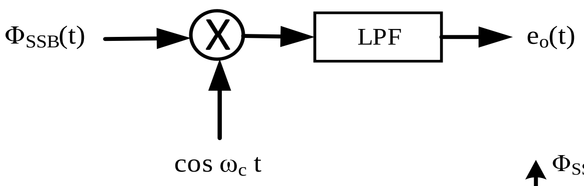
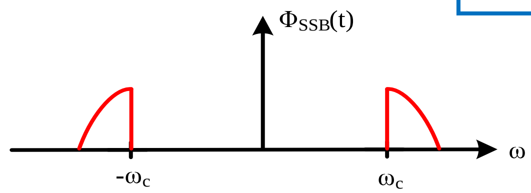
Demodulation of SSB Signals

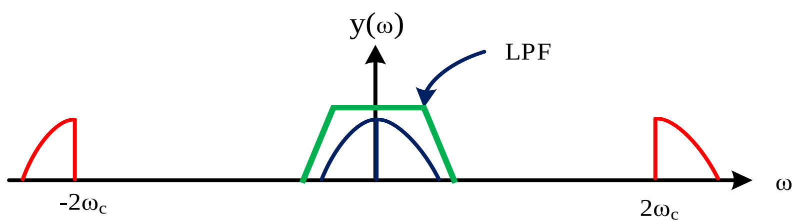
1- SSB-SC:

$$\emptyset_{SSB_{\pm}} = f(t)cos\omega_c t \mp \widehat{f(t)}sin\omega_c t$$

- Using synchronous detection →
  - Direct connection (if mod & demod are near each other)
  - Pilot carrier (if mod & demod are far from each other)







$$y(t) = f(t)cos^2\omega_c t \mp \widehat{f(t)}sin\omega_c t cos\omega_c t$$

$$= \frac{1}{2}f(t) + \frac{1}{2}f(t)cos2\omega_c t \mp \frac{1}{2}\widehat{f(t)}sin2\omega_c t$$

$$e_o(t) = \frac{1}{2}f(t)$$

2- SSB-SL:

$$\emptyset_{SSB_{-LC\pm}} = A_c cos\omega_c t + f(t)cos\omega_c t \mp \hat{f}(t)\, sin\omega_c t \quad \ldots(4\text{-}25)b$$

- Using noncoherent detection → Envelope Detector

  (if $m \leq 1$)

- Using coherent detection

  (if $m > 1$)

Ex 4-8:

A carrier signal given by $cos\omega_c t$ is modulated by a single tone signal given by $f(t) = 0.3cos\omega_m t \quad (\omega_m \ll \omega_c)$. Determine and plot the envelope of the modulated signal in the following modulation types are used:

1- AM/DSB-LC (AM)

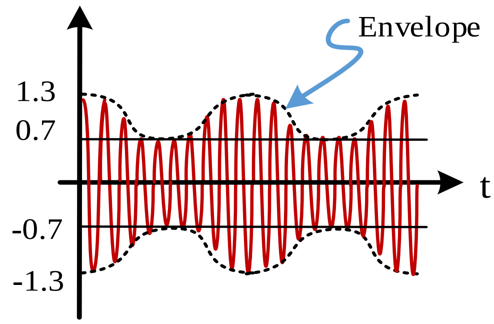
2- AM/SSB-LC (AM)

Solution:

1-

$$\emptyset_{AM}(t) = cos\omega_c t + 0.3\ cos\omega_m t cos\omega_c t$$

$$= \underbrace{(1 + 0.3\ cos\omega_m t)}_{\text{Envelope}} cos\omega_c t$$



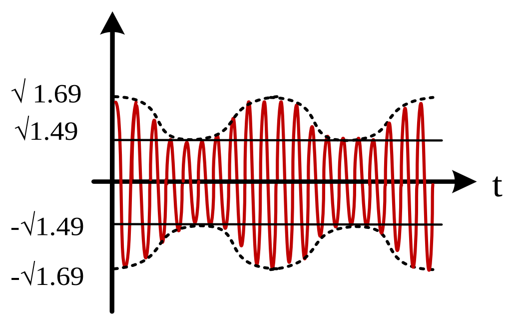
2-

$$\emptyset_{SSB_{\pm LC}}(t) = cos\omega_c t + 0.3\ cos\omega_m t cos\omega_c t - j0.3\ cos\omega_m t sin\omega_c t$$

$$= (1 + 0.3\ cos\omega_m t)cos\omega_c t - j(0.3\ cos\omega_m t)sin\omega_c t$$

$$= \sqrt{(1 + 0.3\ cos\omega_m t)^2 + (1 + 0.3\ cos\omega_m t)^2} \cos(\omega_c t - \theta)$$

$$= \sqrt{\underbrace{1.09 + 0.6cos\omega_m t}_{\text{Envelope}}} \cos(\omega_c t - \theta)$$



- In general :

  The envelope of $\emptyset_{SSB_{-LC}}(t)$

$$r(t) = \sqrt{[A + f(t)]^2 + \left[\widehat{f(t)}\right]^2} \ldots \qquad (4\text{-}26)$$

4 AM/VSB (Vestigial sideband):

- It is used to modulate the video signals which have a large bandwidth (0→4 MHz).
- It represents a compromise between SSB and DSB techniques [DSB requires large BW and SSB requires sharp filtering].
- In this type of modulation, a special filter $H_V(\omega)$ is used to pass one sideband and a vestige of other one.

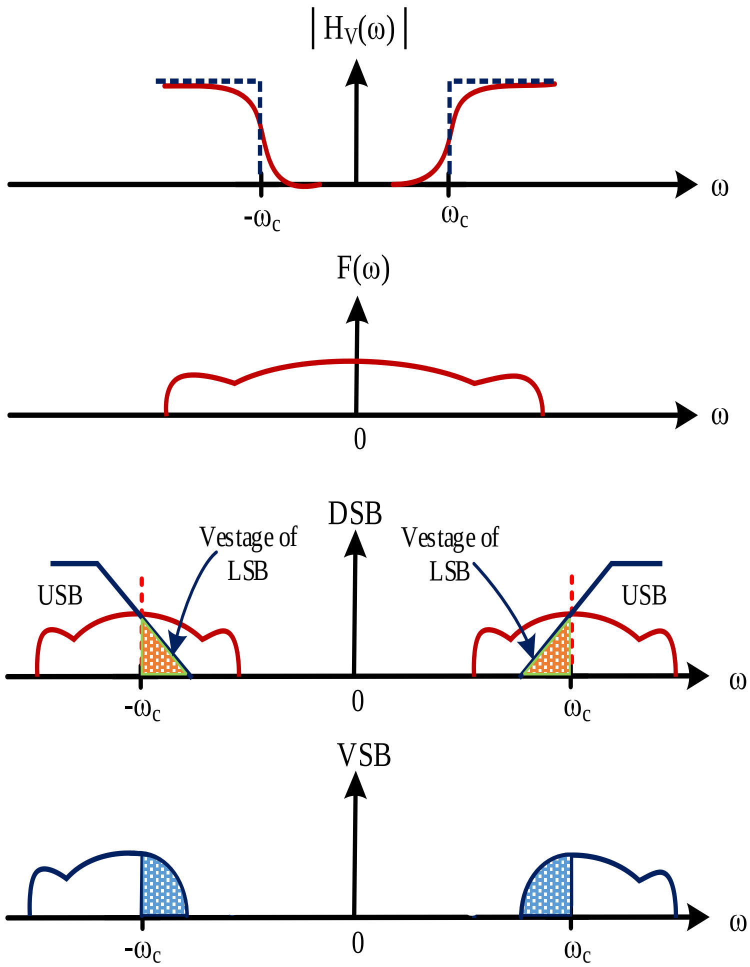
$$\emptyset_{VSB\_SC}(\omega) = \left[\frac{1}{2}F(\omega-\omega_c)\right] + \left[\frac{1}{2}F(\omega+\omega_c)\right] H_V(\omega) \quad \ldots (4\text{-}27)$$

