Analog Communication Systems (ELE 280)

LEC (02)

Modulation , AM

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LECTURE OUTLINES

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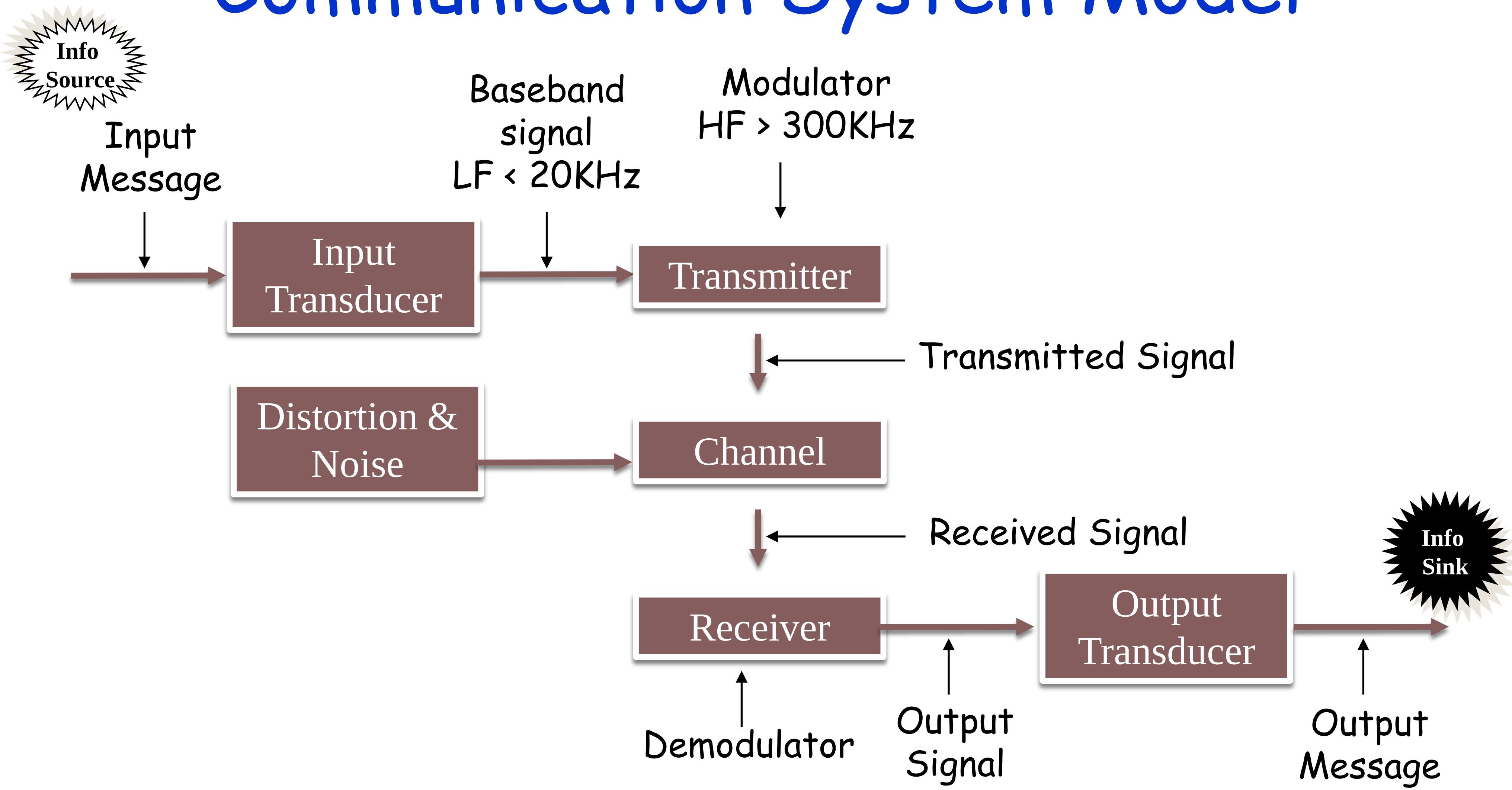
1 - Communication System Model

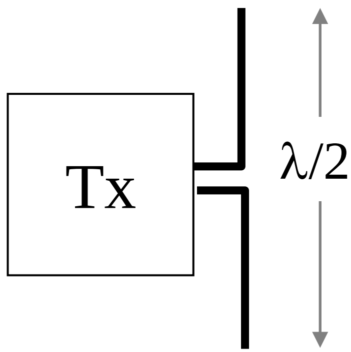
Communication System Model



2 - Why go to higher frequencies?

Why go to higher frequencies?

