CHAPTER 5

Amplitude Modulation

(Part 2 of 4)

5.1 Principles of AM

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Frequency domain description of single-tone AM signal

- When a sinusoidal carrier signal is modulated by a a single-tone modulating signal, the resultant AM signal is NOT a sinusoidal signal.

Double-sided amplitude spectrum of AM signals

↓

Fourier transform

5.1 Principles of AM

$V_s(f) = \frac{V_s}{2}\delta(f-f_s) + \frac{V_s}{2}\delta(f+f_s)$

Frequency domain description of single-tone AM signal

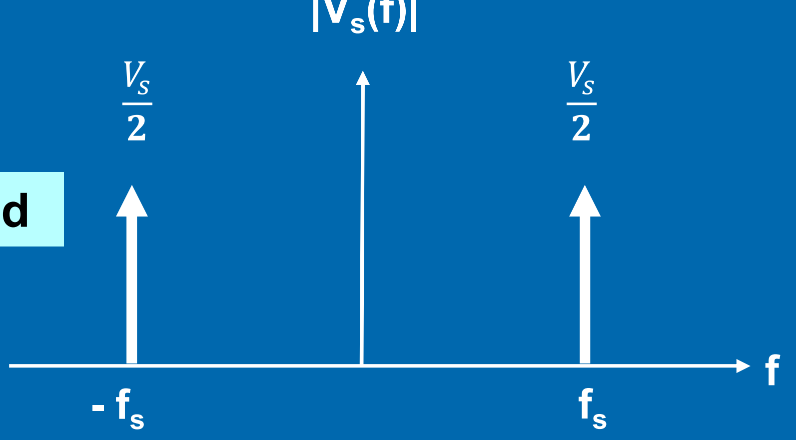
Double-sided amplitude spectrum

Fourier transform

The amplitude is halved

$$v_s(t) = V_s\cos 2\pi f_s t \overset{FT}{\Longleftrightarrow} V_s(f) = \frac{V_s}{2}\delta(f-f_s) + \frac{V_s}{2}\delta(f+f_s)$$

Standard Fourier transform of $V_s\cos 2\pi f_s t$



5.1 Principles of AM

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Frequency domain description of single-tone AM signal

Double-sided amplitude spectrum

Fourier transform

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

The amplitude is halved

$$v_s(t) \times \cos 2\pi f_c t \overset{FT}{\Longleftrightarrow} \frac{1}{2}\left[V_s(f + f_c) + V_s(f - f_c)\right]$$

