Data Communication IT243
Lecture 10,11,12

Unit 5
Modulation

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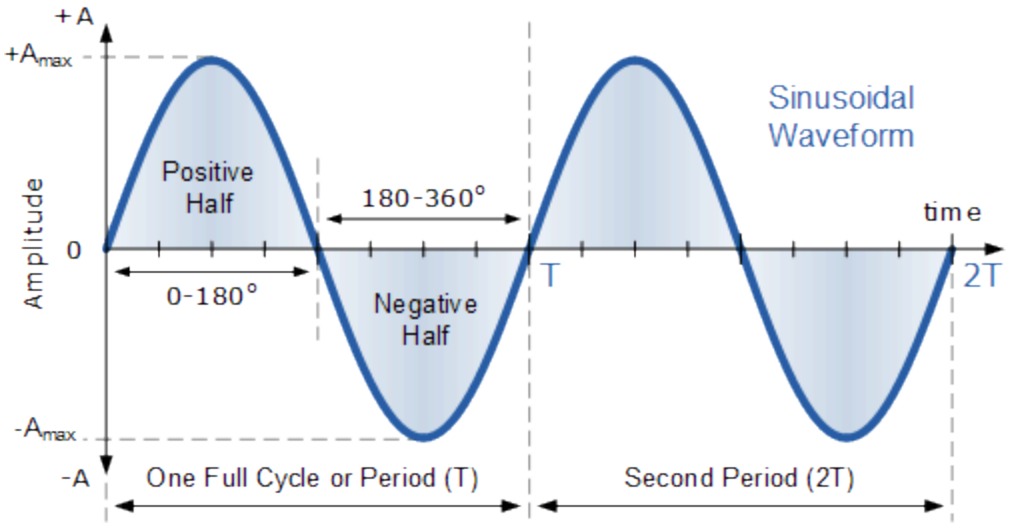
Recapitulate

* Transmission Medium
  * Guided Medium
    * *Twisted Pair Cable*
    * *Coaxial Cable*
    * *Fiber Optic Cable*
  * Unguided Medium
    * *Modes of Propagation*
    * *Electromagnetic Spectrum*
    * *Classification of Electromagnetic waves : Properties & Antenna and Application*
      * **Radio , Microwaves and Infrared waves**

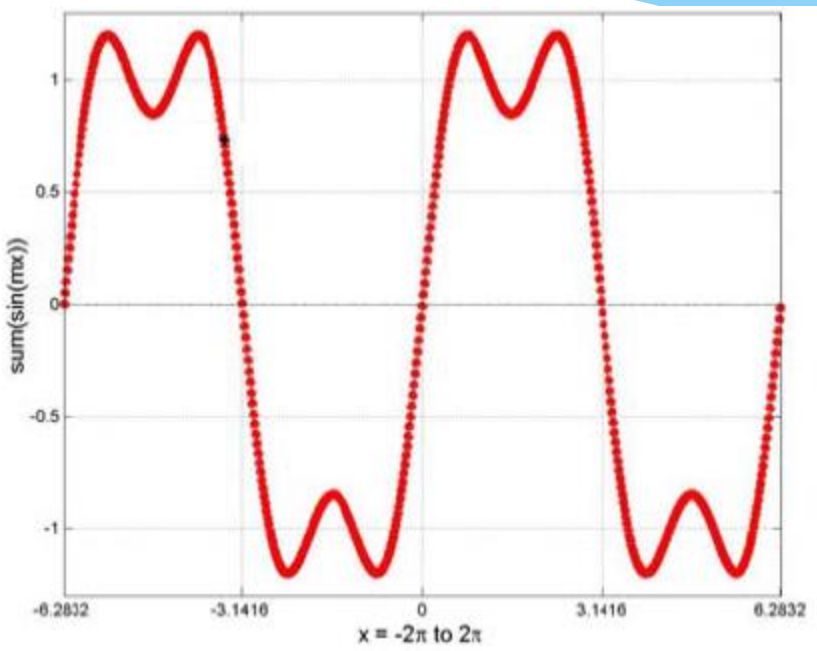
Transformation[1]