Half-wave dipole antenna



c = f l

c = 3E+08 ms-1

Calculate l for

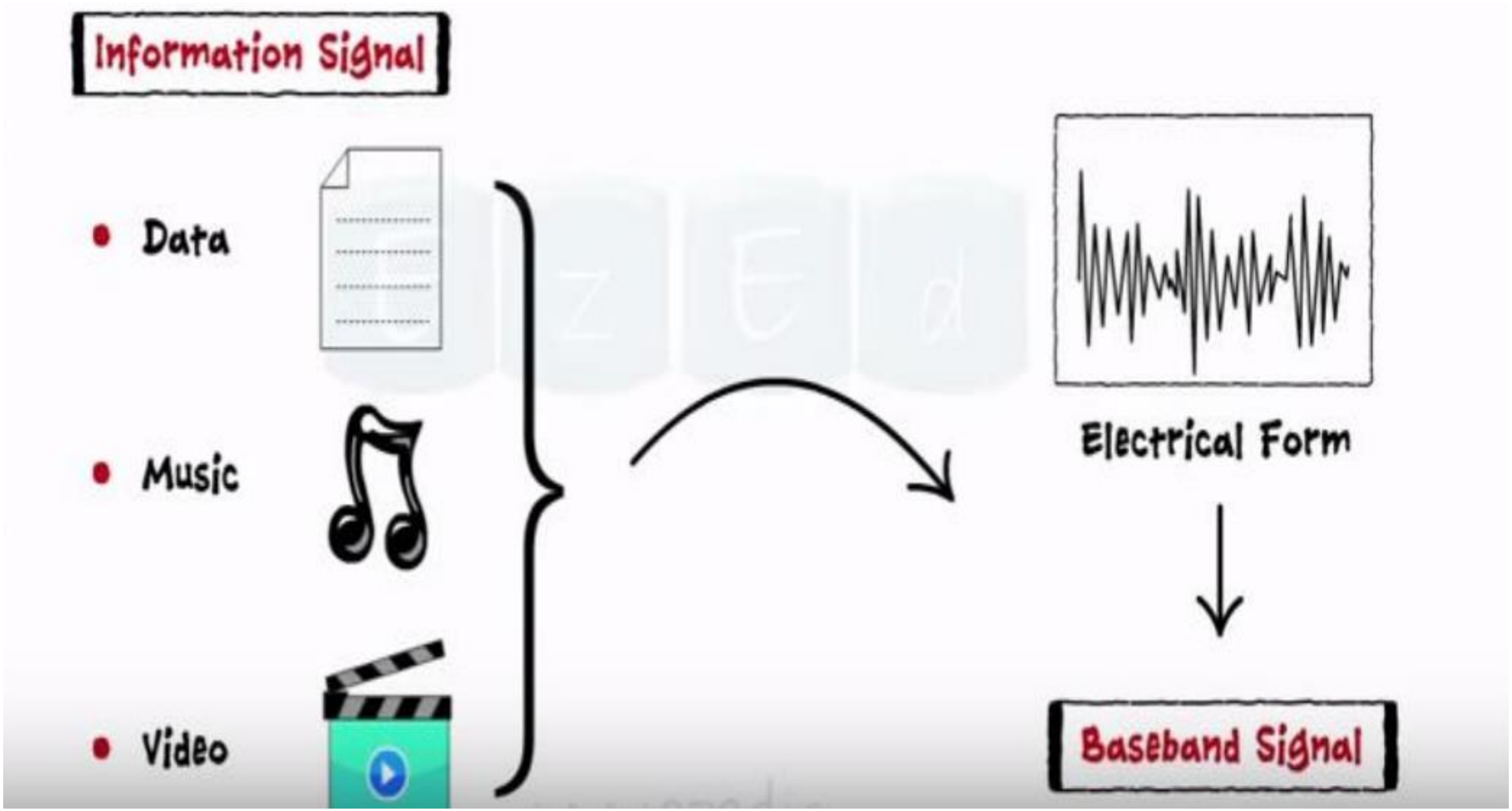
f = 5 kHz

f = 300 kHz

There are also other reasons for going from baseband to bandpass

3 - Baseband communications

Baseband communications



Baseband communications

- Analog signal generated by the message source is called "baseband signal".
- However, baseband signals are not always suitable for direct transmission.
- Baseband signals such as audio and video contain significant low-frequency content, Baseband signals may be directly transmitted without modulation (e.g. audio telephone signal with approx. (0-3 KHz) bandwidth.

Baseband communications

- Audio and video signals cannot be effectively transmitted over radio (wireless) link. They may transmitted on twisted pair wire with almost the same bandwidth); NTSC –TV video baseband is video band (0 - 4.3 MHz).
- As a result, dedicated user channel such as twisted pairs of copper wires and coaxial cables are assigned to each user for long distance communications. Thus, the message signal must be modified for possible (efficient) transmission. This modification is called "modulation".

4 - Modulation

Modulation: is the process of encoding information from a message source in a manner suitable for transmission.

- It involves translating a baseband message signal to a bandpass signal at frequencies that are very high compared to the baseband frequency.

- Baseband signal is called modulating signal
- Bandpass signal is called modulated signal

(a) - Why we need Modulation

Important Reasons for Modulation

The need for modulation:

- Ease of radiation (*dimensions of antenna decreased*)
- Separation of channels.
- Simultaneous transmission of multiple signals (ease of multiplexing).

Important Reasons for Modulation

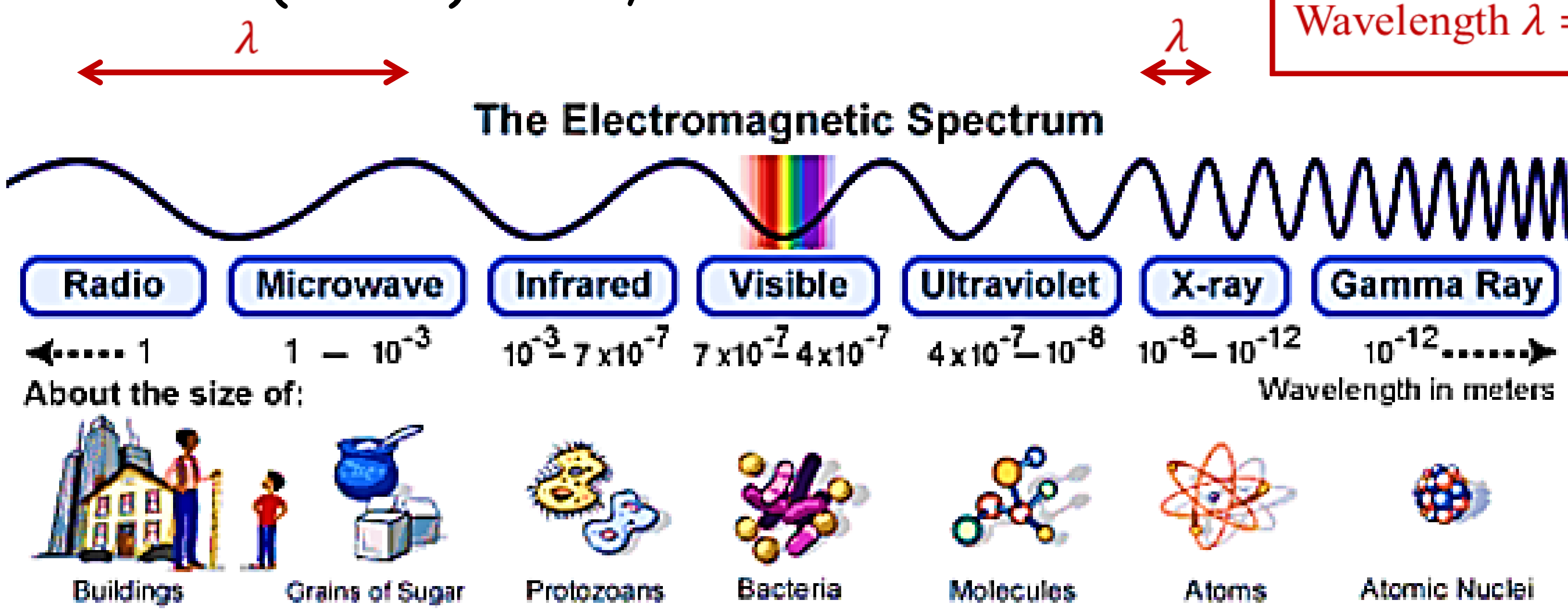
i. Ease of radiation (*dimensions of antenna decreased*)

- The dimensions of the transmitting antenna must be comparable to the wavelength of the transmitted signal.

-if f=1kHz(Audio) Then, L=150km , c = light speed , $\lambda = c/f$, L= $\lambda/2$ (half wave dipole)

- if f=100MHz(Audio) Then, L=1.5m.

$$\text{Wavelength } \lambda = \frac{c}{f}$$



Electromagnetic spectrum in terms of wavelength.

Important Reasons for Modulation

ii. Separation of channels.

- All similar information signals (e.g. audio signals, video signals ..etc. have the same bandwidth. Transmission in baseband may cause interference.
- Modulation allows each information signal to have a certain channel (frequency) and thus allows the receiver to select any desired channel (tuning).

