CS311: Data Communication

Transmission of Analog Signal - I

by

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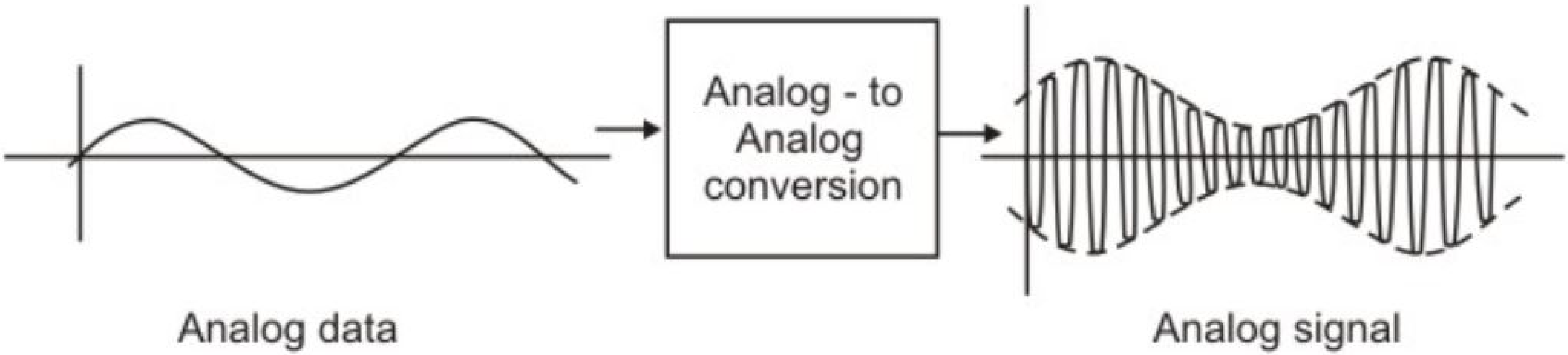
Outline

- Analog Transmission
- Why modulation?
- Basic concepts of AM (amplitude modulation)
- Frequency spectrum of AM
- Avg. power of different frequency components
- SSB and DSBBC transmission
- Recovery of baseband signal

Analog Data – Analog Signal

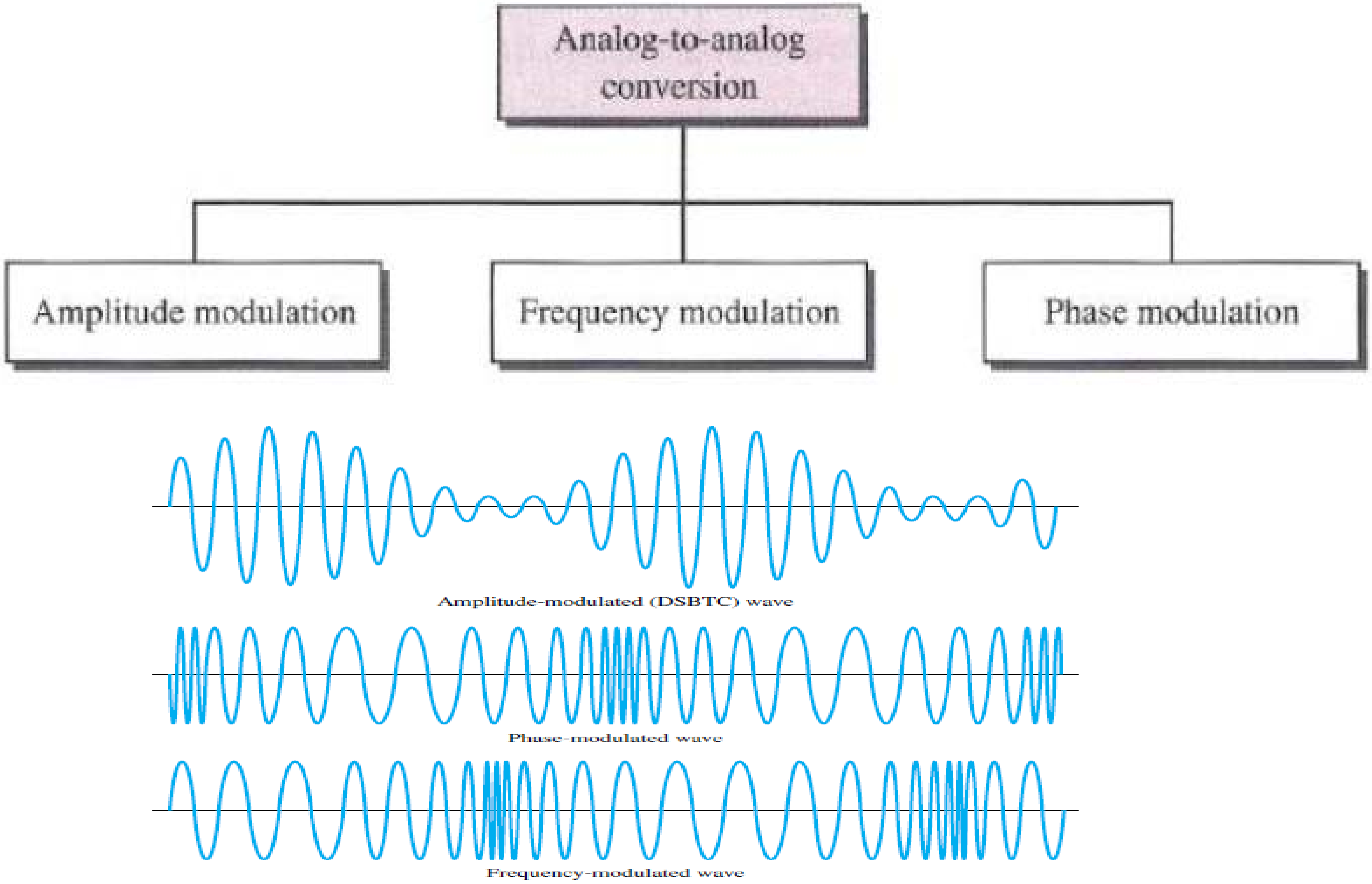


- The Process is known as modulation, which involves manipulation of one or more of the parameters of the carrier that characterizes a analog signal.