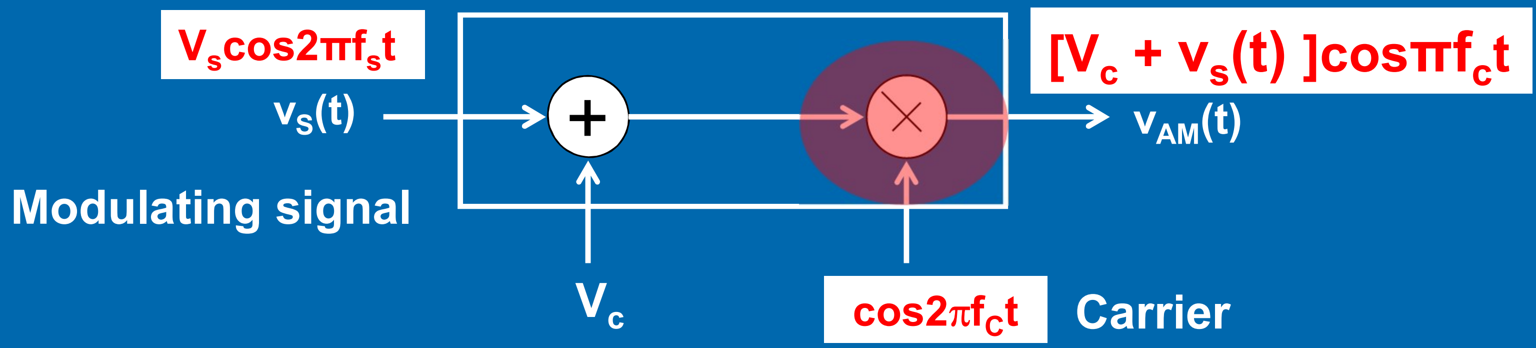
Shift $V_s(f)$ left by f_c

Shift $V_s(f)$ right by f_c

The spectrum of an amplitude modulated signal, $v_s(t)\cos 2\pi f_c t$, consists of two frequency shifted version of $V_s(f)$.

5.1 Principles of AM

Frequency domain description of single-tone AM signal



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

$$= V_c \cos 2\pi f_c t$$

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

Standard equation for AM signals

$$V_{AM}(f) =$$

$$\frac{V_c}{2}[\delta(f + f_c) + \frac{V_c}{2}\delta(f - f_c)] \quad \textbf{carrier}$$

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

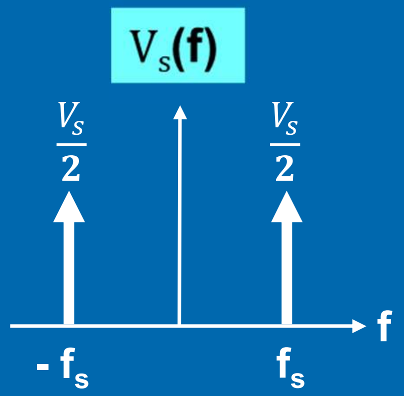
Shift $V_s(f)$ left by f_c

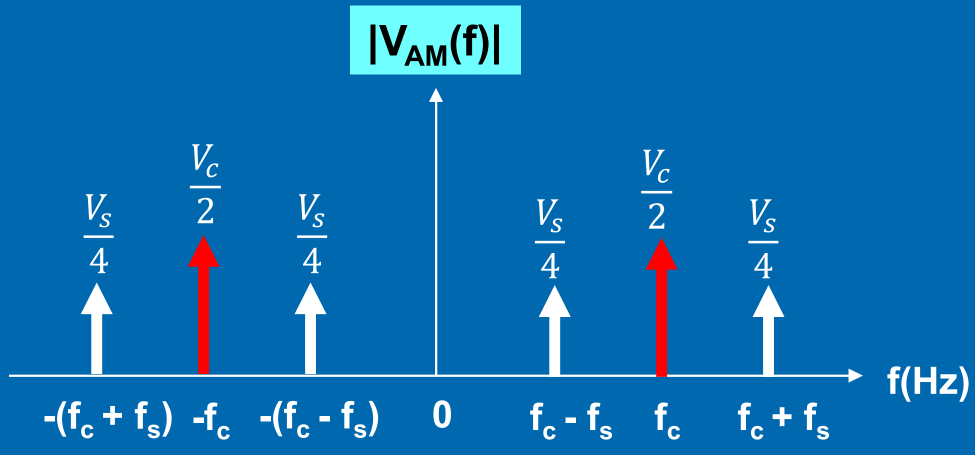
Shift $V_s(f)$ right by f_c

5.1 Principles of AM

Frequency domain description of single-tone AM signal

Double-sided amplitude spectrum of single-tone AM 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

Modulation process shifts baseband frequency to higher frequencies.