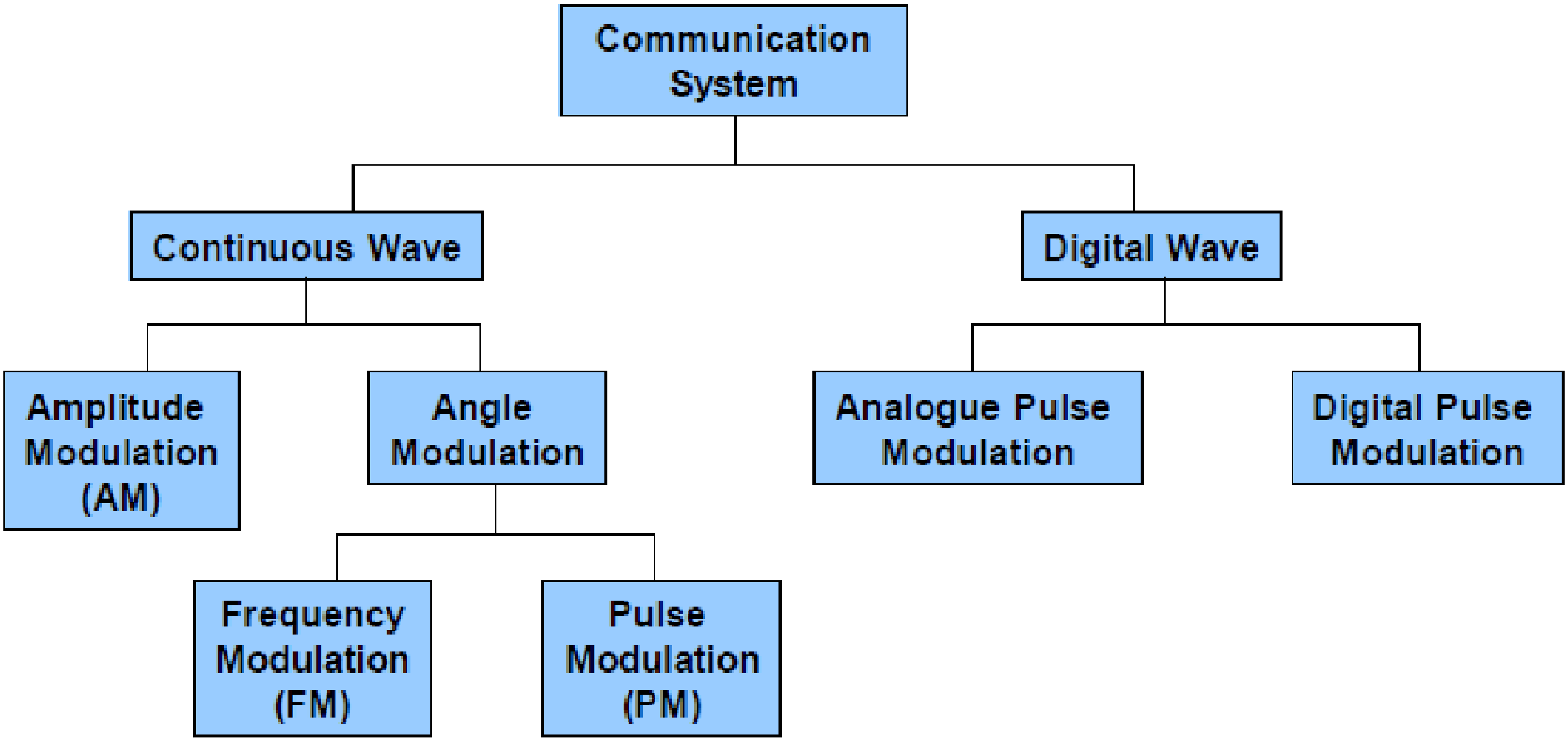
Important Reasons for Modulation

iii. ease of multiplexing

- For multi input-multi output communications, we use modulation to combine several information signals (users) on one channel.
- Consider TV signals, without modulation, multiple video signals will be interfering with each other (because all video signals inherently have the same bandwidth of approx. 4.5 MHz).

(b) - Types of Modulation (Modulation Techniques)

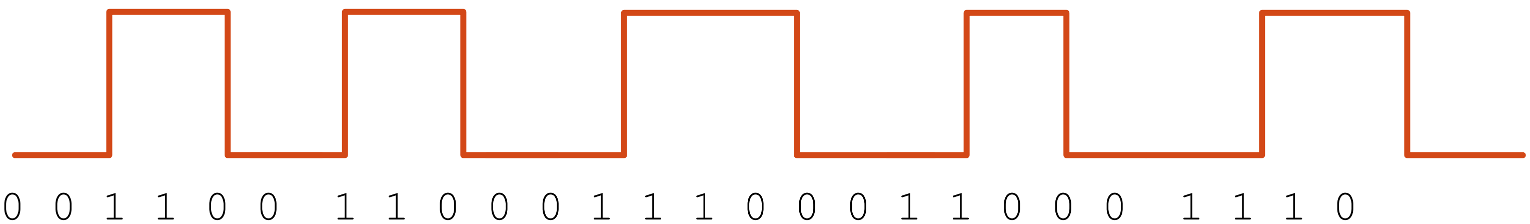
Types of Modulation (Modulation Techniques)

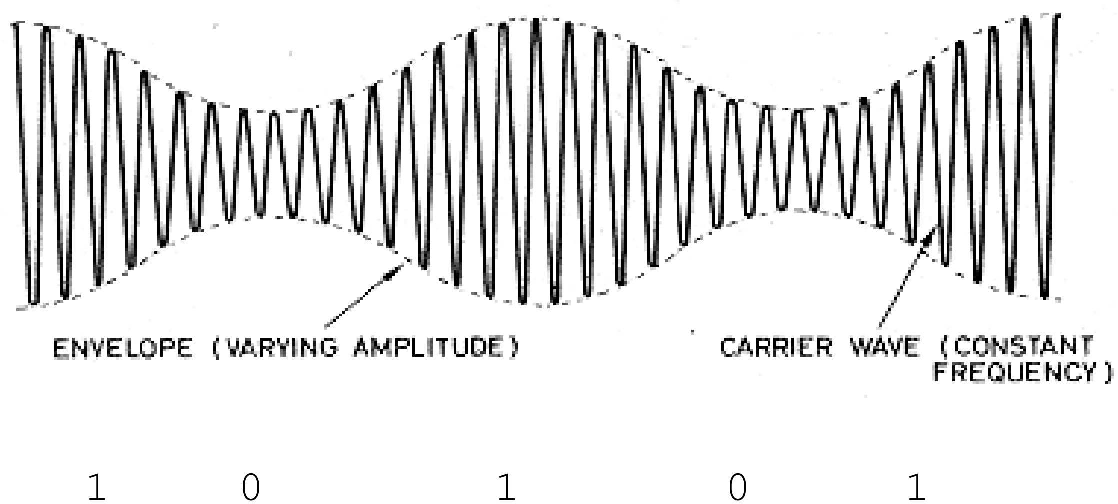


- AM / FM radios and old TV signals are based on analog modulation techniques.
- 2G, 3G, HDTV and DSL are based on digital modulation techniques.

