Transmission of Analog Signals - I

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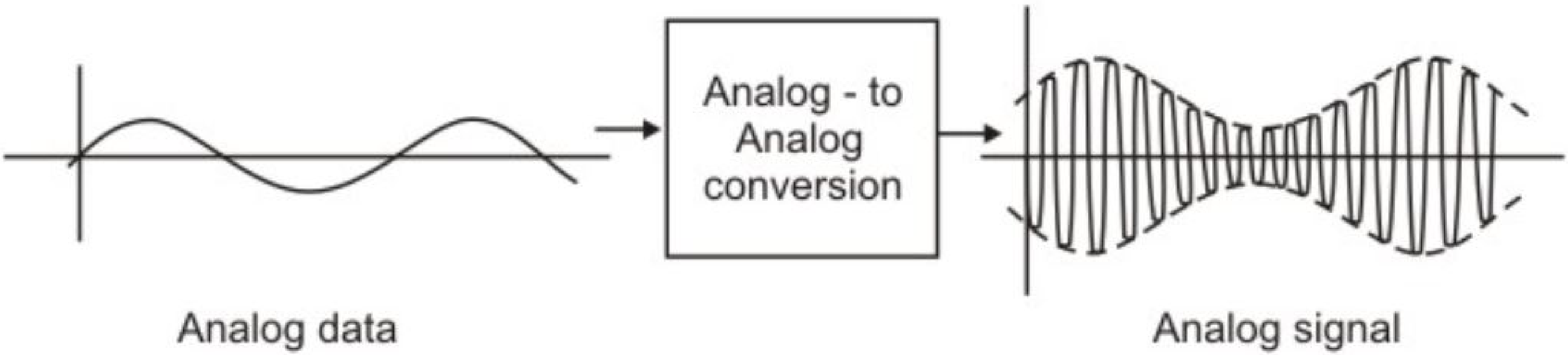
Analog Data – Analog Signal



- The Process is known as modulation, which involves manipulation of one or more of the parameters of the carrier that characterizes a analog signal.

Why Modulation?

- **Frequency Translation**: Translates the signal from one region of frequency domain to another region.

Why Modulation?

- **Practical Size of Antenna**: Modulation translates the baseband signal to higher frequency, which can be transmitted through a bandpass channel using an antenna of smaller size.

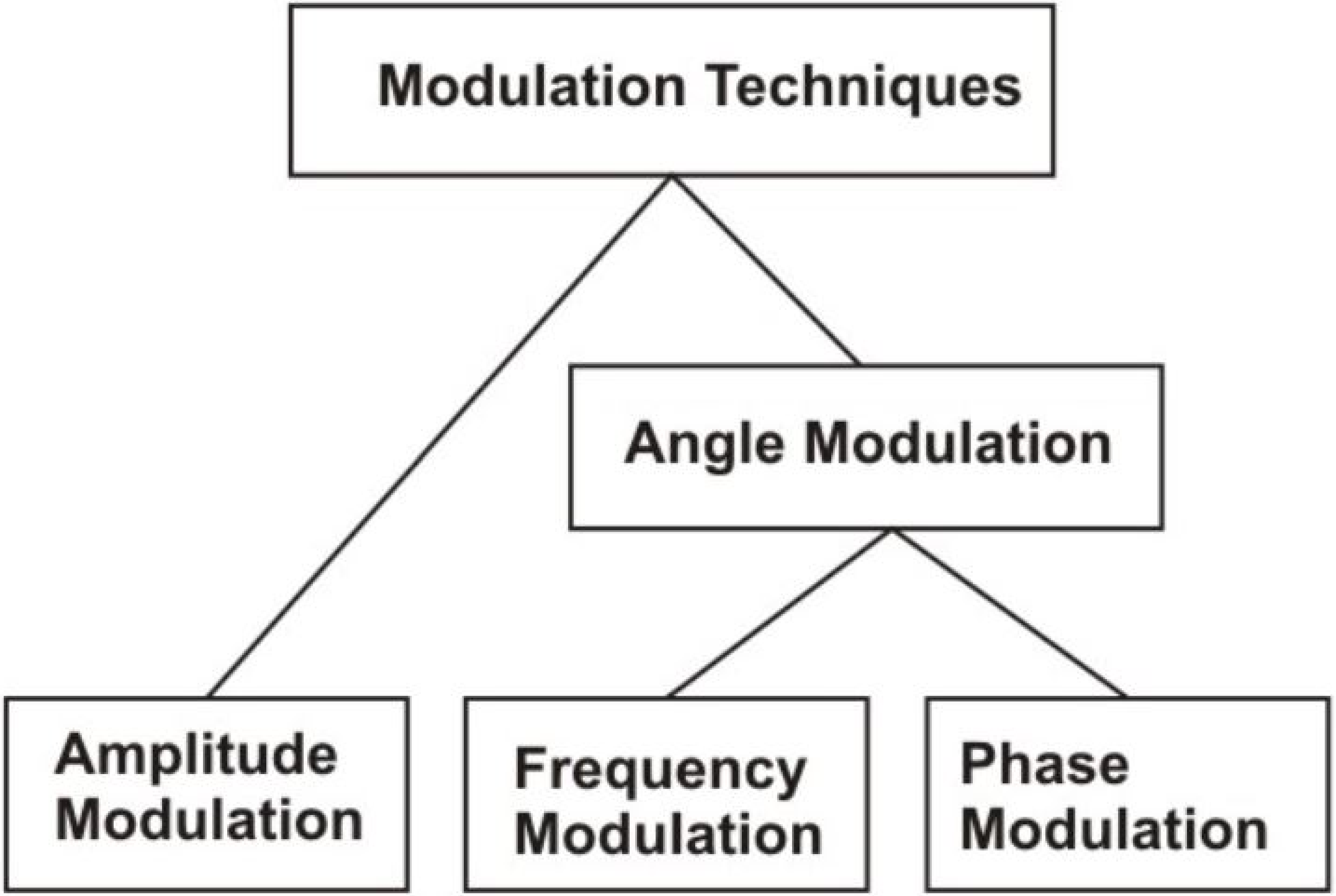
Why Modulation?

