كلية الهندسة بشبرا

FACULTY OF ENGINEERING AT SHOUBRA

Analog Communication Systems (ELE 280)

LEC (03)

Full AM (DSBLC/DSBFC)

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LECTURE OUTLINES

Content

1 - Review on modulation

Consider the carrier signal below:

$$s_c(t) = A_c(t) \cos(2\pi f_c t + \theta)$$

1. Changing of the carrier amplitude $A_c(t)$ produces

   Amplitude Modulation signal **(AM)**

2. Changing of the carrier frequency f_c produces

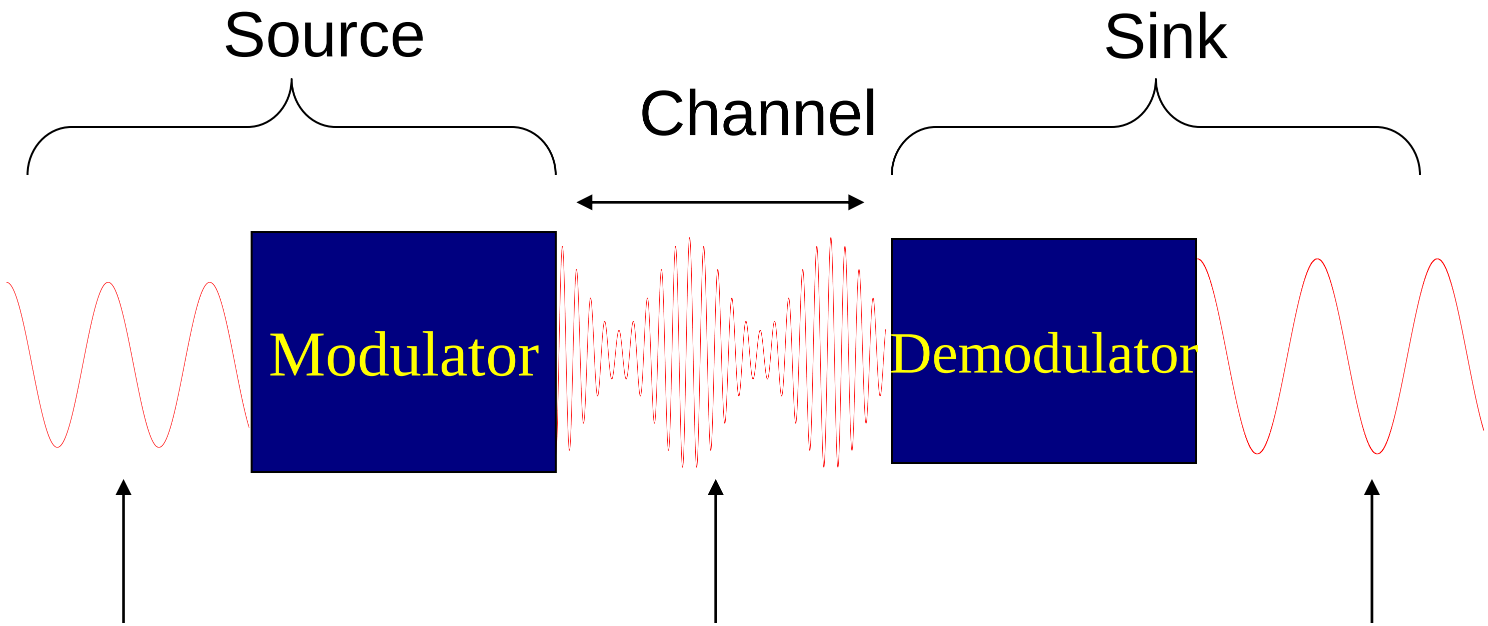
   Frequency Modulation signal **(FM)**

3. Changing of the carrier phase θ produces

   Phase Modulation signal **(PM)**

2 - Types of Amplitude Modulation

Amplitude Modulation



Baseband Signal with frequency f_m (Modulating Signal)

Bandpass Signal with frequency f_c (Modulated Signal)

