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CHAPTER 5

Amplitude Modulation

(Part 1 of 4)

Introduction

Amplitude Modulation (AM)

- The process of varying the amplitude of a high frequency sinusoidal carrier in accordance with the modulating signal (information signal).

- Two things that happened:

  - The modulating signal is impressed onto the carrier.

  - The modulating signal is shifted to a higher frequency band.

5.1 Principles of AM

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Carrier: $v_c(t) = V_c \cos(2\pi f_c t + \theta) = V_c \cos(\omega_c t + \theta)$ or $v_c(t) = V_c \sin(2\pi f_c t + \theta)$

Initial phase $\theta = 0$

Carrier frequency f_c

Peak Amplitude

modulating signal, $v_s(t)$, impressed onto the carrier **amplitude**

AM modulated signal: $v_{AM}(t) = [V_c + v_s(t)] \cos(\omega_c t) = V_c \cos(\omega_c t) + v_s(t) \cos(\omega_c t)$

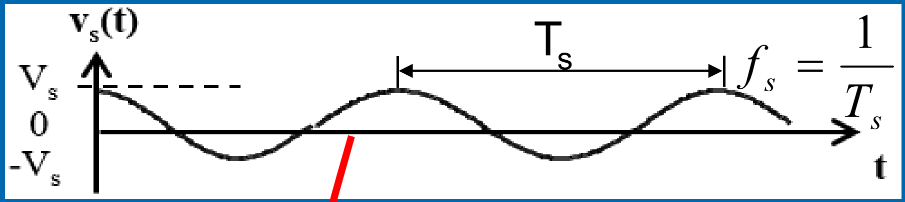
$[V_c + v_s(t)]$ varying with the instantaneous amplitude of the modulating signal $v_s(t)$

5.1 Principles of AM

Time domain description of single-tone AM signals

Single-tone modulating signal

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

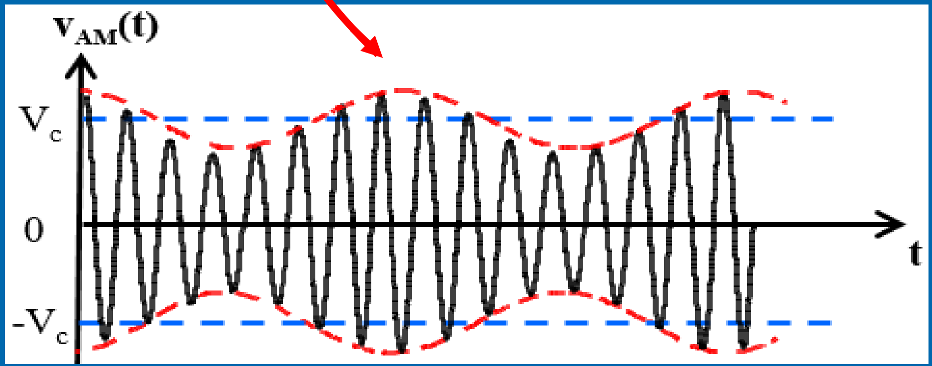


$v_{AM}(t) = [V_c + V_s \cos 2\pi f_s t] \cos 2\pi f_c t$

Single-tone AM signal

$v_s(t)$, impressed onto carrier amplitude

Time domain description of Single-tone AM signals



5.1 Principles of AM

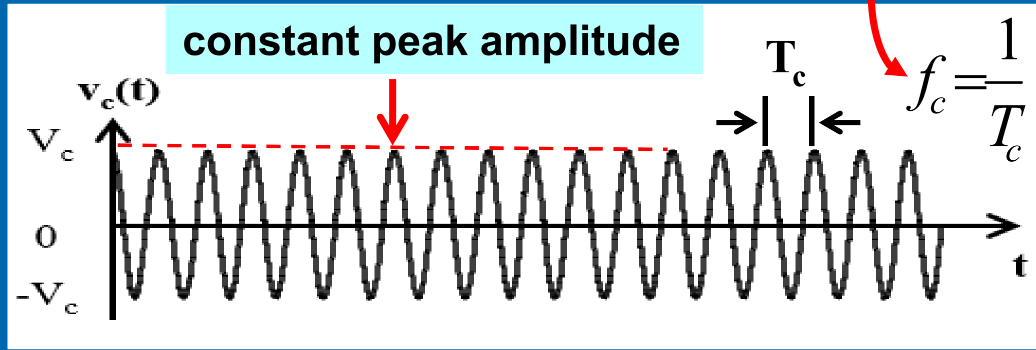
Time domain description of single-tone AM signals

Before modulation:

$v_{AM}(t) = v_c(t) = V_c \cos\omega_c t$

constant peak amplitude

Carrier frequency, f_c

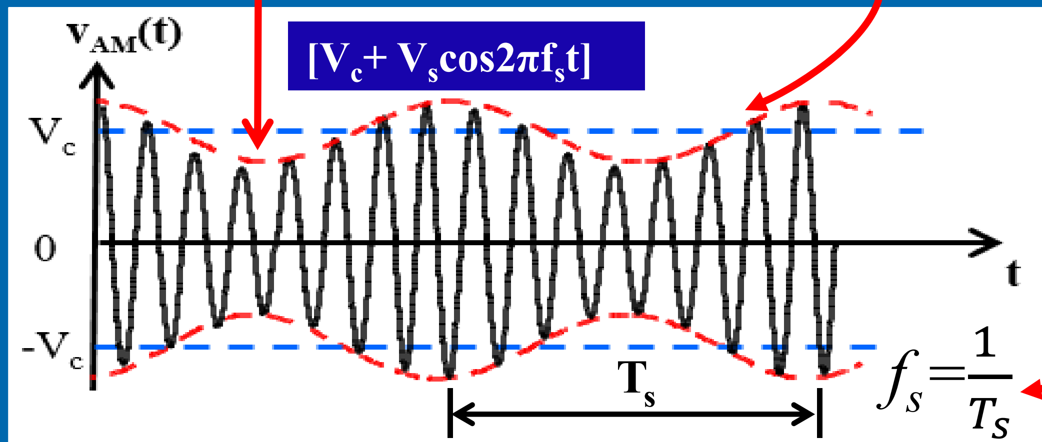


instantaneous peak amplitude follow the change in $v_s(t)$

Envelope

After modulation:

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



Modulating signal Frequency, f_s

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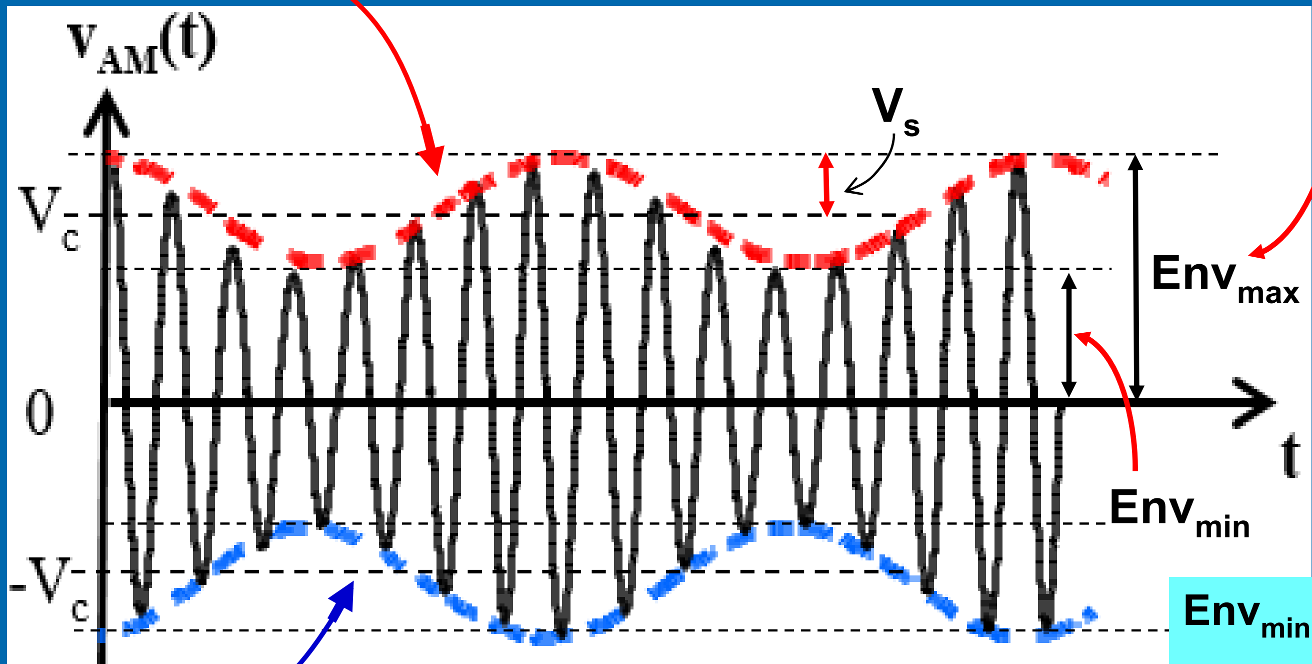
Time domain description of single-tone AM signals

Positive envelope:

$[V_c + V_s\cos\omega_s]$

Maximum envelope

$Env_{max} = V_c + V_s$



$Env_{min} = V_c - V_s$

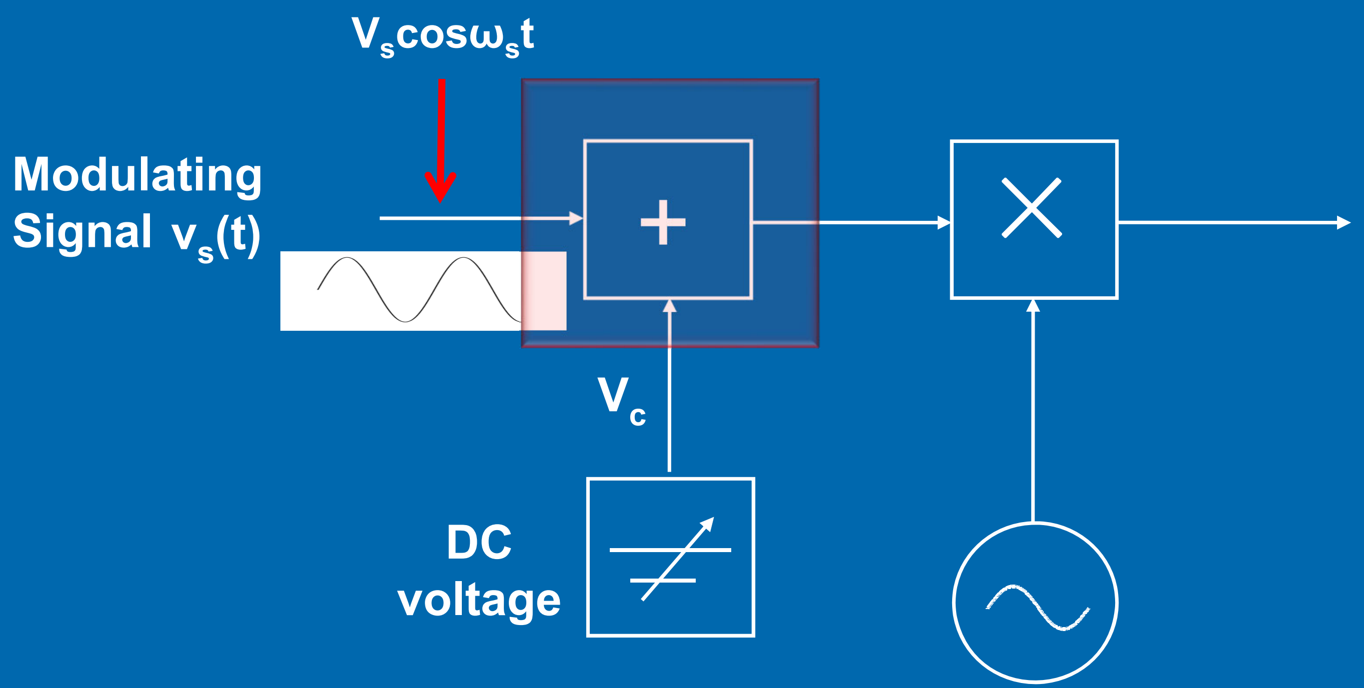
Minimum envelope

Negative envelope:

$-[V_c + V_s\cos\omega_s t]$

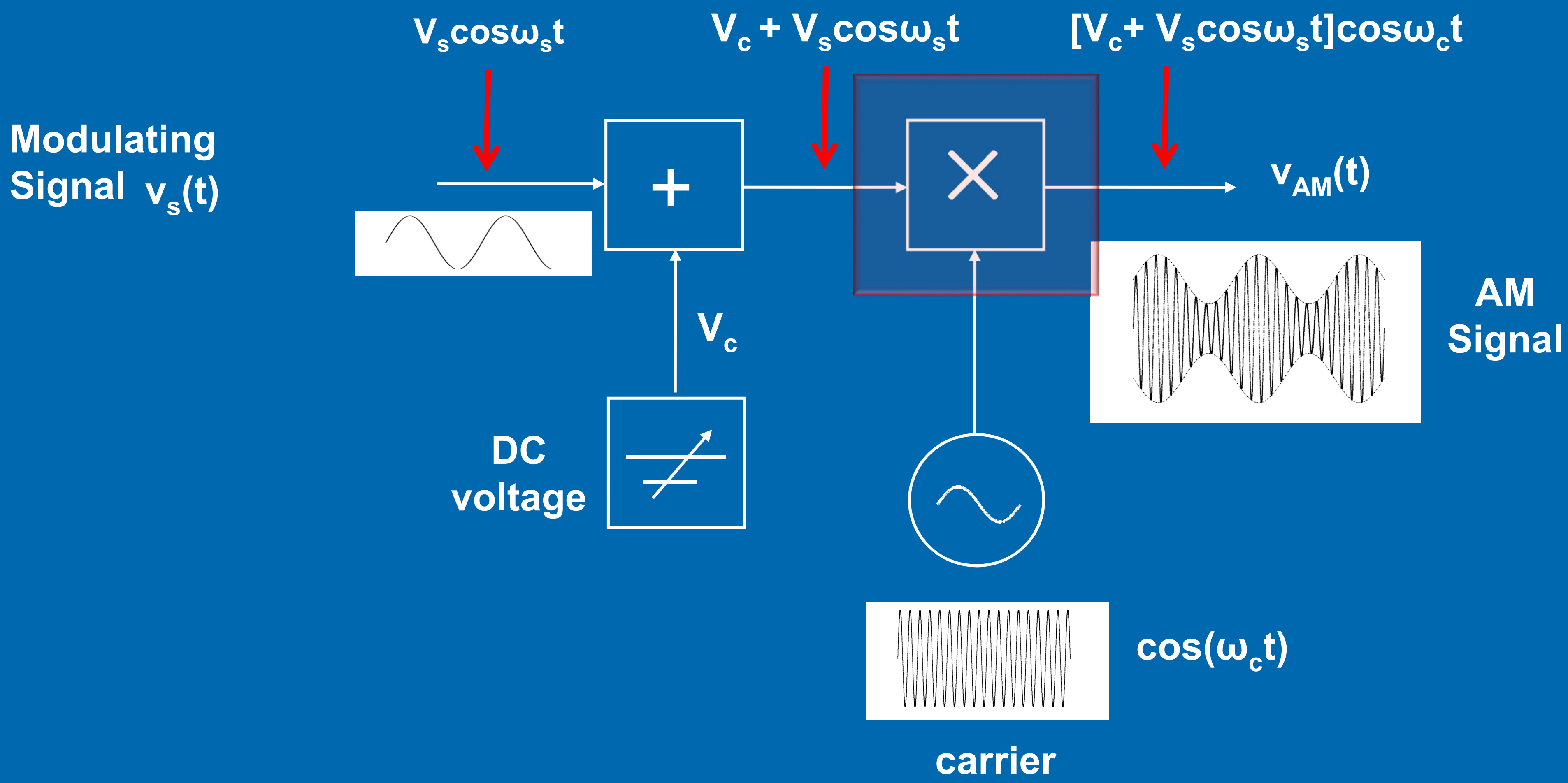
5.1 Principles of AM

Time domain description of single-tone AM signals



5.1 Principles of AM

<u>Time domain description of single-tone AM signals</u>



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Example 5.1

A carrier signal $v_c(t) = 10\cos(2\pi \times 10^5 t)$ is amplitude modulated by a modulating signal $v_s(t)=5\cos(2\pi \times 10^3 t)$. Determine:

(a) The values of V_c, V_s, T_c, T_s, Env_{max} and $Env_{min.}$

(b) The expression of the AM signal.

