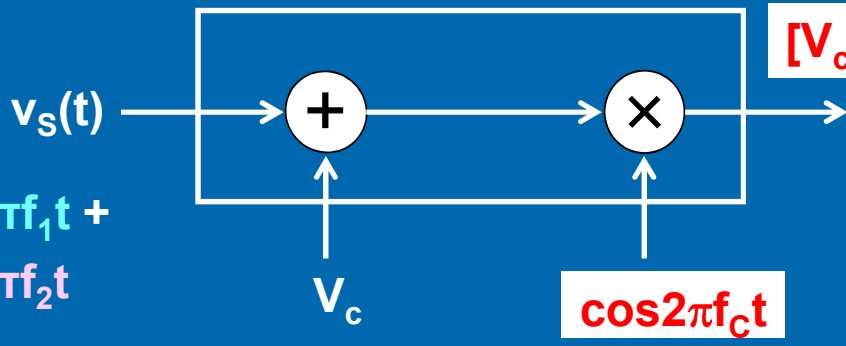
$$v_s(t) = V_1\cos 2\pi f_1 t + V_2\cos 2\pi f_2 t \quad \text{where } V_1 > V_2 \text{ and } f_2 > f_1$$

$$v_s(t) = V_1\cos 2\pi f_1 t + V_2\cos 2\pi f_2 t \xrightarrow{FT} V_s(f) = \frac{V_1}{2}\delta(f - f_1) + \frac{V_1}{2}\delta(f + f_1) + \frac{V_2}{2}\delta(f - f_2) + \frac{V_2}{2}\delta(f + f_2)$$



5.2 Multi-tone AM signals

$\frac{V_c}{2}\delta(f + f_c) + \frac{V_c}{2}\delta(f - f_c)$



$v_s(t) = V_1\cos 2\pi f_1 t + V_2\cos 2\pi f_2 t$

$v_s(t) \overset{FT}{\Longleftrightarrow} V_s(f)$

$v_{AM}(t) = [V_c + v_s(t)]\cos\pi f_c t \overset{FT}{\Longleftrightarrow}$

$= V_c\cos 2\pi f_c t$

$+ v_s(t) \times \cos 2\pi f_c t$

Standard equation for AM signals

$V_{AM}(f) =$

$\frac{V_c}{2}\delta(f + f_c) + \frac{V_c}{2}\delta(f - f_c)$ **carrier**

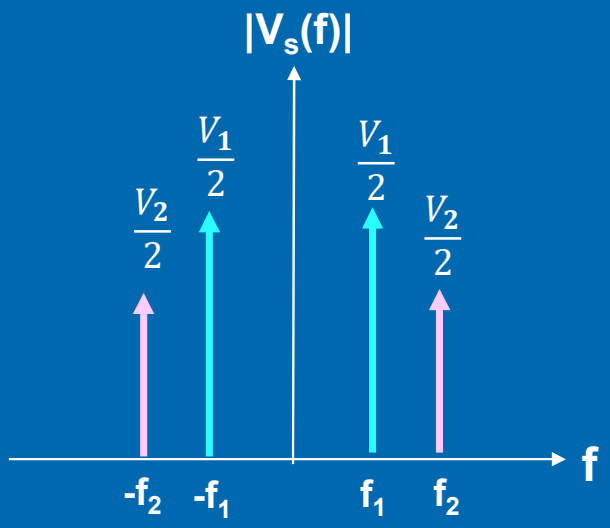
$+ \frac{1}{2}[V_s(f + f_c) + V_s(f - f_c)]$

