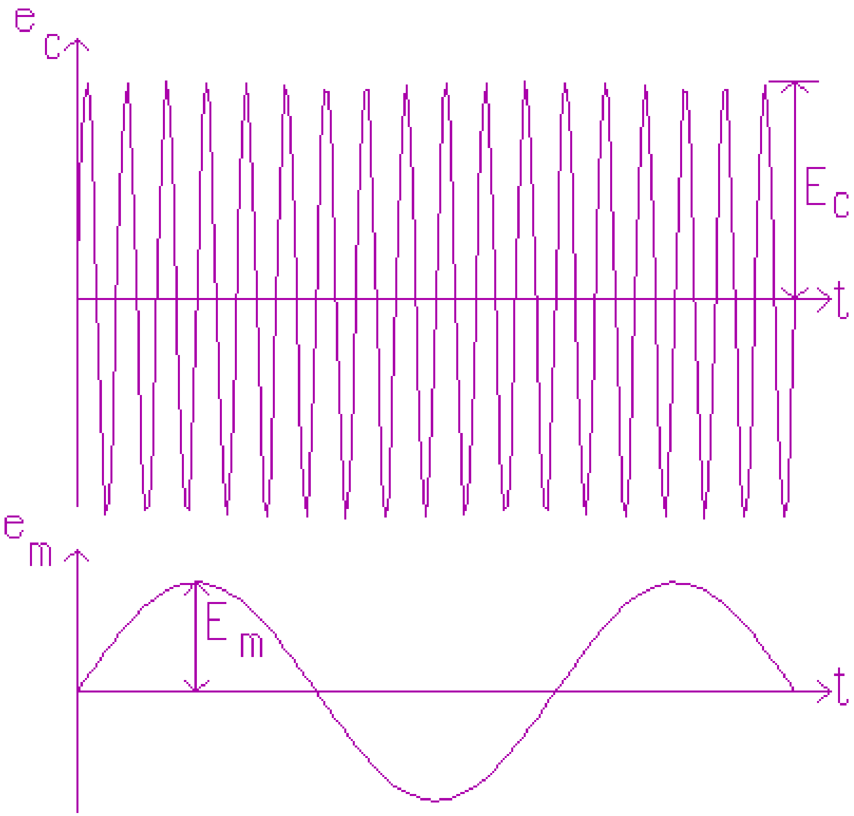
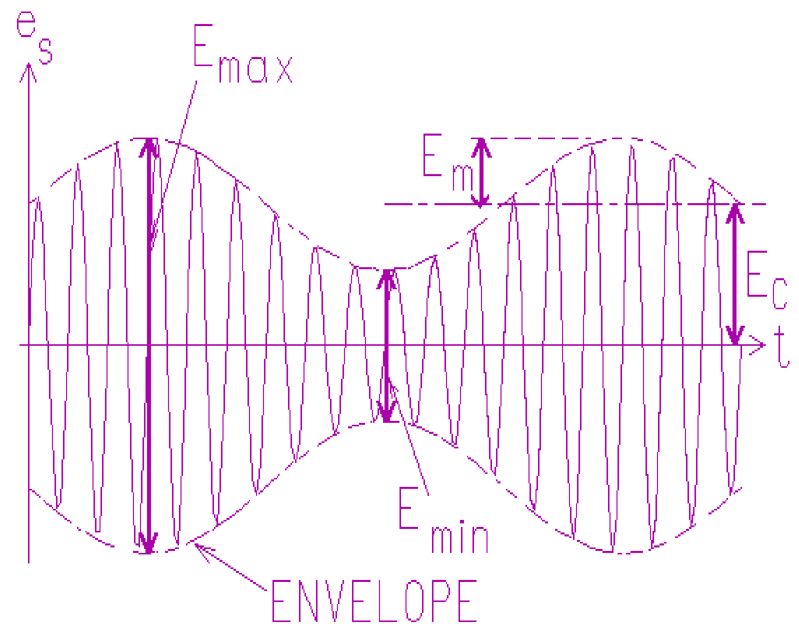
Amplitude Modulation