Generation of VSB Signals:

Modulation and filtering (VSB/SC and VSB/LC)

Demodulation of VSB Signals:

- Synchronous detection for (VSB/SC)
- Asynchronous detection for (VSB-LC)

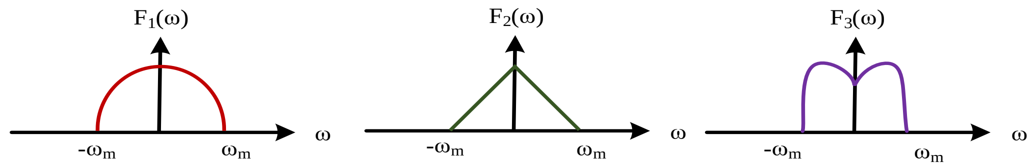


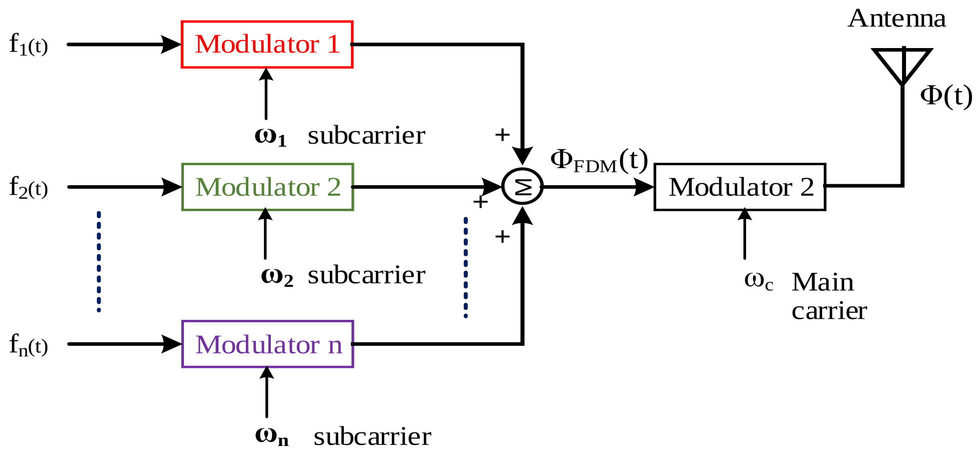
$$2W > BW_{VSB} > W \quad \ldots (4\text{-}28)$$

Frequency Division Multiplexing (FDM):

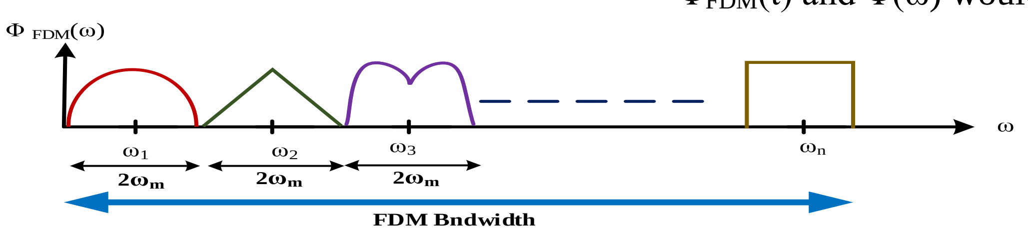
A mode of transmission by which several signals may be send simultaneously by positioning their spectra such that each signal spectrum can be separated out from all others by filtering.