Solution

(a) Carrier: $v_c(t) = 10\cos(2\pi \times 10^5 t)$

standard equation $v_c(t) = V_c \cos(2\pi f_c t)$

$V_c = 10$ volt

$T_c = 1/f_c = 1/10^5$

$= 10\ \mu s$

Modualting signal: $v_s(t) = 2\cos(2\pi \times 10^3 t)$

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

$V_s = 2$ volt

$T_s = 1/f_s = 1/10^3$

$= 1$ ms

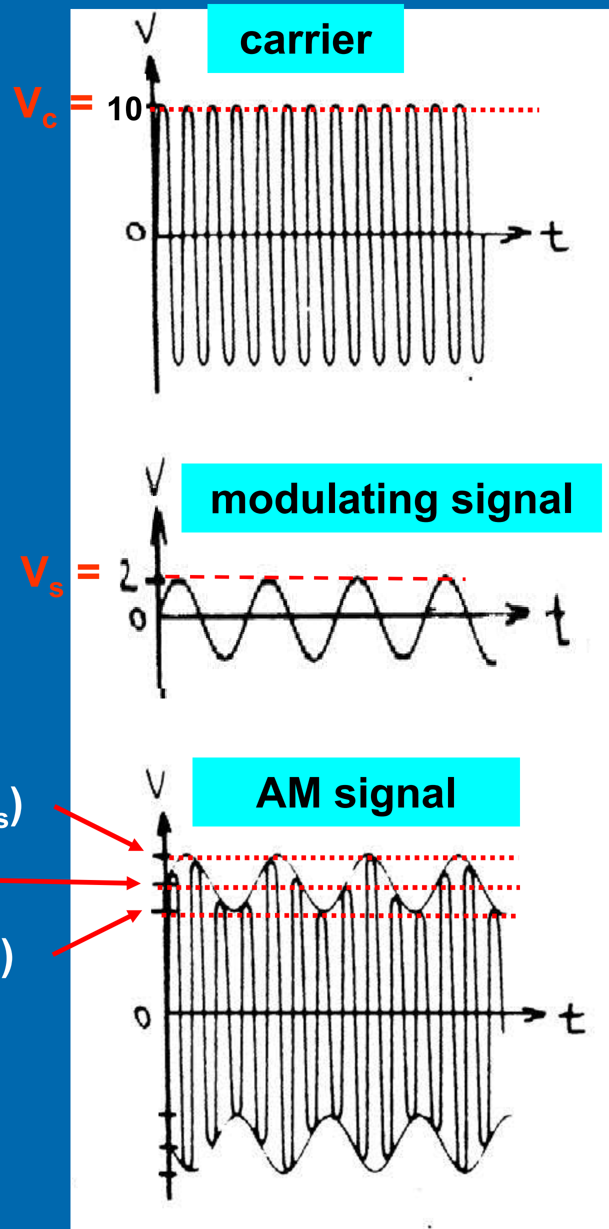
$Env_{max} = V_c + V_s = 12$ volt

$Env_{min} = V_c - V_s = 8$ volt

$Env_{max} = (V_c + V_s)$

V_c

$Env_{max} = (V_c - V_s)$



(b) $v_{AM}(t) = [V_c + V_s \cos 2\pi f_s t]\cos 2\pi f_c t$ standard AM equation

$= [10 + 5\cos(2\pi \times 10^3 t)]\cos 2\pi \times 10^5 t$

5.1 Principles of AM

Modulation index, m

- Defined as the ratio of the peak amplitudes of modulating signal to the peak amplitude of unmodulated carrier.

$$m = \frac{V_s}{V_c}$$

Constant

$0 \leq m \leq 1$

- Also expressed in percentage, known as percentage modulation.
- Controlled by varying the peak amplitude of the modulating signal as carrier amplitude is usually fixed in practice.
- Describes the size of the envelope.