- **Narrowbanding**: Ratio between highest to lowest frequency becomes close to 1.

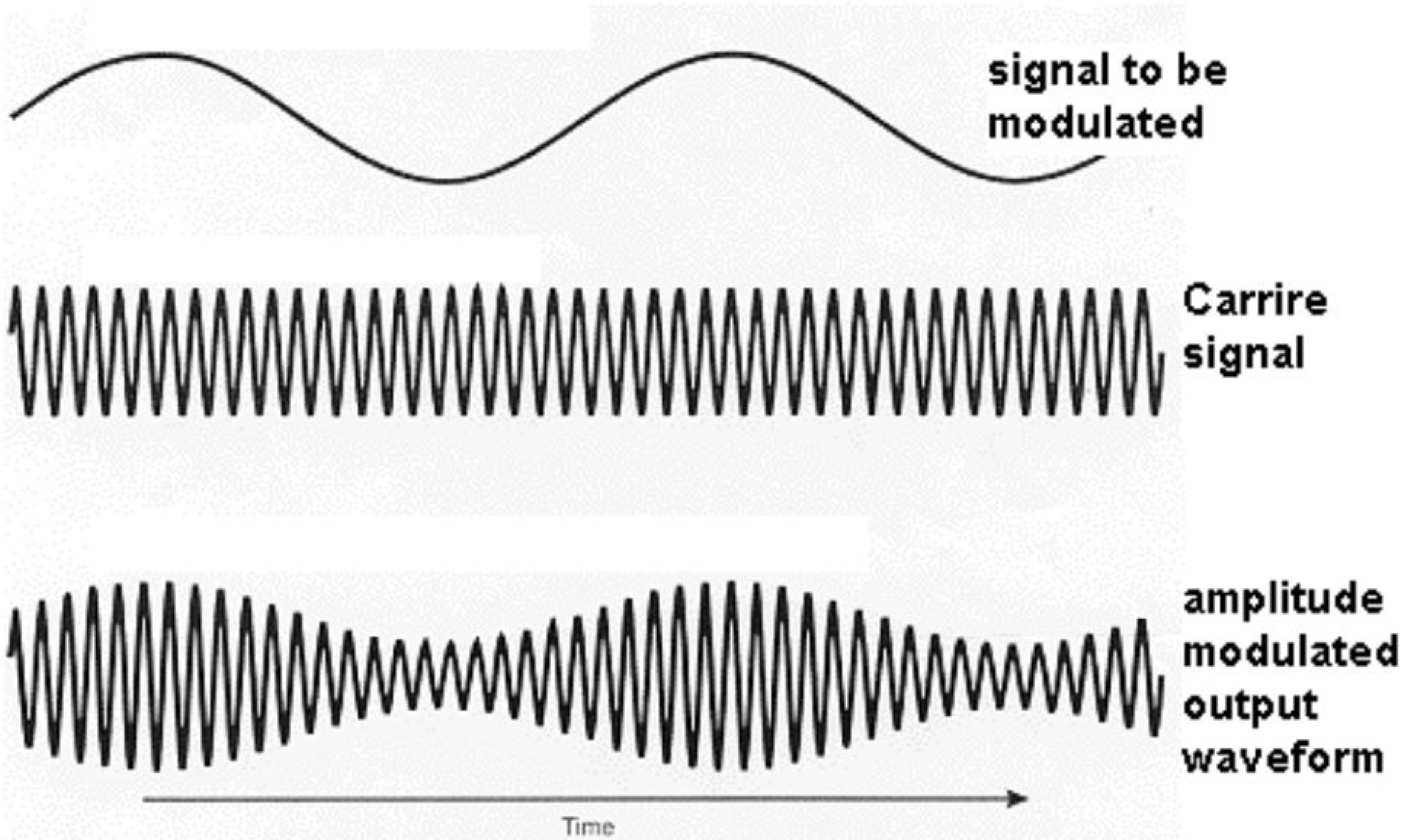
Why Modulation?

- **Multiplexing**: Modulation allows frequency-division multiplexing.