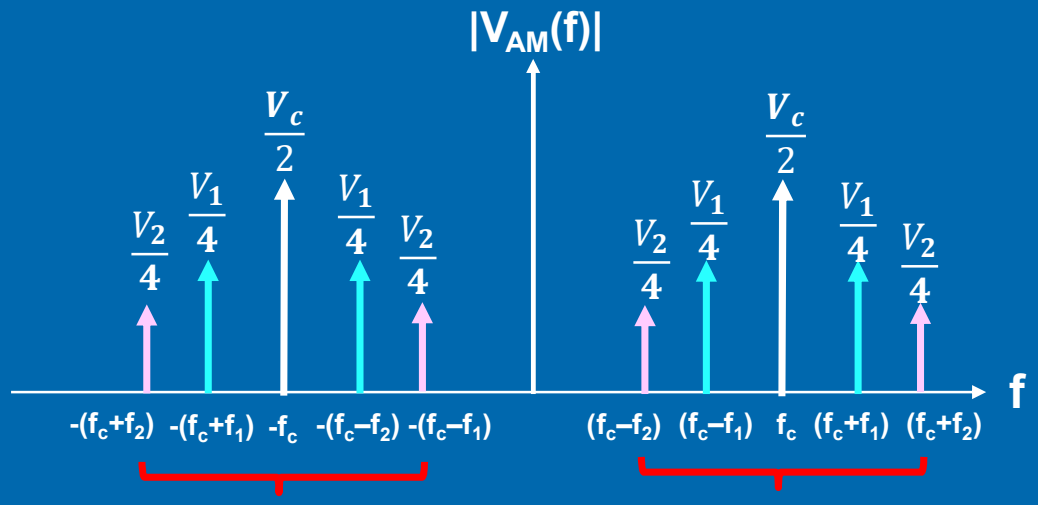
Shift $V_s(f)$ left by f_c

Shift $V_s(f)$ right by f_c

5.2 Multi-tone AM signals

Spectrum of multi-tone AM signal





$\frac{V_c}{2}\delta(f + f_c) + \frac{1}{2}V_s(f + f_c)$

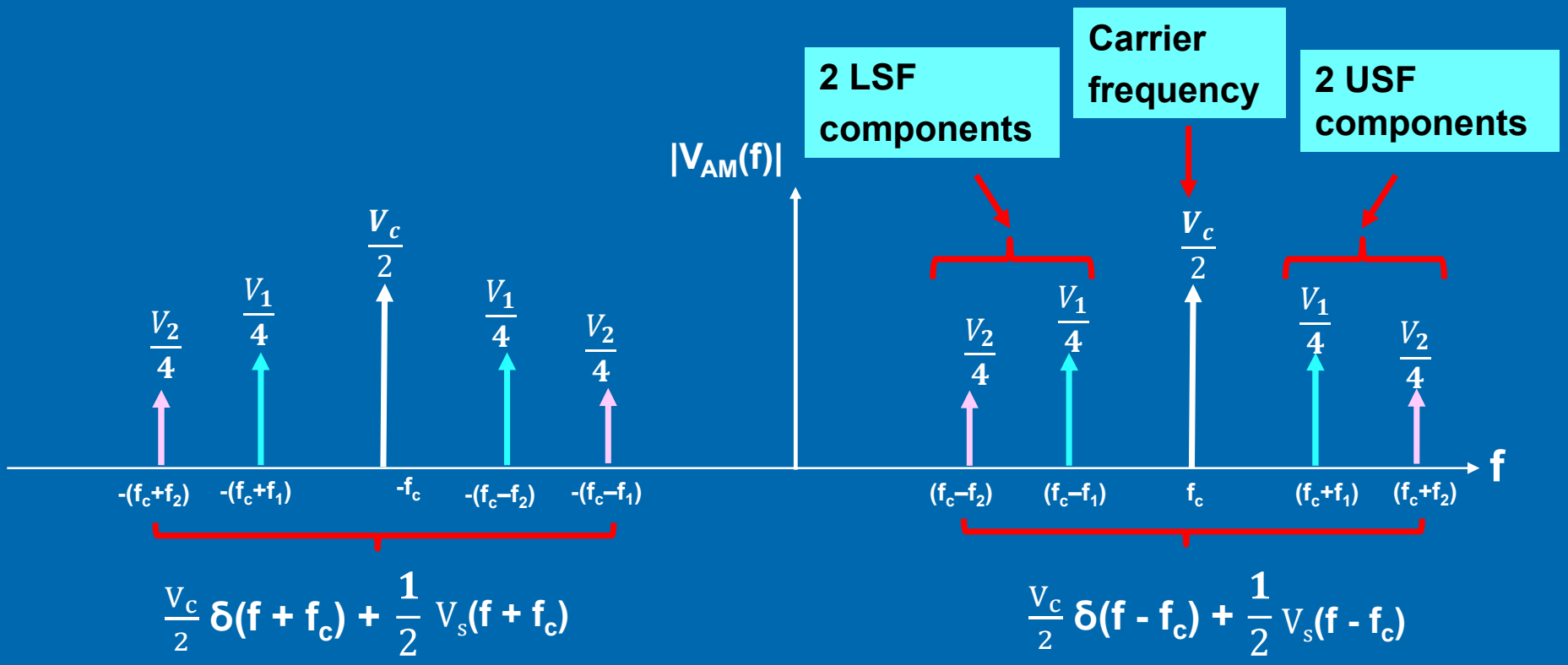
$\frac{V_c}{2}\delta(f - f_c) + \frac{1}{2}V_s(f - f_c)$