- AM Frequency and Amplitude spectrum
- Modulation Index
- Net Modulation Index for multi-tone modulation
- Single tone Modulation
- Power Contents in AM
- Transmission(modulation) Efficiency
- Generation of AM
- Demodulation of AM

AM Waveform





$$e_c = E_c \sin \omega_c t$$
$$e_m = E_m \sin \omega_m t$$

AM signal:

$$e_s = (E_c + e_m) \sin \omega_c t$$

Amplitude Modulation

- The **Complex Envelope** of an AM signal is given by

$$g(t) = A_c[1 + m(t)]$$

A_c indicates the power level of AM and $m(t)$ is the Modulating Signal

- Representation of an **AM signal** is given by

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

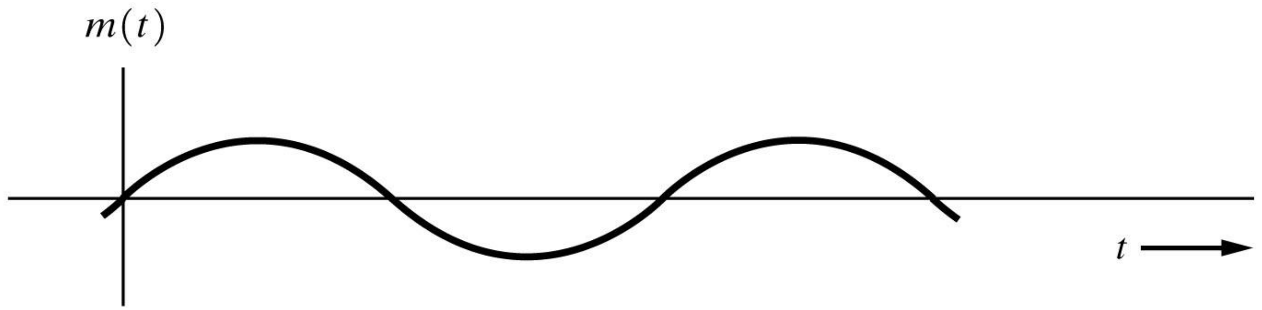
- $A_c[1+m(t)]$ In-phase component x(t)

- **If** $m(t)$ has a peak positive values of +1 and a peak negative value of -1

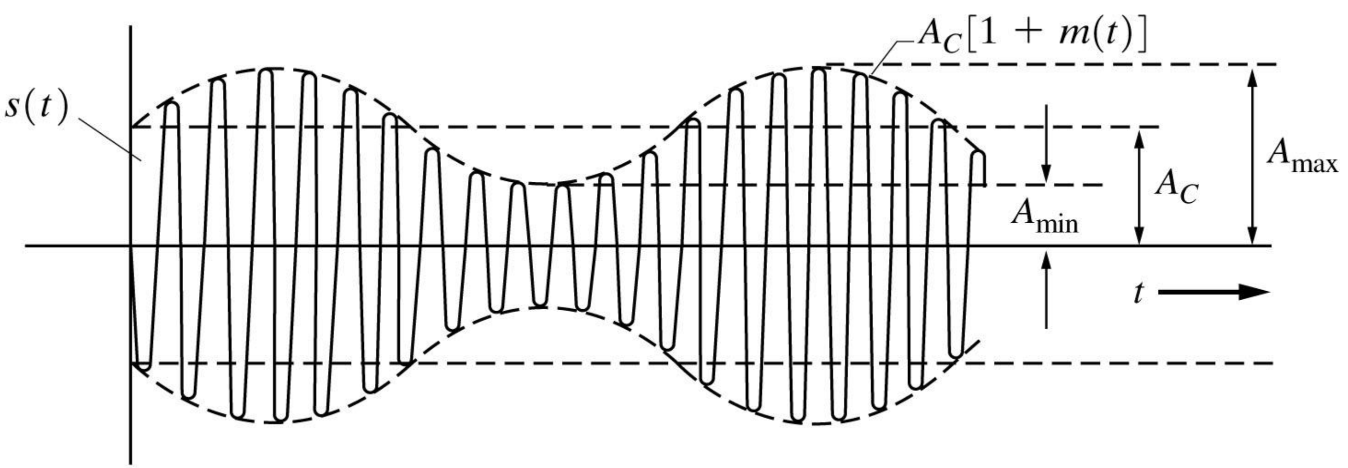
  AM signal → 100% modulated

- **Envelope detection can be used if % modulation is less than 100%.**

AM Signal Waveform



(a) Sinusoidal Modulating Wave



(b) Resulting AM Signal

$A_{max} = 1.5A_c$

$A_{min} = 0.5\ A_c$

% Positive modulation= 50%

% Negative modulation =50%

Overall Modulation = 50%

AM in Frequency Domain

- The expression for the AM signal:

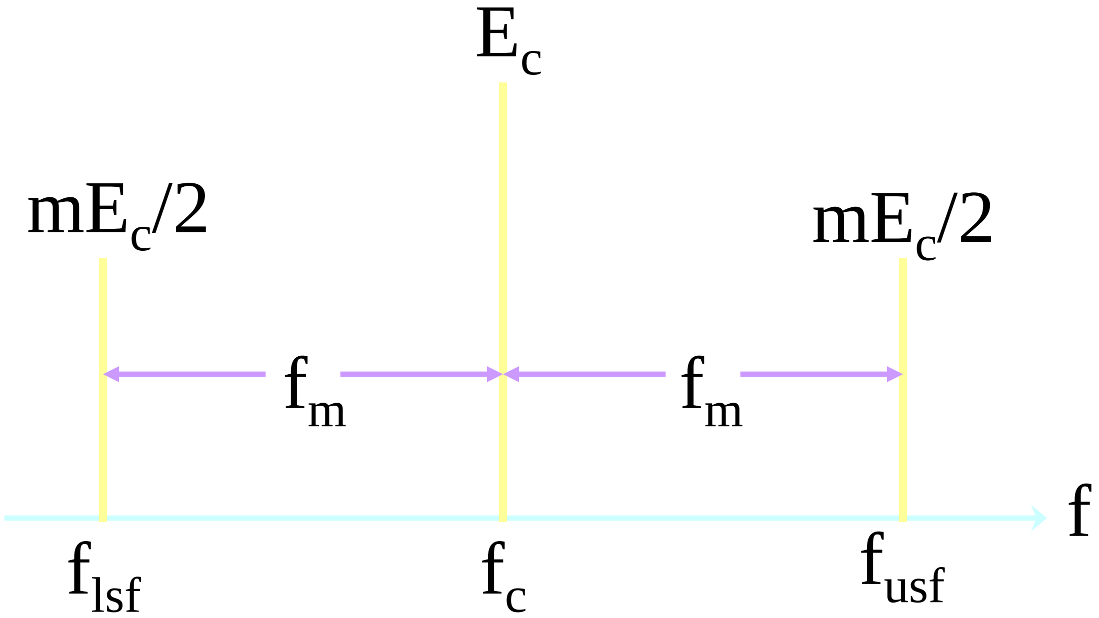
$$e_s = (E_c + e_m) \sin \omega_c t$$

can be expanded to:

$$e_s = E_c \sin \omega_c t + \frac{1}{2} mE_c[\cos (\omega_c - \omega_m)t - \cos (\omega_c + \omega_m)t]$$

- The expanded expression shows that the AM signal consists of the original carrier, a lower side frequency, $f_{lsf} = f_c - f_m$, and an upper side frequency, $f_{usf} = f_c + f_m$.