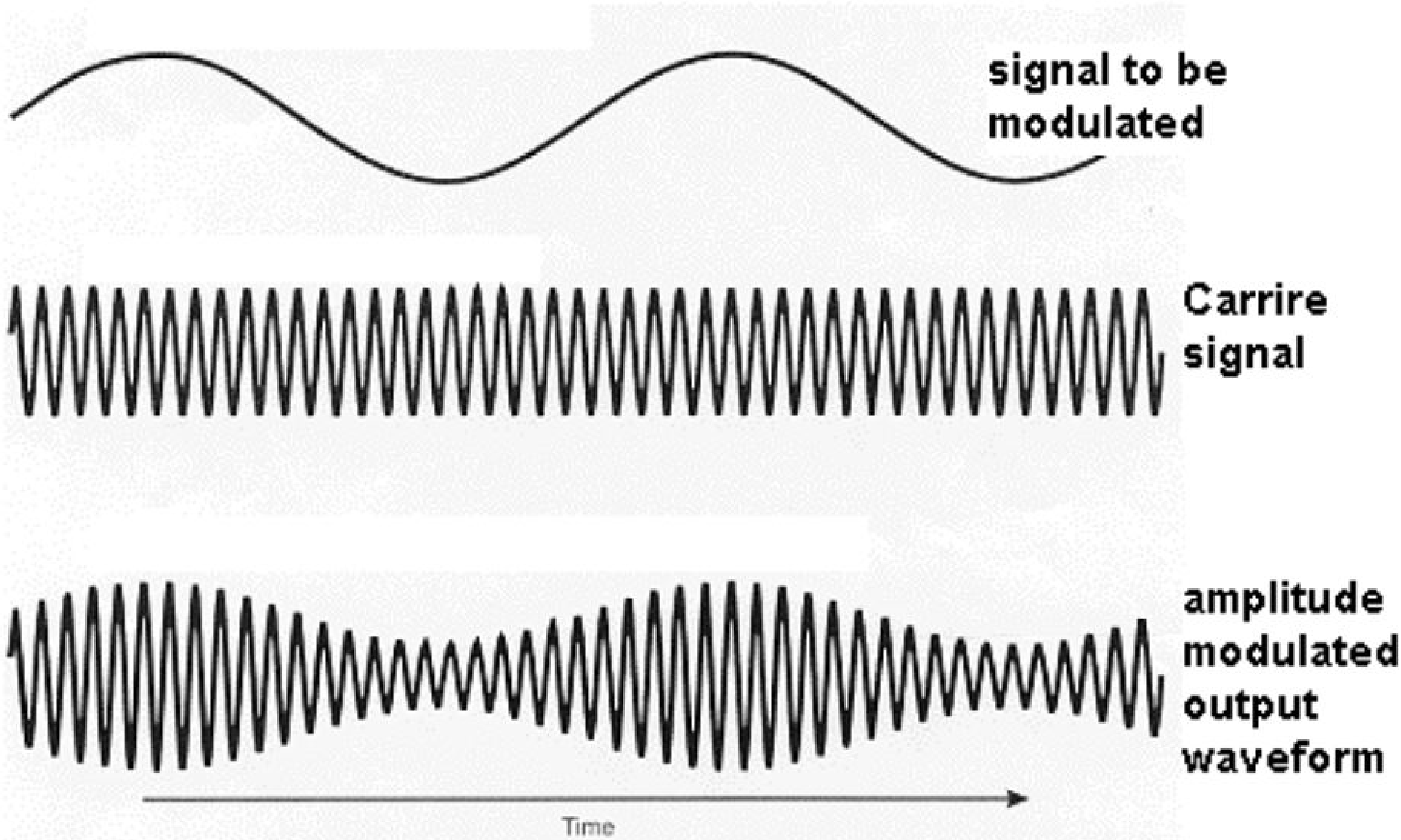
Why Modulation?

- Frequency Translation: Translates the signal from one region of frequency domain to another region.
- 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
- Narrowbanding: Ratio between highest to lowest frequency becomes close to 1.
- 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