Shift $V_s(f)$ left by f_c

Shift $V_s(f)$ right by f_c

5.2 Multi-tone AM signals

Spectrum of multi-tone AM signal



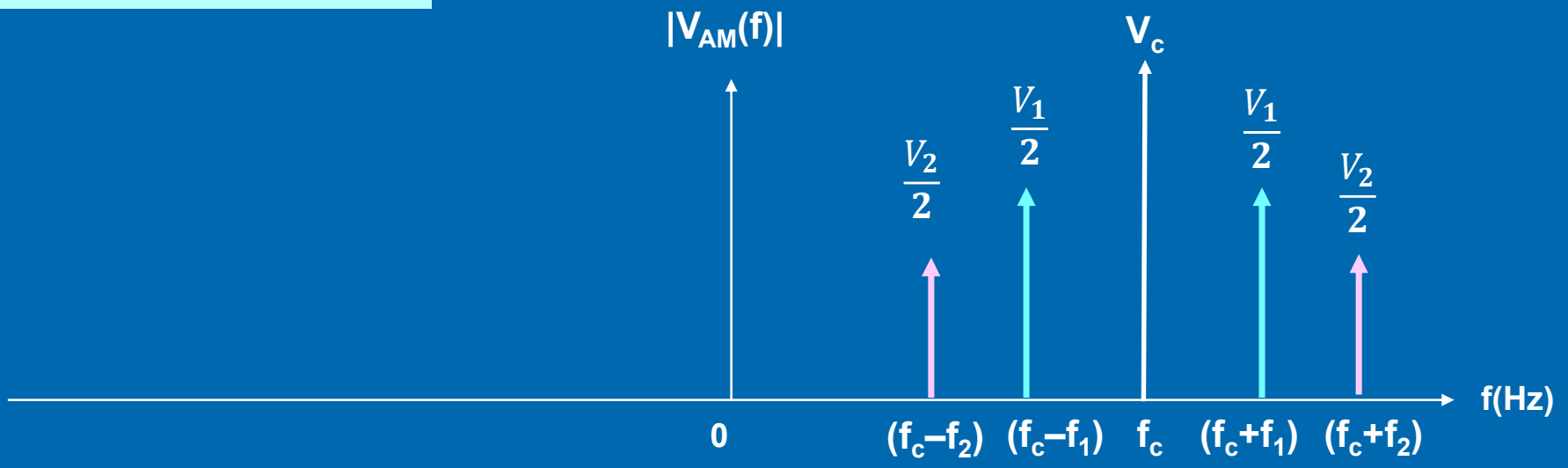
5.2 Multi-tone AM signals

Single-sided amplitude spectrum

Modulating Signal

$$v_s(t) = V_1\cos 2\pi f_1 t + V_2\cos 2\pi f_2 t$$

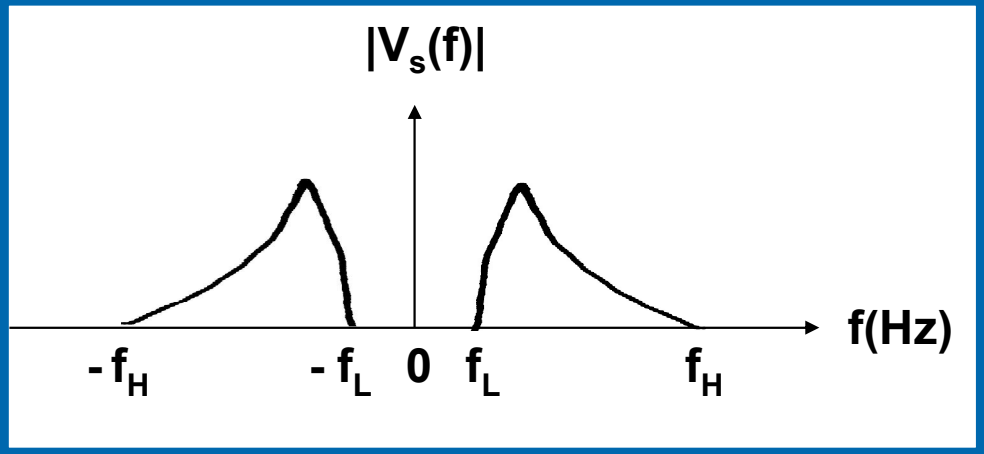
Combine negative and positive frequency components → $2 \times \frac{1}{2}$ $V_s(f - f_c)$



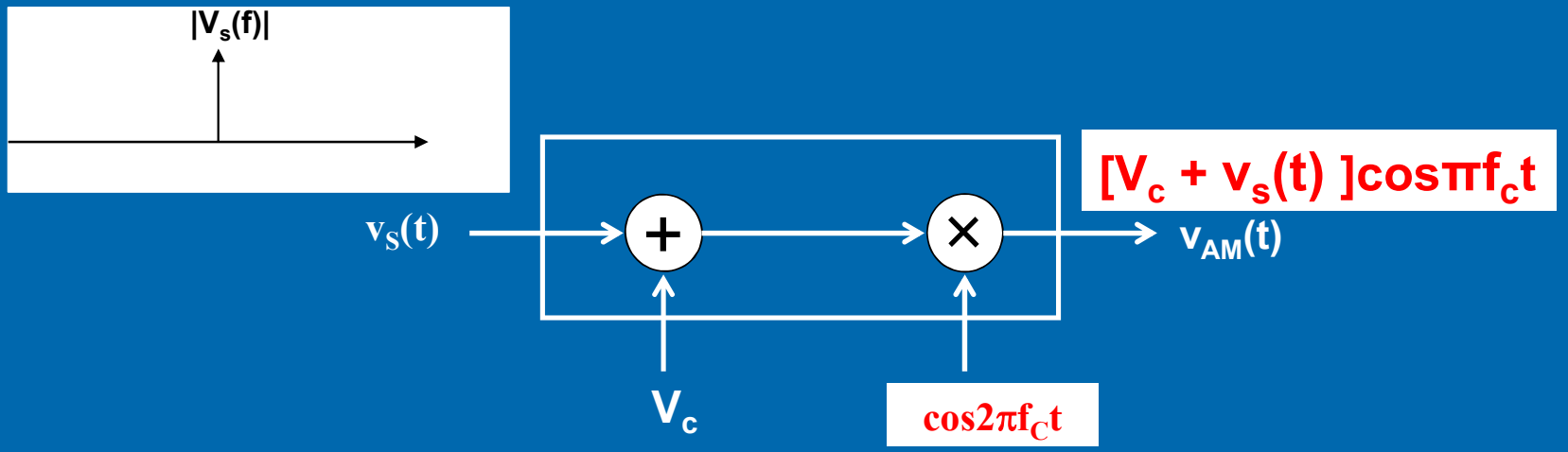
5.2 Multi-tone AM signals

- Consider a multi-tone modulating signal below

Spectrum of a multi-tone modulating signals $v_s(t)$



5.2 Multi-tone AM signals



$v_{AM}(t) = [V_c + v_s(t)]\cos\pi f_c t$

$= V_c \cos 2\pi f_c t$

$+ v_s(t) \times \cos 2\pi f_c t$

$\xleftrightarrow{FT}$

Standard equation for AM signals

$$V_{AM}(f) = \frac{V_c}{2}\delta(f + f_c) + \frac{V_c}{2}\delta(f - f_c) + \frac{1}{2}[V_s(f + f_c) + V_s(f - f_c)]$$