Amplitude Modulation

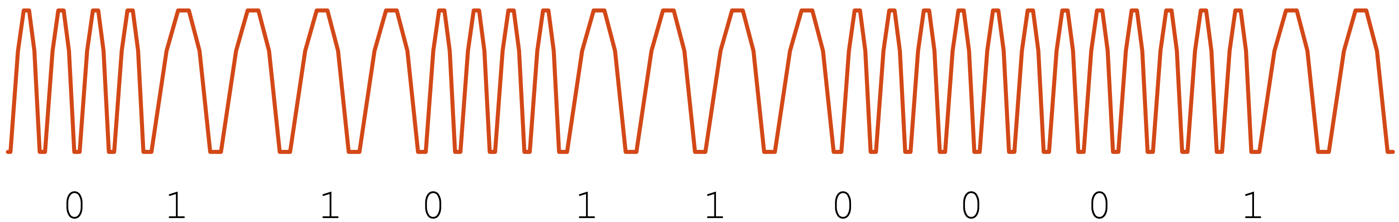
- AM: change the strength of the signal.
- Example: High voltage for a 1, low voltage for a 0

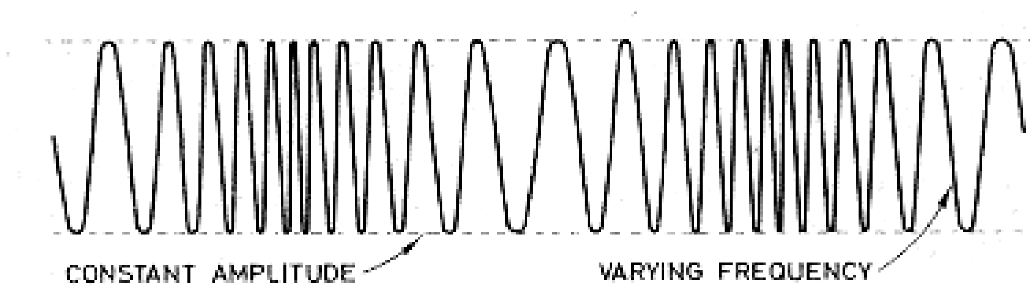




Frequency Modulation

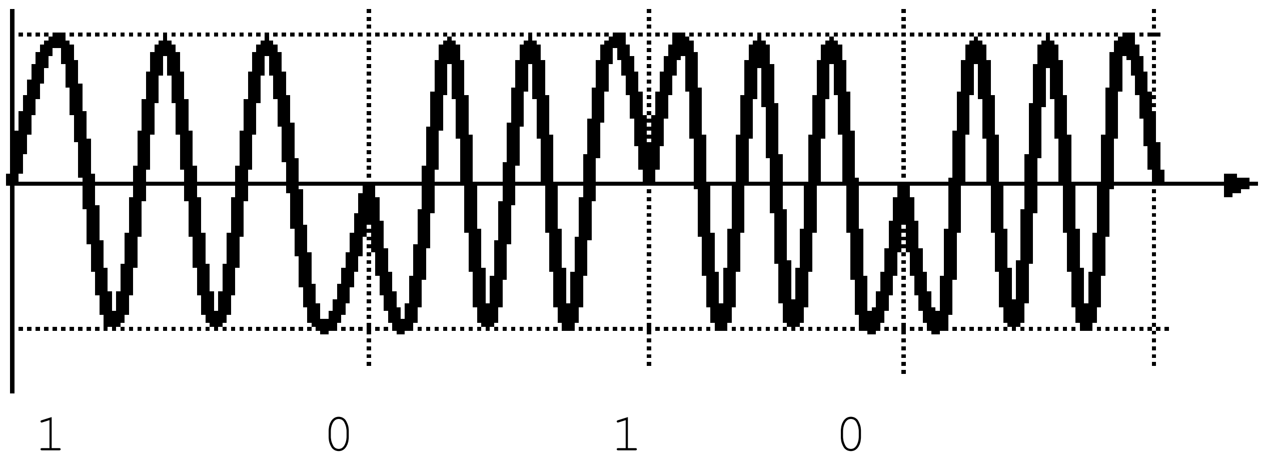
- FM: change the frequency





Phase Modulation

- PM: Change the phase of the signal



(c)-Why Different Modulation Methods?

Why Different Modulation Methods?

- Transmitter/Receiver complexity
- Power requirements
- Bandwidth
- Medium (air, copper, fiber, …)
- Noise immunity
- Range
- Multiplexing

(d)-What Do We Care About?

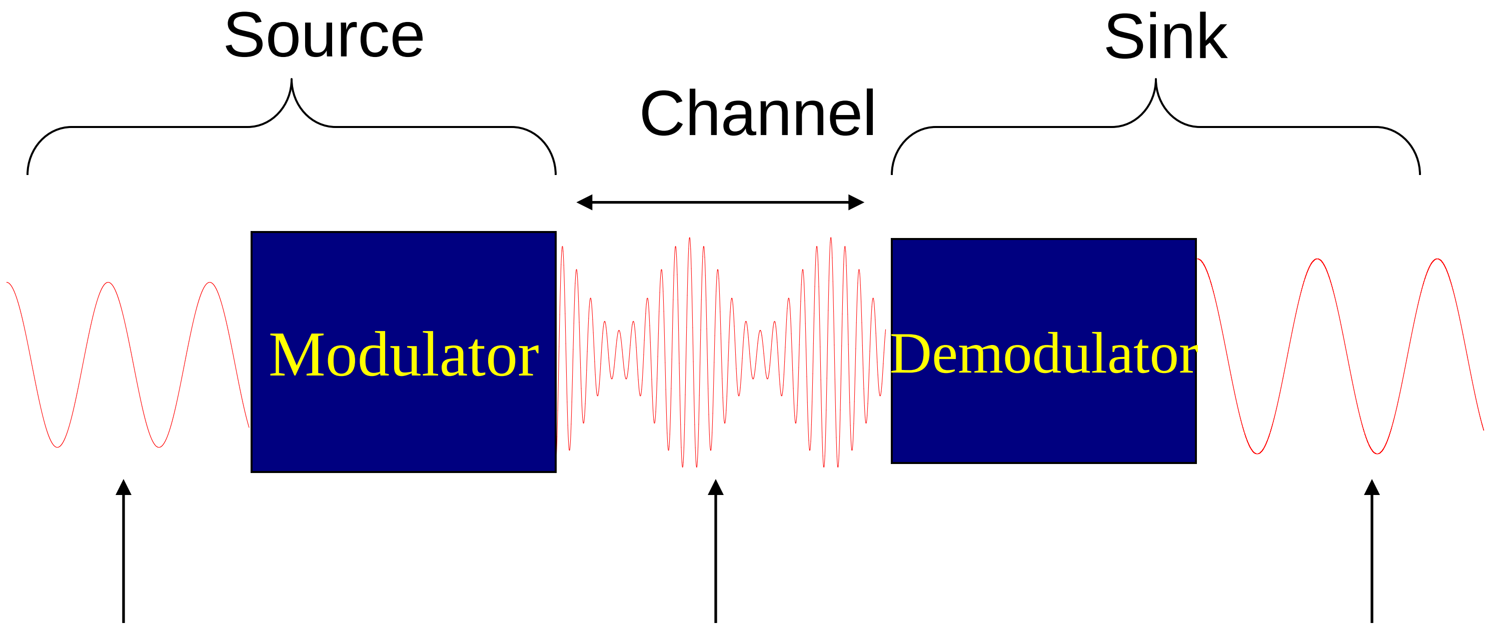
What Do We Care About?

- How much bandwidth can I get out of a specific wire (transmission medium)?
- What limits the physical size of the network?
- How can multiple hosts communicate over the same wire at the same time?
- How do the properties of copper, fiber, and wireless compare?