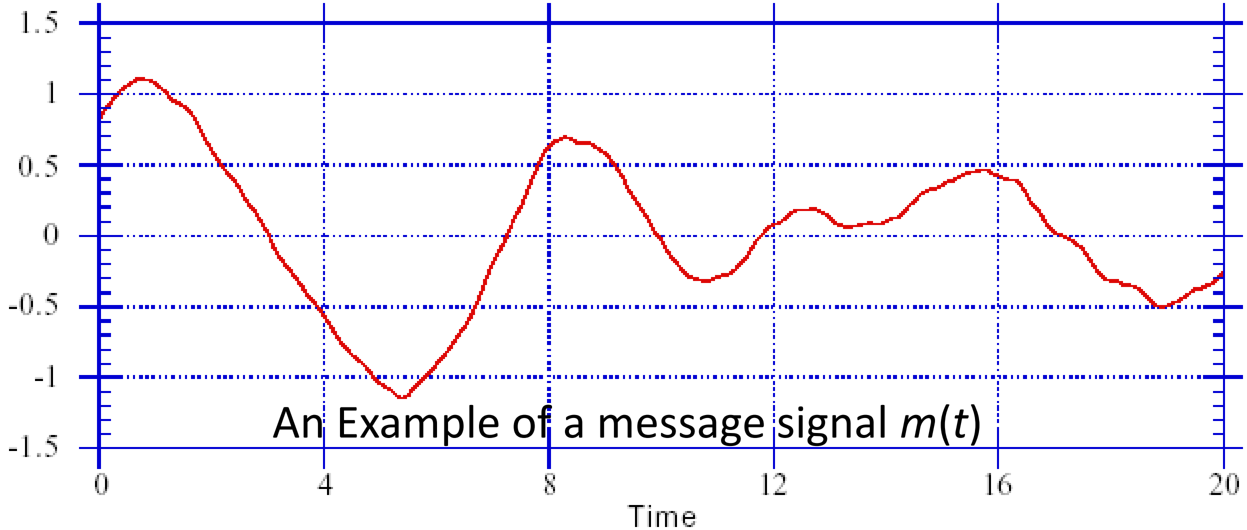
AM Spectrum



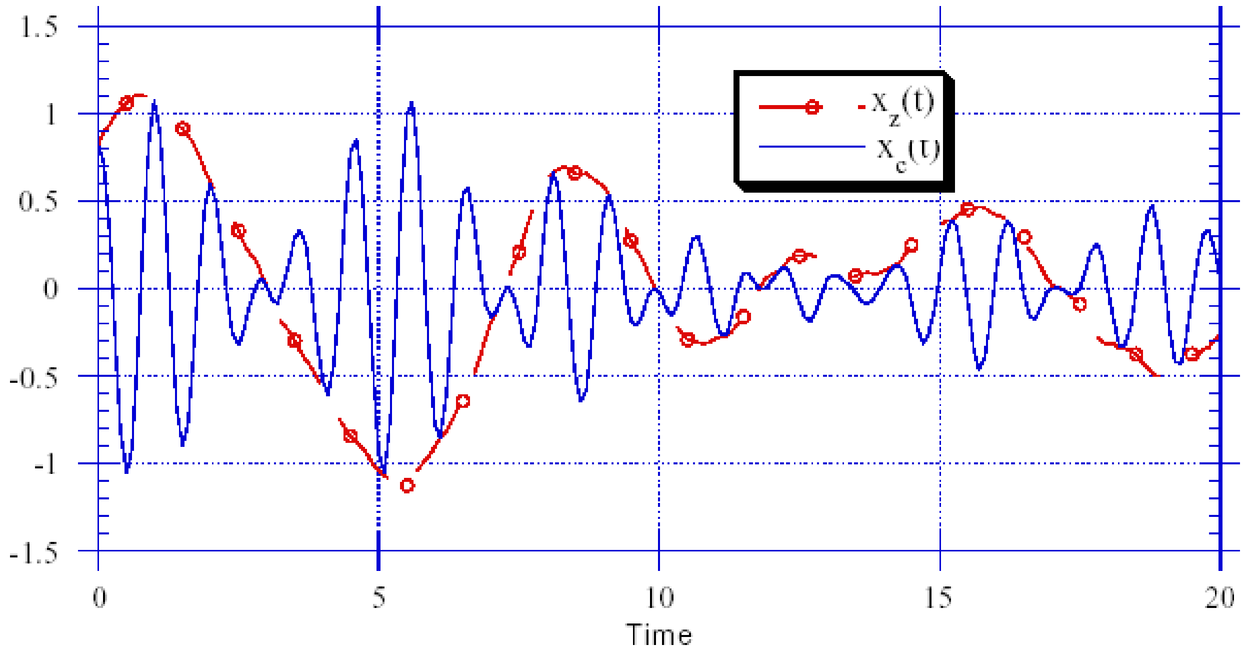
$$f_{usf} = f_c + f_m \; ; \;\; f_{lsf} = f_c - f_m \; ; \;\; E_{sf} = mE_c/2$$