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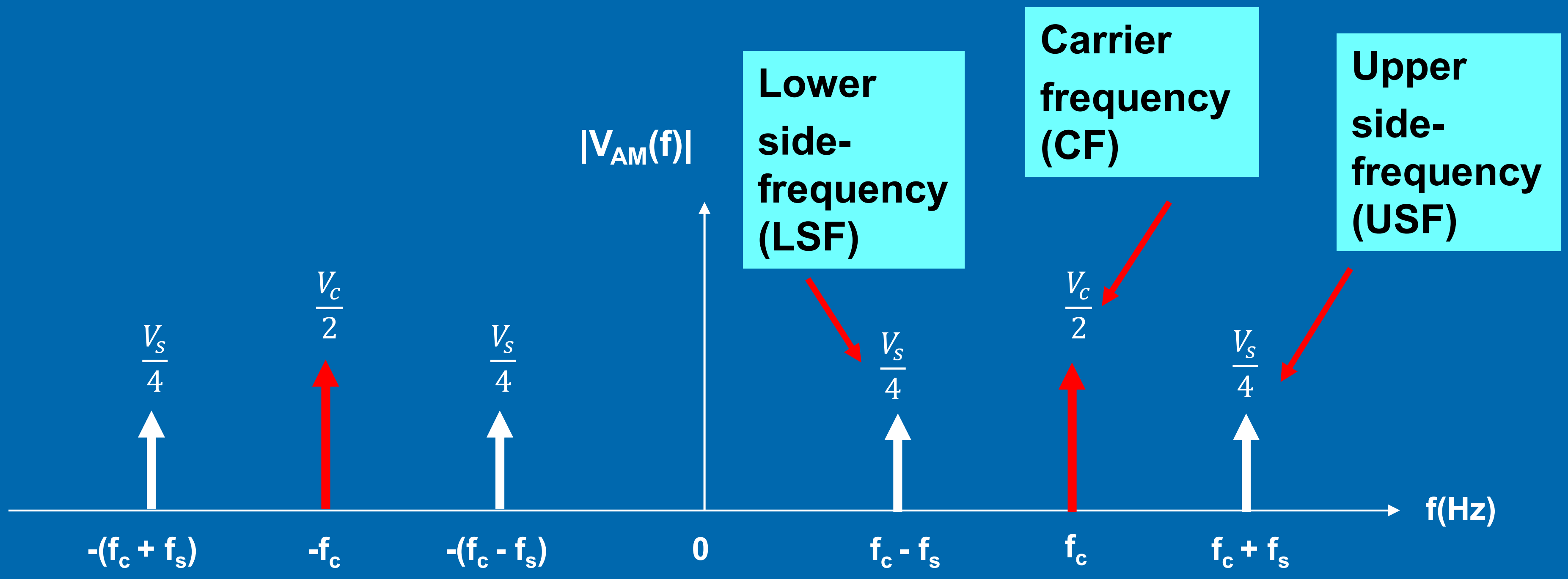
Frequency domain description of single-tone AM signal