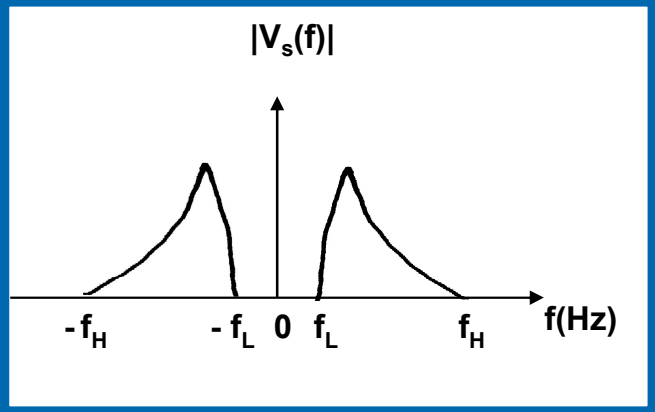
carrier

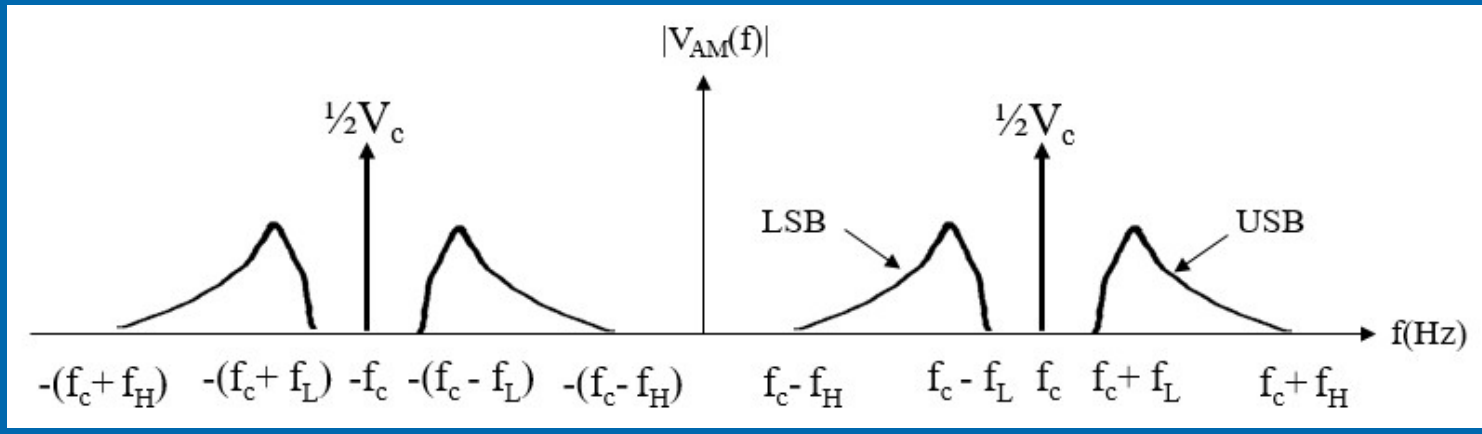
Shift $V_s(f)$ left by f_c

Shift $V_s(f)$ right by f_c

5.2 Multi-tone AM signals

Spectrum of AM signal





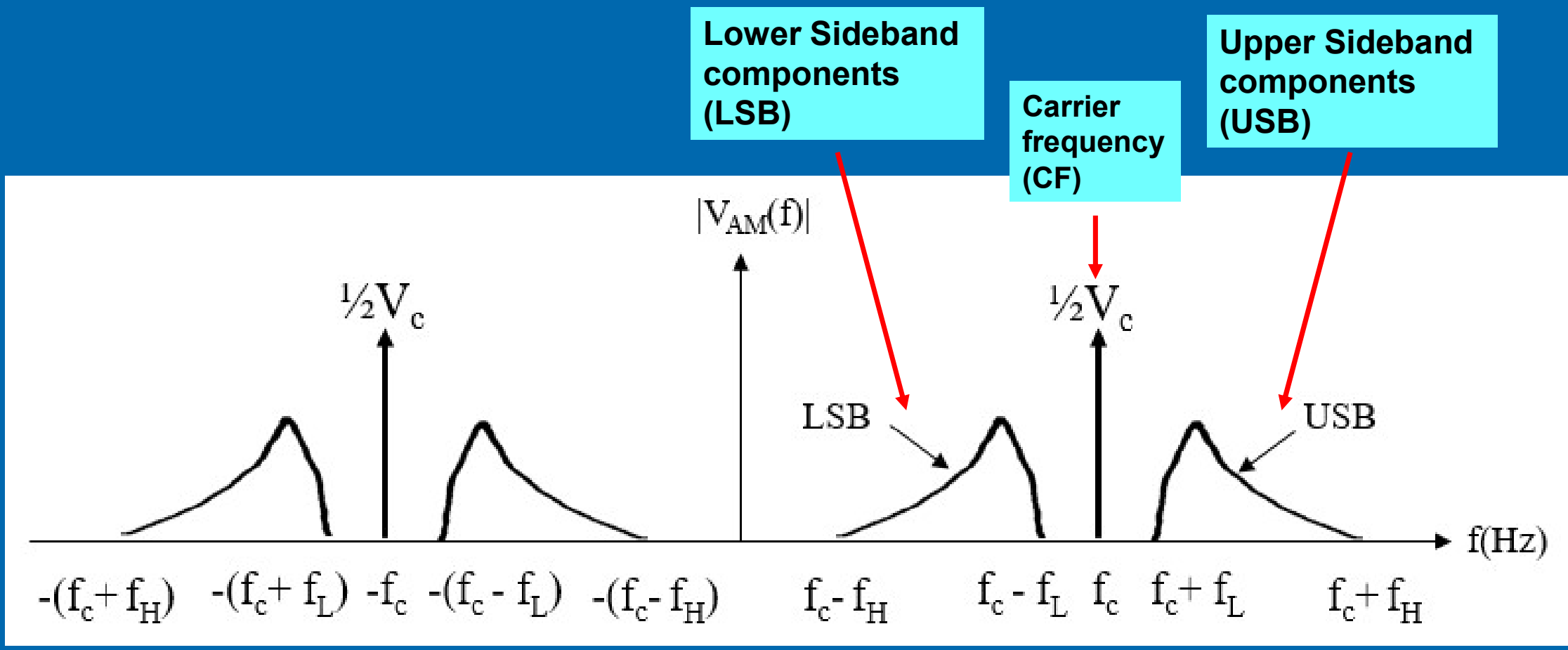
Multi-tone modulating signals

Shift $V_s(f)$ left by f_c

Shift $V_s(f)$ right by f_c

AM Modulation process shifts baseband frequencies to higher frequencies.

