Lecture 8

Topics

- VSB: Modulation
- VSB: Demodulation
- Spectrum Drawing for VSB filter
- Carrier Acquisition
- Pilot Carrier & PLL

Pros and Cons of DSB and SSB

- DSB: Less error-prone, but requires more bandwidth!
- SSB: Requires less bandwidth, but more error-prone!
- VSB (Vestigial Sideband): Sending more than SSB, but less than DSB!!
    - Actual filter won’t be able to provide a sharp cutoff (exact USB/LSB) -> VSB is much easier to produce

VSB: Modulation

(2) m(t) Modulation / Transmitted Signal

$$DSB = m(t)\cos\omega_c t$$

$$VSB = DSB \times H_i(\omega)$$

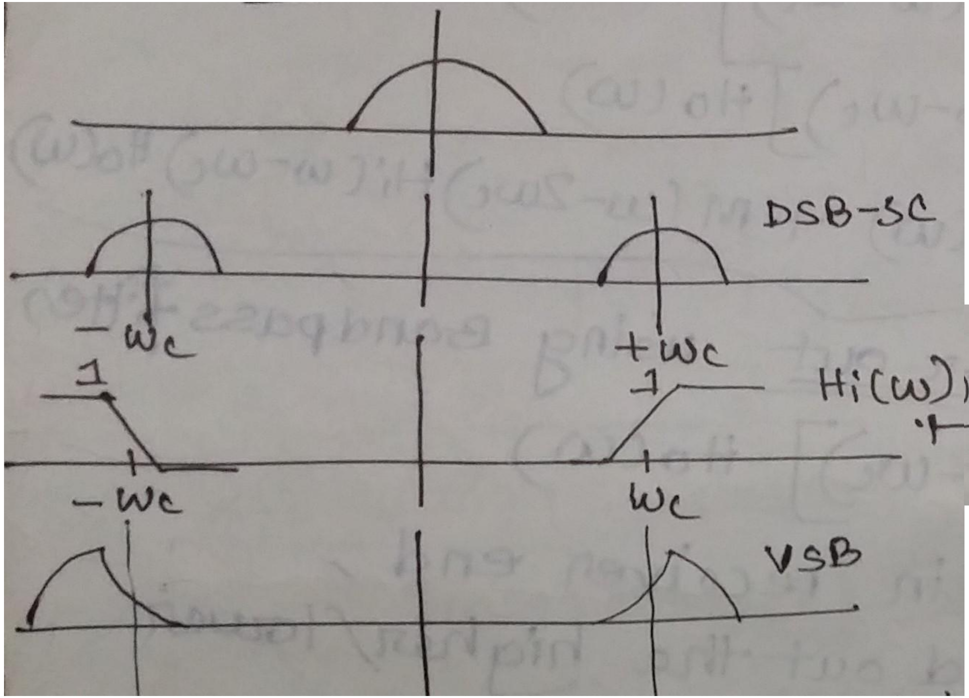
In freq domain,

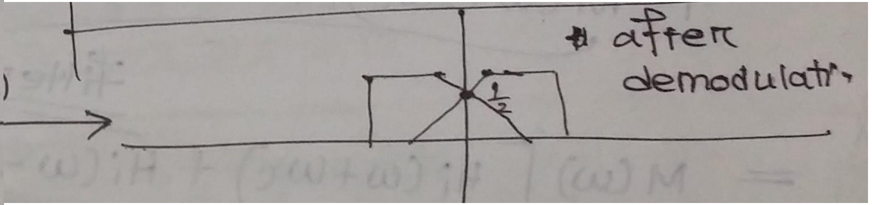
$$M_{DSB}(\omega) = M(\omega+\omega_c) + M(\omega-\omega_c)$$

$$M_{VSB}(\omega) = [M(\omega+\omega_c) + M(\omega-\omega_c)] \times H_i(\omega) \quad \text{—— (1)}$$