Double-sided amplitude spectrum of single-tone AM signal

Modulatind Signal
$v_s(t) = V_s \cos 2\pi f_s t$



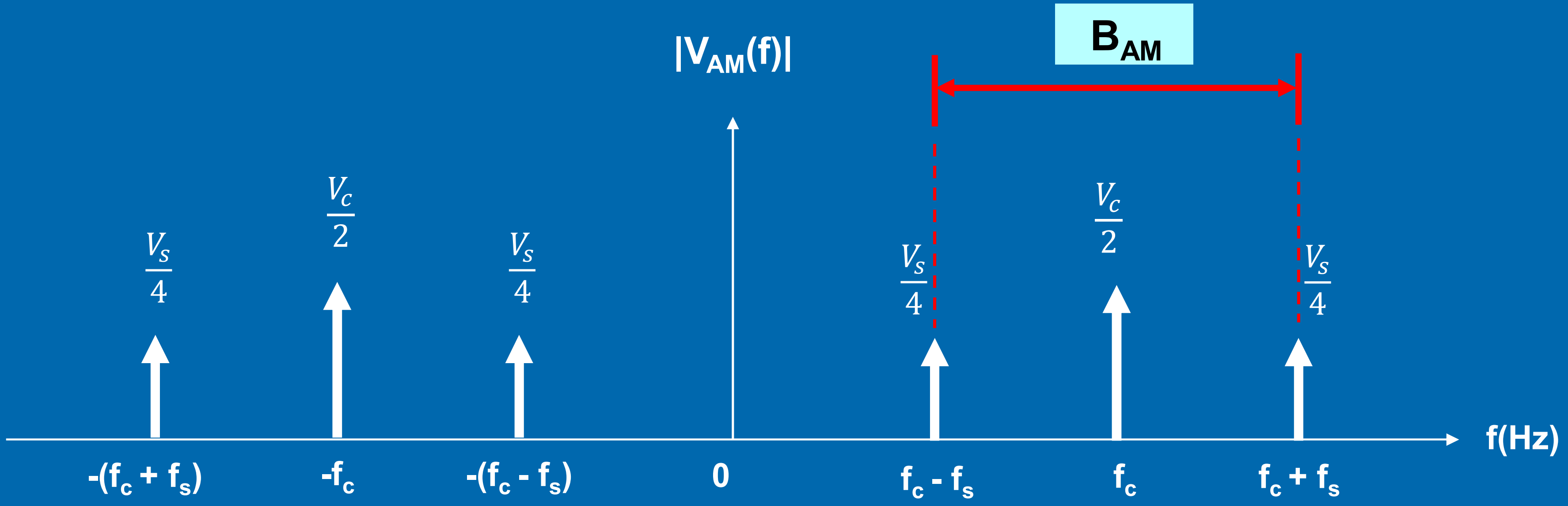
5.1 Principles of AM

<u>**Frequency domain description of single-tone AM signal**</u>

Bandwidth of single-tone AM signal , B_{AM}

$$B_{AM} = (f_c + f_s) - (f_c - f_s) = 2f_s$$

f_s is frequency of the modulating signal.



Example 5.3

A carrier signal with amplitude of 4 Volt and frequency of 500 kHz is amplitude modulated by a sinusoidal modulating signal with frequency of 3 kHz and amplitude of 2.4 Volt. Draw the double-sided amplitude spectrum of the AM signal.