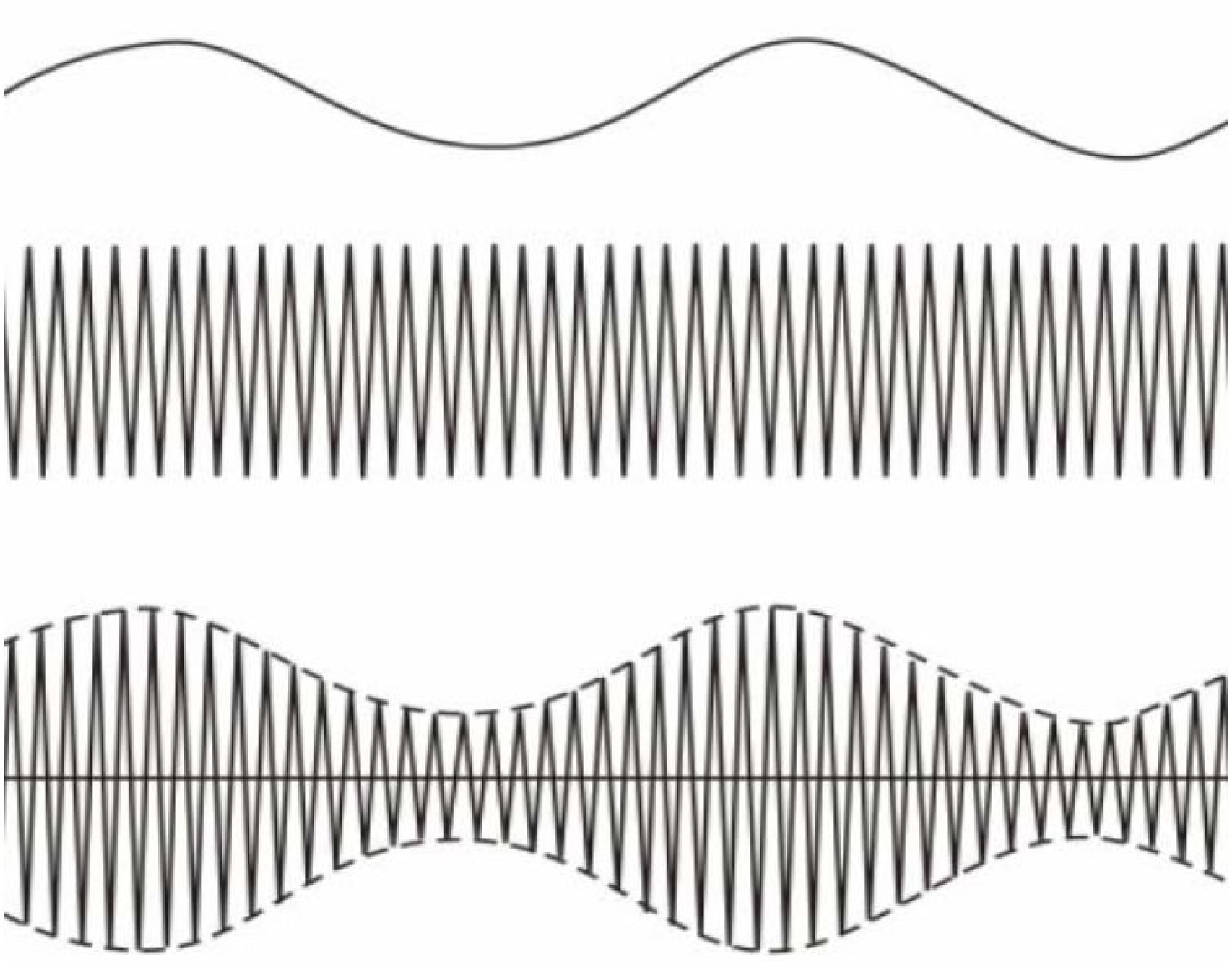
$$E_{max} = E_c + E_m, \qquad E_{min} = E_c - E_m$$