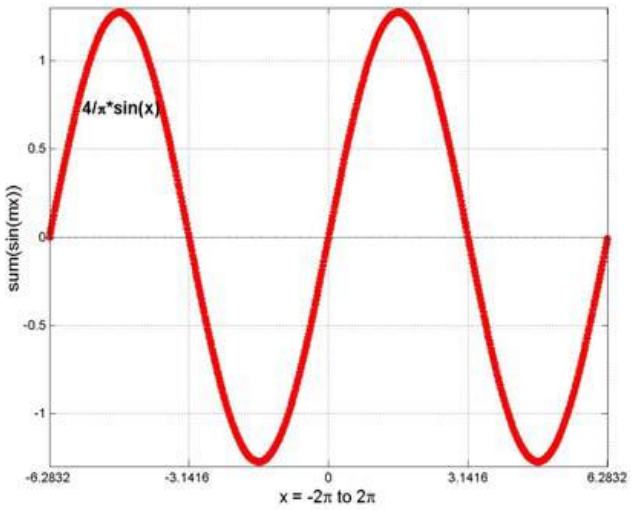
Sinusoidal wave

- $A_{max}\sin wt$
- $W = 2\pi / T$

Transformation^2



Transformation^3



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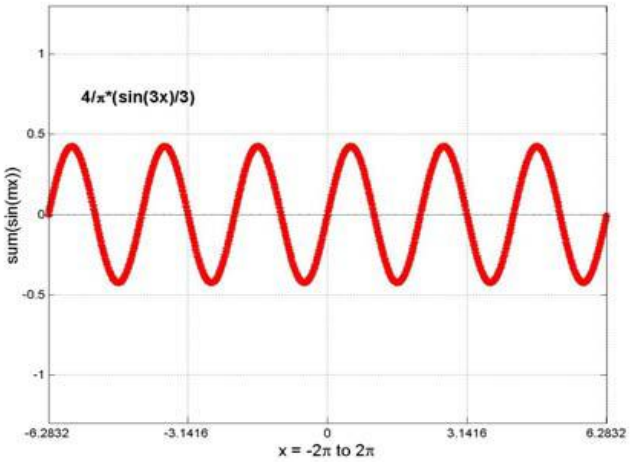
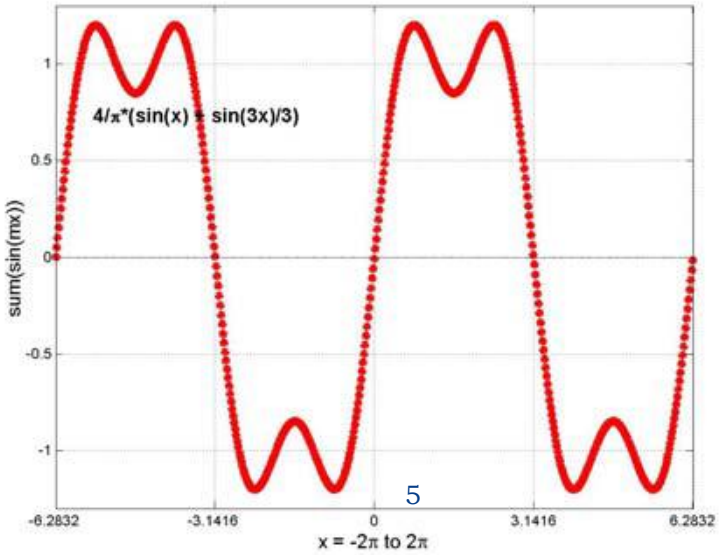
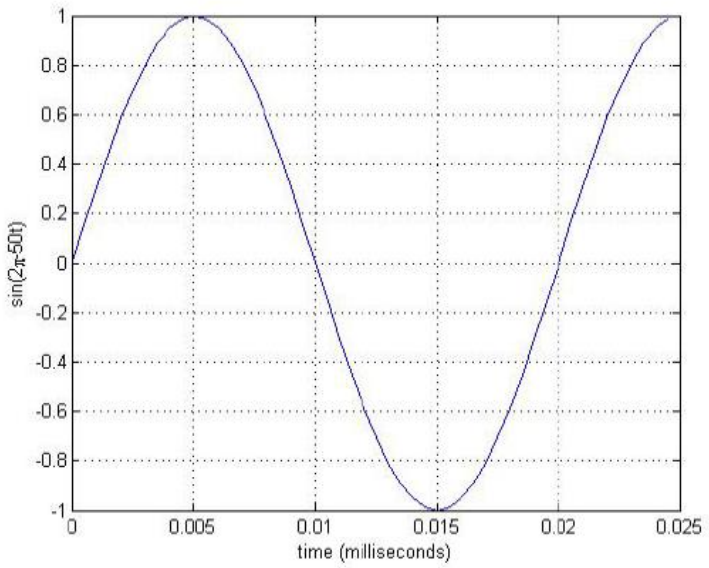
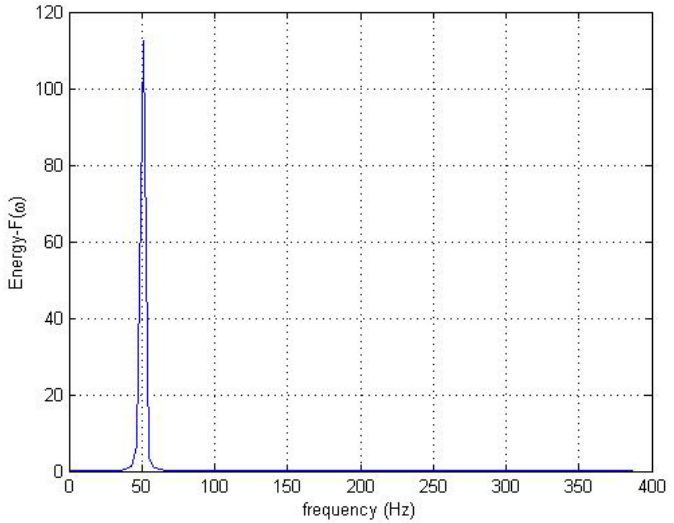