Amplitude Modulation

(a) Basic block diagram

Amplitude Modulation



Baseband Signal with frequency f_m (Modulating Signal)

Bandpass Signal with frequency f_c (Modulated Signal)

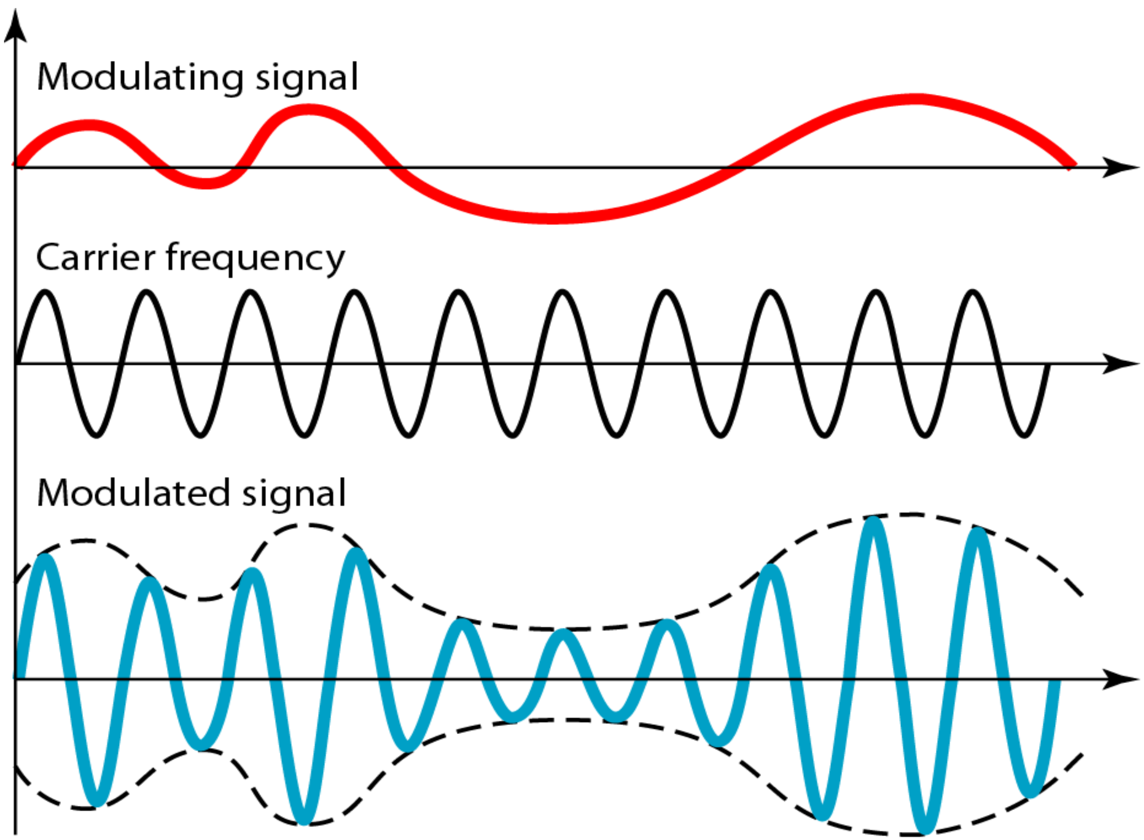
Original Signal with frequency f_m

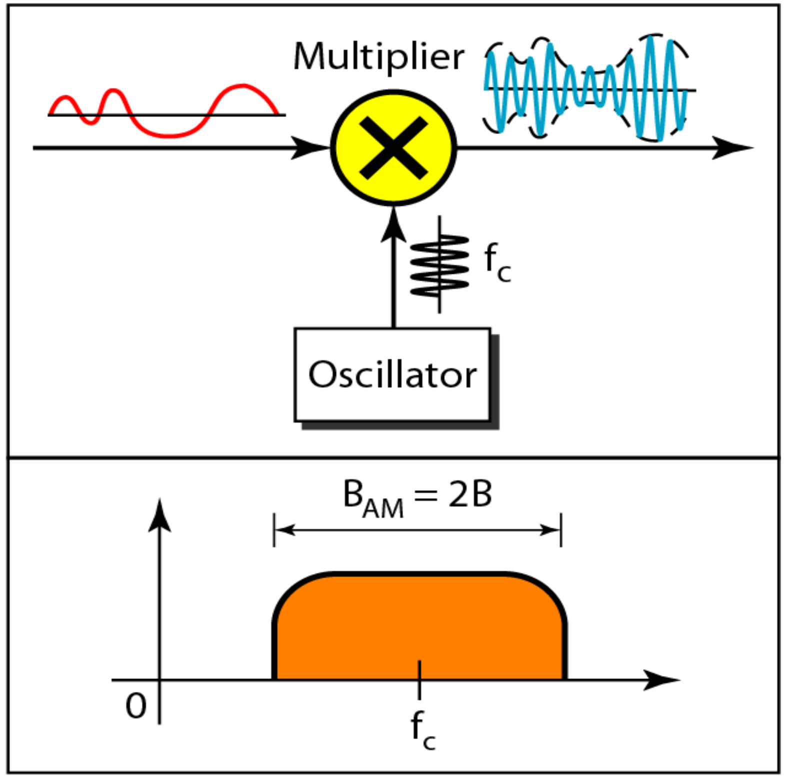
$f_c \gg f_m$

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

(b) How AM generated?