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

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

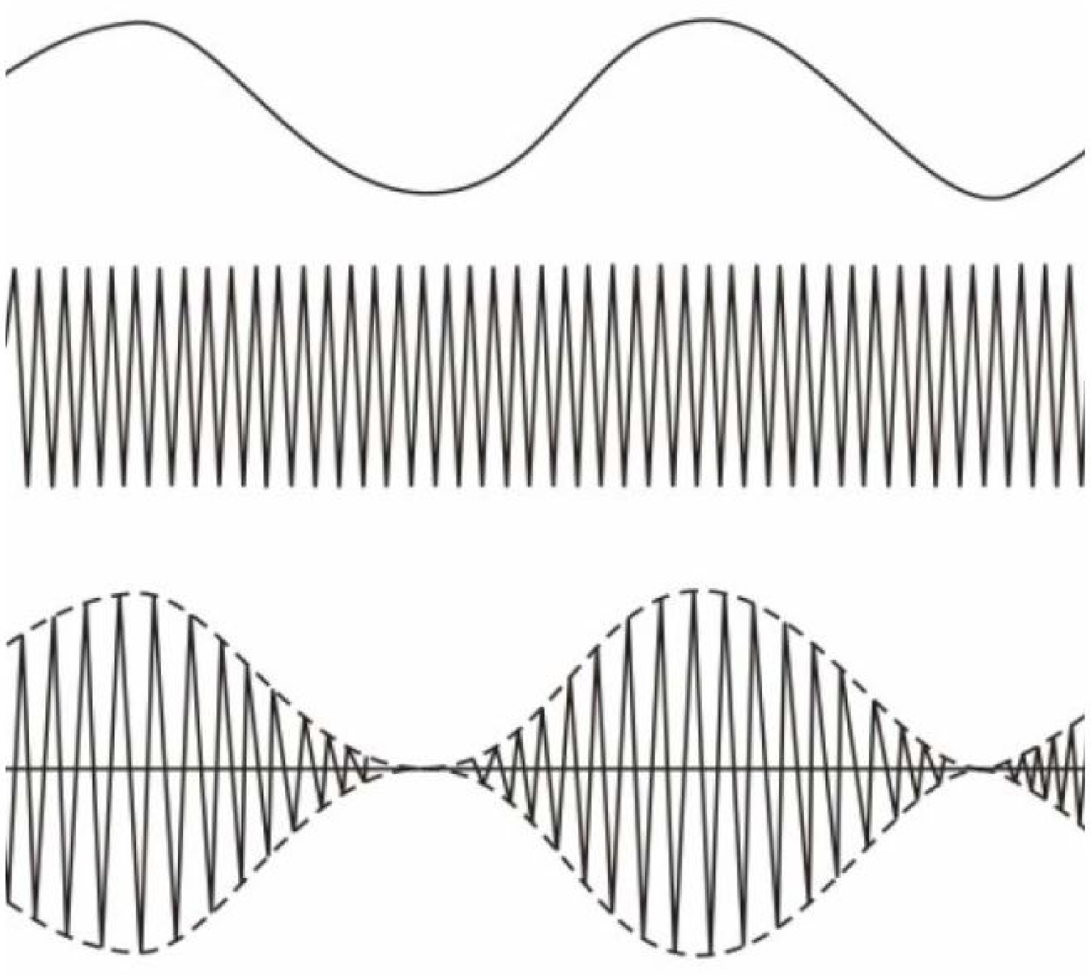
Modulation Index

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