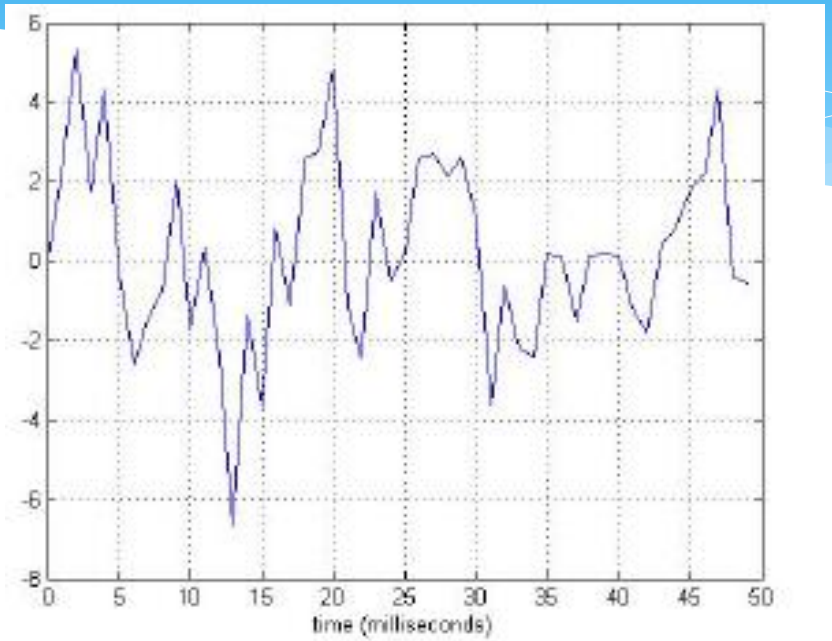
Transformation[4]