Modulation Techniques



Amplitude Modulation



Modulation Using a Sinusoid Signal

Let the modulation waveform is given by

$$e_m(t) = E_m \cos(2\pi f_m t)$$

And the carrier signal is given by

$$e_c(t) = E_c \cos(2\pi f_c t + \emptyset_c)$$

Then the equation of the modulated signal is given by

$$s(t) = (E_c + E_m \cos 2\pi f_m t) \cos 2\pi f_c t$$

Modulation Index

The Modulation Index, represented by m, is given by

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

Where

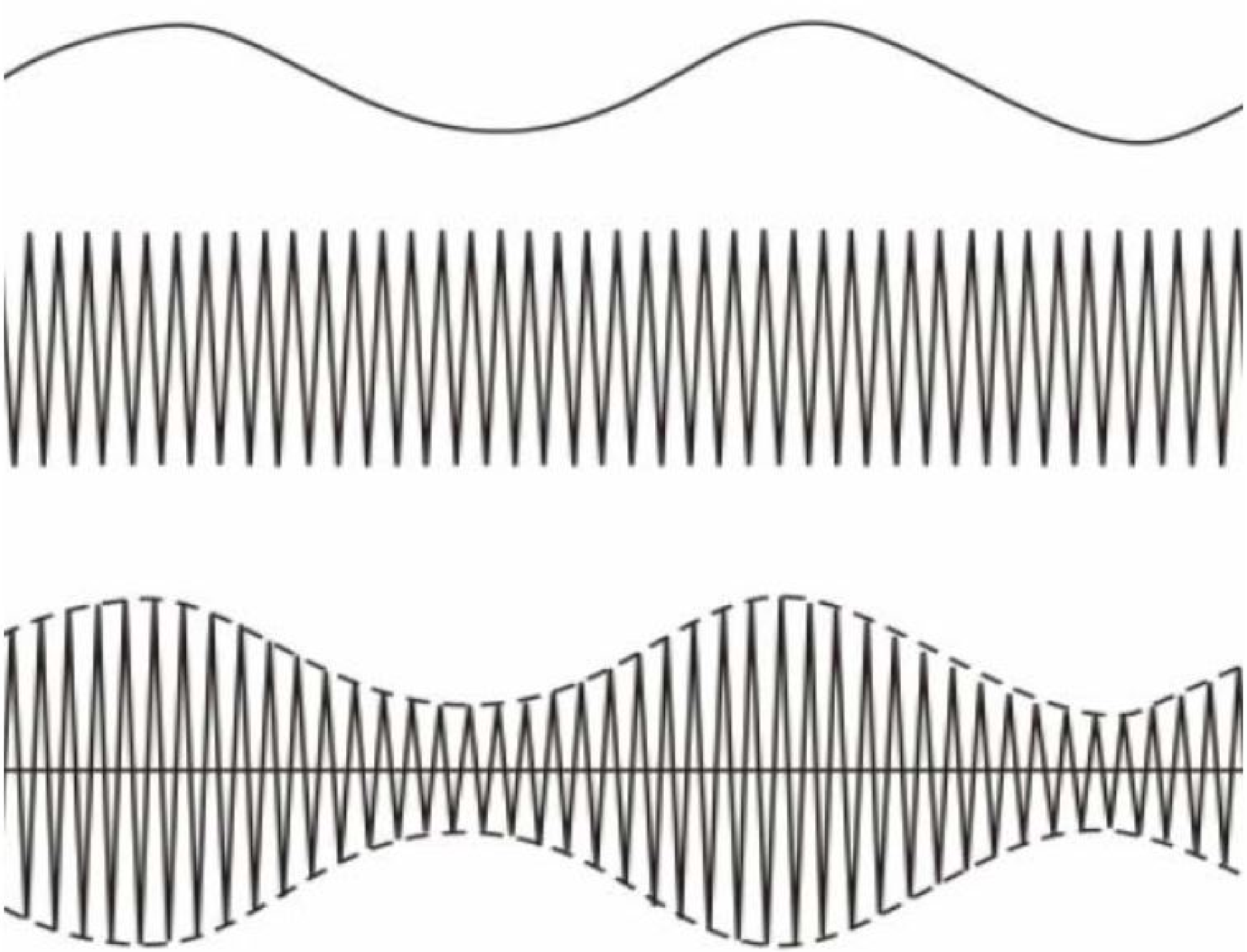
$$E_{max} = E_c + E_m, \qquad E_{min} = E_c - E_m$$