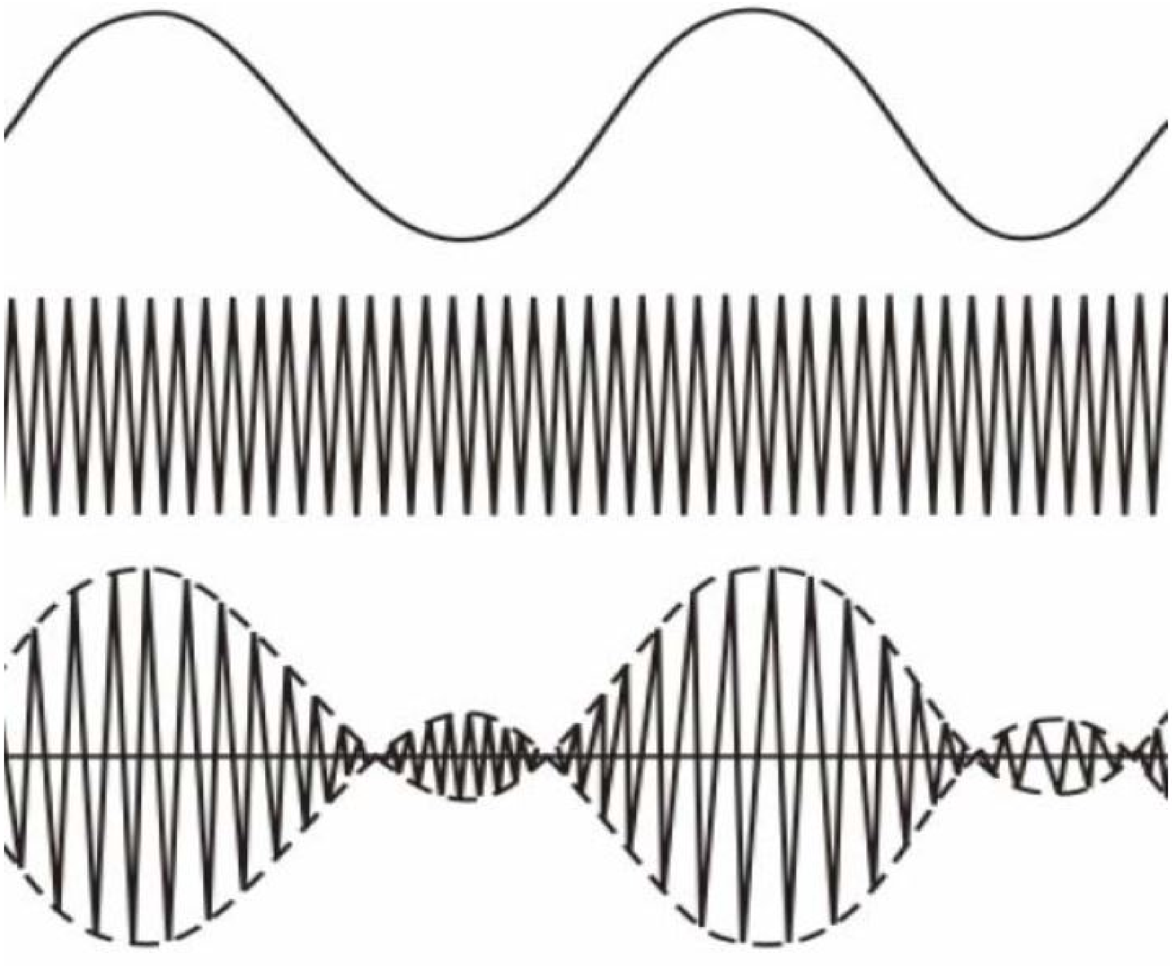
Modulation Index

Envelope of the signal for m = 1



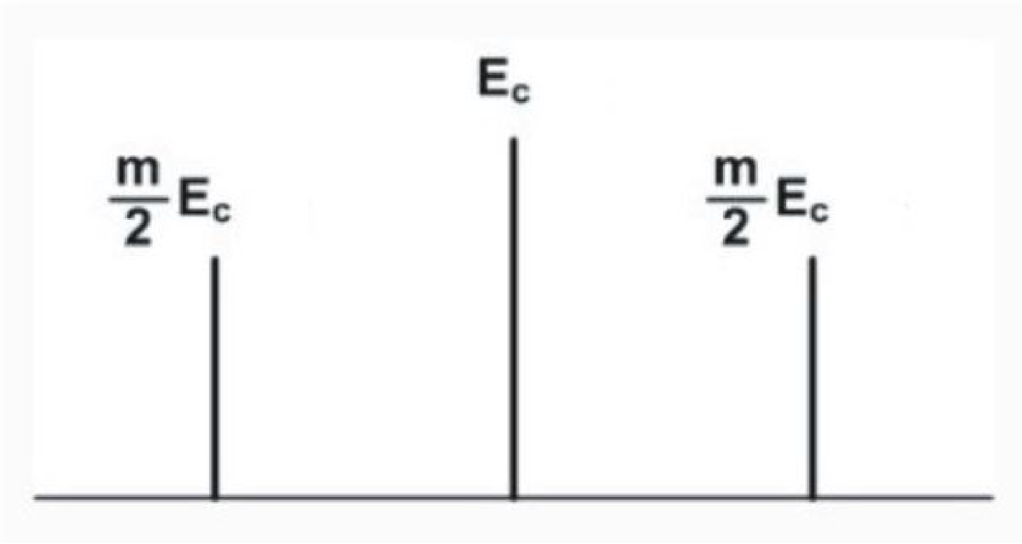
Modulation Index

<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 $\frac{\mathrm{m}}{2} E_c$