Fig(a)Time Domain signal



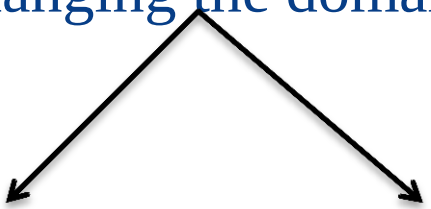
Fig(b)Frequency Domain signal



* Example : Voice Signal

Why Transformation

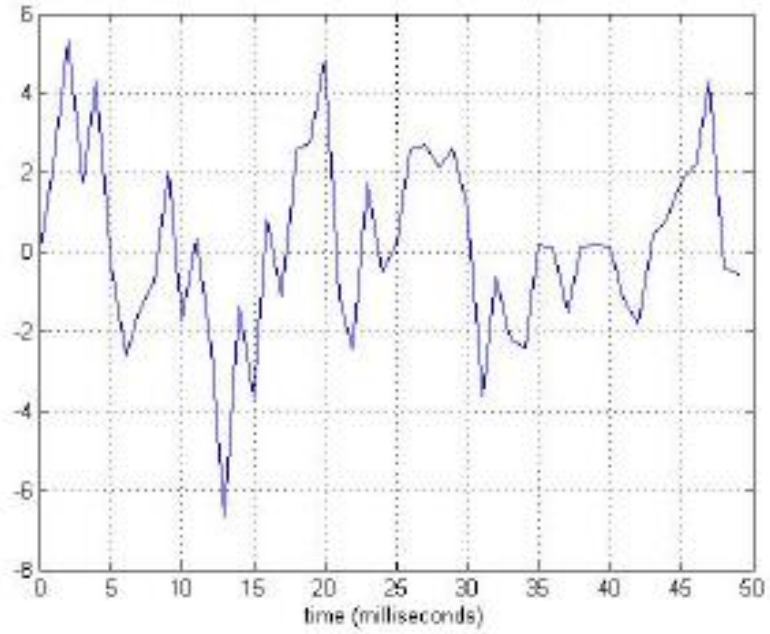
* Sometimes time domain analysis is difficult for signals
* Transformation: changing the domain

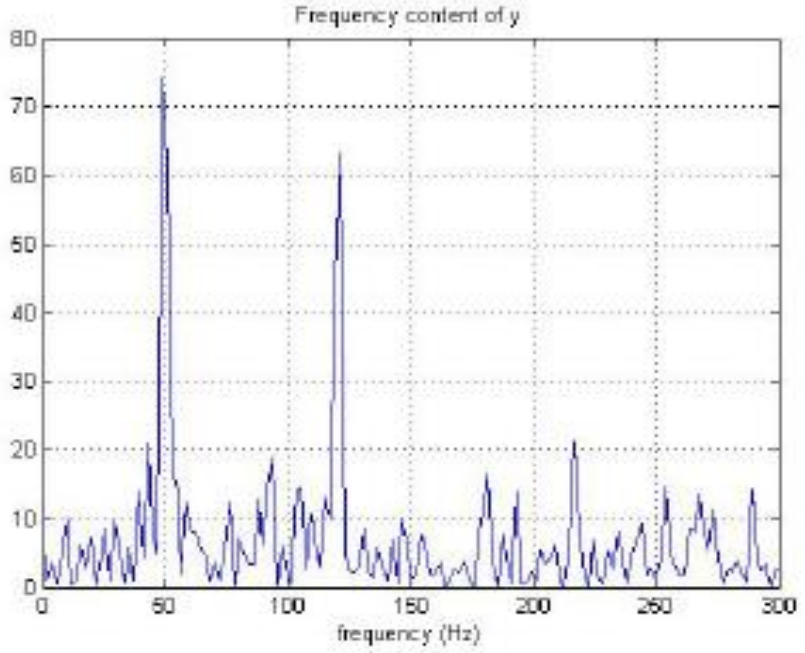


Time domain to frequency domain

Frequency domain to time domain

Frequency Transformation





* Example :Voice Signal

Fourier Analysis

* There are two methods –
  1. Fourier Series (for periodic signal)
  2. Fourier Transform (for aperiodic signal)

Fourier Analysis

Jean Baptiste Joseph Fourier
French Mathematician

The **Fourier transform** is a mathematical transformation employed to transform signals between time (or spatial) domain and frequency domain.