5.2 Multi-tone AM signals

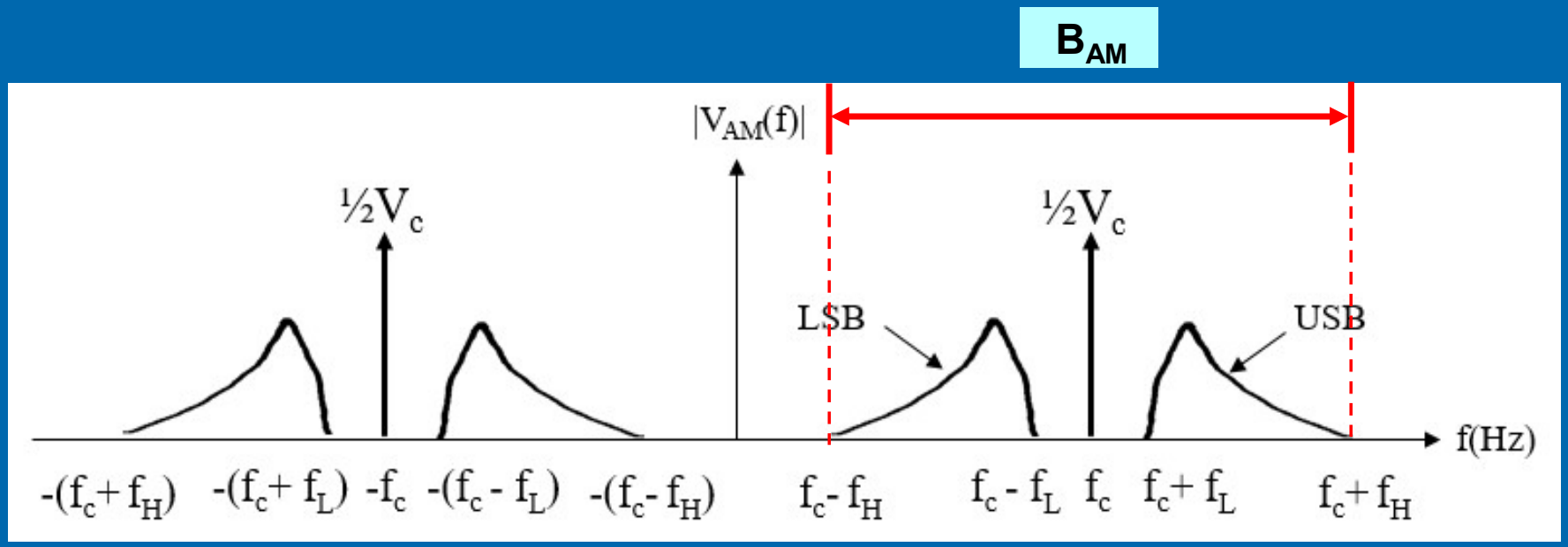


5.2 Multi-tone AM signals

Bandwidth of multi-tone AM signal

$$B_{AM} = (f_c + f_H) \quad - (f_c - f_H) = 2f_H$$

f_H : maximum frequency of modulating signal

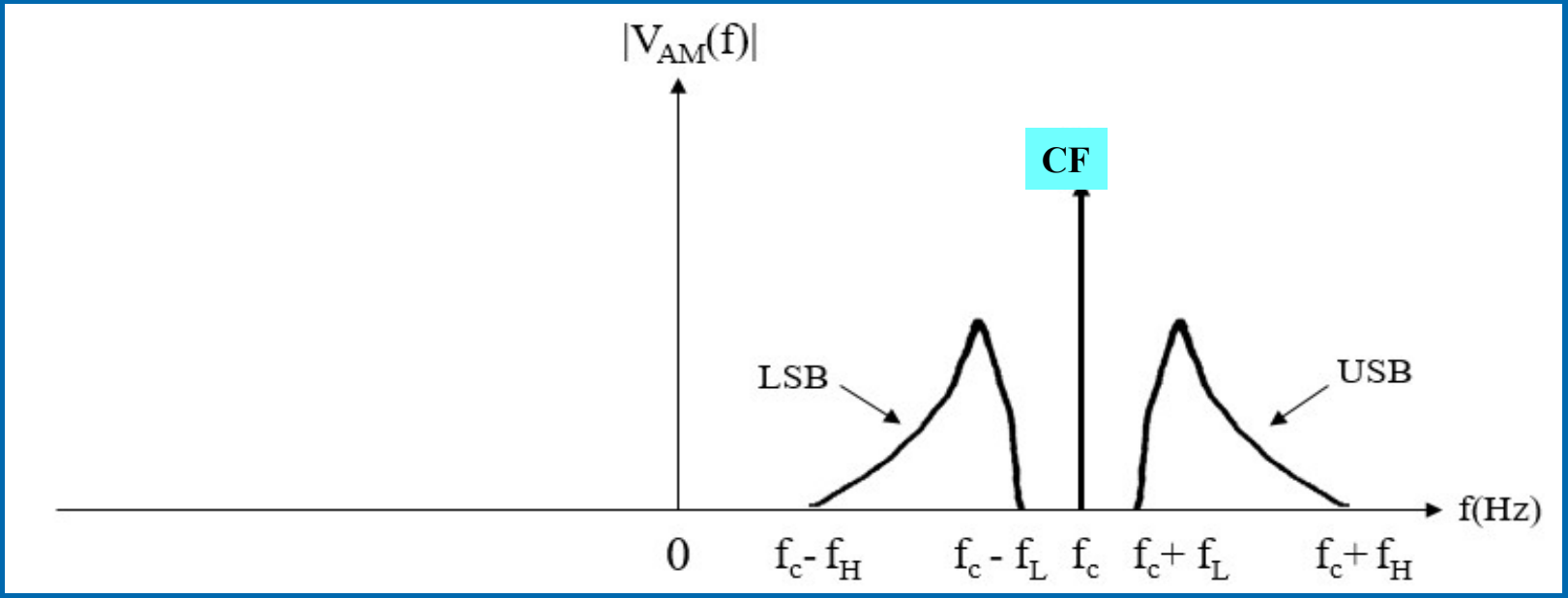


5.2 Multi-tone AM signals

Frequency domain description of AM signal

Single-sided amplitude spectrum of AM signal

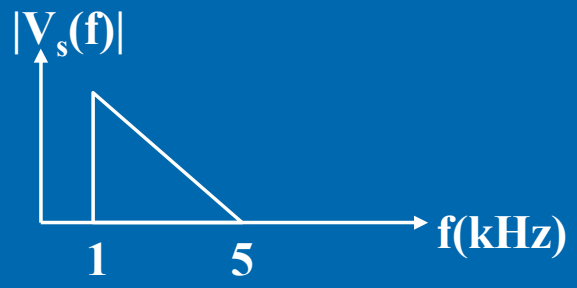
Combine negative and positive frequency components → $2 \times \frac{1}{2} V_s(f - f_c)$



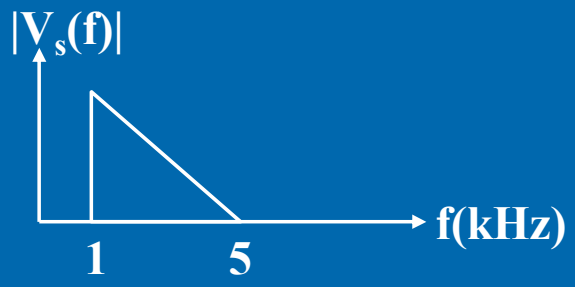
5.2 Multi-tone AM signals

Example 5.4

A carrier signal with amplitude of 6 volt and frequency of 100 kHz is amplitude modulated by a modulating signal that has an amplitude spectrum as shown below. Plot the double-sided amplitude spectrum of the AM signal.