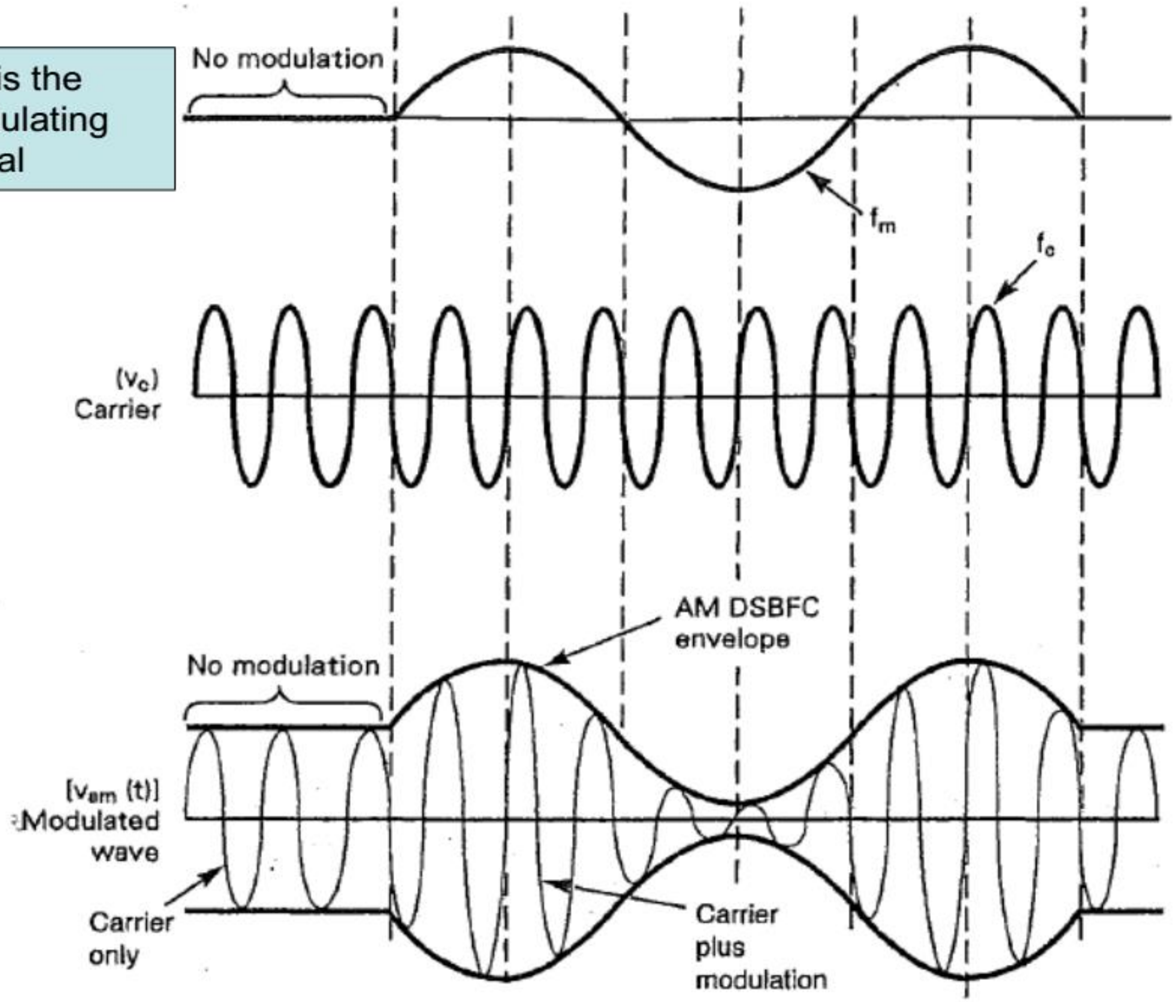
Original Signal with frequency f_m

$f_c \gg f_m$

Voice: 300-3400Hz GSM Cell phone: 900/1800MHz

Amplitude Modulation

Vm is the modulating signal



Types of Amplitude Modulation (AM)

(1) Double Sideband with full/large carrier (DSBFC)(DSBLC) (ordinary AM): This is the most widely used type of AM modulation. In fact, all radio channels in the AM band use this type of modulation.

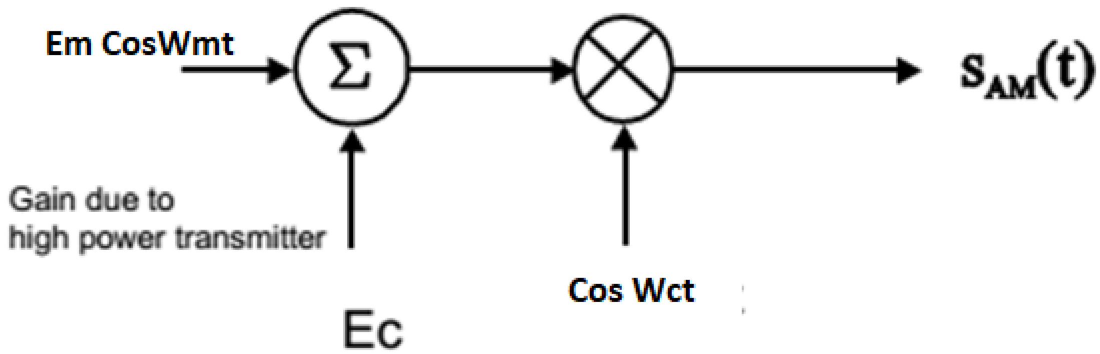
(2) Suppressed carrier (SC)

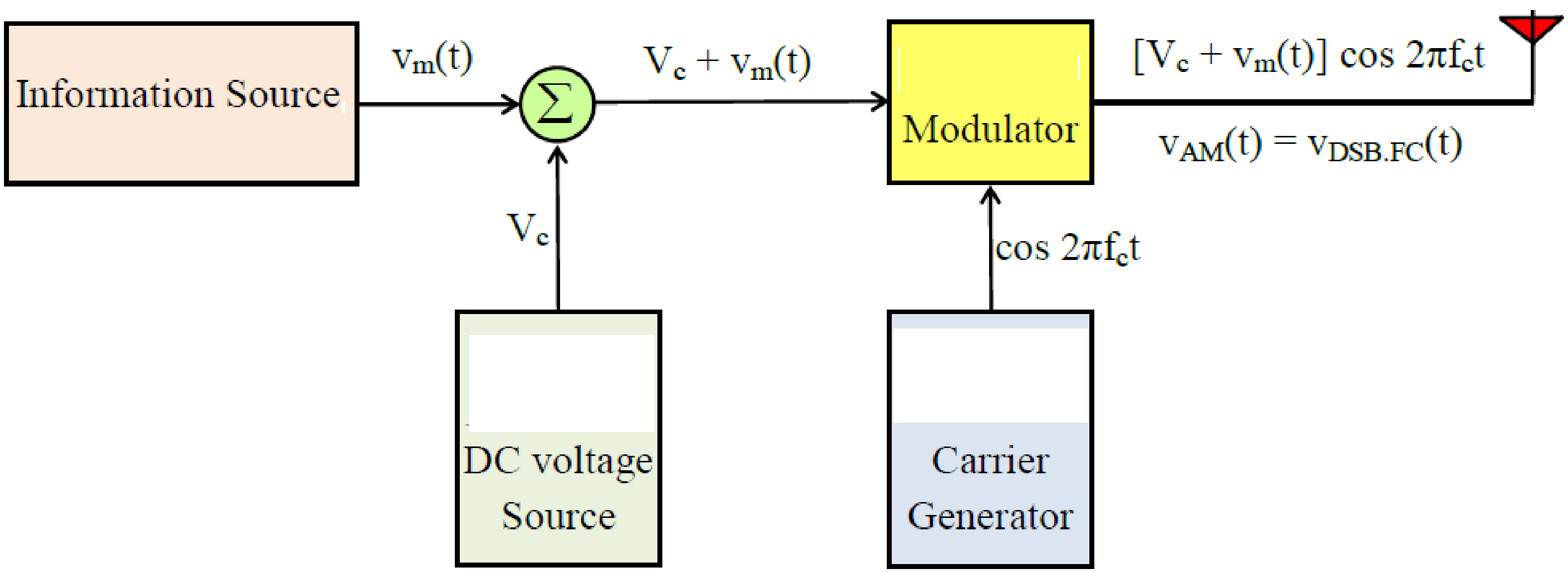
- **(i) Double Sideband Suppressed Carrier (DSBSC)**: This is the same as the AM modulation above but without the carrier.
- **(ii) Single Sideband (SSB):** In this modulation, only half of the signal of the DSBSC is used.