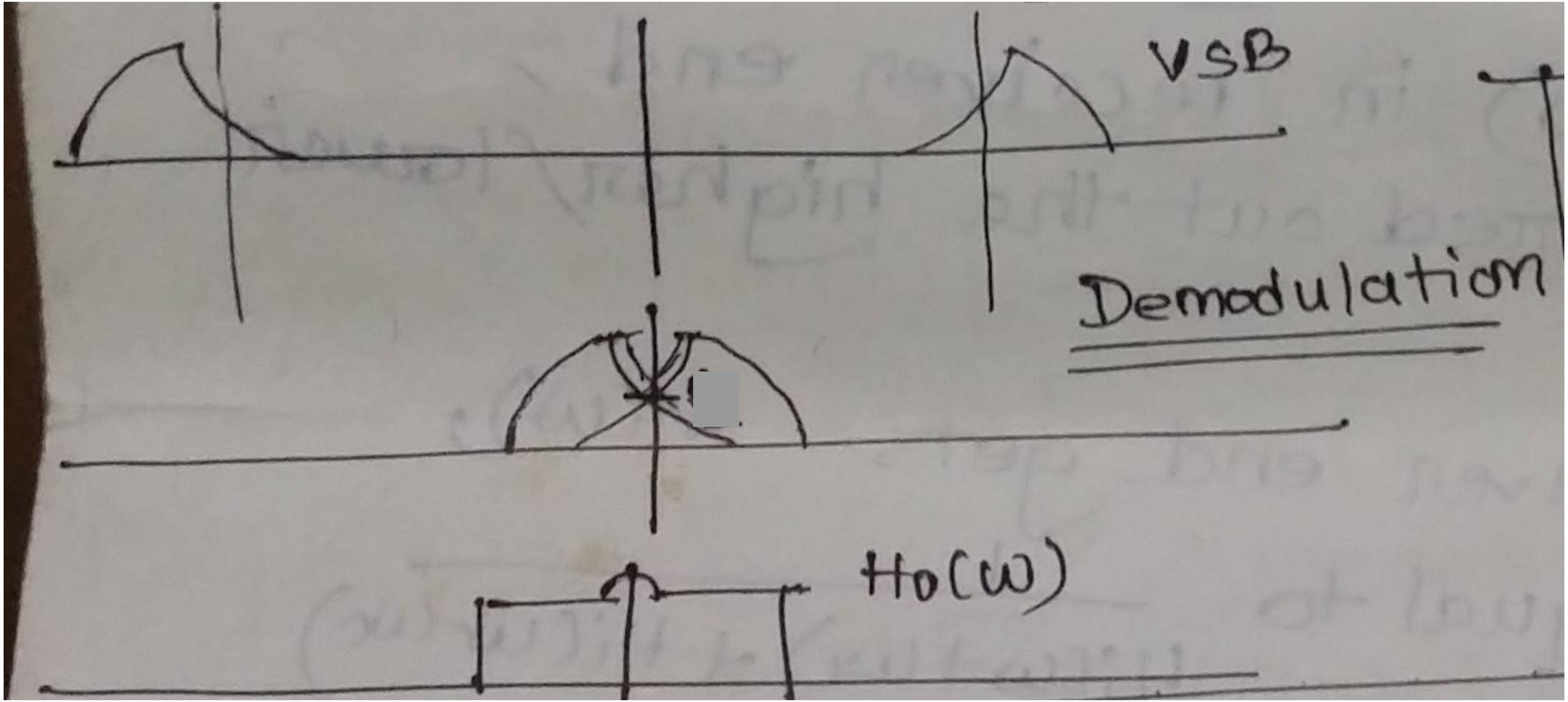
$$m(t) \Longleftrightarrow M(\omega)$$

VSB: Modulation





VSB: Demodulation



VSB: Demodulation

Demodulation :

$$= \underline{M_{VSB} \times \cos\omega_c t} \times H_o(\omega)$$

$$= \left[M_{VSB}(\omega+\omega_c) + M_{VSB}(\omega-\omega_c) \right] H_o(\omega)$$