$$\text{Bandwidth, } B = 2f_m$$

Amplitude Modulation

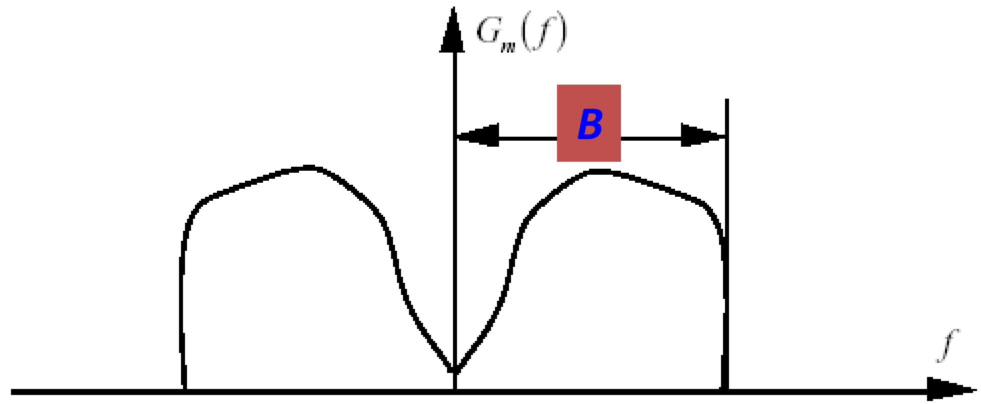


An Example of a message signal $m(t)$

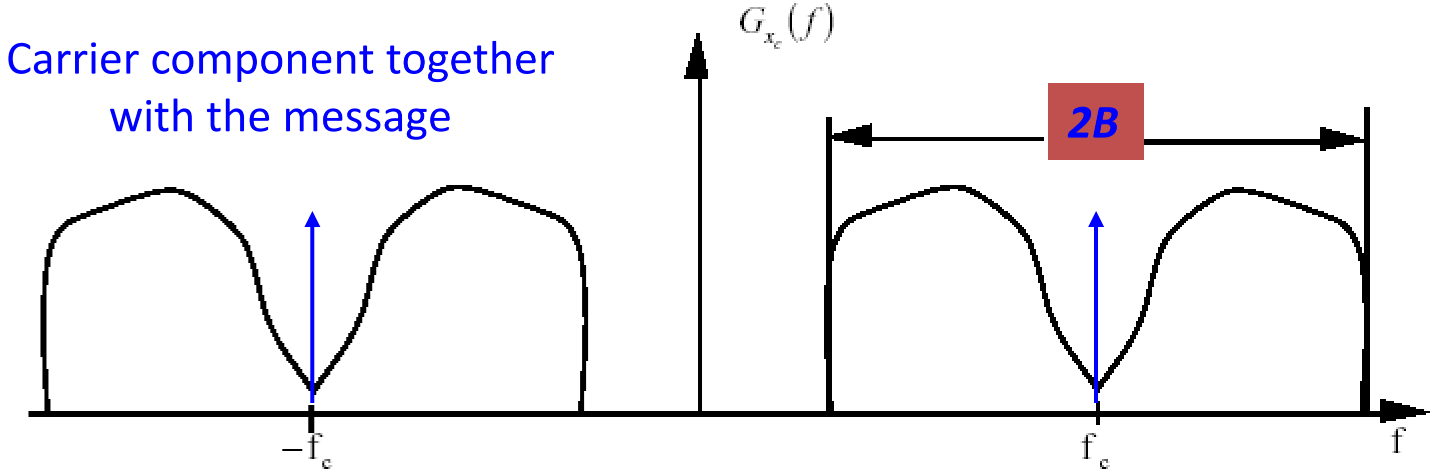


Waveform for Amplitude modulation of the message signal $m(t)$

Amplitude Modulation



An Example of message energy spectral density.



Energy spectrum of the AM modulated message signal.