Amplitude Modulation





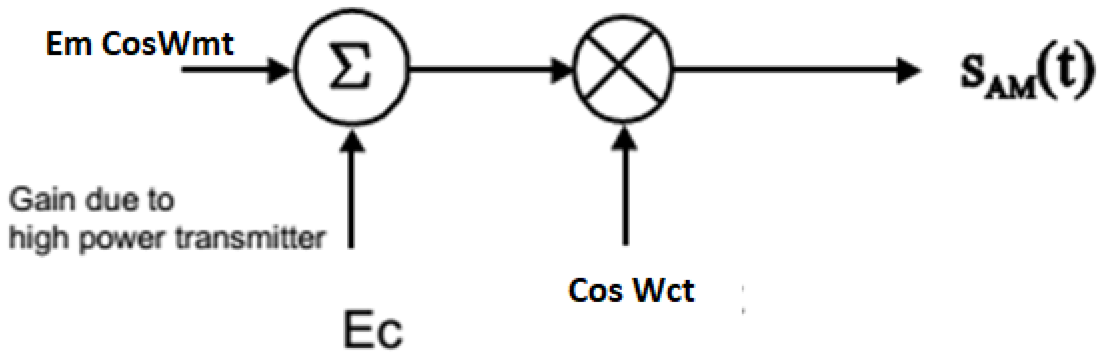
(c) AM Types

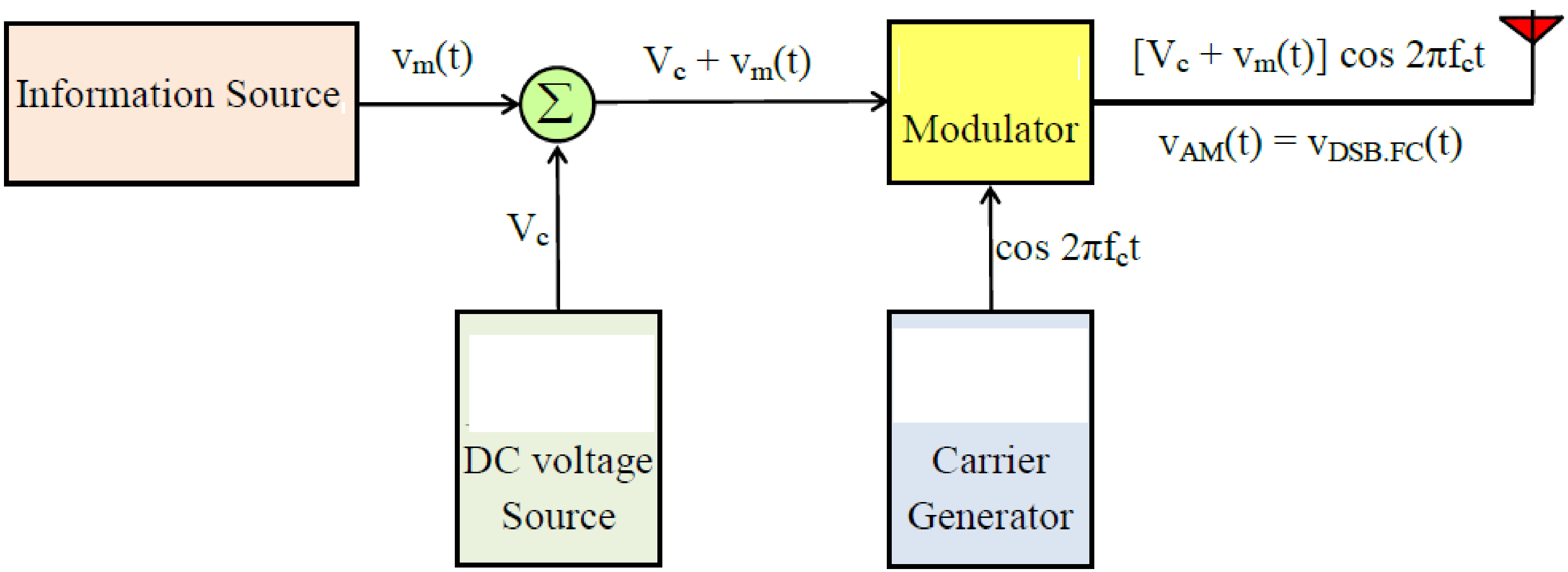
Types of Amplitude Modulation (AM)

- Double Sideband with full carrier (DSBFC) (we will call it 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.
- Double Sideband Suppressed Carrier (DSBSC): This is the same as the AM modulation above but without the carrier.
- Single Sideband (SSB): In this modulation, only half of the signal of the DSBSC is used.

(d) AM Representation DSBFC

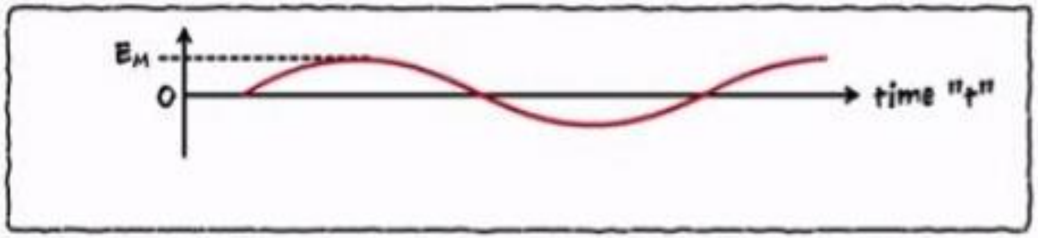
DSBFC block diagram

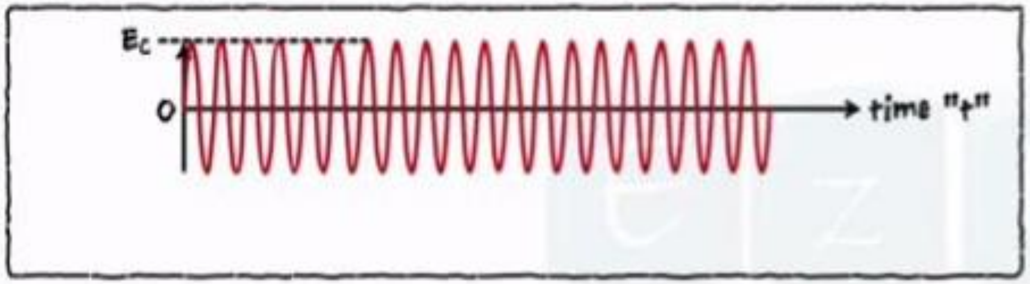




Mathematical representation of AM

Mathematical Representation of AM Wave





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

Where,

e_m = Instantaneous amplitude of modulating signal.

E_m = Peak Amplitude

$\omega_m = 2\pi f_m$

f_m = frequency of modulating signal.

$$e_c = E_c \cos \omega_c t$$

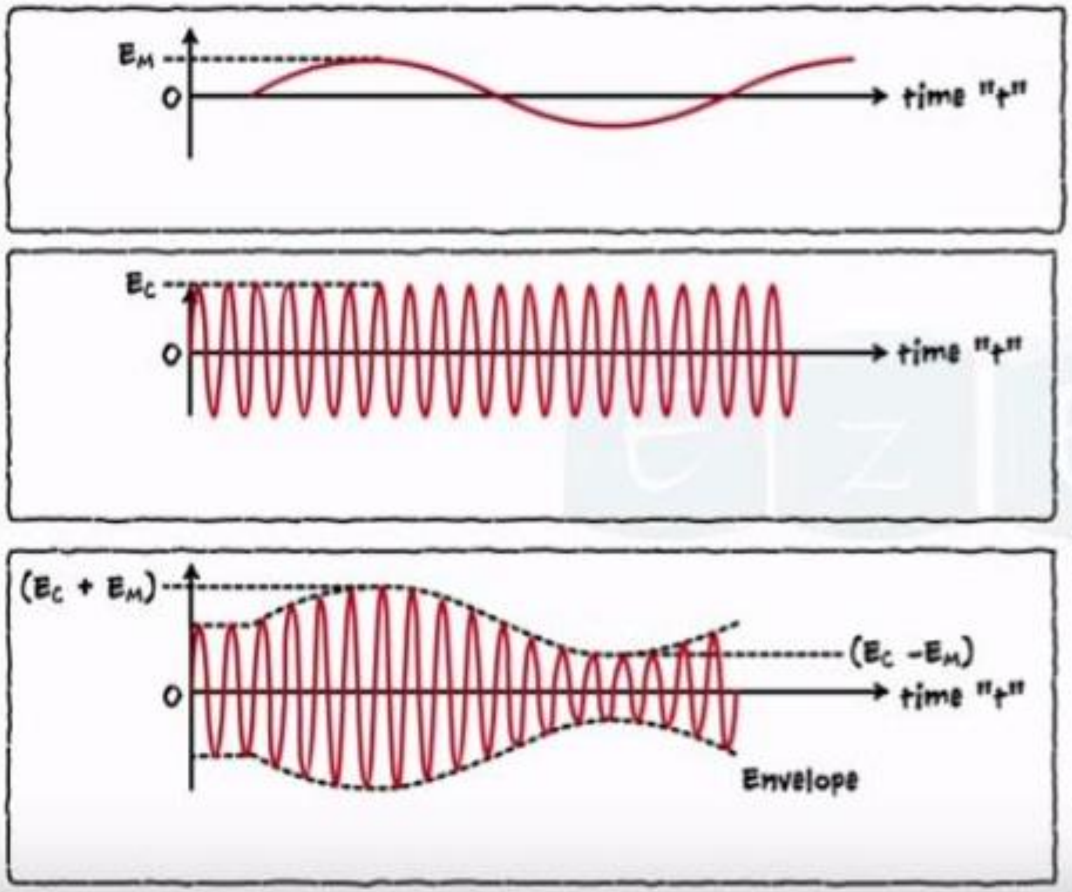
Where,

E_c = Peak Carrier amplitude

f_c = carrier frequency ($\omega_c = 2\pi f_c$)

Mathematical representation of AM

Mathematical Representation of AM Wave



The Amplitude Modulated wave is given as:

$$e_{AM} = A \cos(2\pi f_c t)$$

Where

A = Instantaneous amplitude of an envelope

Hence we can represent this instantaneous value as:

$$A = E_c + e_m$$
$$= E_c + E_m \cos \omega_m t$$
$$= E_c + E_m \cos(2\pi f_m t)$$

Substituting A,

$$e_{AM} = \{E_c + E_m \cos(2\pi f_m t)\} \cos(2\pi f_c t)$$
$$= E_c \{1 + \frac{E_m}{E_c} \cos(2\pi f_m t)\} \cos(2\pi f_c t)$$

Let $m = \frac{E_m}{E_c}$ be the modulation index.