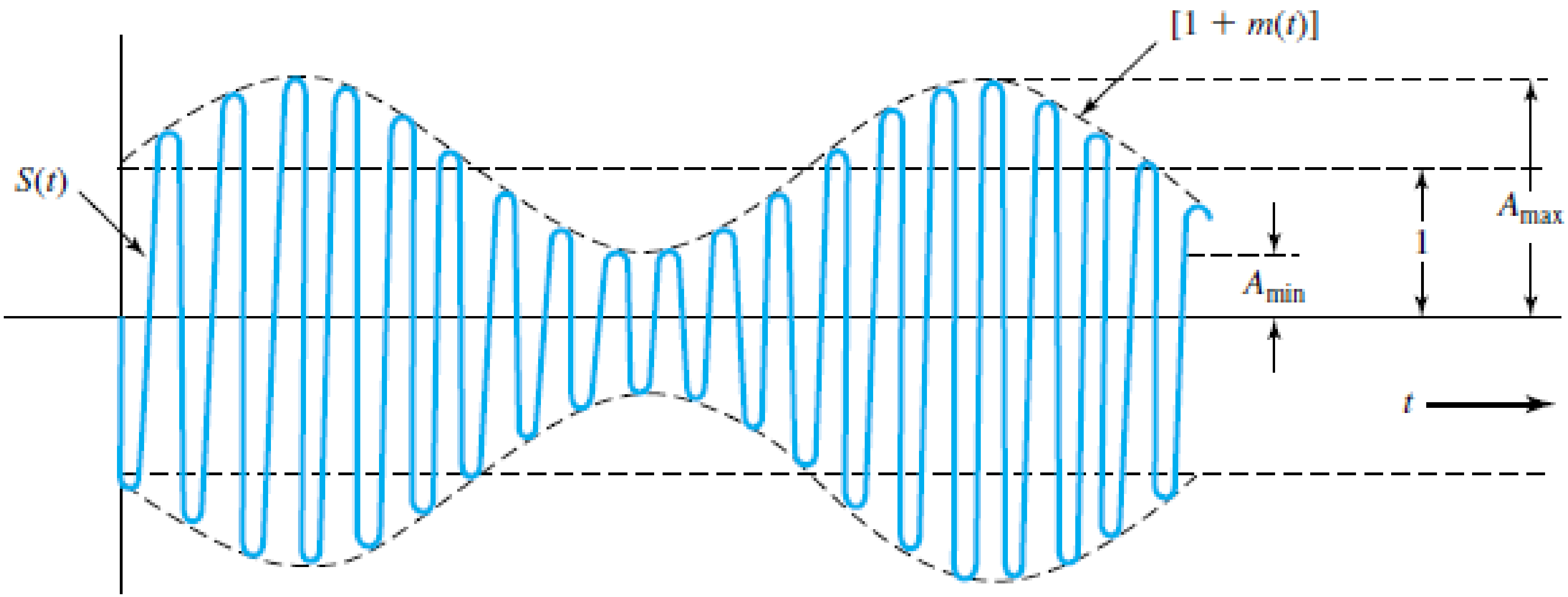


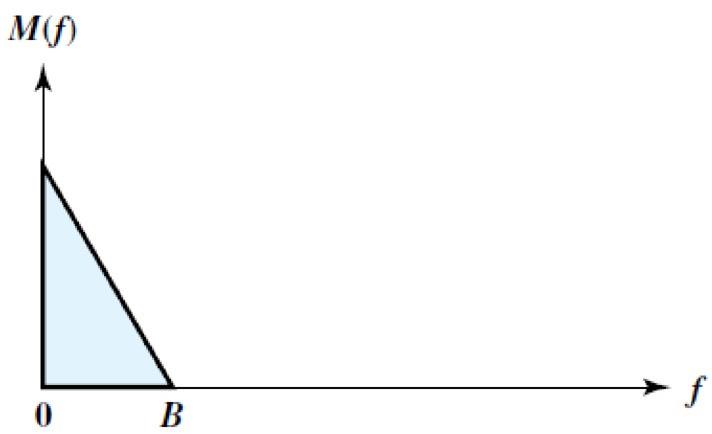
Frequency Spectrum

- Frequency Spectrum of the sinusoidal AM signal

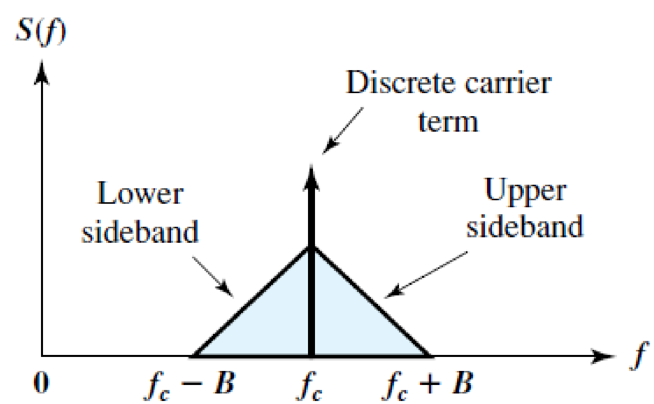
$$s(t) = E_c\,[1 + m\cos 2\pi f_m t]\cos 2\pi f_c t$$
$$= E_c \cos 2\pi f_c t + mE_c \cos 2\pi f_m t \cos 2\pi f_c t$$
$$= E_c \cos 2\pi f_c t + \frac{m}{2} E_c \cos 2\pi (f_c - f_m) t$$
$$+ \frac{m}{2} E_c \cos 2\pi (f_c + f_m) t$$

- There are three frequency components.





(a) Spectrum of modulating signal



(b) Spectrum of AM signal with carrier at f_c

Average Power of the sin 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 transmitted Power in modulated signal

$$P_t = P_c\,(1 + 2(m^2/4)) = P_c(1 + m^2/2)$$

- This scheme is known as DSBTC (double sideband transmitted carrier)
- Contains unnecessary components
- So, requires high power

- Popular variants: SSB and DSBSC

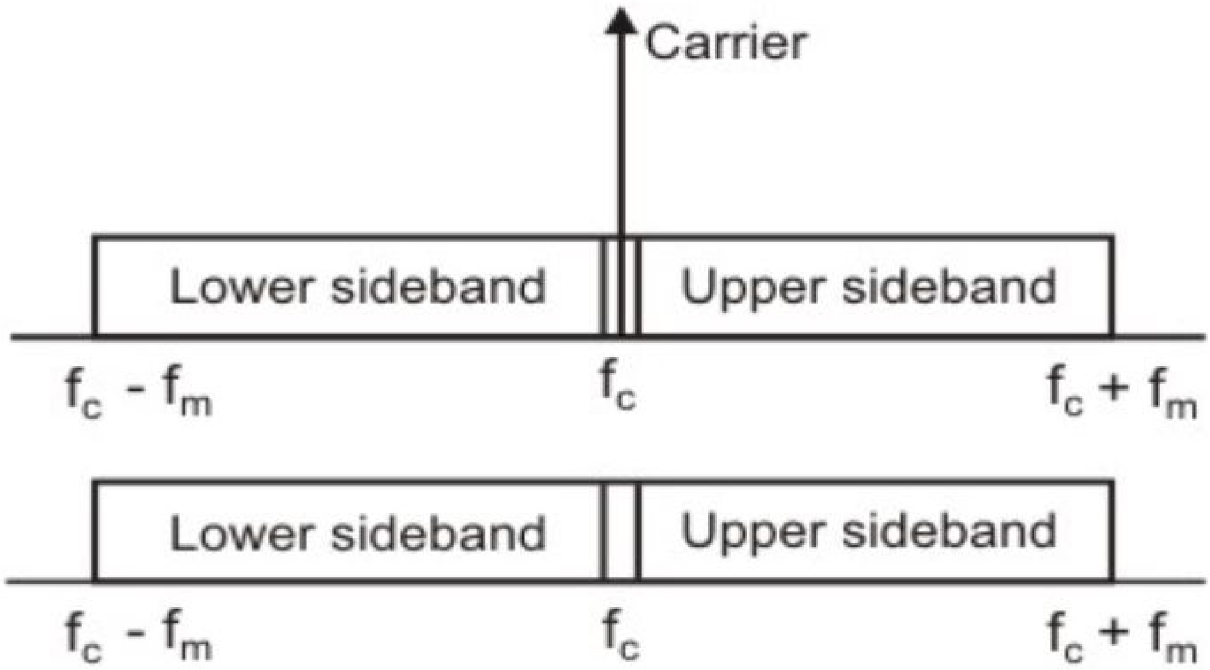
DSBSC and SSB Transmission

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

- DSBSC: Double-Sideband with Suppressed Carrier Modulation
- SSB: Single Sideband Modulation