$\longrightarrow$ from (i)

$$= \Big[\left[M(\omega+2\omega_c) + M(\omega) \right] H_i(\omega+\omega_c) + \left[M(\omega-2\omega_c) + M(\omega) \right] H_i(\omega-\omega_c) \Big] H_o(\omega)$$

$$= \left[M(\omega) H_i(\omega+\omega_c) + M(\omega) H_i(\omega-\omega_c) \right] H_o(\omega) + \underbrace{M(\omega+2\omega_c) H_i(\omega+\omega_c) H_o(\omega) + M(\omega-2\omega_c) H_i(\omega-\omega_c) H_o(\omega)}_{\text{filter out using Bandpass filter}}$$

$$= M(\omega) \left[H_i(\omega+\omega_c) + H_i(\omega-\omega_c) \right] H_o(\omega)$$

VSB: Demodulation

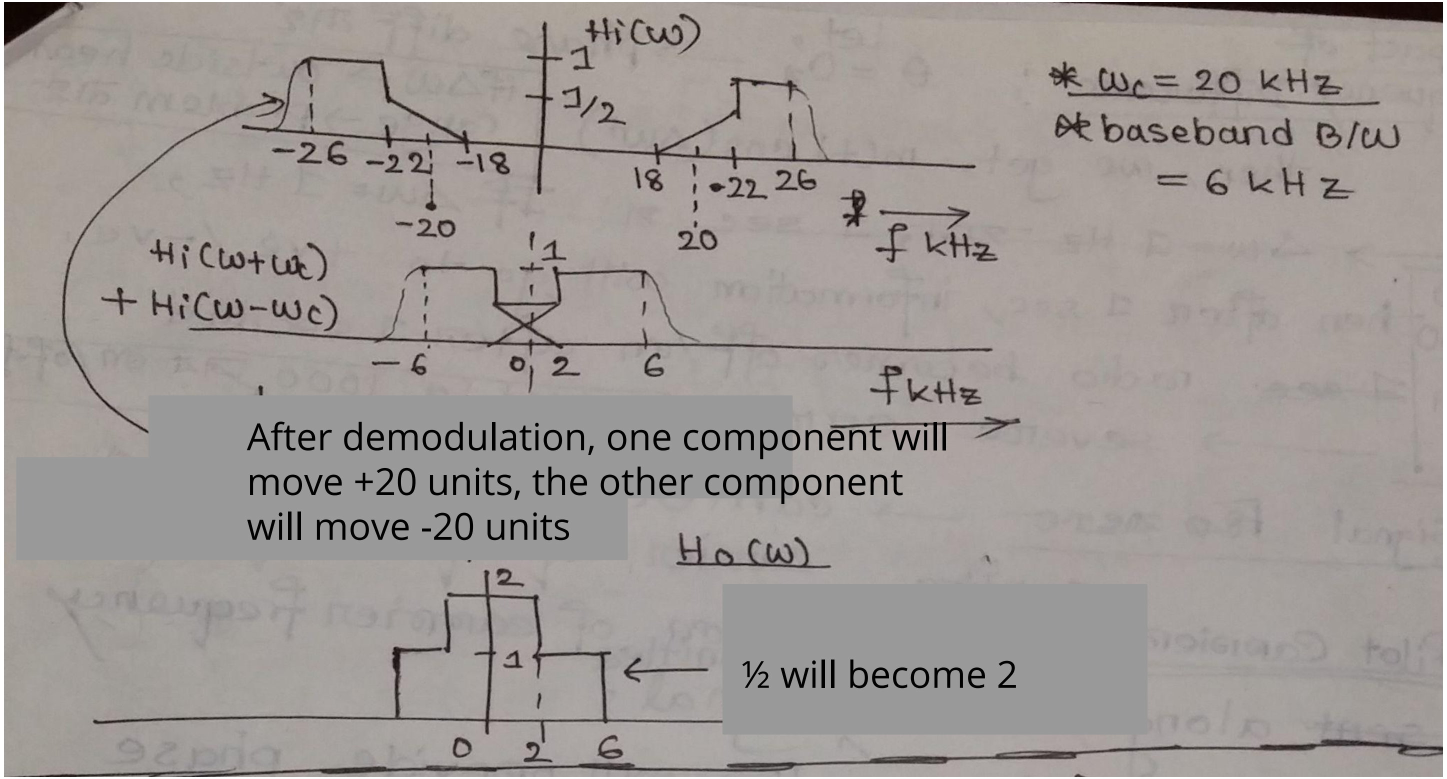
$$= M(\omega)\left[H_i(\omega+\omega_c) + H_i(\omega-\omega_c)\right] H_o(\omega)$$

Now, we only want $M(\omega)$ in receiver end, and have already filtered out the higher/lower frequency portions.