And $s(t) = E_c(1 + m\cos 2\pi f_m t) \cos 2\pi f_c t$,

The envelope of the modulated signal is represented by 1 + $me_m(t)$ for m<1

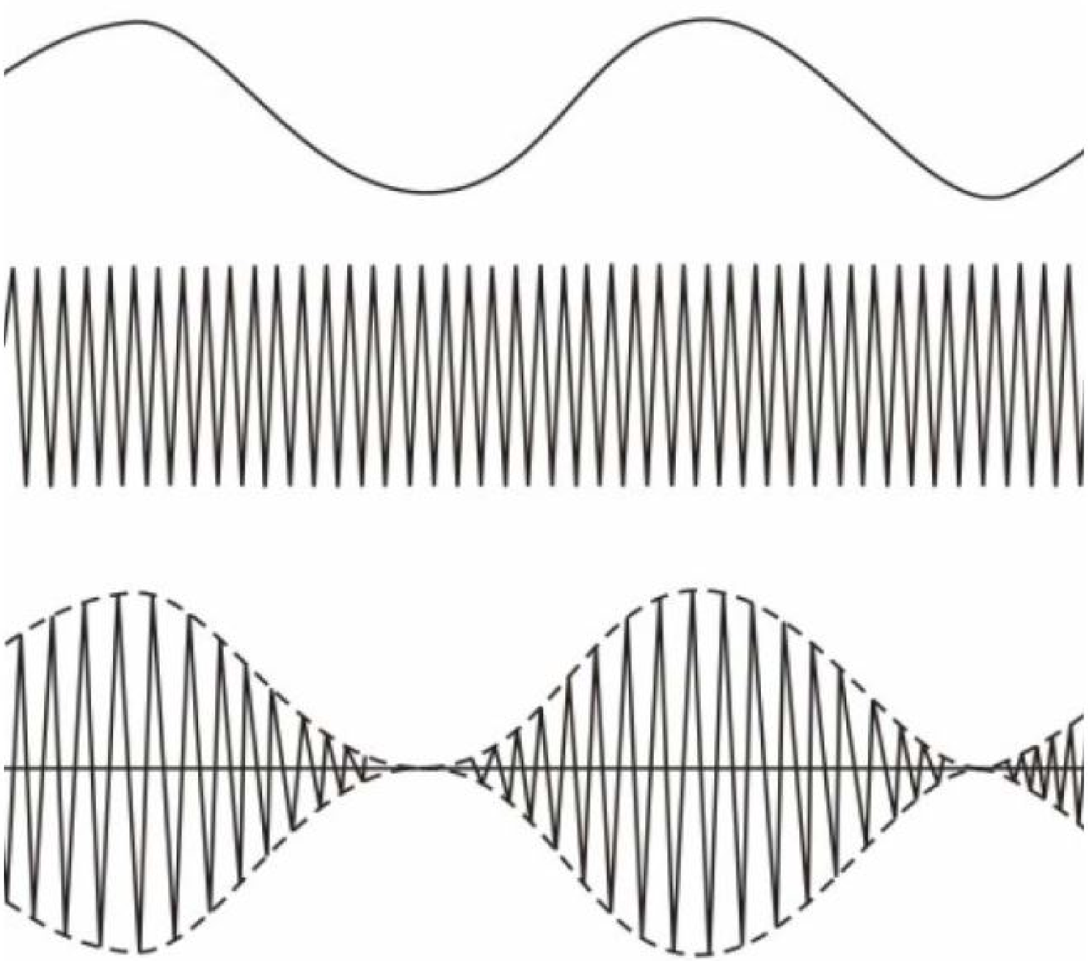
Modulation Index

Envelope of the signal 1 + $me_m(t)$ for m < 1



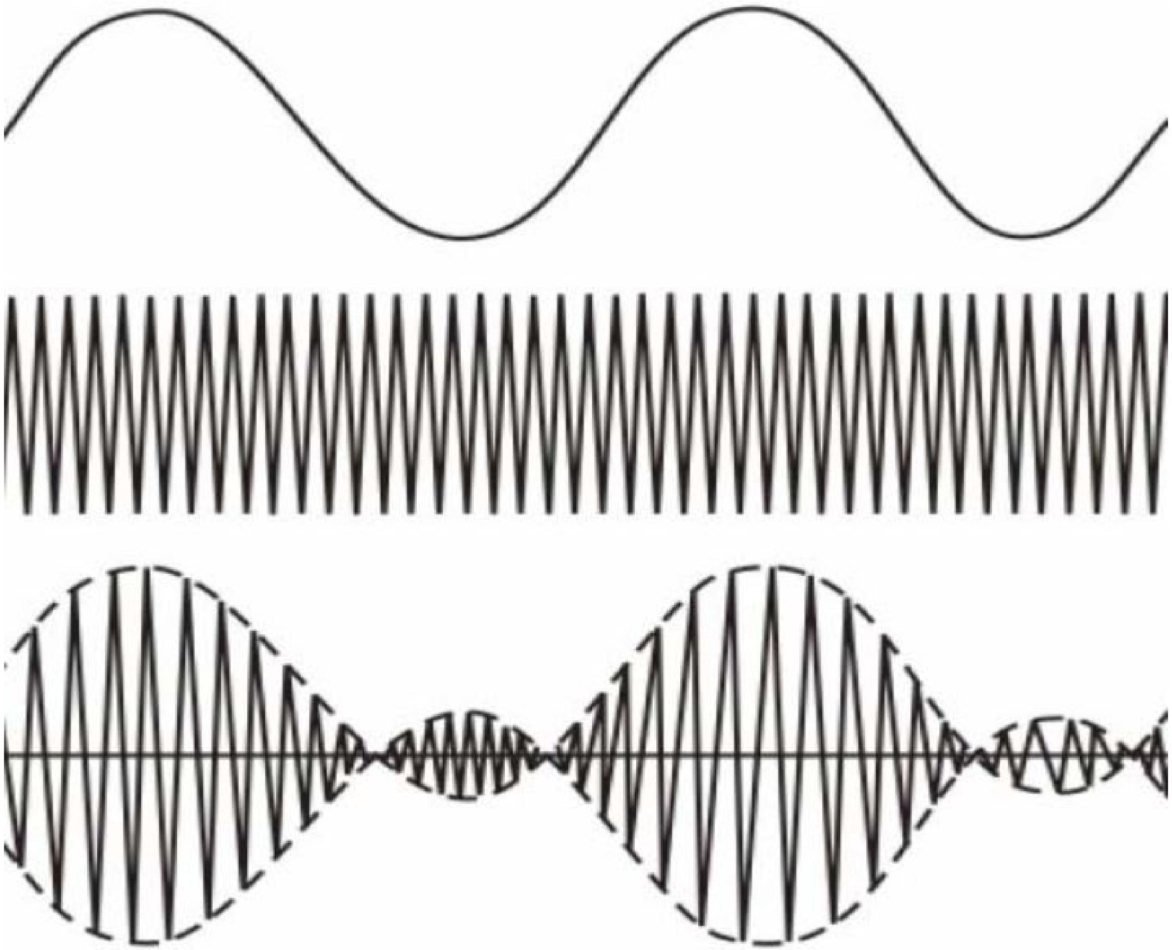
Modulation Index

Envelope of the signal for m = 1



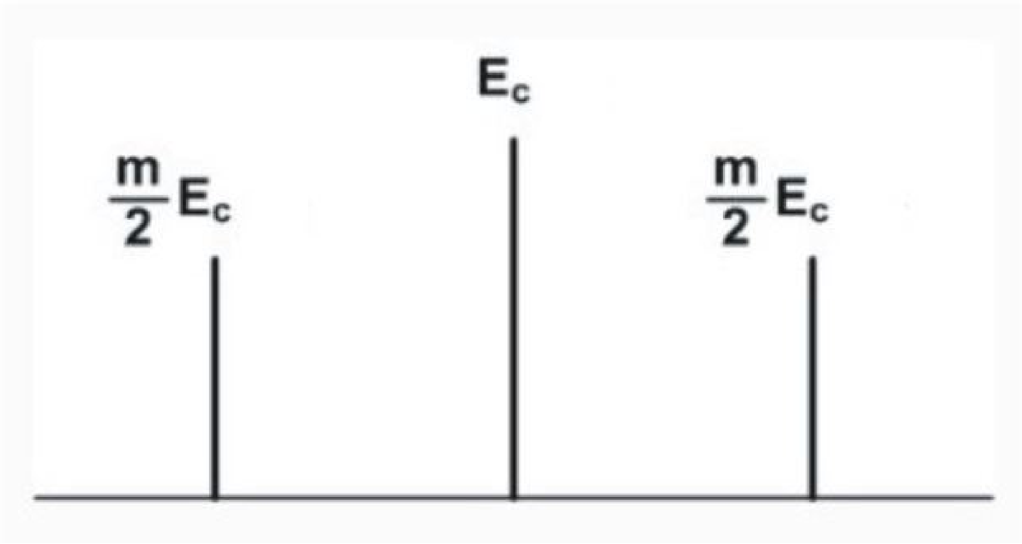
Modulation Index

<u>Loss of information occurs when m > 1</u>



Frequency Spectrum

- Three Components:
  - Carrier wave of amplitude E_c
  - Lower Sideband of amplitude $\frac{\mathrm{m}}{2}E_c$
  - Higher Sideband of amplitude $\frac{\mathrm{m}}{2}E_c$