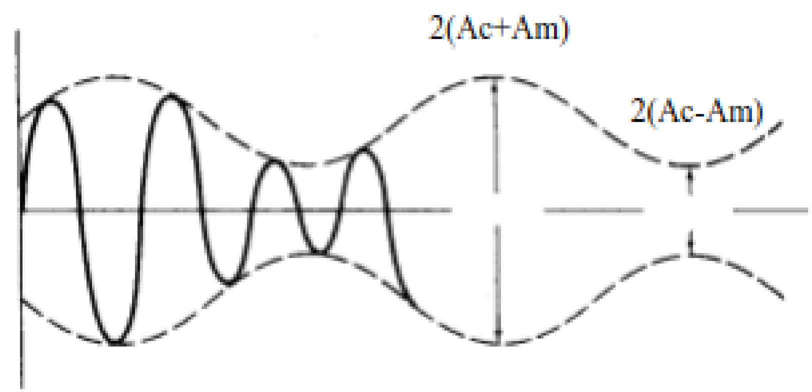
$1 > m > 0$

Modulation index (m)

Then if the modulation is symmetrical

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

$$= \frac{2(Ac + Am) - 2(Ac - Am)}{2(Ac + Am) + 2(Ac - Am)}$$

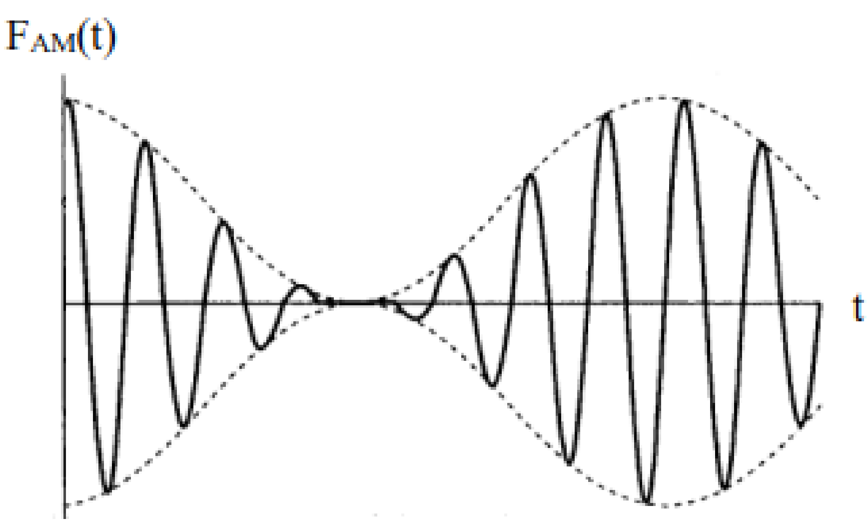


1>m>0

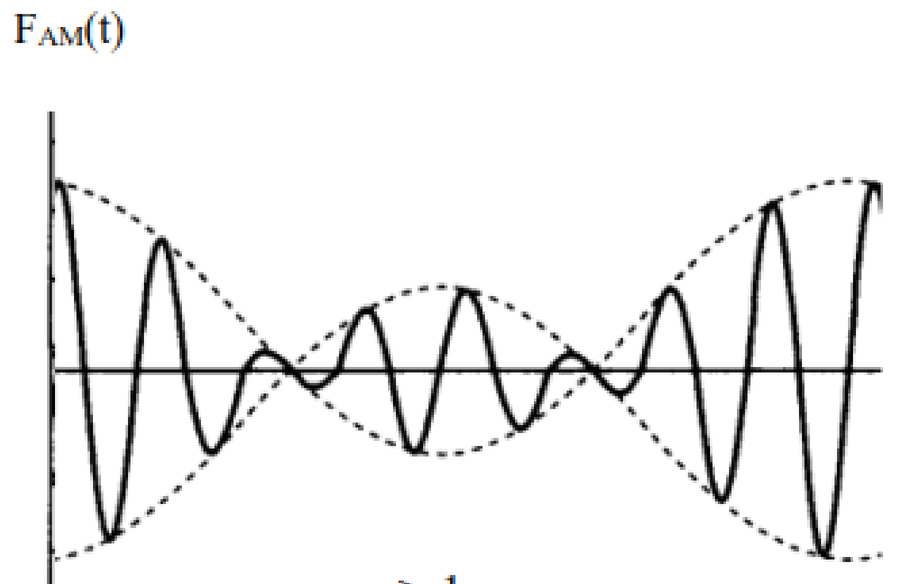
Modulation index (m)

$A(t)=A_c(1+m\cos w_m t)$ envelop

$$\left.\begin{aligned} A_{max} &= A_c(1+m) \\ A_{min} &= A_c(1-m) \end{aligned}\right\} \quad 0 \le m \le 1$$