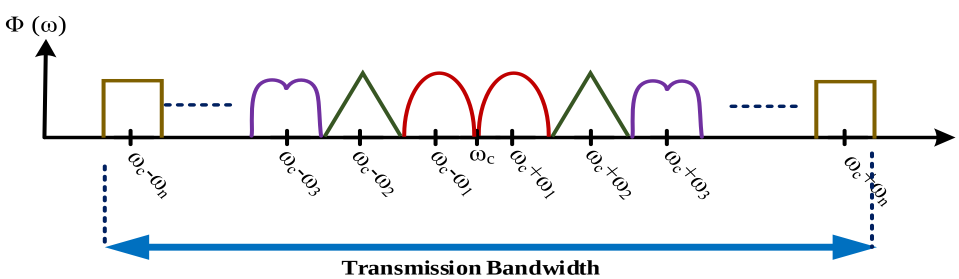
Transmission:





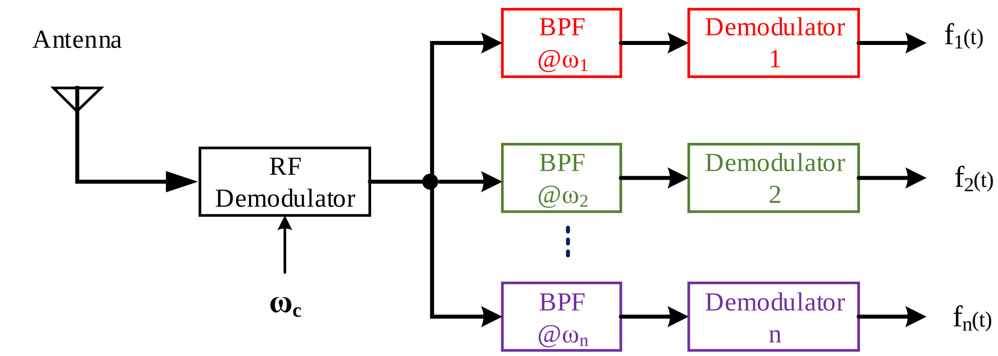
If the modulators are of type AM/DSB-SC, then the spectrum of $\Phi_{FDM}(t)$ and $\Phi(\omega)$ would be:



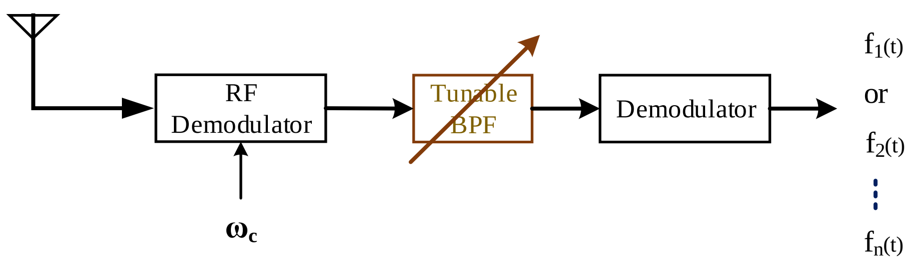


<u>Reception</u>:

1- <u>Simultaneous Reception:</u>



2- <u>Selective Reception:</u>



<u>Ex 4-9:</u>

Twenty speech signal each bandlimited to 4 kHz are FDM/SSB multiplexed, then RF modulated by a main carrier using AM modulator. Calculate the bandwidth of multiplexing (minimum) and final transmission bandwidth (minimum).

<u>Solution:</u>

Since the multiplexing scheme using SSB modulation

$\therefore\ BW_{FDM_{min}} = n * 4\ kHz$ (n:no. of signals)

$$= 20 * 4\ kHz$$

$$= 80\ kHz$$

Since the RF modulation is AM(DSB-LC)

$$\therefore\ BW_{FDM_{min}} = 2 * BW_{FDM_{min}}$$

$$= 160\ kHz$$

Ex 4-10:

Repeat the previous example if there is a 0.7 kHz guard band between each two signals and below the first signal during multiplexing.