DSBFC or DSBLC

(a) DSBFC block diagram

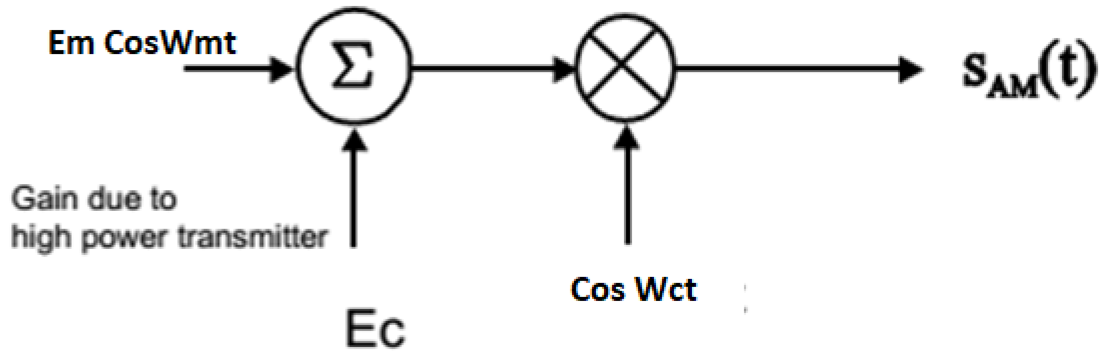
DSBFC block diagram





(b) Mathematical representation for Modulated Signal

Mathematical representation for DSBFC



1 The carrier signal is

$$s_c(t) = A_c \cos(\omega_c t) \quad \text{where } \omega_c = 2\pi f_c$$

2 In the same way, a modulating signal (information signal) can also be expressed as

$$s_m(t) = A_m \cos \omega_m t$$

Mathematical representation for DSBFC

3 The amplitude-modulated wave can be expressed as

$$s(t) = [A_c + s_m(t)]\cos(\omega_c t)$$

4 By substitution

$$s(t) = [A_c + A_m \cos(\omega_m t)]\cos(\omega_c t)$$

5 The modulation index.

$$m = \frac{A_m}{A_c}$$

Mathematical representation for DSBFC

6 Therefore The full AM signal may be written as

$$s(t) = A_c(1 + m\cos(\omega_m t))\cos(\omega_c t)$$

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

$$s(t) = A_c(\cos\omega_c t) + \frac{mA_c}{2}\cos(\omega_c + \omega_m)t + \frac{mA_c}{2}\cos(\omega_c - \omega_m)t$$