Fourier Transform^2

* **Fourier Transform** of a time domain signal g(t) is given by :-

$$\mathcal{F}\{g(t)\} = G(f) = \int_{-\infty}^{\infty} g(t) e^{-2\pi i f t}\, dt$$

* To obtain time domain signal we apply **Inverse Fourier Transform** which is given by : -

$$\mathcal{F}^{-1}\{G(f)\} = \int_{-\infty}^{\infty} G(f) e^{2\pi i f t}\, df = g(t)$$

Fourier Series

* **Fourier series** is a way to represent a (wave-like) function as the sum of simple sine waves

$$f(x) = a_0 + \sum_{n=1}^{\infty} (a_n \cos nx + b_n \sin nx)$$

$$= a_0 + a_1 \cos x + a_2 \cos 2x + a_3 \cos 3x + \cdots$$

$$+ b_1 \sin x + b_2 \sin 2x + b_3 \sin 3x + \cdots$$

Barrier's to communication

* Long distance communication
* Practical length of antenna
* Multiplexing
* Avoid interference
* Reduce Noise

MODULATION

Modulation

* **Modulation*** is systematic alteration of one signal (high frequency - *carrier signal*) as per instantaneous value of another signal (low frequency - *message signal*).

* Source : NPTEL

Types of modulation

1. Amplitude Modulation
2. Frequency Modulation
3. Phase Modulation

Amplitude Modulation

* In Amplitude modulation, the **amplitude** of carrier signal varies as per instantaneous value of message signal.

Frequency Modulation

* In Frequency modulation, the **frequency** of carrier signal varies as per instantaneous value of message signal.

Phase Modulation

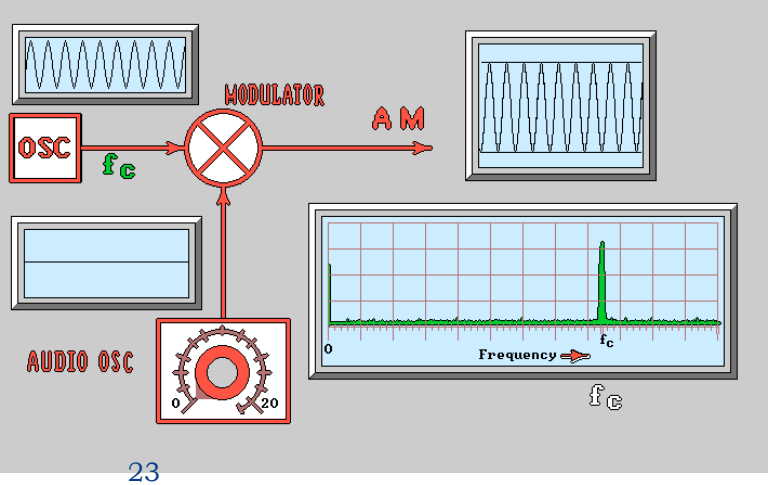
* In Phase modulation, the **phase** of carrier signal varies as per instantaneous value of message signal.

* Definition
* Mathematical Analysis
* Waveform
* Generation (Modulation) Method
* Demodulation Method
* Advantages
* Disadvantages
* Applications

AMPLITUDE MODULATION

Amplitude Modulation (AM)

* In Amplitude modulation, the **amplitude** of carrier signal varies as per instantaneous value of message signal.