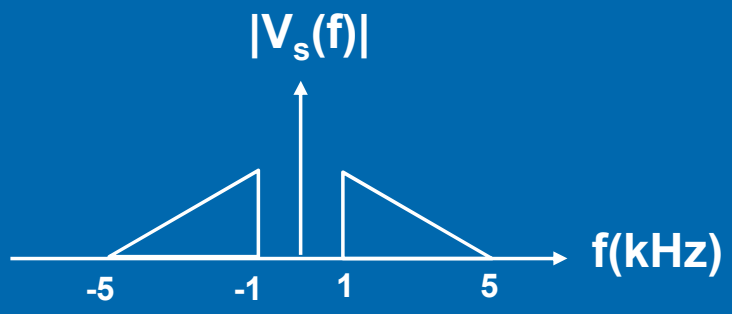


Solution

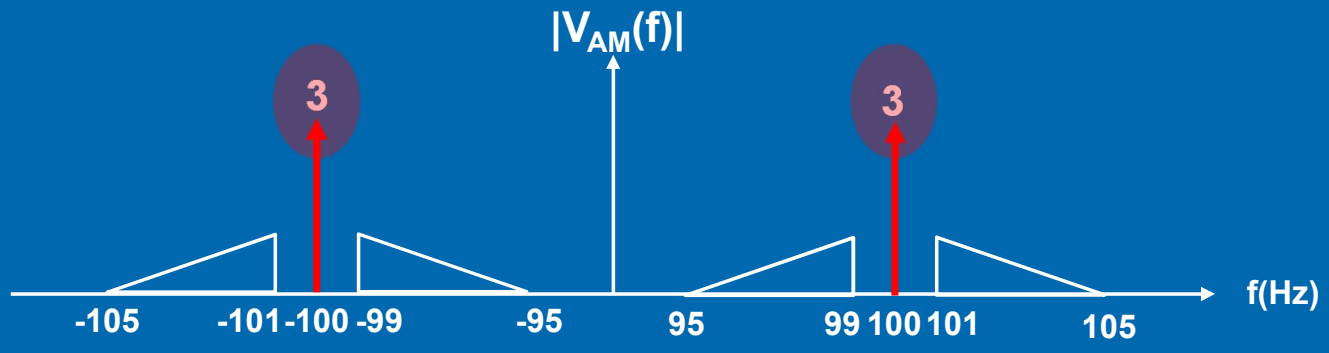


Standard equation for $V_{AM}(f)$

$$V_{AM}(f) = \frac{V_c}{2}\delta(f + f_c) + \frac{V_c}{2}\delta(f - f_c) + \frac{1}{2}[V_s(f + f_c) + V_s(f - f_c)]$$



Double-sided spectrum of modulating signal



$$\frac{V_c}{2}\delta(f + f_c) + \frac{1}{2}V_s(f + f_c)$$

Shift $V_s(f)$ left by f_c

$$\frac{V_c}{2}\delta(f - f_c) + \frac{1}{2}V_s(f - f_c)$$

Shift $V_s(f)$ right by f_c

5.3 Demodulation of AM signals

Demodulation

- The process of recovering the original modulating signal from a modulated carrier at the receiver.

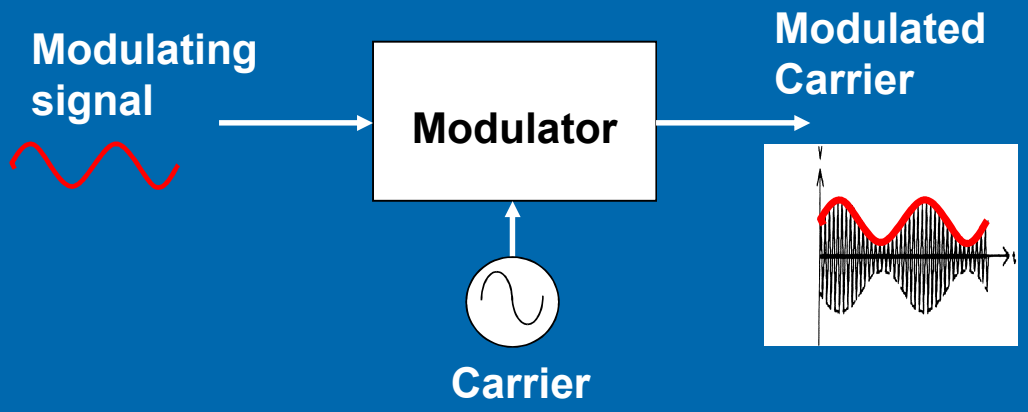
- There are several techniques for demodulation of AM signal:

  - Coherent/synchronous detection,
  - Square-law detection and
  - Envelope detection.

- Envelope detection technique is the simplest and most widely used technique.

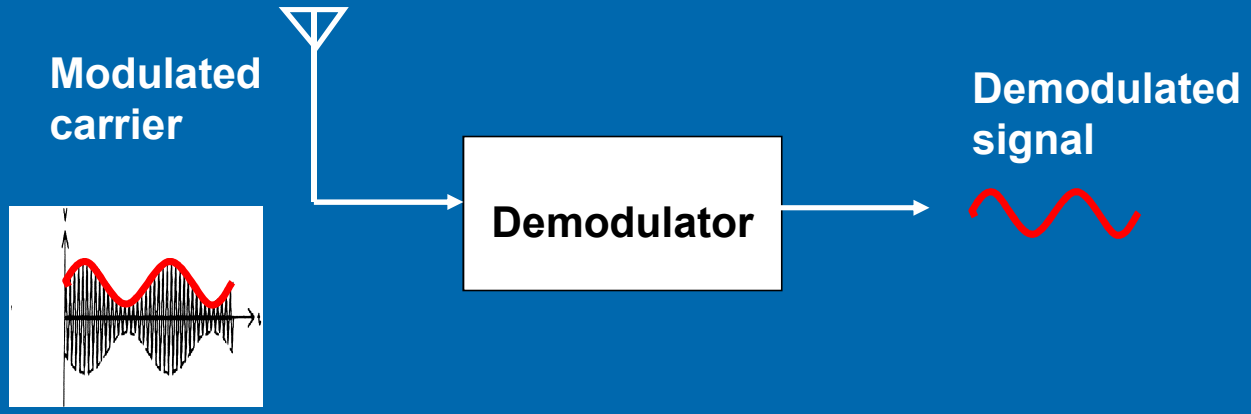
5.3 Demodulation of AM signals

At transmitter:



The modulating signal is in the envelope of the AM signal.