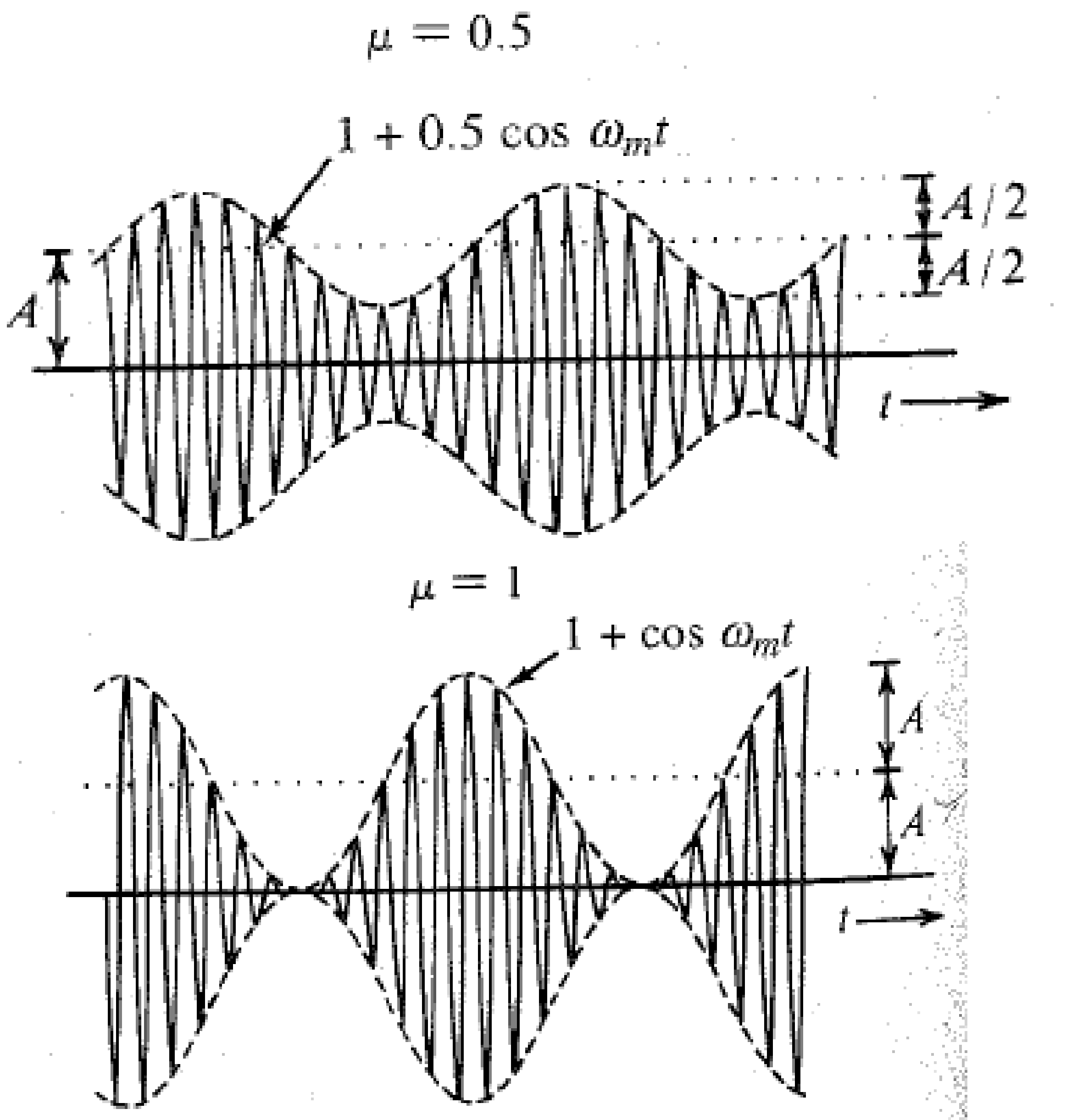


m = 1



m > 1

Modulation index (m)



(f) Frequency spectrum of AM

Frequency spectrum of AM

Frequency Spectrum of AM Wave

Frequency Spectrum is a graph of amplitude on Y axis and frequency on X axis.

Consider the equation for AM Wave :

$$e_{AM} = E_c \{1 + m\cos(2\pi f_m t)\}\cos(2\pi f_c t)$$

$$= E_c \{1 + m\cos(\omega_m t)\}\cos(\cancel{2}\omega_c t)$$

$$= E_c \cos(\omega_c t) + m E_c \cos(\omega_m t)\cos(\cancel{2}\omega_c t)$$

Using Trigonometric Identity:

$$2\cos A\cos B = \cos(A + B) + \cos(A - B)$$

$$\cos(\omega_m t)\cos(\cancel{2}\omega_c t) = \frac{1}{2}\cos(\omega_c + \omega_m)t + \frac{1}{2}\cos(\omega_c - \omega_m)t$$

Frequency spectrum of AM

Frequency Spectrum of AM Wave

Frequency Spectrum is a graph of amplitude on Y axis and frequency on X axis.

Consider the equation for AM wave :

$$e_{AM} = E_C \{1 + m\cos(2\pi f_m t)\}\cos(2\pi f_C t)$$

$$= E_C \{1 + m\cos(\omega_m t)\}\cos(\omega_C t)$$

$$= E_C \cos(\omega_C t) + m E_C \cos(\omega_m t)\cos(\omega_C t)$$

The equation of the AM wave thus becomes

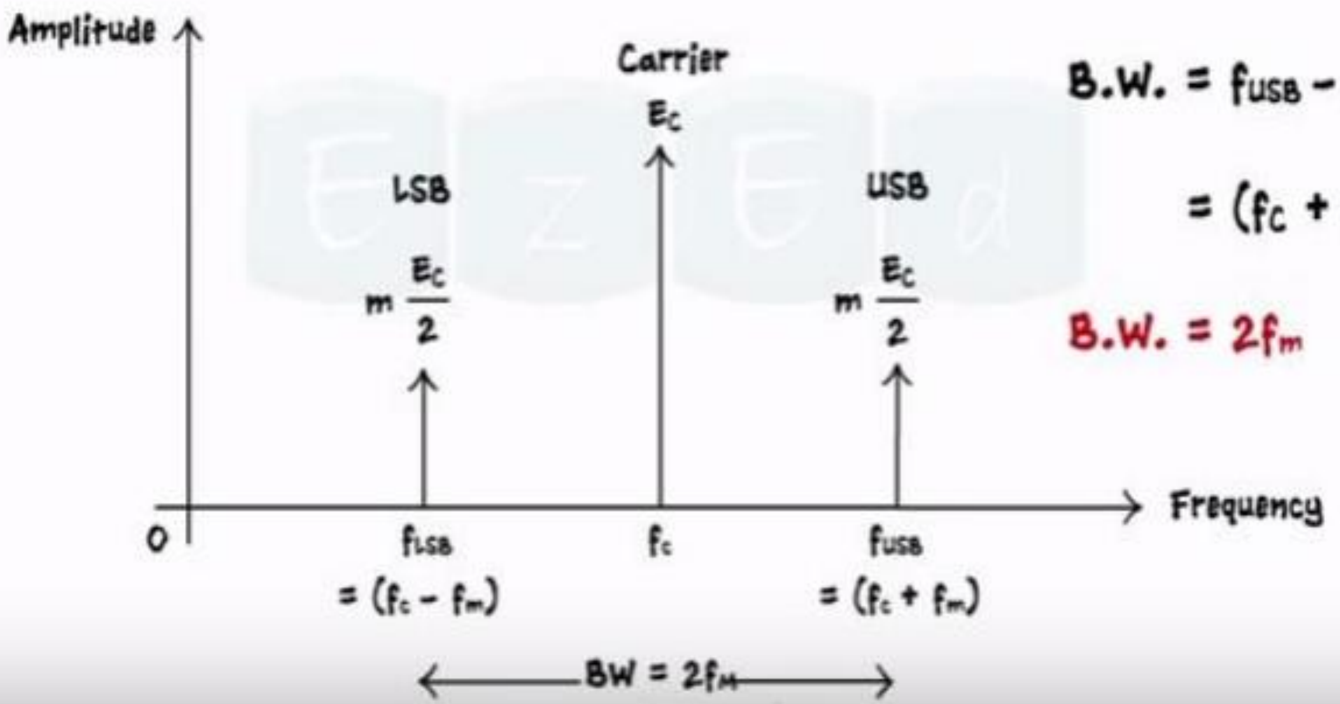
$$e_{AM} = \underbrace{E_C \cos(\omega_C t)}_{\text{Carrier Signal}} + \underbrace{\frac{(m E_C)}{2}\cos(\omega_C + \omega_m)t}_{\text{Upper Side Band}} + \underbrace{\frac{(m E_C)}{2}\cos(\omega_C - \omega_m)t}_{\text{Lower Side Band}}$$

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



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

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

$$\text{B.W.} = 2f_m$$

Thank you for your attention

Dr. Moataz Elsherbini