Solution

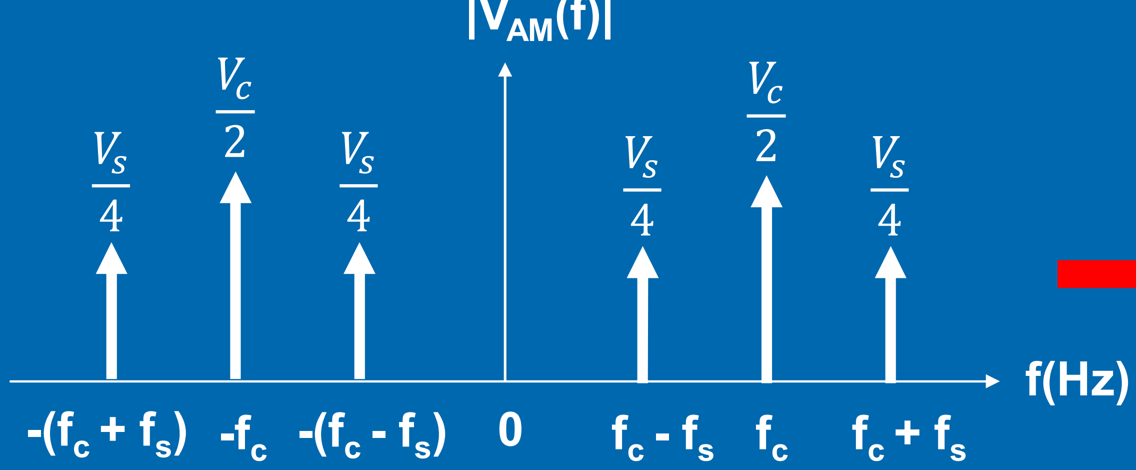
V_c = 4 volt, V_s = 2.4 volt

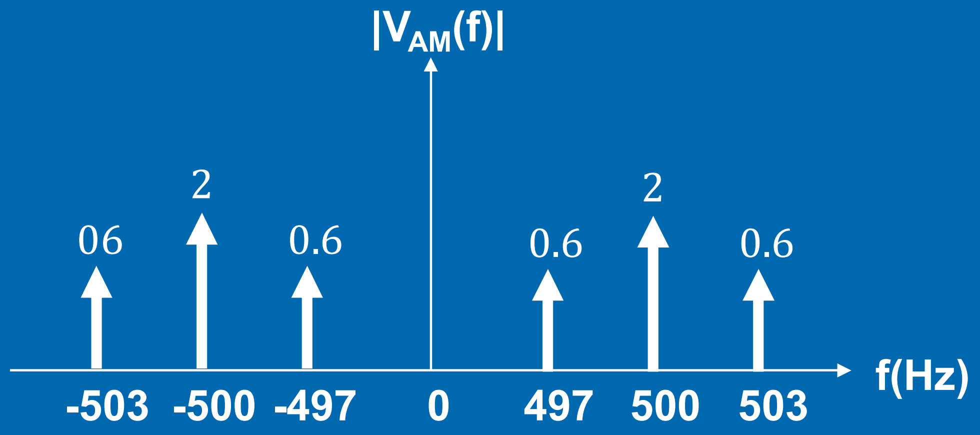
f_c = 500 kHz, f_s = 3 kH

Double-sided amplitude spectrum

$v_s(t) = V_s \cos 2\pi f_s t$

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





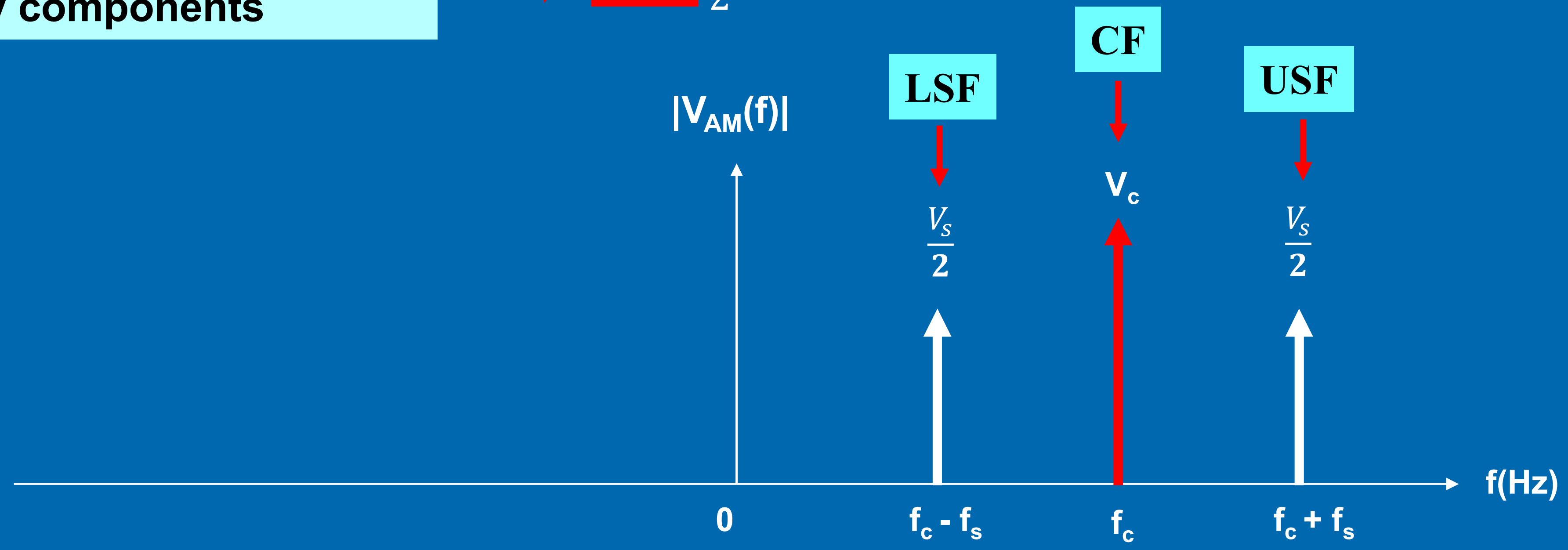
5.1 Principles of AM

Frequency domain description of single-tone AM signal

Single-sided amplitude spectrum of AM signal

Modulating Signal
$v_s(t) = V_s \cos 2\pi f_s t$

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



5.1 Principles of AM

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Frequency domain description of single-tone AM signal