5.1 Principles of AM

Modulation index, m

$m = V_s/V_c$

m is a number that tells us the size of the envelope

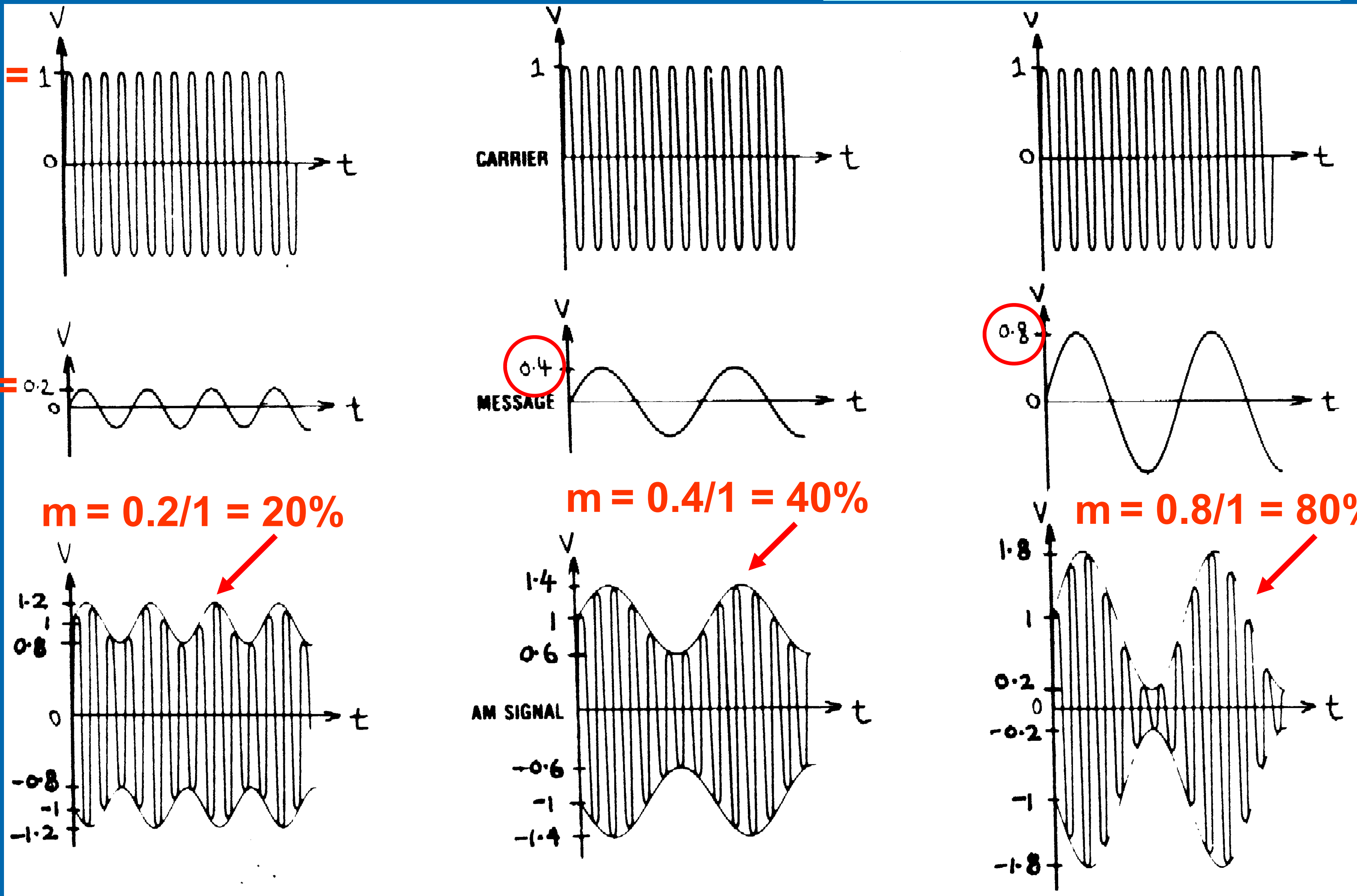
$V_c = 1$

$V_s = 0.2$

m = 0.2/1 = 20%

m = 0.4/1 = 40%

m = 0.8/1 = 80%



5.1 Principles of AM

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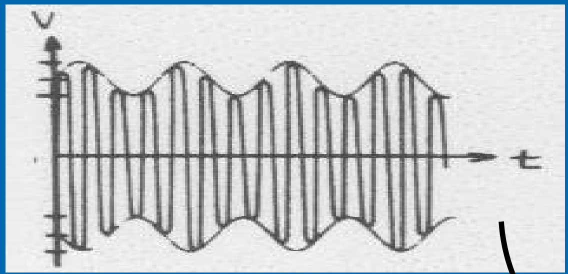
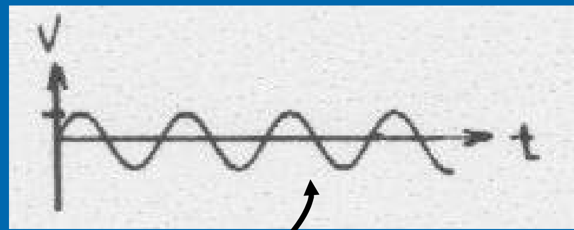
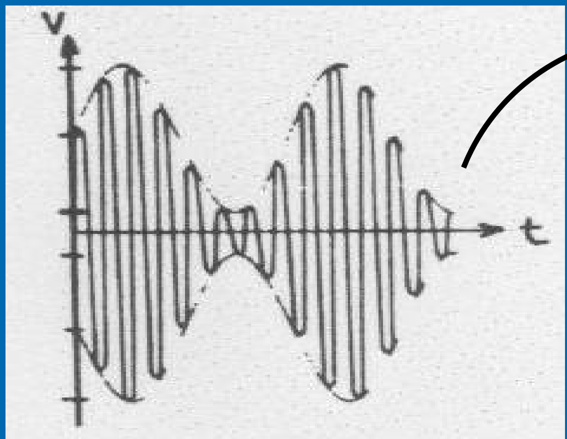
small m → small envelope → **small Receiver o/p → low SNR**

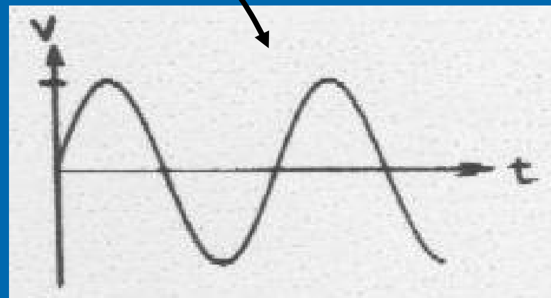




Envelope Detector

Keep m as high as possible.





Big m → big envelope → **Big Receiver o/p → high SNR**

Example 5.2

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.

(a) Write the expression for the resulting AM signal.

(b) Determine the modulation index.