(c) Time and Frequency Spectrum of AM wave

Time Spectrum of AM wave

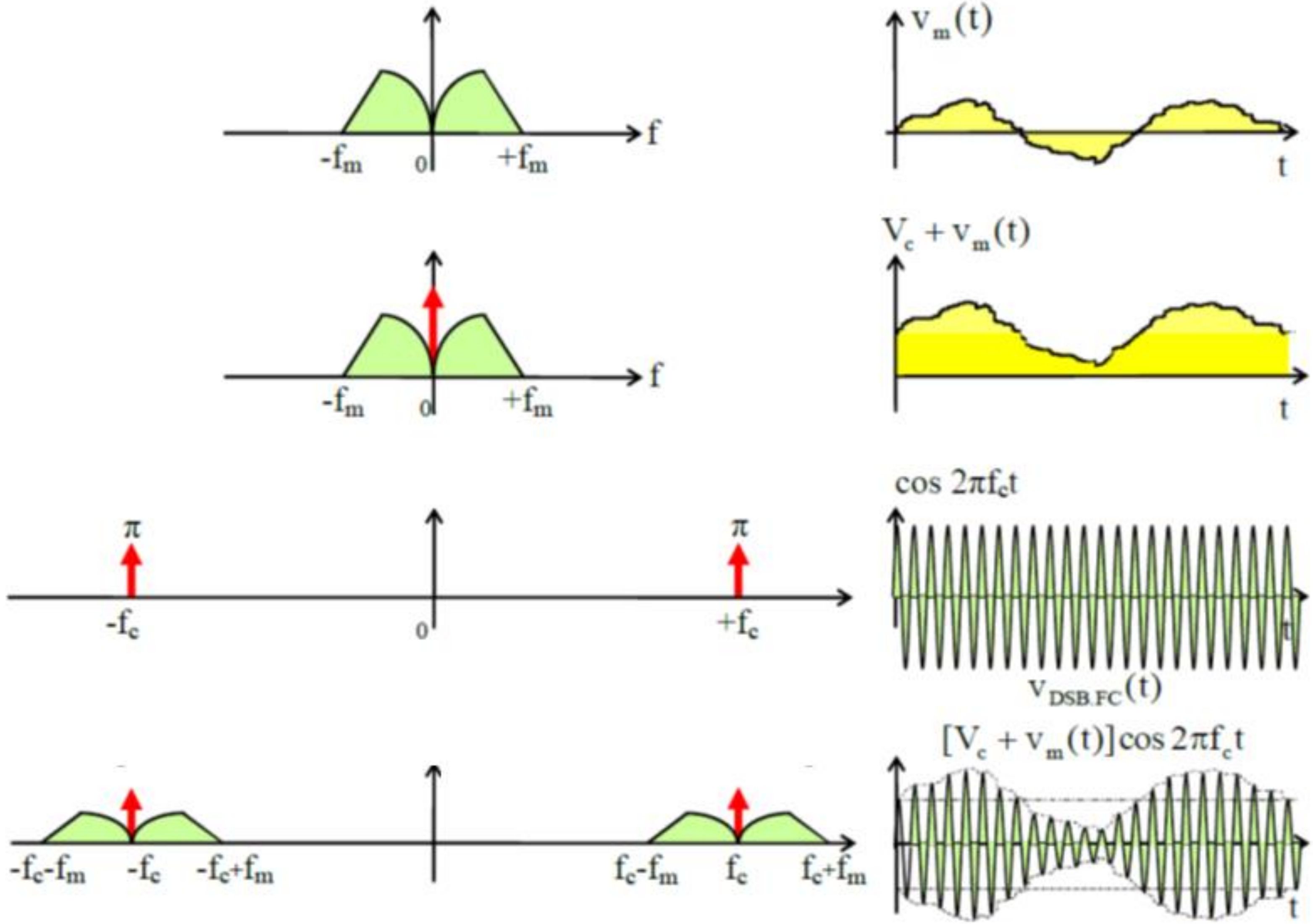
$$s(t) = A_c(\cos\omega_c t) + \frac{mA_c}{2}\cos(\omega_c + \omega_m)t + \frac{mA_c}{2}\cos(\omega_c - \omega_m)t$$

The frequency spectrum of AM waveform contains three parts:

1. A component at the carrier frequency fc
2. An upper side band (USB), whose highest frequency component is at fc+fm
3. A lower side band (LSB), whose highest frequency component is at fc-fm

The bandwidth of the modulated waveform is twice the information signal bandwidth.