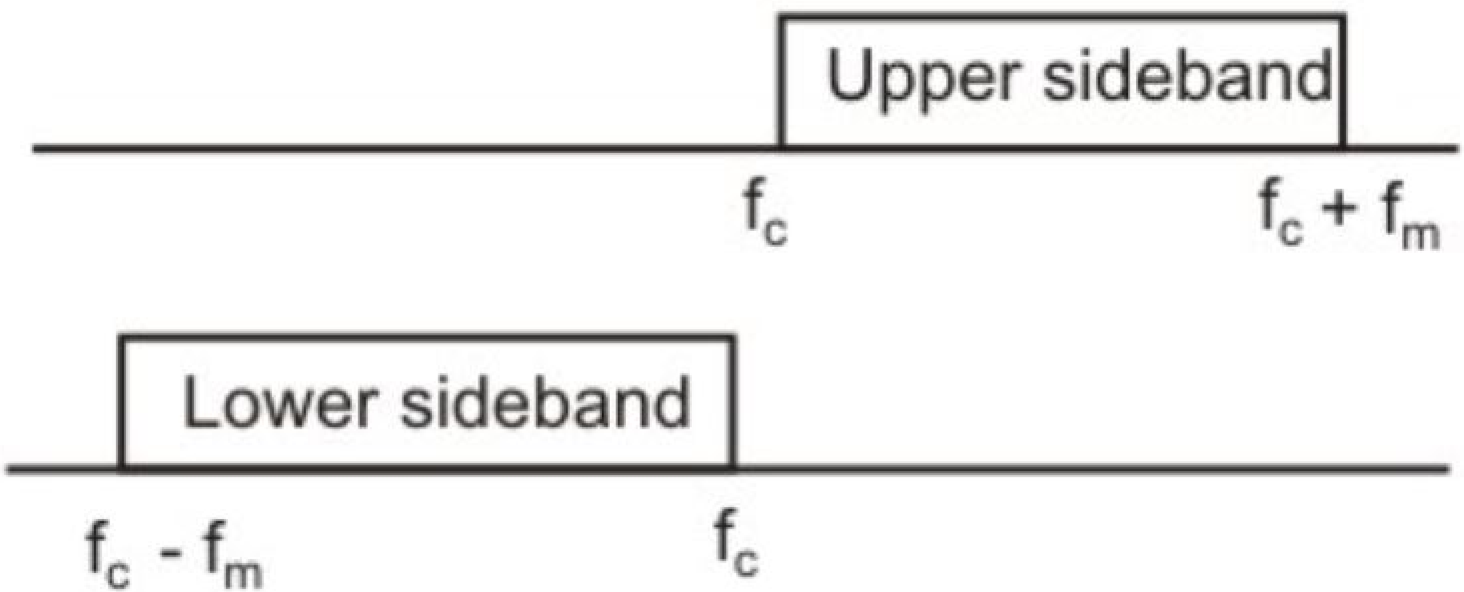
DSBSC Modulation

- 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 $CosW_ct$ to get $m(t)CosW_ct$, the modulated signal.

- By multiplying second time with the carrier we get $(m(t)CosW_ct)\ CosW_ct$

$$= m(t)Cos^2W_ct = m(t)(\frac{1}{2} + \frac{1}{2}Cos2W_ct)$$

$$= \frac{m(t)}{2} + \frac{m(t)}{2}Cos2W_ct$$

- The baseband signal reappears.

Recovery of the Baseband Signal

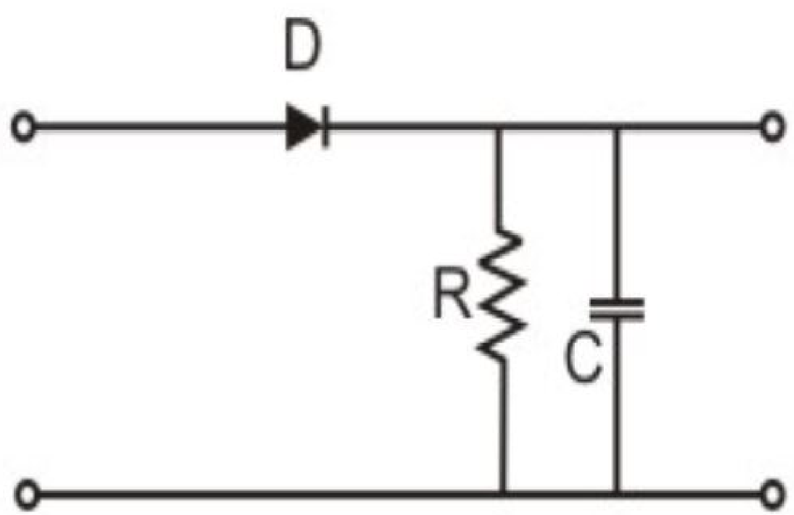
- The spectral components $2f_c - f_m$ to $2f_c + f_m$ can be easily removed by a low-pass filter.

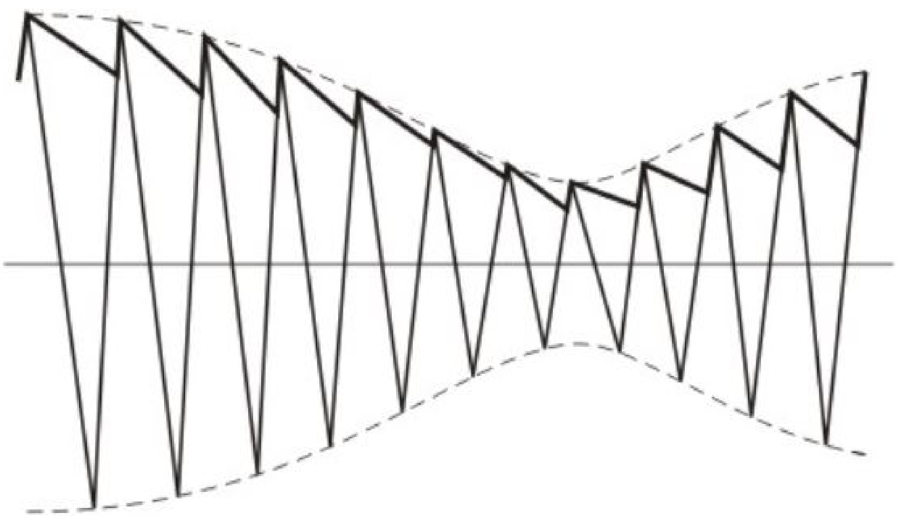
- This process is known as **Synchronous Detection**.