Frequency Spectrum

- Frequency Spectrum of the sinusoidal AM signal

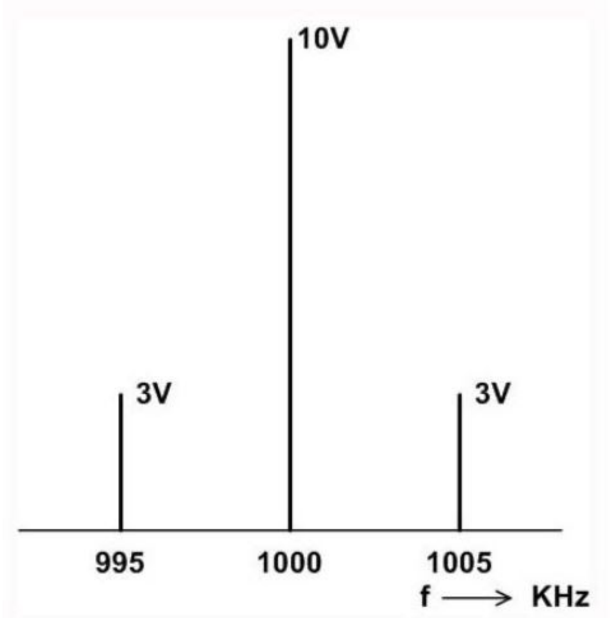
$$
\begin{aligned}
s(t) &= E_c\,[1 + m\cos 2\pi f_m t]\cos 2\pi f_c t \\
&= E_c \cos 2\pi f_c t + mE_c \cos 2\pi f_m t \cos 2\pi f_c t \\
&= E_c \cos 2\pi f_c t + \frac{m}{2} E_c \cos 2\pi (f_c - f_m) t \\
&\qquad + \frac{m}{2} E_c \cos 2\pi (f_c + f_m) t
\end{aligned}
$$

- There are three frequency components.

Frequency Spectrum

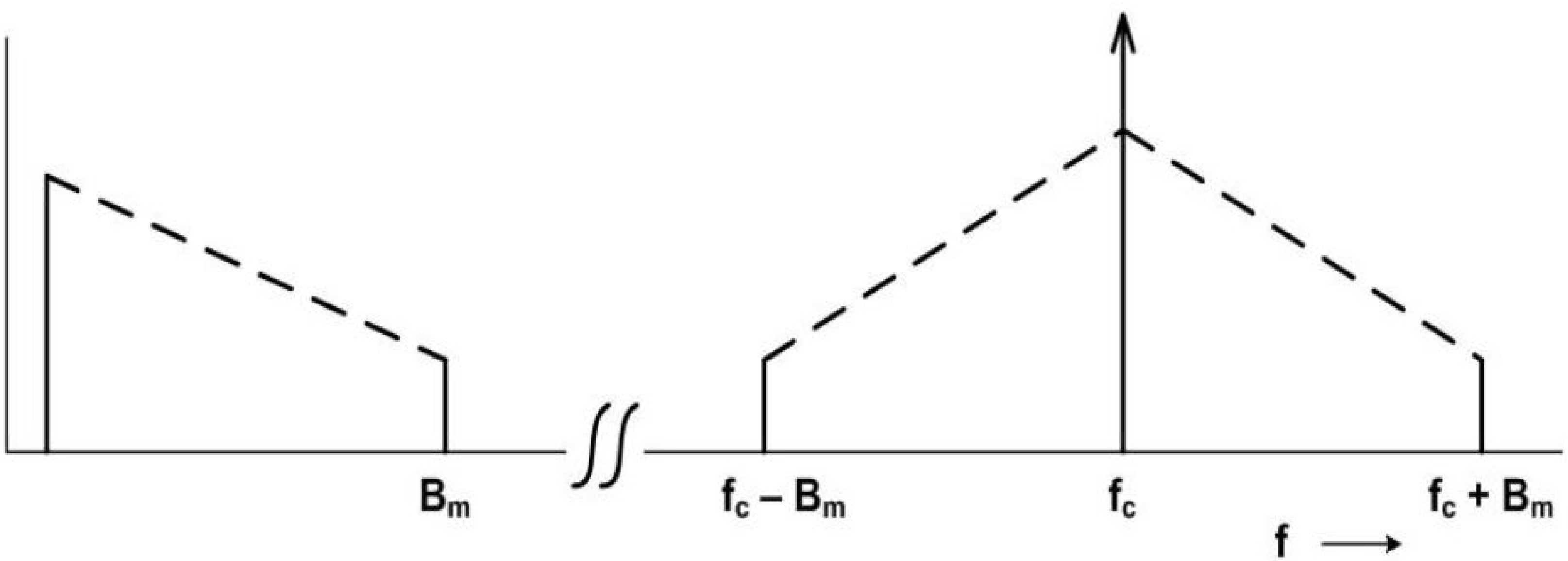
- **Example**: A carrier of 1 MHz with peak value of 10V is modulated by a 5 KHz sine wave amplitude 6V. Determine the modulation index and frequency spectrum.
- **Answer**: m = 6/10 = 0.6.

  The side frequencies are
(1000 – 5) = 995 KHz
and (1000 + 5) = 1005 KHz
having amplitude of 0.6 × 10/2 = 3V



Modulation using Audio Signal

- Let the bandwidth of the modulating signal is B_m.
- The bandwidth of the modulated signal is $2B_m$.