Single-sided amplitude spectrum of AM signal

Alternative method

Modulating Signal

$v_s(t) = V_s \cos 2\pi f_s t$

$$v_{AM}(t) = [V_c + V_s \cos\omega_s t]\cos\omega_c t$$

cosAcosB=1/2[cos(A-B)+cos(A+B)]

$$= V_c \cos\omega_c t + V_s \cos\omega_s t \times \cos\omega_c t$$

$$= V_c \cos\omega_c t + \frac{V_s}{2}\cos(\omega_c - \omega_s)t + \frac{V_s}{2}\cos(\omega_c + \omega_s)t$$

Three frequency components

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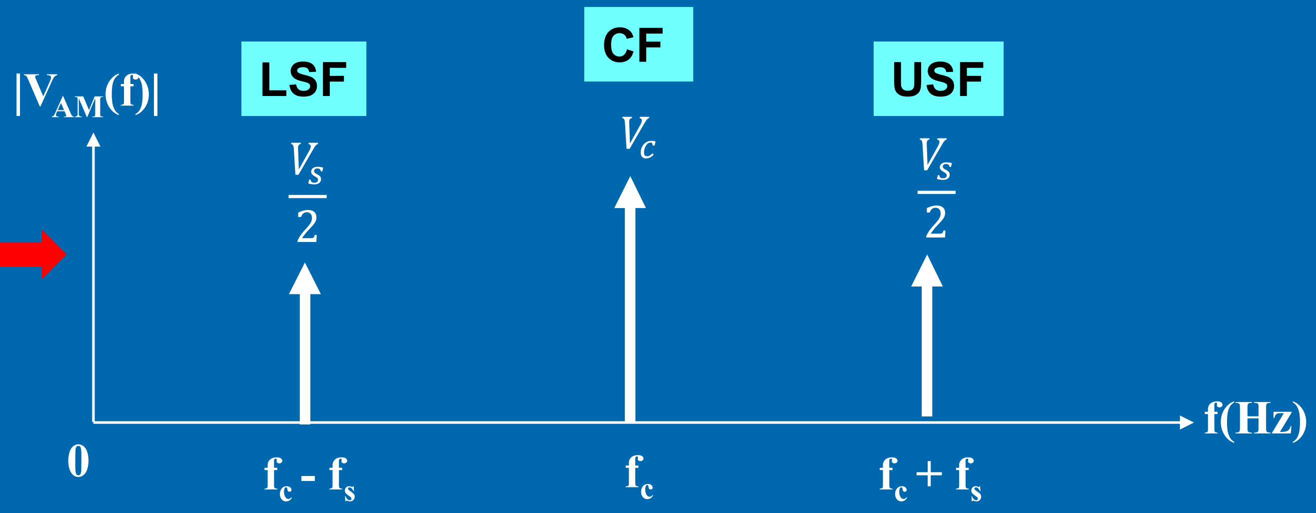
Frequency domain description of single-tone AM signal

Alternative method

$$v_{AM}(t) = \underbrace{V_c\cos\omega_c t}_{\text{CF}} + \underbrace{\frac{V_s}{2}\cos(\omega_c + \omega_s)t}_{\text{LSF}} + \underbrace{\frac{V_s}{2}\cos(\omega_c - \omega_s)t}_{\text{USF}}$$

Single-sided amplitude spectrum of AM signal

$v_s(t) = V_s\cos 2\pi f_s t$



End

CHAPTER 5

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