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.

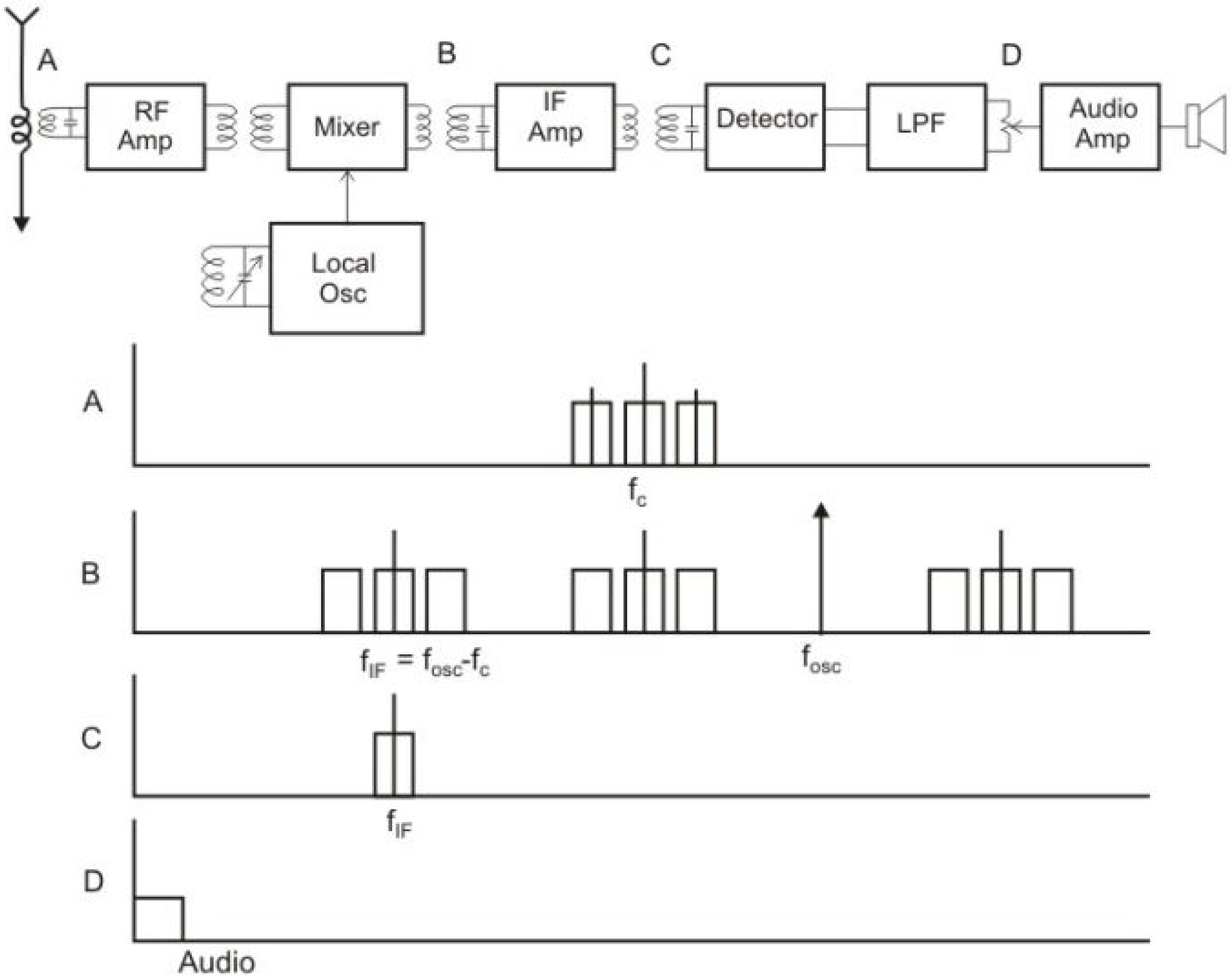




Superhetrodyne Approach

- 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.

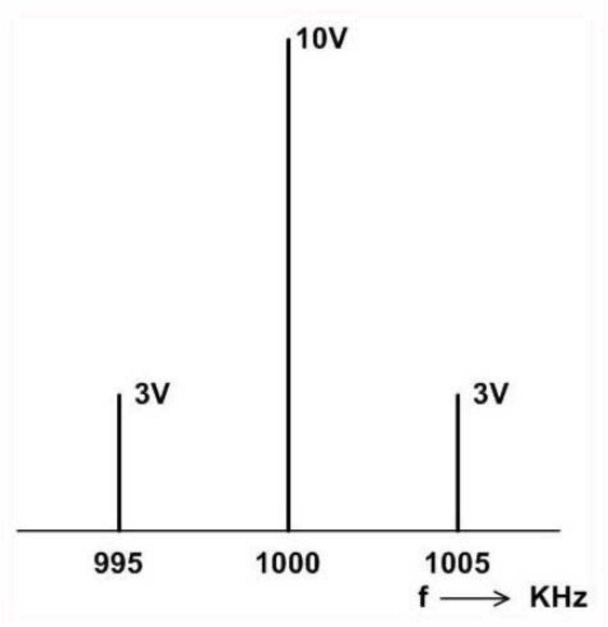
Thanks!

Figure and slide materials are taken from the following sources:

1. W. Stallings, (2010), Data and Computer Communications
2. NPTL lecture on Data Communication, by Prof. A. K. Pal, IIT Kharagpur
3. B. A. Forouzan, (2013), Data Communication and Networking

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 $2B_m$.