AM – Mathematical Analysis

* As per definition of AM

$$y_{AM}(t) = [V_C + m(t)]\cos w_c t$$

* Let us consider single tone sinusoid modulation i.e.
* $m(t) = V_m \cos w_m t$
* Then amplitude modulated wave becomes

$$y_{AM}(t) = [V_C + V_m \cos w_m t]\cos w_c t$$

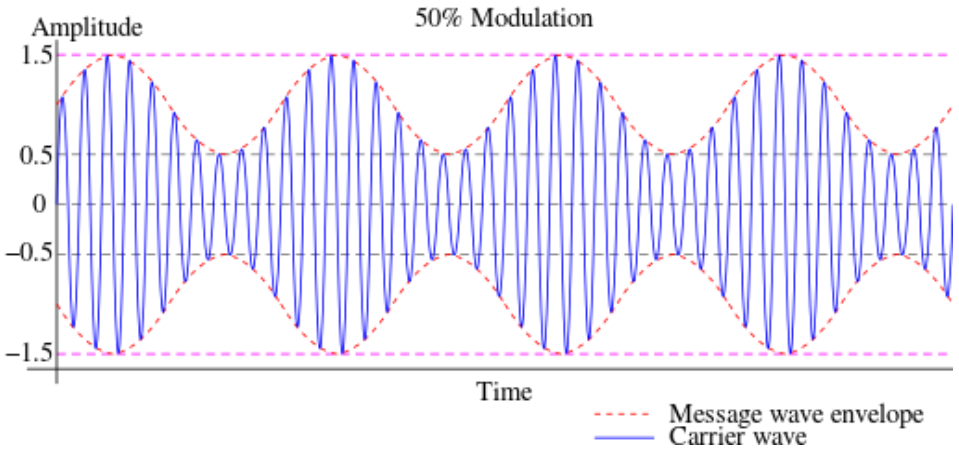
$$y_{AM}(t) = V_C[1 + m_a \cos w_m t]\cos w_c t$$

$\mathbf{m_a}$: modulation index of AM

$$y_{AM}(t) = [V_C \cos w_c t + m_a V_C \cos w_m t \cos w_c t]$$

$$y_{AM}(t) = V_C \cos w_c t + \frac{m_a V_C}{2}\cos(w_c + w_m)t + \frac{m_a V_C}{2}\cos(w_c - w_m)t$$

AM - Waveform


50% Modulation
Amplitude
1.5
0.5
0
–0.5
–1.5
Time
Message wave envelope
Carrier wave

Versions of AM

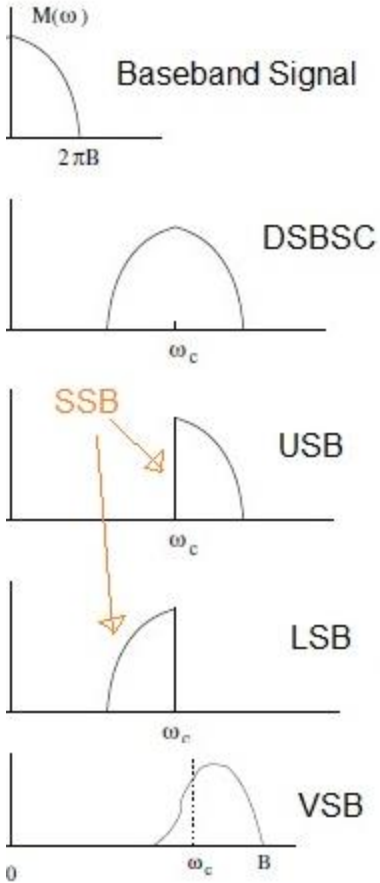
* **AM or DSBFC** -Double side band Full carrier
* **DSBSC** -Double side band Suppressed carrier.
* **SSB** – Single Side Band
* **VSB** - Vestigial Side Band

* The underlying difference between all of these in *waveform, radiated power and bandwidth* of modulated carrier signal