Average power of the sinusoidal wave

Average power developed across a resistor R for the carrier signal

$$P_c = E_c{}^2/2R$$

For sideband frequencies $P_{SF} = (mE_c/2)^2/2R$

$$= P_c\, m^2/4$$

Total Power = $P_c(1 + 2(m^2/4))$ = $P_c(1 + m^2/2)$

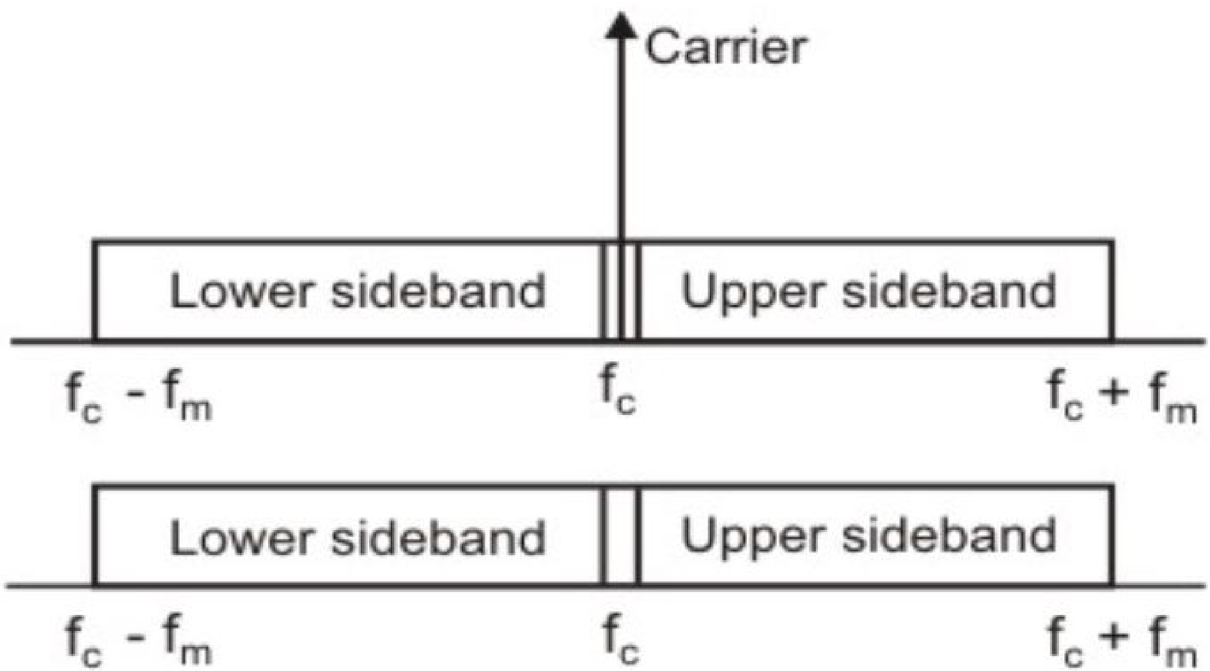
DSBSC and SSB Transmission

To minimize power for transmission, there are two other alternatives:

- Double-Sideband with Suppressed Carrier (DSBSC) Modulation
- Single Side Band (SSB) Modulation

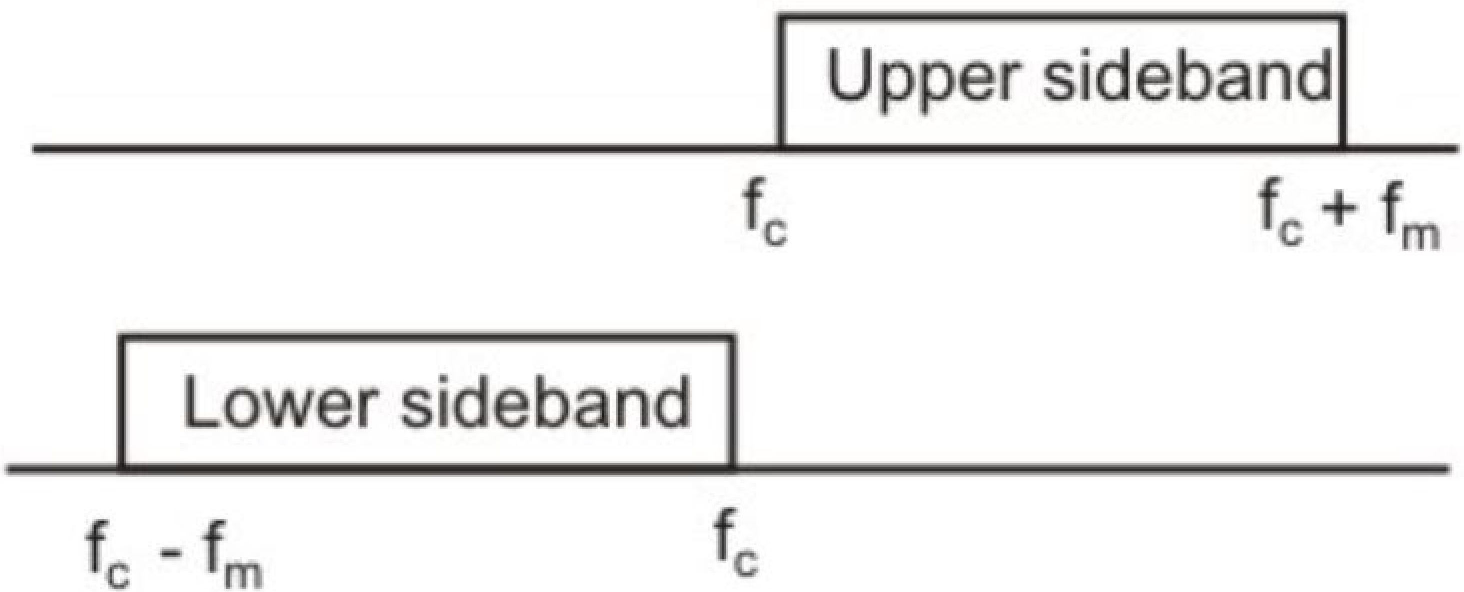
DSBSC Modulation

- Double-Sideband with Suppressed Carrier (DSBSC) Modulation utilizes the transmitted power more efficiently than DSB AM.



SSB Modulation

- Single Side Band (SSB) Modulation not only conserves energy, it also reduces bandwidth.