To ensure that the receiver end gets $M(\omega)$, $H_o(\omega)$ must be equal to $\dfrac{1}{H_i(\omega+\omega_c) + H_i(\omega-\omega_c)}$

$$\therefore H_o(\omega) = \frac{1}{H_i(\omega+\omega_c) + H_i(\omega-\omega_c)}$$

Spectrum Drawing for VSB Filter



After demodulation, one component will move +20 units, the other component will move -20 units

½ will become 2

Carrier Acquisition

Carrier Acquisition

* Demodulation : $\cos\omega_c t$ has to be perfectly accurate,

$$[m(t)\cos\omega_c t] \times 2\cos((\omega_c+\Delta\omega)t+\theta)$$

$$= m(t)[2\cos\omega_c t\cos(\omega_c t+\Delta\omega t+\theta)]$$

$$= m(t)[\cos(\omega_c t+\omega_c t+\Delta\omega t+\theta) + \cos(\Delta\omega t+\theta)]$$

$$= m(t)[\cos(2\omega_c t+\Delta\omega t+\theta) + \cos(\Delta\omega t+\theta)]$$

$$= m(t)[\underbrace{\cos((2\omega_c+\Delta\omega)t+\theta)}_{\text{high freq} \rightarrow \text{filter out}} + \cos(\Delta\omega t+\theta)]$$

So, we get, $m(t)\cos(\Delta\omega t+\theta)$

In ideal scenario. $\Rightarrow$ $\Delta\omega = 0$, $\theta = 0$ $[m(t)\cos 0 = m(t)]$

Carrier Acquisition

* Impact of phase diff (θ)

Let, $\Delta\omega = 0$ [freq same]

Then, we get, $m(t)\cos(0 \times t + \theta)$

$= m(t)\cos\theta$, $\rightarrow$ constant value

So, Scaled by a constant value

Amplitude is always reduced by a certain amount (since cosθ -> -1 to +1) -> leads to information loss (since we don’t know the by how much the reduction occurs)

Carrier Acquisition

*** Impact of Frequency Difference :**

Let, $\theta = 0 \longrightarrow$ There is no phase difference

Then, we get, $m(t)\cos(\Delta\omega t)$

If $\Delta\omega \longrightarrow$ outside of human hearing range
$\longrightarrow$ no problem

If $\Delta\omega = 1$ Hz, then after 1 sec $\longrightarrow$ information signal will go +ve/ −ve

For example, radio becomes on/off after every 1 second !! $\longrightarrow$ This is a severe error

If there are 1000 on/off s per second $\longrightarrow$ no problem will occur

Carrier Acquisition

* **Impact of both phase & freq. difference:**

If $\theta > 0$ & $\Delta\omega > 0$ $\longrightarrow$ signal will be completely damaged

To ensure that there is no information loss $\longrightarrow$ carrier should be exact, carrier acquisition

Pilot Carrier

Pilot Carrier: Carrier frequency information is sent along with the transmitted signal

Phase Lock Loop (PLL)

- Phase Lock Loop (PLL): This will provide phase and frequency synchronization
  - The pilot carrier will be sent by the transmitter
- PLL is basically a feedback circuit, consisting of
  - A multiplier
  - A filter
  - A VCO (voltage controlled oscillator)