At receiver:

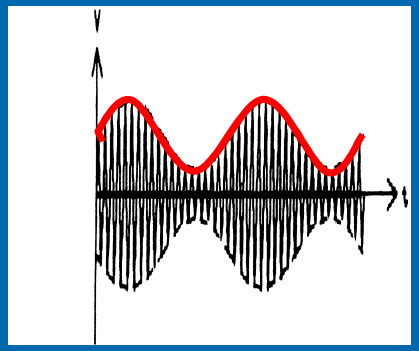


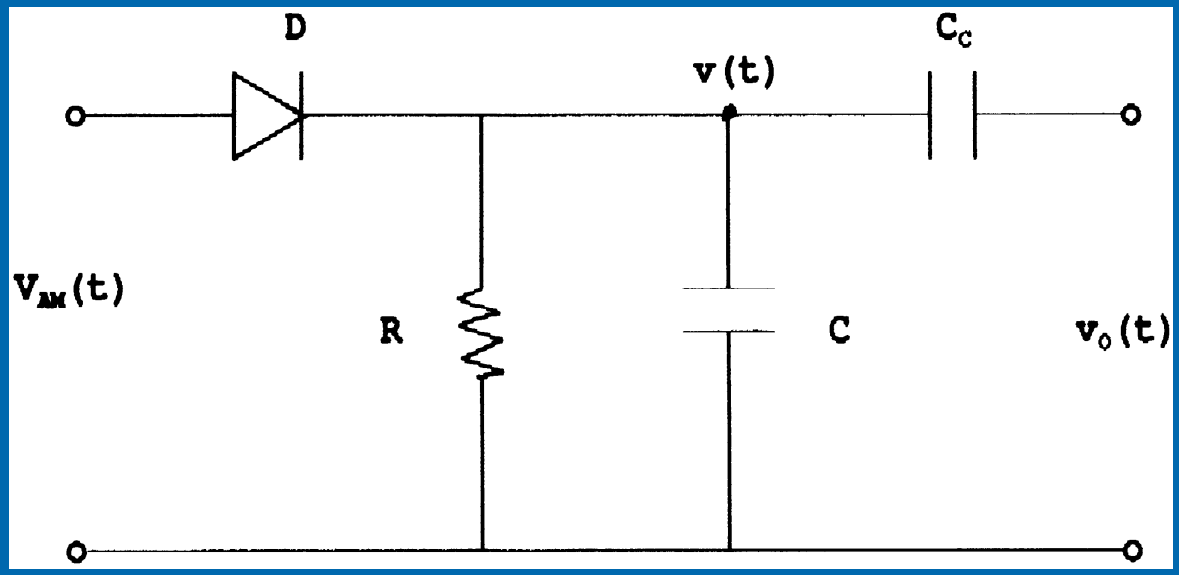
The modulating signal can be recovered by extracting the envelope of the AM signal.

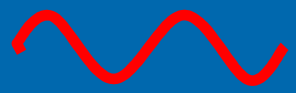
5.3 Demodulation of AM signals

Envelope Detector

- Recover the modulating by Extracting the envelope of the AM signal.



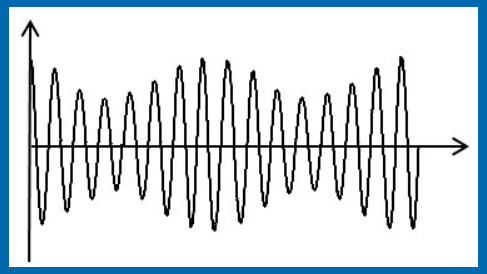


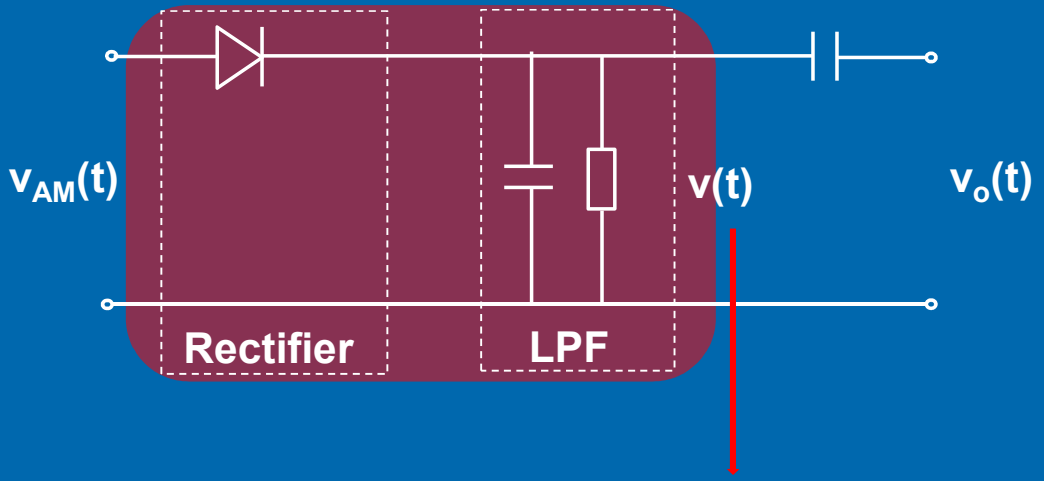


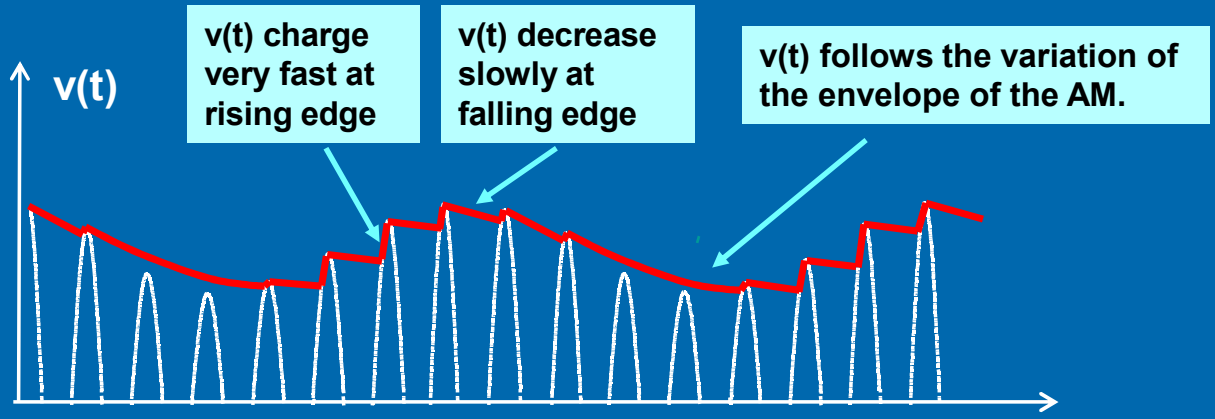
5.3 Demodulation of AM signals

How the Envelope Detector works?