Modulation Index

- The amount of amplitude modulation in a signal is given by its modulation index:

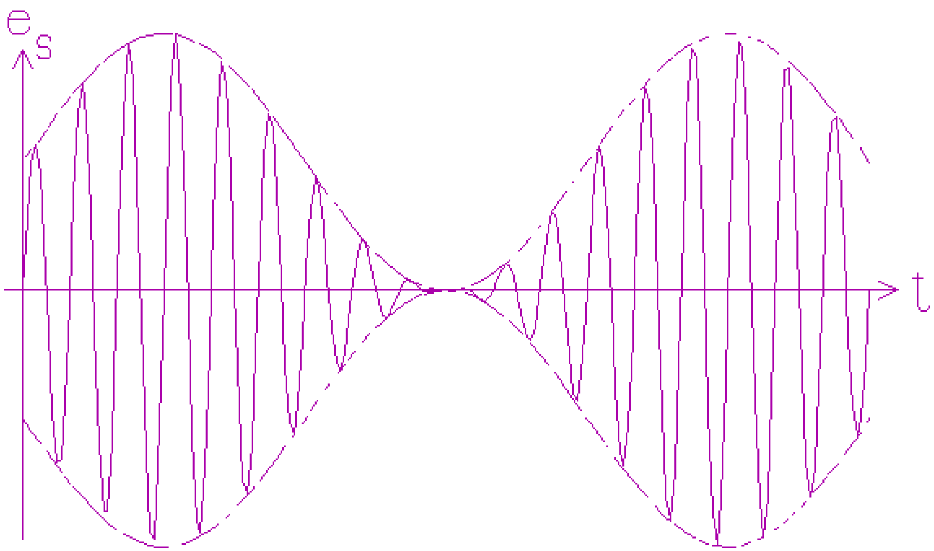
$$m = \frac{E_m}{E_c} \text{ or } \frac{E_{\max} - E_{\min}}{E_{\max} + E_{\min}}$$

where, $E_{max} = E_c + E_m$; $E_{min} = E_c - E_m$ (all pk values)

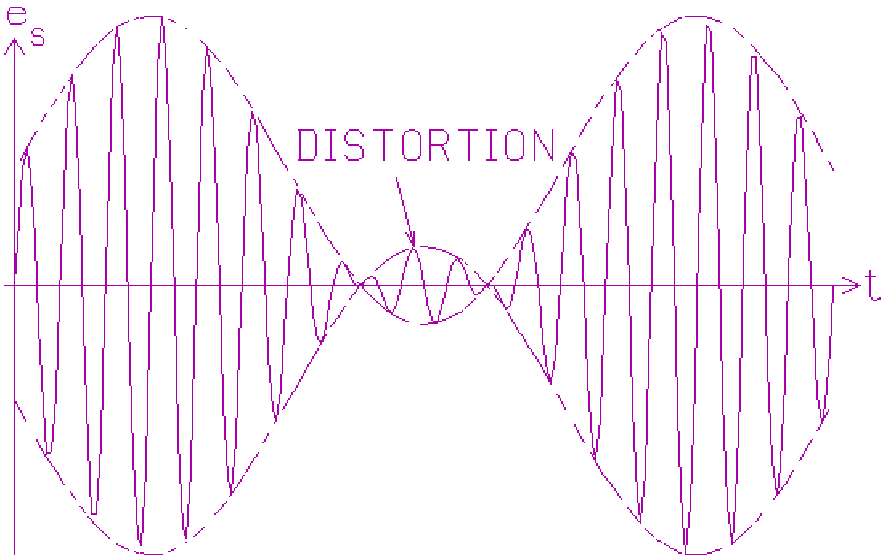
When $E_m = E_c$, m =1 or 100% modulation.

Over-modulation, i.e. $E_m > E_c$, should be avoided because it will create distortions and splatter.