Recovery of the Baseband Signal

- Let a baseband signal $m(t)$is translated out by multiplication with the carrier signal $CosW_c t$ to get $m(t)CosW_c t,$ the modulated signal.
- By multiplying second time with the carrier we get $(m(t)CosW_c t)\ CosW_c t$

$$= m(t)Cos^2 W_c t = m(t)(\frac{1}{2} + \frac{1}{2}Cos2W_c t)$$

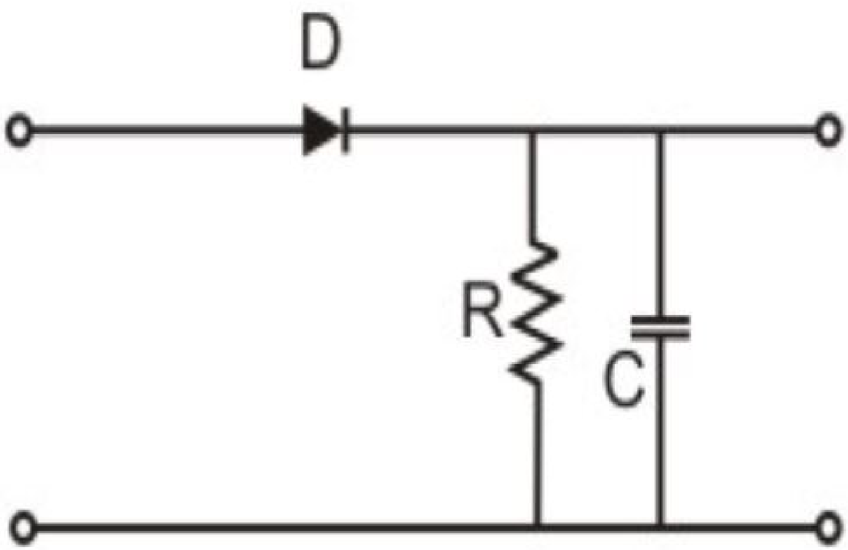
$$= {}^{m(t)}/_{2} + \frac{1}{2}m(t)Cos2W_c t$$

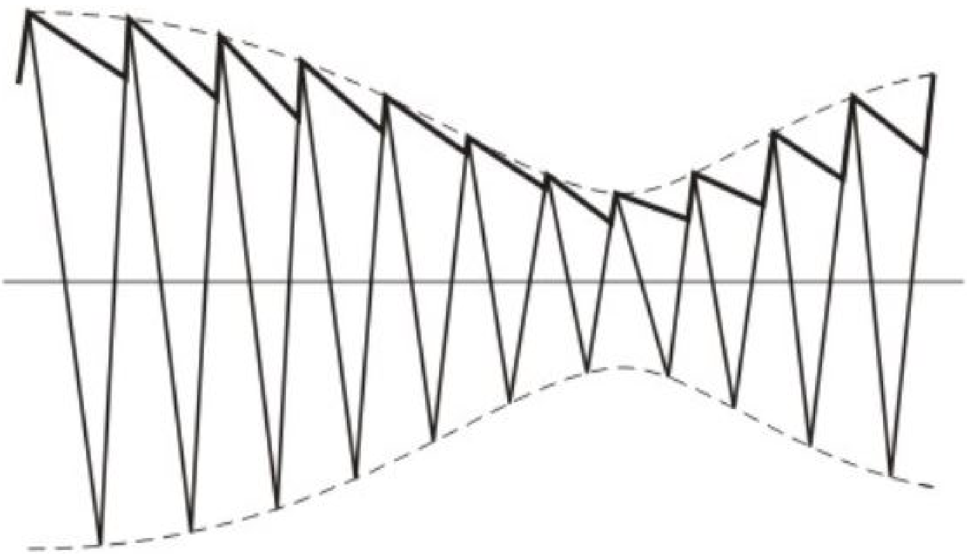
Recovery of the Baseband Signal

- The baseband signal reappears.
- The spectral components $2f_c - f_m$ to $2f_c + f_m$ can be easily removed by a low-pass filter.
- This process is known as **Synchronous Detection**.

Recovery of the Baseband Signal

- The synchronous detection approach has the disadvantage that the carrier signal used in the second multiplication has to be precisely synchronous.
- A very simple circuit can accomplish the recovery of the baseband signal.