Solution

(a) $V_c = 4$ volt, $V_s = 2.4$ volt

$f_c = 500$ kHz, $f_s = 3$ kH

$$v_{AM}(t) = [V_c + v_s(t)]\cos 2\pi f_c t$$

$$v_{AM}(t) = [V_c + V_s \cos 2\pi f_s t]\cos 2\pi f_c t$$

standard single-tone AM equation

$$= [4 + 2.4\cos(6\pi \times 10^3 t)]\cos 10\pi \times 10^5 t$$

(b) $m = V_s / V_c = 2.6 / 4 = 0.6$

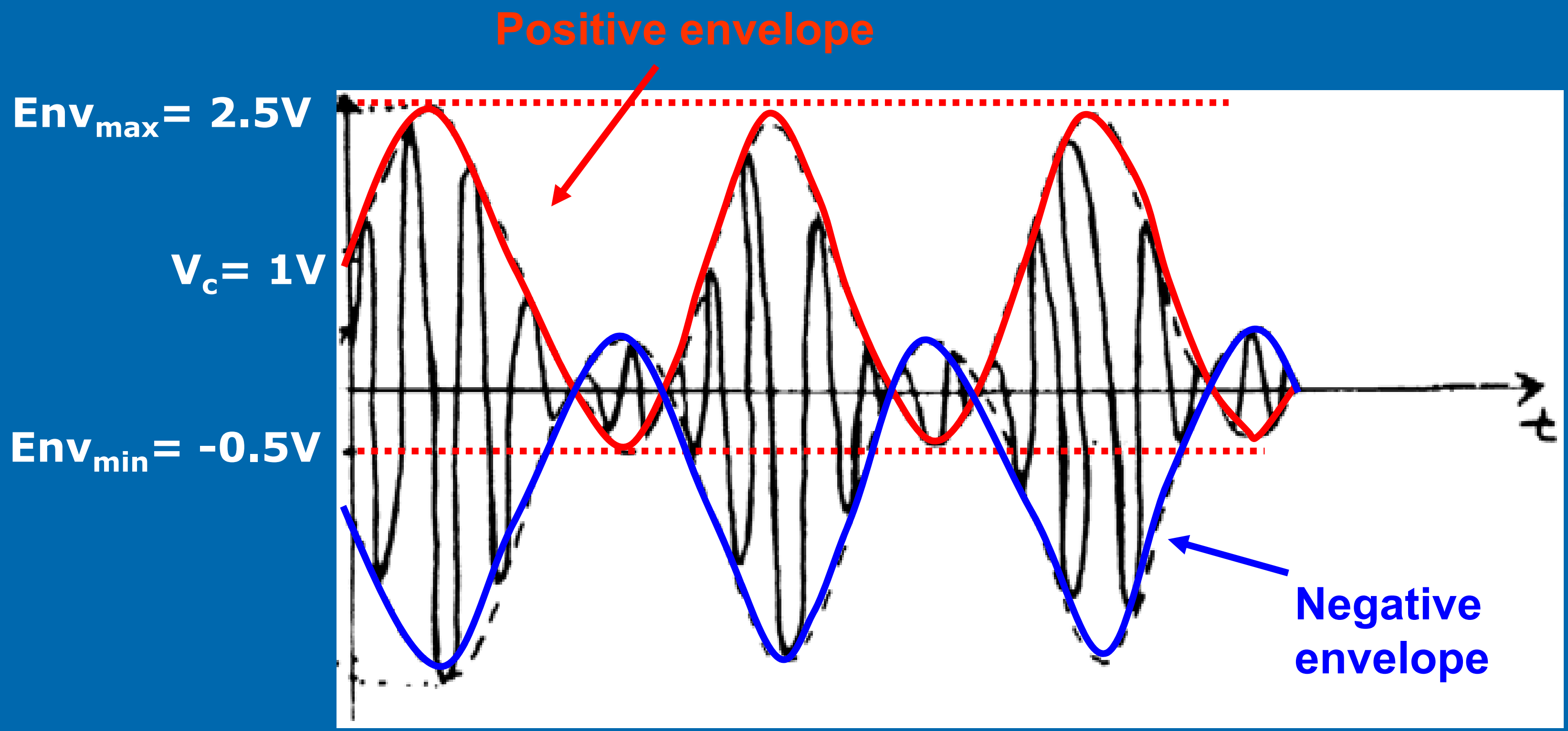
5.1 Principles of AM

Over-modulation

- m must be large, but it must not however exceed 1.

What happens if m is greater than 1?

for example, V_s = 1.5V and V_c = 1V → m = 1.5



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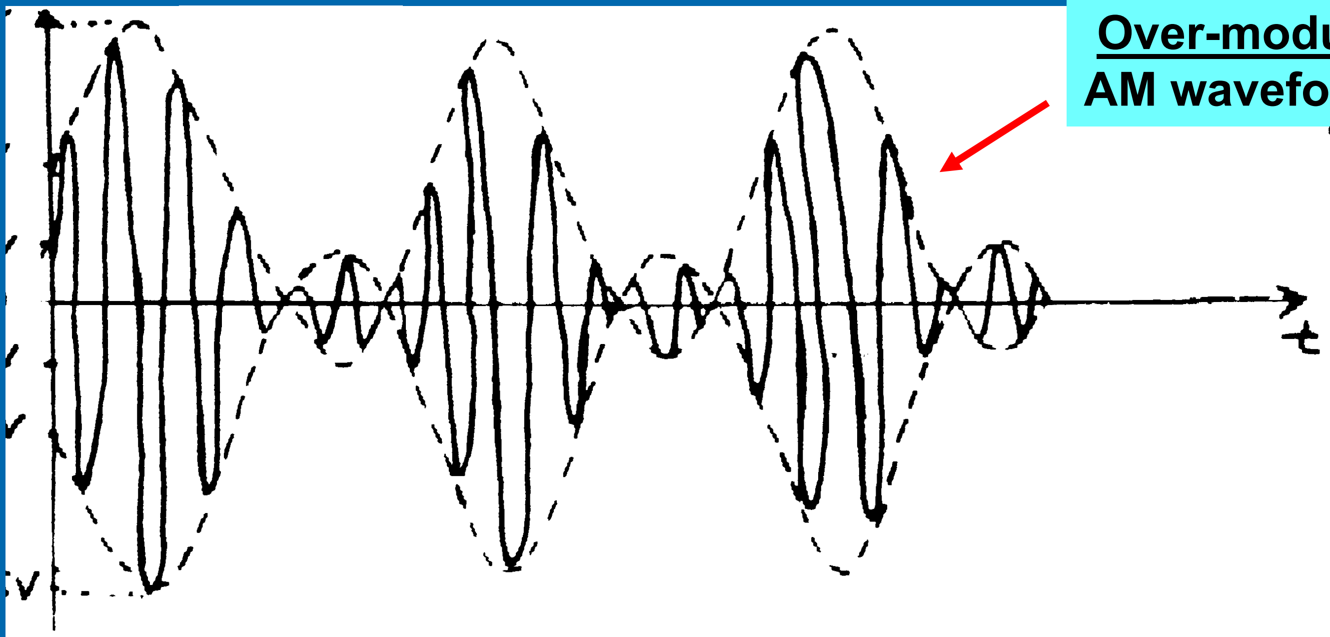
Over-modulation