Effects of Modulation Index



m = 1

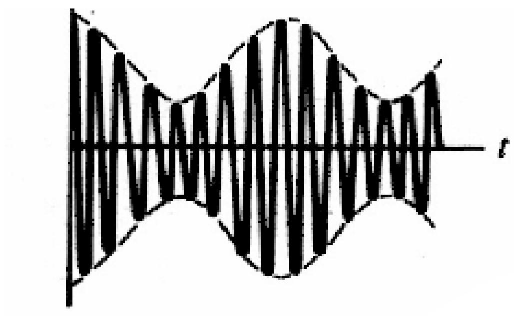


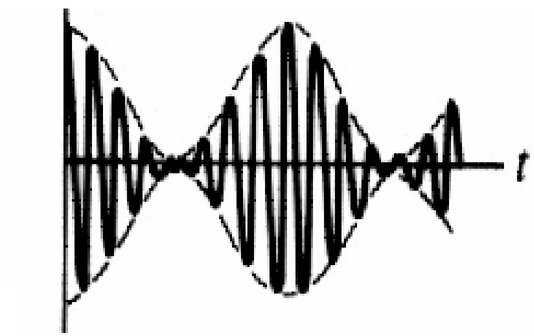
m > 1

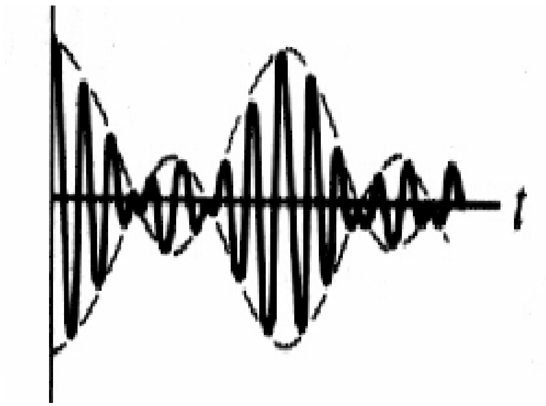
In a practical AM system, it usually contains many frequency components. When this is the case,

$$m_T = \sqrt{m_1^2 + m_2^2 + \ldots + m_n^2}$$

AM – Percentage Modulation







Under modulated (<100%)

100% modulated

Over Modulated (>100%)

Envelope Detector

Can be used

Envelope Detector

Gives Distorted signal

AM Power

- Total average (i.e. rms) power of the AM signal is: $P_T = P_c + 2P_{sf}$, where
  P_c = carrier power; and P_{sf} = side-frequency power
- If the signal is across a load resistor, R, then: $P_c = E_c^2/(2R)$; and $P_{sf} = m^2P_c/4$. So,

$$P_T = P_c(1+\frac{m^2}{2})$$

AM – Normalized Average Power

The **normalized average power** of the AM signal is

$$\langle s^2(t)\rangle = \frac{1}{2}\langle |g(t)|^2 \rangle = \frac{1}{2}A_c^2\langle [1+m(t)]^2 \rangle$$
$$= \frac{1}{2}A_c^2\langle [1+2m(t)+m^2(t)]\rangle$$
$$= \frac{1}{2}A_c^2 + A_c^2\langle m(t)\rangle + \frac{1}{2}A_c^2\langle m^2(t)\rangle$$

If the modulation contains no dc level, then $\langle m(t)\rangle = 0$

The **normalized power** of the AM signal is

$$\langle s^2(t)\rangle = \underbrace{\frac{1}{2}A_c^2}_{\text{Discrete Carrier Power}} + \underbrace{\frac{1}{2}A_c^2\langle m^2(t)\rangle}_{\text{Sideband power}}$$

Discrete Carrier Power **Sideband power**

AM – Modulation Efficiency

- **Definition** : The **Modulation Efficiency** is the percentage of the total power of the modulated signal that conveys information.

Only **"Sideband Components"** – Convey information

Modulation Efficiency:

$$E = \frac{\langle m^2(t) \rangle}{1 + \langle m^2(t) \rangle} \times 100$$

Highest efficiency for a 100% AM signal : **50%** - square wave modulation

Normalized Peak Envelope Power (PEP) of the AM signal:

$$P_{PEP} = \frac{A_c^2}{2} \{1 + \max[m(t)]\}^2$$

Voltage Spectrum of the AM signal**:**

$$S(f) = \frac{A_c}{2}\left[\delta(f - f_c) + M(f - f_c) + \delta(f + f_c) + M(f + f_c)\right]$$

Unmodulated Carrier Spectral Component

Translated Message Signal