Versions of AM

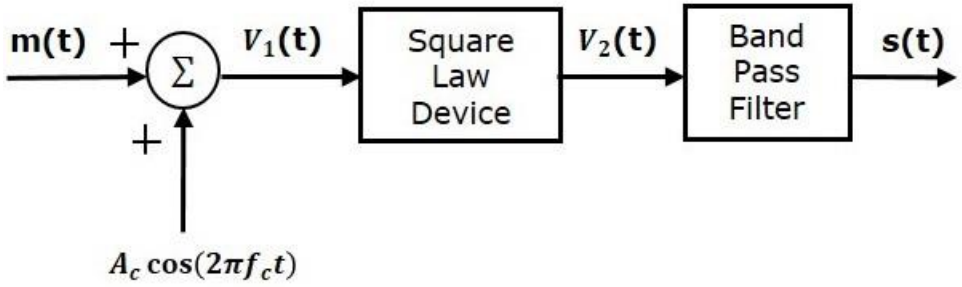
Version	Bandwidth	Component	Transmitted Power
DSBFC	$2f_m$	Carrier + Two side bands	Pc $(1+m^2/2)$
DSBSC	$2f_m$	Two side bands	Pc $(m^2/2)$
SSB	f_m	One side Band (USB/LSB)	Pc $(m^2/4)$
VSB	$f_{m+}f_v$	One side Band + Vestigeal part of other sideband	$P_{SSB} < P_{VSB} < P_{DSB}$

Version	
DSBFC	Double Side Band Full Carrier
DSBSC	Double Side Band Suppressed Carrier
SSB	Single Side Band
VSB	Vestigeal Side Band



AM Generation and Demodulation

* **AM Generation/ AM Modulation**
  * *Square Law Modulator*



* **AM Detection/AM Demodulation**
  * *Envelope Detector ($m_a \leq 1$)*

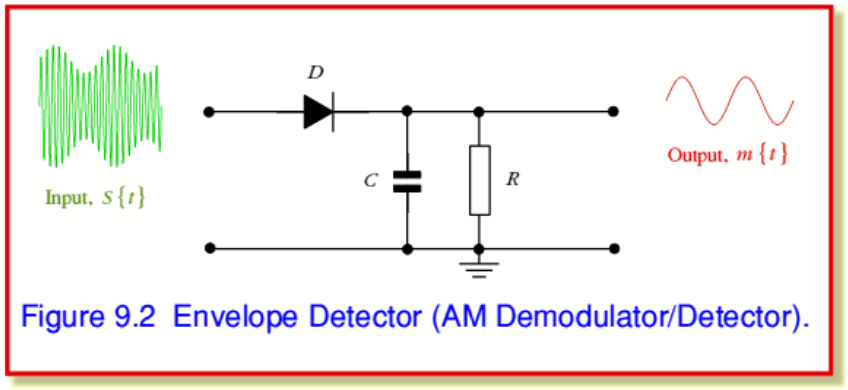
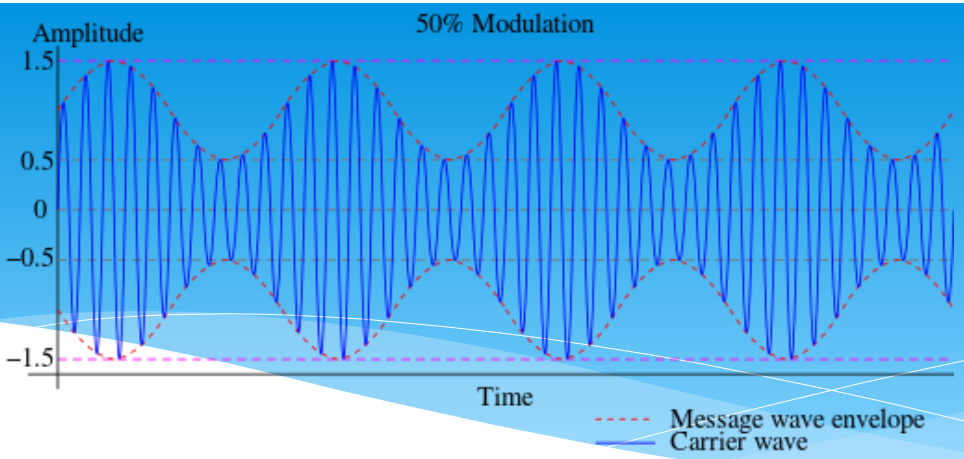
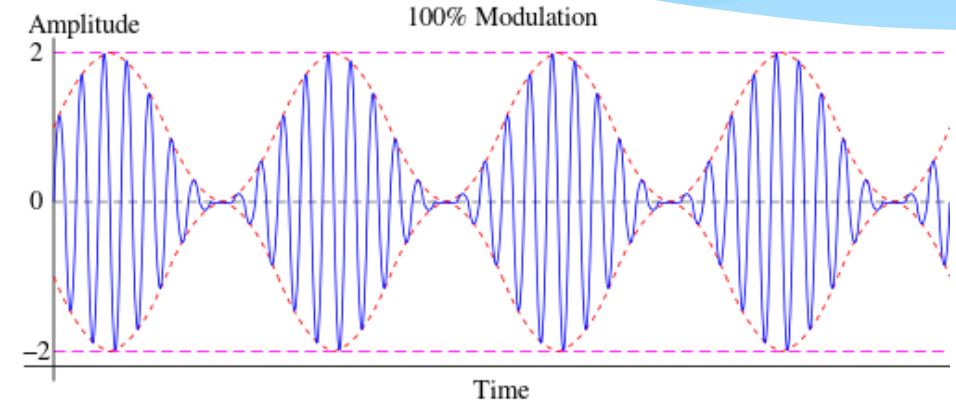