Time and Frequency Spectrum of AM wave



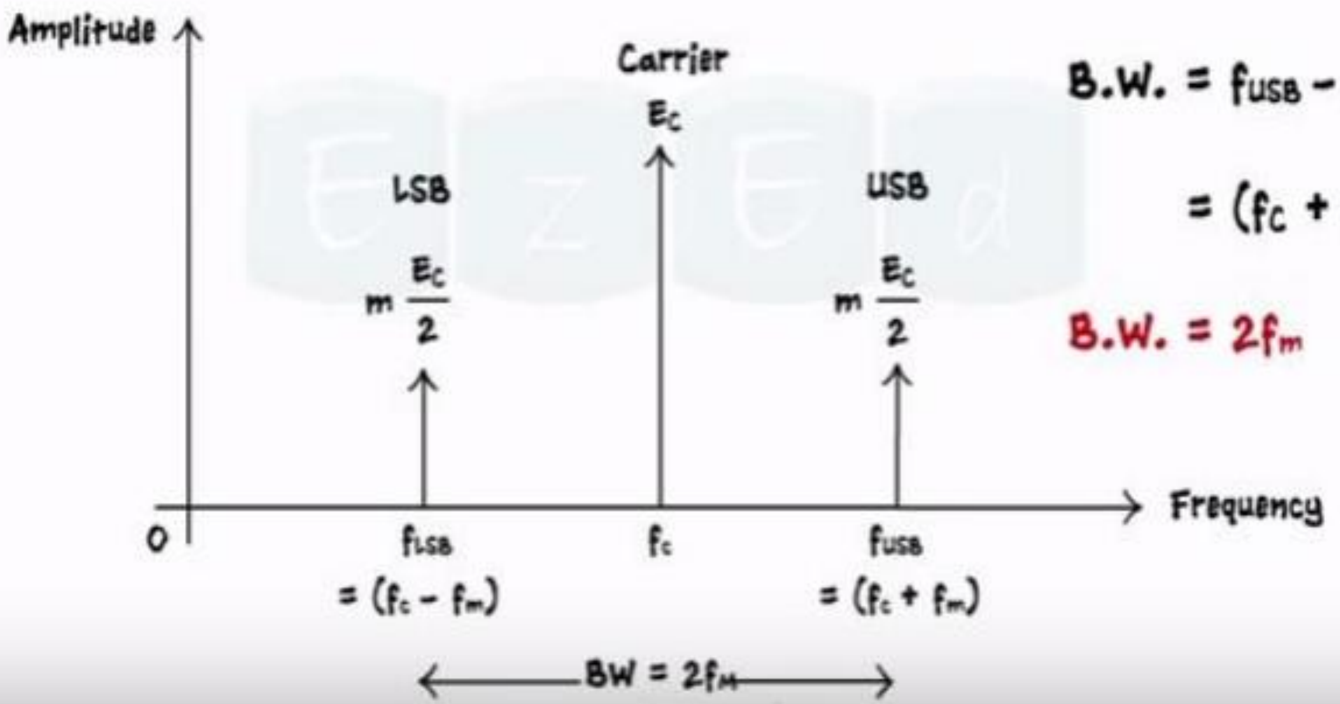
(d) USB , LSB and BW

USB , LSB and BW

The equation of the AM wave thus becomes

$$e_{AM} = \underbrace{E_C \cos(2\omega_C t)}_{\text{Carrier Signal}} + \underbrace{\frac{(m\,E_C)}{2}\cos(\omega_C + \omega_m)t}_{\text{Upper Side Band}} + \underbrace{\frac{(m\,E_C)}{2}\cos(\omega_C - \omega_m)t}_{\text{Lower Side Band}}$$

Single sided frequency spectrum of AM wave



$$B.W. = f_{USB} - f_{LSB}$$

$$= (f_C + f_m) - (f_C - f_m)$$

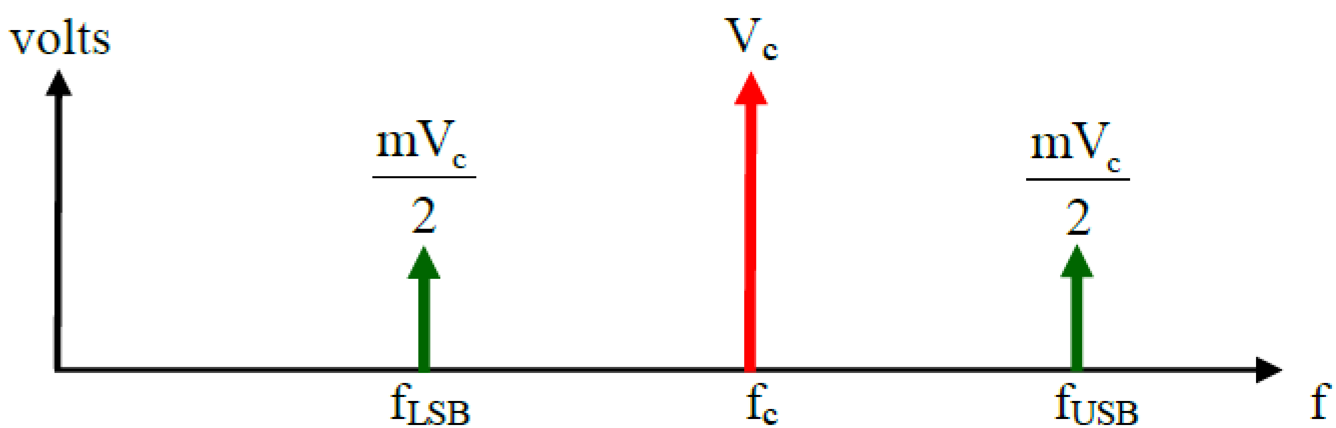
$$B.W. = 2f_m$$

(e) AM Voltage Distribution

AM Voltage Distribution

$$V_c(\text{Modulated}) = V_c(\text{Non} - \text{Modulated})$$

$$V_{LSB} = V_{USB} = \frac{mV_c}{2}$$



(f) AM Power Distribution

AM Power Distribution

$$P_{av} = \frac{V_{rms}^{2}}{R_L} \qquad V_{rms} = \frac{V_m}{\sqrt{2}} \qquad P_{av} = \frac{V_m^{2}}{2R_L}$$

$$P_c = \frac{V_c^{2}}{2R_L} \qquad P_{LSB} = P_{USB} = \frac{\left(\frac{mV_c}{2}\right)^2}{2R_L} = \frac{m^2 V_c^2}{8R_L}$$

$$P_{LSB} = P_{USB} = \frac{1}{4} m^2 P_c$$

$$P_T = P_c + P_{LSB} + P_{USB} = P_c + \frac{1}{4} m^2 P_c + \frac{1}{4} m^2 P_c = \left(1 + \frac{m^2}{2}\right) P_c$$

The power used to transmitte information for simple AM is thus :

$$\eta_{AM} = \frac{P_{Info}}{P_T} = \frac{\frac{A_c^2 m^2}{8R} + \frac{A_c^2 m^2}{8R}}{\frac{A_c^2}{2R} + \frac{A_c^2 m^2}{8R} + \frac{A_c^2 m^2}{8R}} = \frac{\frac{m^2}{4} + \frac{m^2}{4}}{1 + \frac{m^2}{4} + \frac{m^2}{4}} = \frac{2m^2}{4 + 2m^2} = \frac{m^2}{2 + m^2}$$