m > 1 is called over-modulation



Over-modulated AM waveform.

Over-modulation will result in a distorted o/p at the receiver.

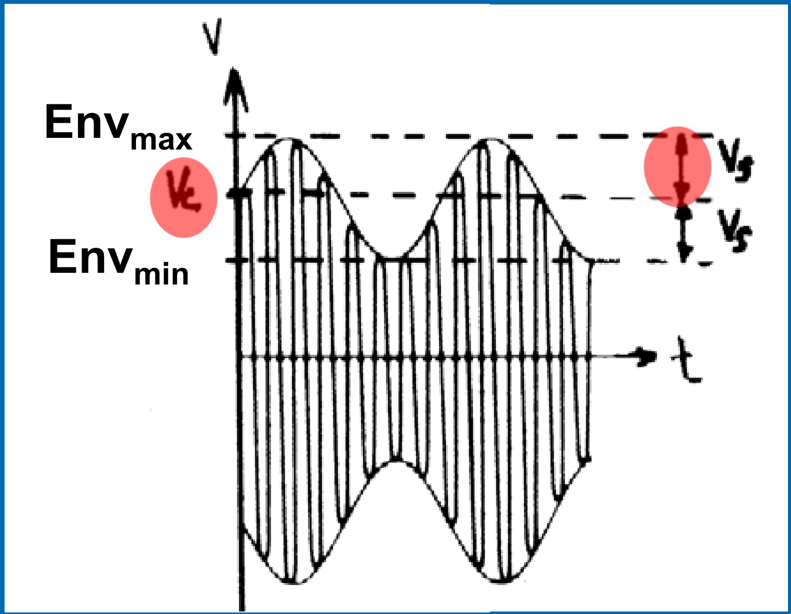
5.1 Principles of AM

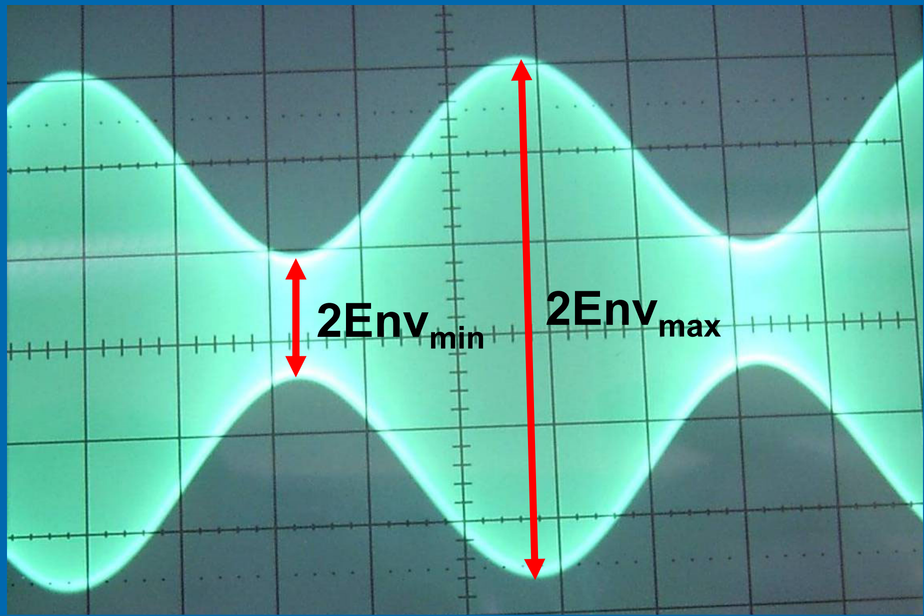
Measurement of modulation index

$$V_s = \frac{Env_{max} - Env_{min}}{2}$$

$$V_c = \frac{Env_{max} + Envmin}{2}$$

$$m = \frac{Env_{max} - Env_{min}}{Env_{max} + Env_{min}}$$





End

CHAPTER 5

(Part 1 of 4)