Figure 9.2 Envelope Detector (AM Demodulator/Detector).

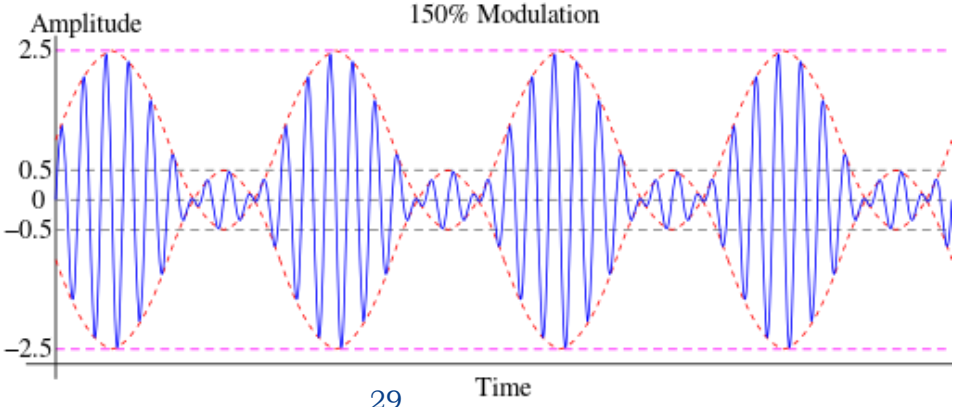
Significance of modulation index



Under-modulation ($m_a < 1$)



Critical-modulation ($m_a = 1$)



Over-modulation ($m_a > 1$)

- Envelope Detector can only by used for under modulation and critical modulation

AM

* Advantages of AM
  * Low circuit complexity than FM, PM
  * Small bandwidth compared to FM,PM
* Disadvantages of AM
  * Easily corrupted by noise compared to FM,PM
  * Less power efficient than FM,PM

Applications of AM

* AM radio
* TV video signal modulation (VSB - Vestigial Sideband)

NUMERICAL

Find out following for modulating signal 4sin(2000*pi*t) and Carrier signal 10cos(2*∏*10^6*t) if Amplitude modulation is employed in order to attain long distance communication.

(a) Carrier Power in Watts

(b) Modulation index

(c) Total Transmitted Power in Watts

(d) Total Sideband Power in Watts

(e) Power in each side band

(f) Lower and upper side band frequency & bandwidth of AM wave

(g) Repeat (c) and (f) if DSBSC is employed instead of AM

(h) Repeat (c) and (f) if SSB is employed instead of AM

(i) AM Waveform