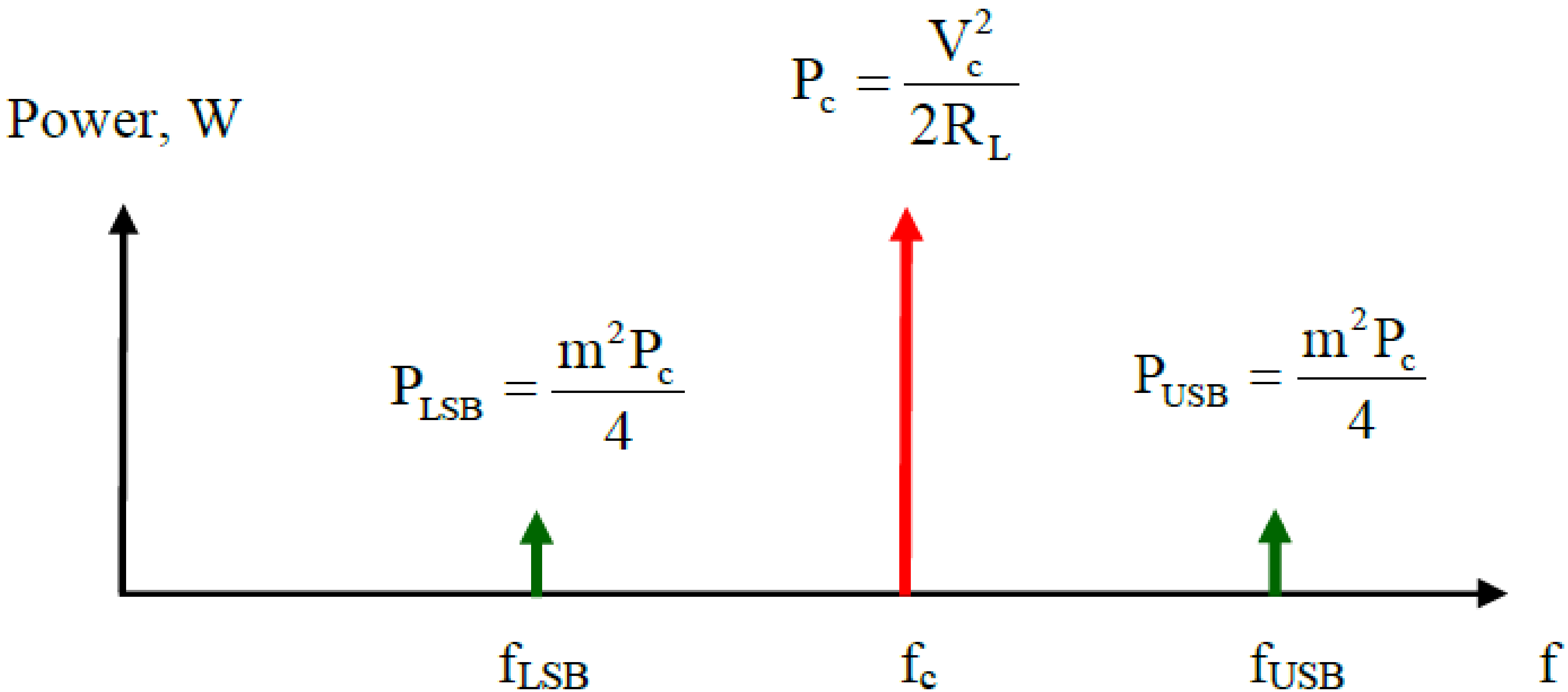
When $m = 1$

$$\eta_{AM} = \frac{1}{3} \quad \Longleftrightarrow \quad \frac{2}{3} = 66.6\% \text{Power Lost}$$

Therefore, simple AM signal is not power-efficienct.

$$\eta_{AM} < 33.3\% = \sup \eta_{AM}$$

AM Power Distribution



Most power wasted in carrier

While most information concentrated in DSB

(g) Modulation index

Modulation index

- **m** is merely defined as a parameter, which determines the amount of modulation.
- What is the degree of modulation required to establish a desirable AM communication link?

Answer is to maintain $m<1.0 (m<100\%)$.

- This is important for successful retrieval of the original transmitted information at the receiver end.