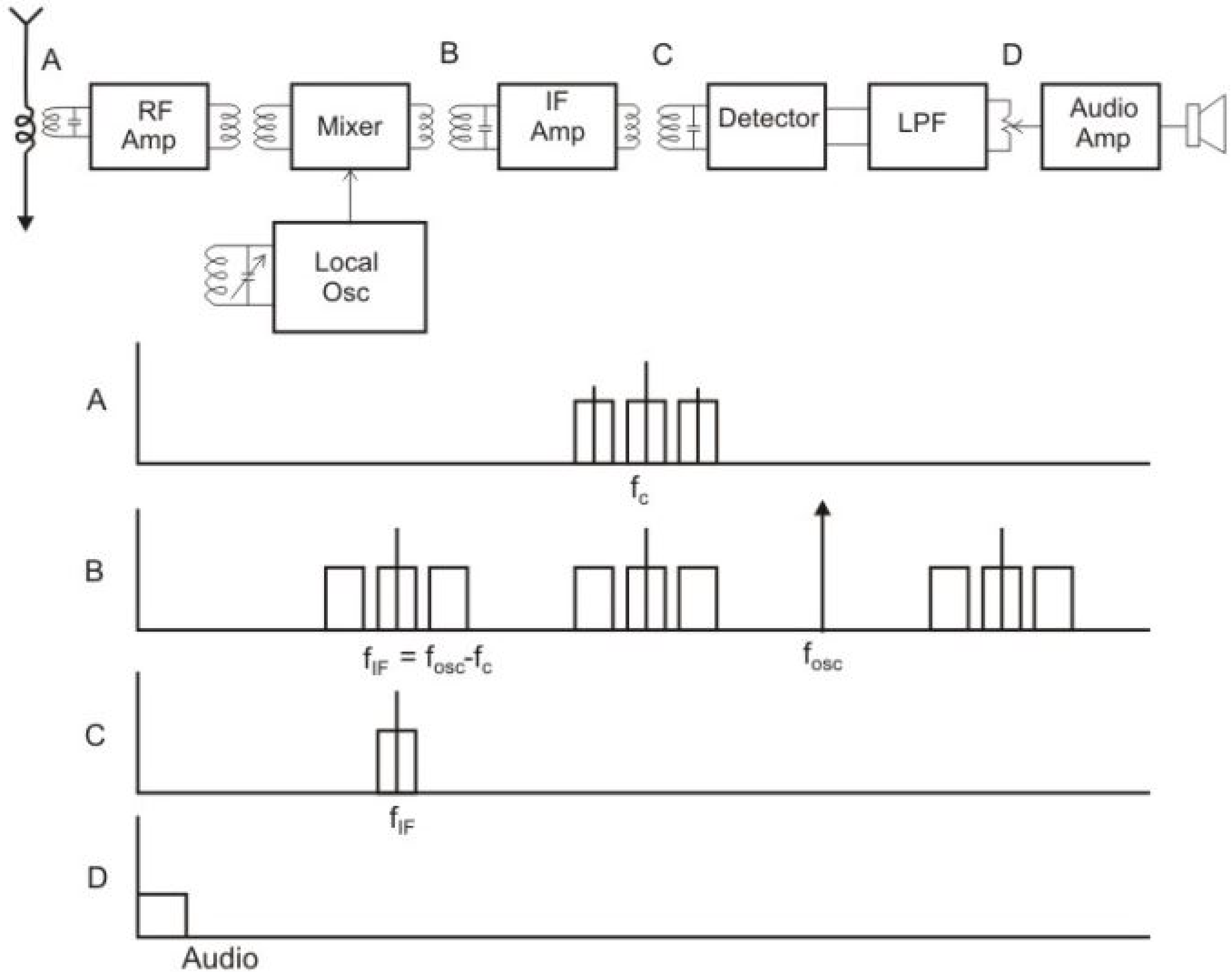




Superhetrodyne Approach

- The modulated signal received at the receiving end is greatly attenuated and mixed with noise.
- There may be other channels adjacent to it.
- The signal has to be amplified before detection.
- The noises to be removed by suitable filtering.
- **Superhetrodyne** approach is commonly used.

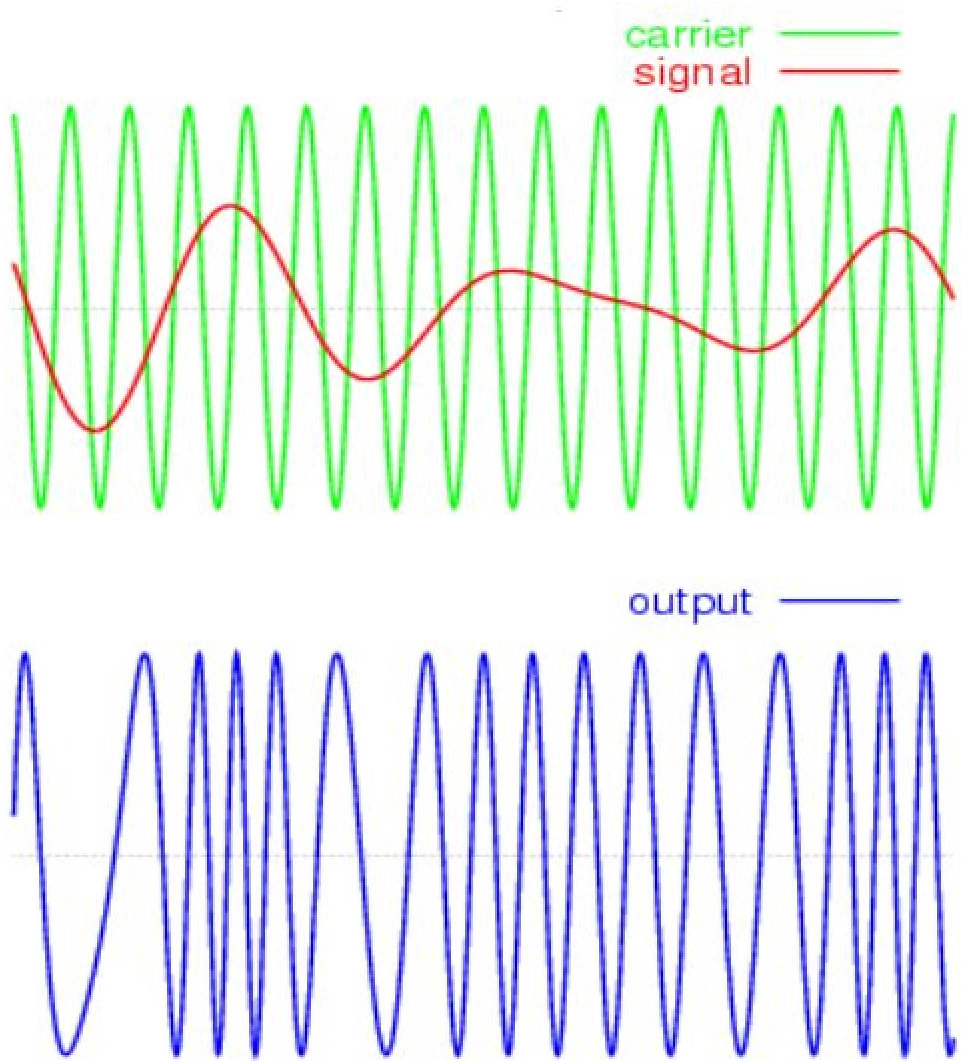
Superhetrodyne AM radio receiver



Superhetrodyne Approach

- It is used to improve adjacent channel selection.
- To provide necessary gain.
- To provide better S/N ratio.
- The commonly used technique of the popular AM receivers.

Angle Modulation



Thanks!