AM input wave



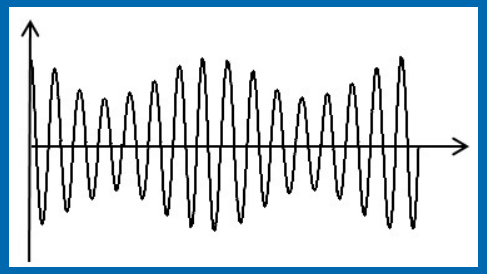


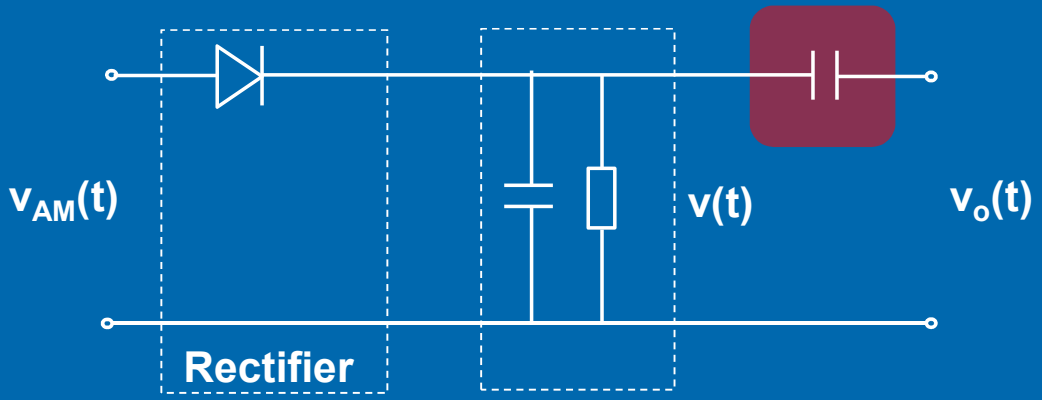


5.3 Demodulation of AM signals

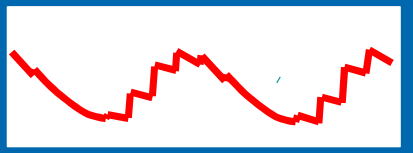
How the Envelope Detector works?

AM input wave





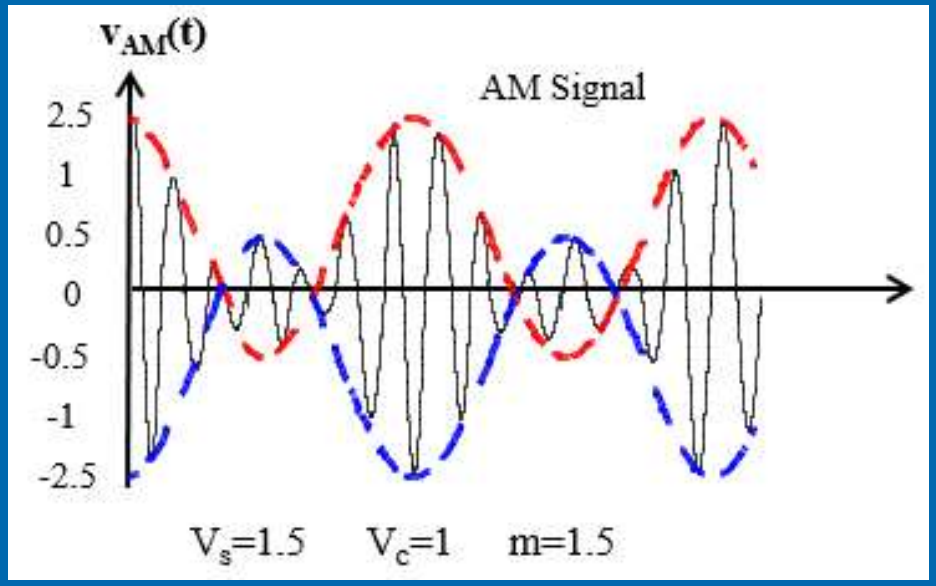
Envelope detected



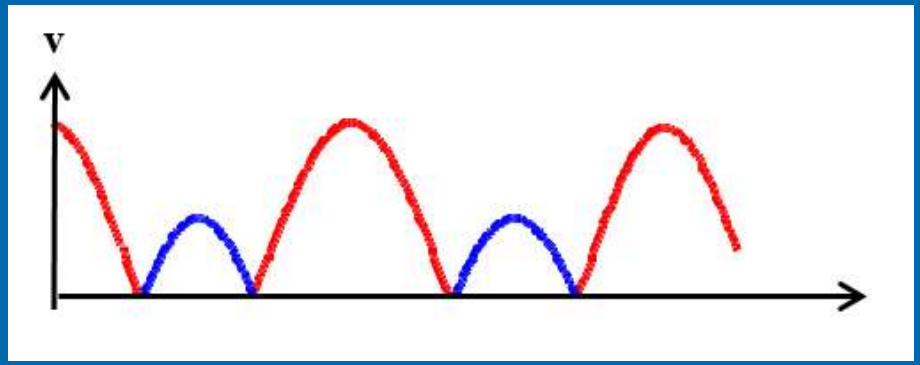
5.3 Demodulation of AM signals

- If the AM signal is over-modulated, the output of the envelope detector is distorted.
- Thus, m should not exceed 1.

Over-modulated AM signal



Distorted output of envelope detector



End

CHAPTER 5

(Part 3 of 4)