Coefficient of Modulation and Its Percentage

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

$$M = \frac{V_m}{V_c} \text{x}100\ \%$$

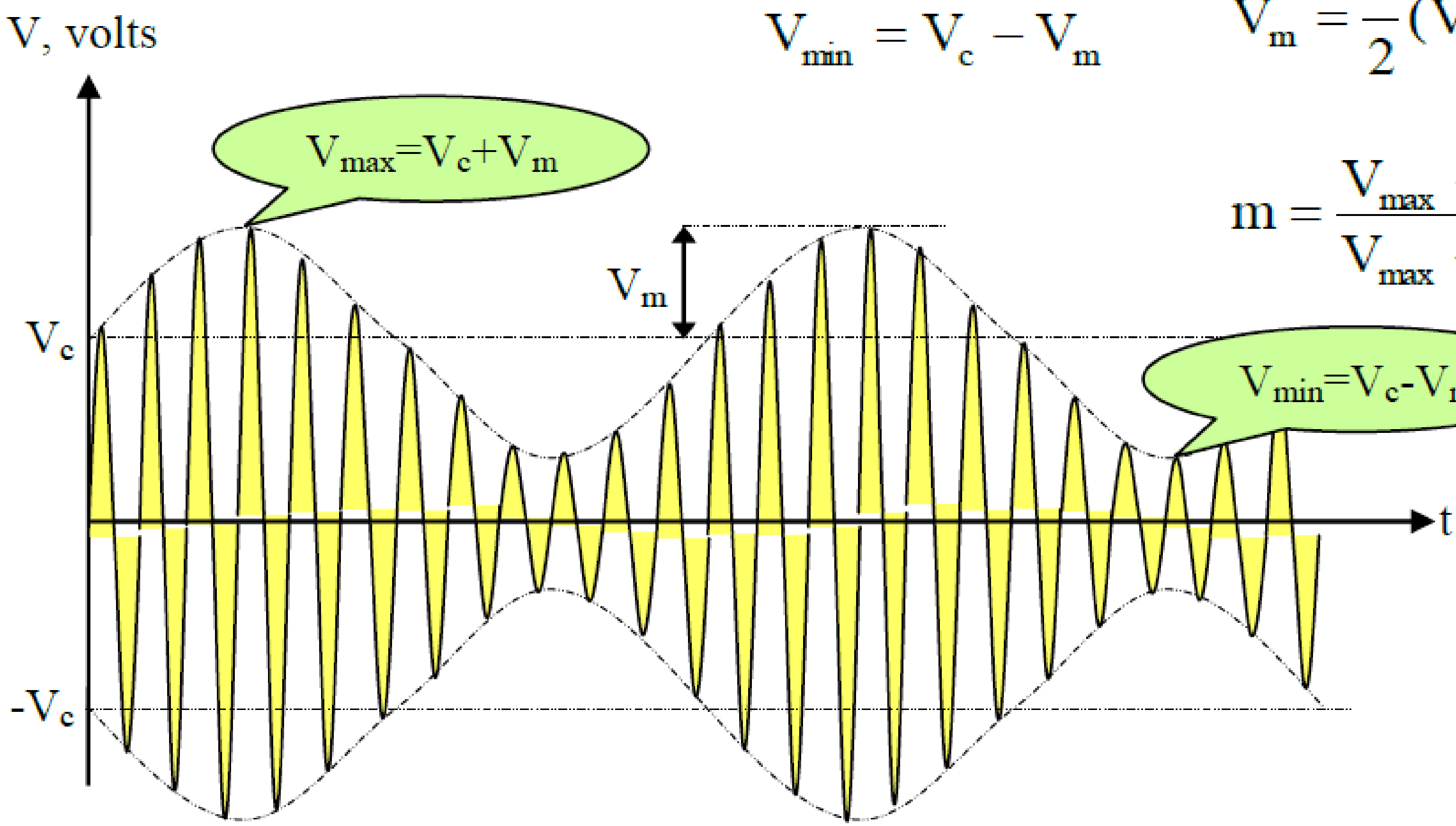
$$V_{max} = V_c + V_m$$

$$V_c = \frac{1}{2}(V_{max} + V_{min})$$

$$V_{min} = V_c - V_m$$

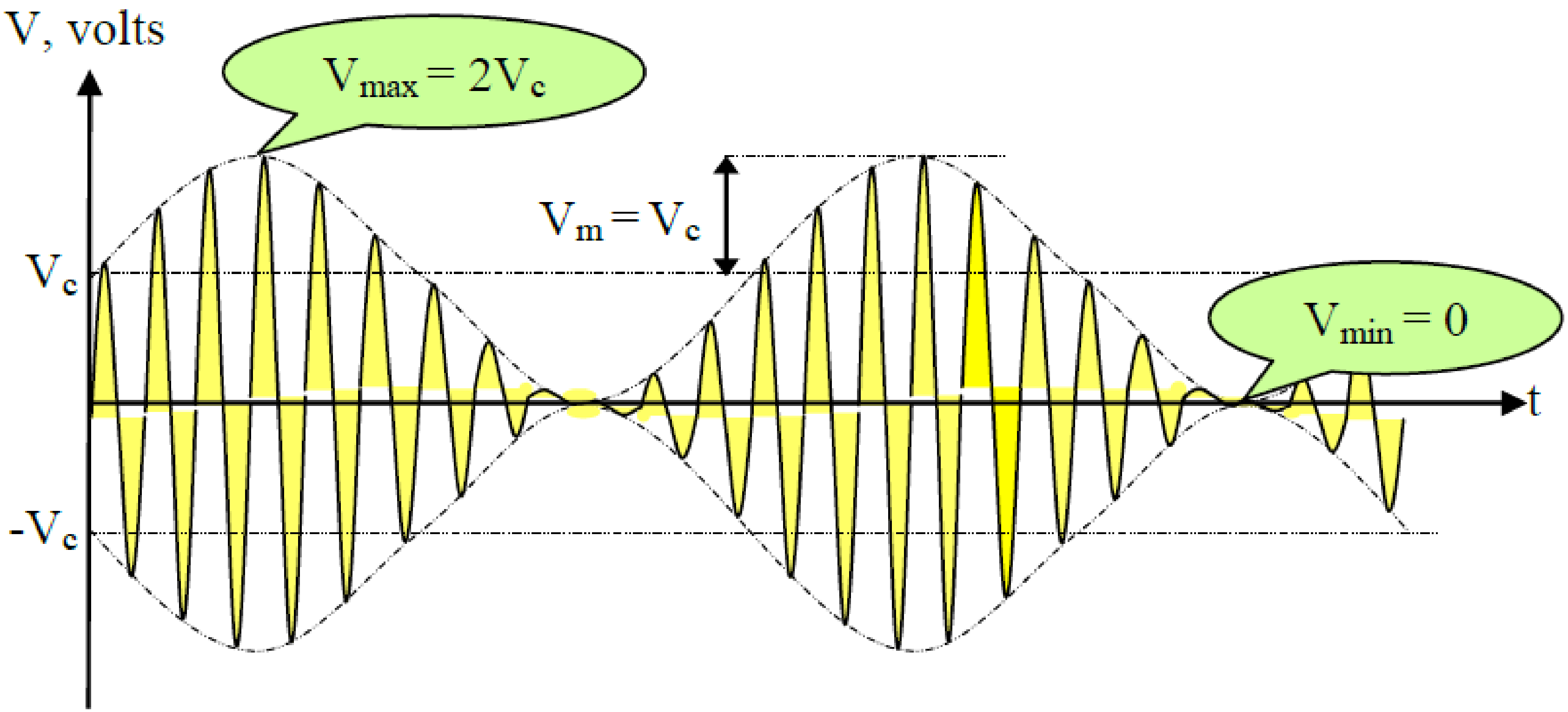
$$V_m = \frac{1}{2}(V_{max} - V_{min})$$