Solution:

$$BW_{FDM} = 20 * 4\ kHz + 20 * 0.7\ kHz = 94\ kHz$$

$$BW_{tr} = 2 * 94\ kHz \quad = 188\ kHz$$

H.W:

Thirty signals, twenty of them have $4kHz$ bandwidth, the other have bandwidth of 3 kHz are FDM/SSB multiplexed then modulated by an RF carrier of 800 kHz using AM modulator:

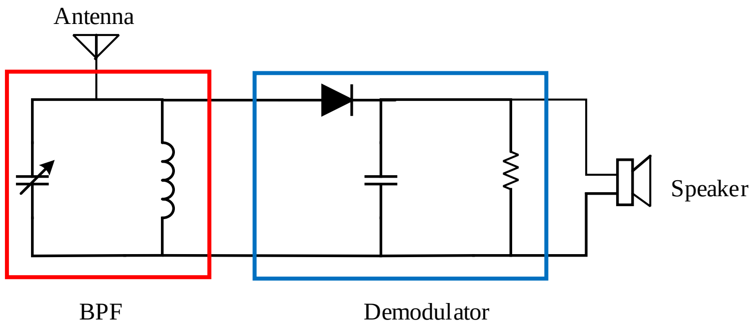
1- Calculate minimum multiplexing and transmission bandwidths.
2- Calculate multiplexing and transmission bandwidths if 0.7 kHz guard band is allowed between each two signals and below the first signal.

Commercial AM Broadcast Transmitters:

- Commercial AM broadcast Tx sends out DSB-LC signals with unique carrier frequency.
- Carrier frequencies are assigned at 10 kHz spacing from 540 kHz to 1600 kHz (MW).

Commercial Receivers:

1- Easier Receivers:

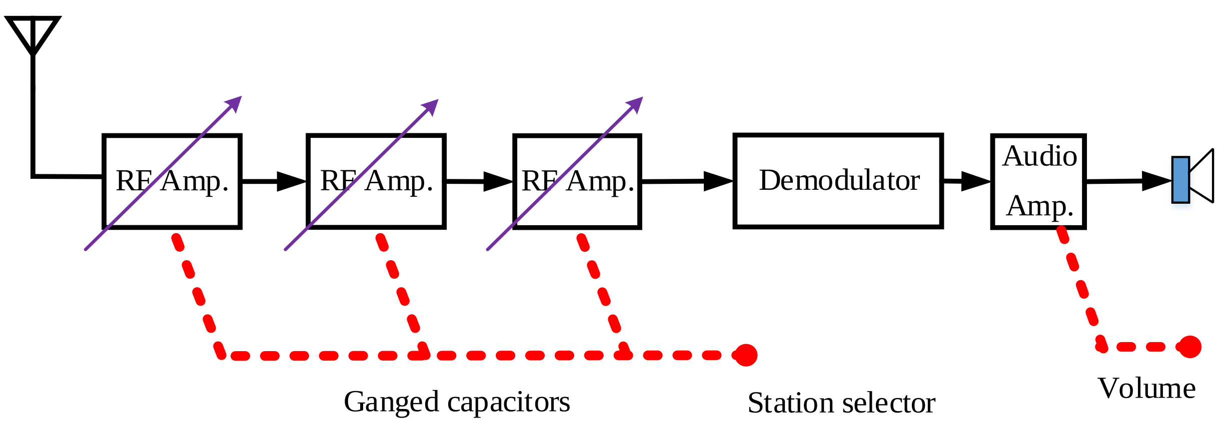


Advantages: simple and low cost.

Disadvantages:

- Less sensitivity for weak signals from far stations
- Less selectivity due to simple filtering.

2- Tuned Radio-Frequency (TRF) receiver:



Advantages: Amplifies the weak radio frequencies (3 stage of amplification) i.e. have high sensitivity.

Disadvantages: Not all stages always changed at the same time unless the bandwidth of each stage increases reducing selectivity and sensitivity.