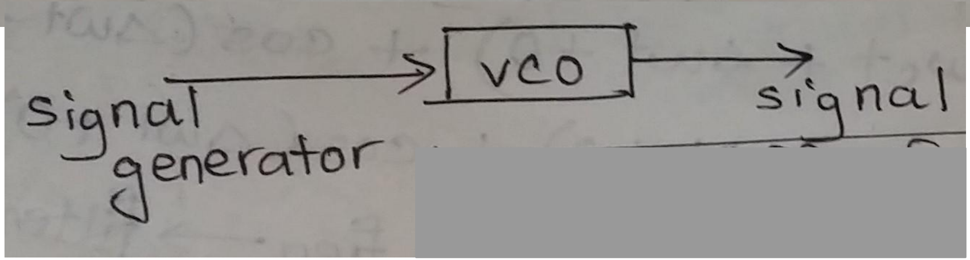
Phase Lock Loop (PLL)

- VCO: Voltage controlled oscillator
  - If voltage difference increases, frequency increases
  - If voltage difference decreases, frequency decreases
  - The rate of frequency change is controlled by the step constant, c

VCO : voltage controlled oscillator, voltage.

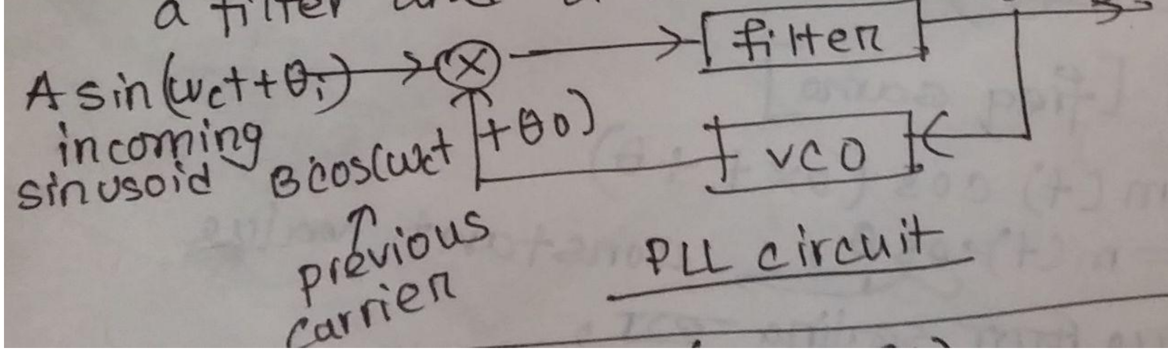
$$\omega(t) = \omega_c + c\, e_o(t)$$

c → step constant.



Phase Lock Loop (PLL)

PLL This is a feedback circuit, consisting of a multiplier, a filter and a VCO.



* the difference betw new signal & old carrier is fed as input the VCO, which in turn, gradually corrects the output over time.

Phase Lock Loop (PLL)

Only phase change

* $A\sin(\omega_c t + \theta_i)$

  $B\cos(\omega_c t + \theta_o)$

If multiplied: $AB\sin(\omega_c t + \theta_i)\cos(\omega_c t + \theta_o)$

$$\Rightarrow \frac{AB}{2}\Big[\underbrace{[\sin(2\omega_c t + \theta_i + \theta_o)]}_{\text{filter out}} + \sin(\theta_i - \theta_o)\Big]$$

Phase Lock Loop (PLL)

$$= \frac{AB}{2}\sin(\underbrace{\theta_i - \theta_o}_{\text{error}})$$

[if no phase diff was present, then $\theta_i - \theta_o = 0$]

$$= \boxed{\frac{AB}{2}\sin\theta_e} \longrightarrow e_o$$

* θ_e (error) ~~goes~~ works as input for VCO and then VCO changes its output to become closer to the input.

Thus, θ_i continuously changes with time.

Phase Lock Loop (PLL)

Frequency changes too

ω_c can be considered with θ_i

change in frequency

$$A \sin(\omega_c t + \theta_i)$$

$$A \sin(\hat{\omega}_c t + \theta_i)$$

$$= A \sin((\omega_c + \Delta\omega)t + \theta_i)$$

$$= A \sin(\omega_c t + \Delta\omega t + \theta_i)$$

$$= A \sin(\omega_c t + \hat{\theta}_i) \quad [\hat{\theta}_i = \Delta\omega t + \theta_i]$$

$\therefore$ Phase lock loop will also work for frequency change.

Reference Book

***Practice the corresponding problems from the exercise section for each problem shown in class.