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



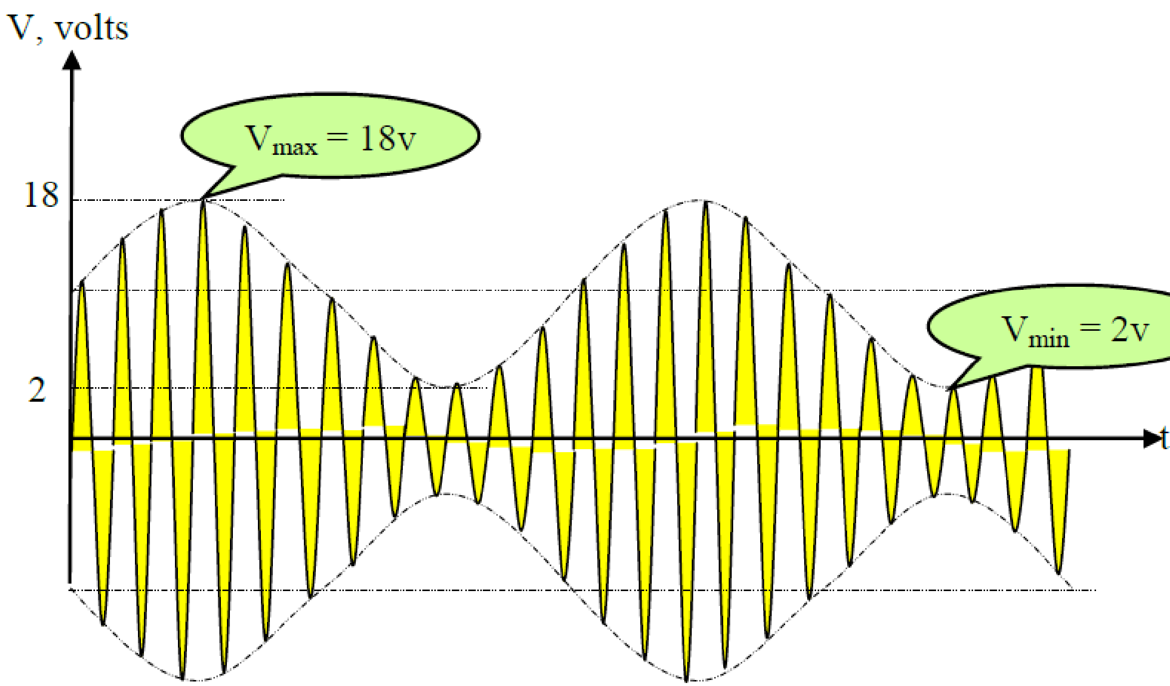
Coefficient of Modulation and Its Percentage

For m=100%



Coefficient of Modulation and Its Percentage

Ex.1 : find m , %m , peak of envelope



$$V_c = \frac{1}{2}(V_{max} + V_{min}) = \frac{1}{2}(18+2) = 10\ V$$

$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} = \frac{18-2}{18+2} = \frac{16}{20} = 0.8$$

$$V_m = \frac{1}{2}(V_{max} - V_{min}) = \frac{1}{2}(18-2) = 8\ V$$

$$M = \frac{V_m}{V_c} x100\ \% = \frac{8}{10} x100\ \% = 80\ \%$$

(g) Solved Example

Solved Example

Q. The modulating signal $20 \cos(2\pi * 10^3 t)$ is used to modulate a carrier signal $40 \cos(2\pi * 10^4 t)$. Find the modulation index, percentage modulation, frequencies of sideband components and their amplitudes.
What is the bandwidth of the modulated signal ?

Given: $e_M = 20 \cos(2\pi * 10^3 t)$

$e_C = 40 \cos(2\pi * 10^4 t)$

To Find: m, % m, f_{USB}, f_{LSB}, Amplitude of each side band and the bandwidth required.

Formula: $e_m = E_m \cos \omega_m t$

$e_C = E_C \cos \omega_C t$

$$m = \frac{E_m}{E_C}$$

$$BW = 2f_m$$

Solved Example

Ans

The modulating signal is given as:

$$e_m = E_m \cos \omega_m t$$

The given signal is :

$$e_M = 20 \cos (2\pi * 10^2 t)$$

On comparing,

$E_m = 20,\ \omega_m = 2\pi * 10^2$

$\therefore f_m = 1000$ Hz = 1 kHz.

The carrier signal is given as:

$$e_C = E_C \cos \omega_C t$$

The given signal is :

$$e_C = 40 \cos (2\pi * 10^4 t)$$

On comparing,

$E_C = 20,\ \omega_m = 2\pi * 10^4$

$\therefore f_C = 10000$ ⊦

The modulation index is given as:

$$m = \frac{E_m}{E_C} = \frac{20}{40} = 0.5$$

$\%\ m = 0.5 * 100 = 50\ \%$

The frequencies are calculated as :

$f_{USB} = f_C + f^m = 10$ kHz + 1 kHz = 11 kHz.

$f_{LSB} = f_C - f_m = 10$ kHz − 1 kHz = 9 kHz.

The amplitudes of each sidebands are:

$$\text{Amplitude of each side band} = \frac{(m\ E_C)}{2} = \frac{(0.5 * 40)}{2} = 10 \text{ Volts}$$

Thank you for your attention

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