ENSC327
Communications Systems
7: Single Sideband (SSB) Modulation

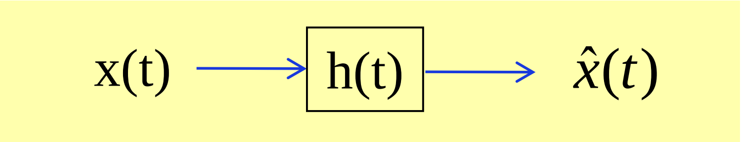
School of Engineering Science
Simon Fraser University

Outline

- Required Background
- Expression of SSB signals
- Waveform of SSB signals
- Modulators for SSB:
  - Frequency discrimination
  - Phase discrimination
- Coherent Detection of SSB

Background

- Hilbert Transform
  - Time: $\hat{x}(t) =$



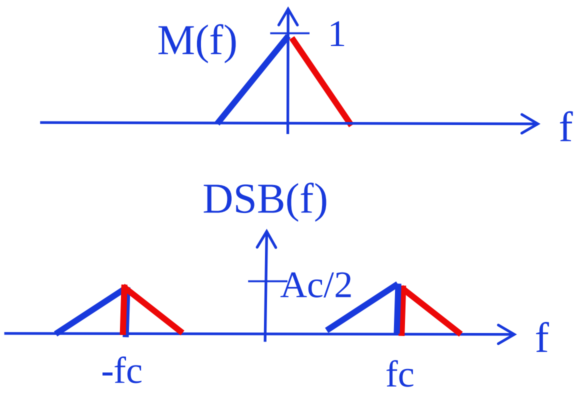
  - Frequency: $\hat{X}(f) =$

- Analytic Signal, positive and negative frequencies:
  - Time:
  - Frequency:

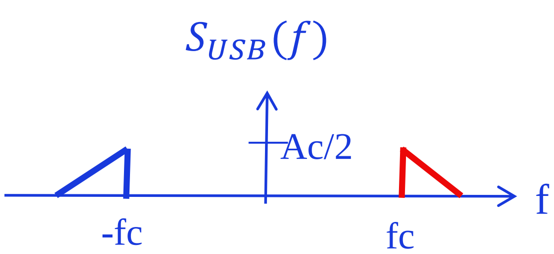
SSB Modulation

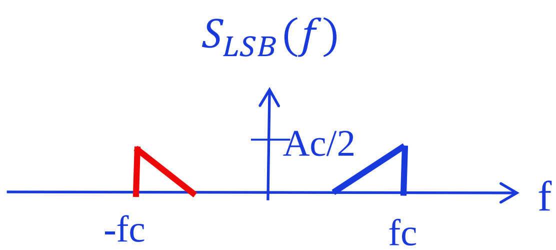
- The DSB signal is: $S_{dsb}(t) = A_c m(t)\cos\left(2\pi f_c t\right)$
- Its FT is:

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



- In SSB modulation, only one of the sideband (USB or LSB) is transmitted.

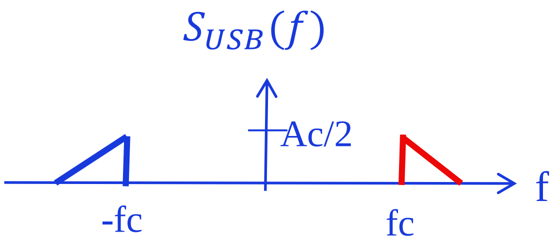




- Advantage of SSB: half the BW of DSB or AM

SSB-USB in Frequency and Time Domain

- Use the “analytic signals” of M(f) to write the expression for $S_{USB}(f)$:

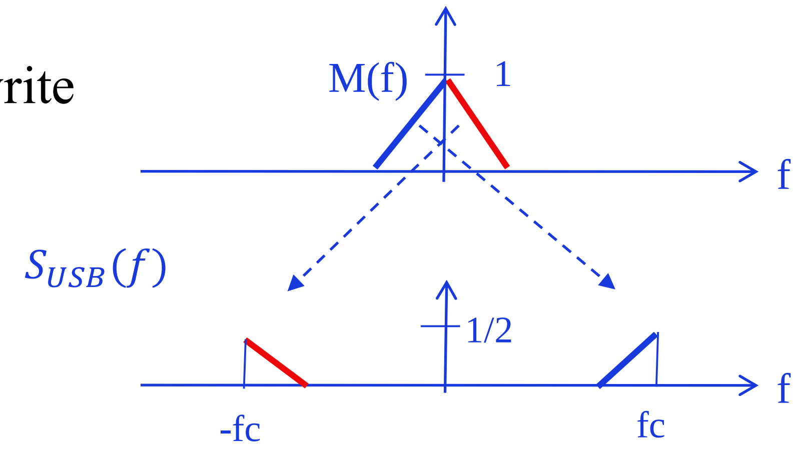


- In time domain:

$s_{USB}(t) =$

SSB-LSB in Frequency and Time Domain

- Use the "analytic signals" of M(f) to write the expression for $S_{LSB}(f)$:



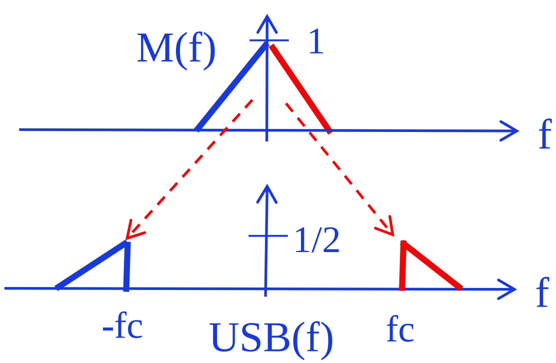
- In time domain:

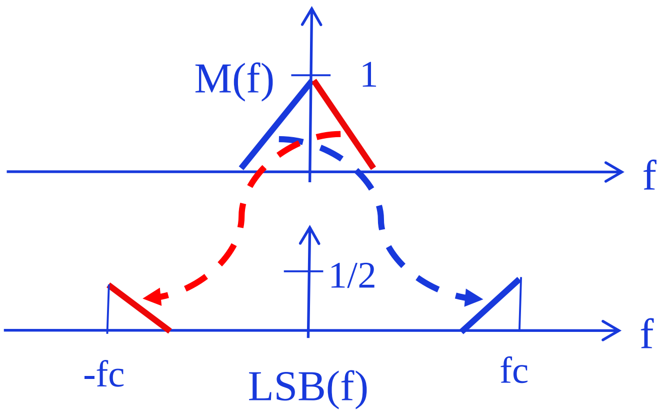
$s_{LSB}(t) =$

Summary of SSB-USB and LSB

$$s_{ssb}(t) = \frac{A_c}{2}\left(m(t)\cos\left(2\pi f_c t\right) \mp \hat{m}(t)\sin\left(2\pi f_c t\right)\right)$$

- The minus sign gives USB.
- The plus sign gives LSB.





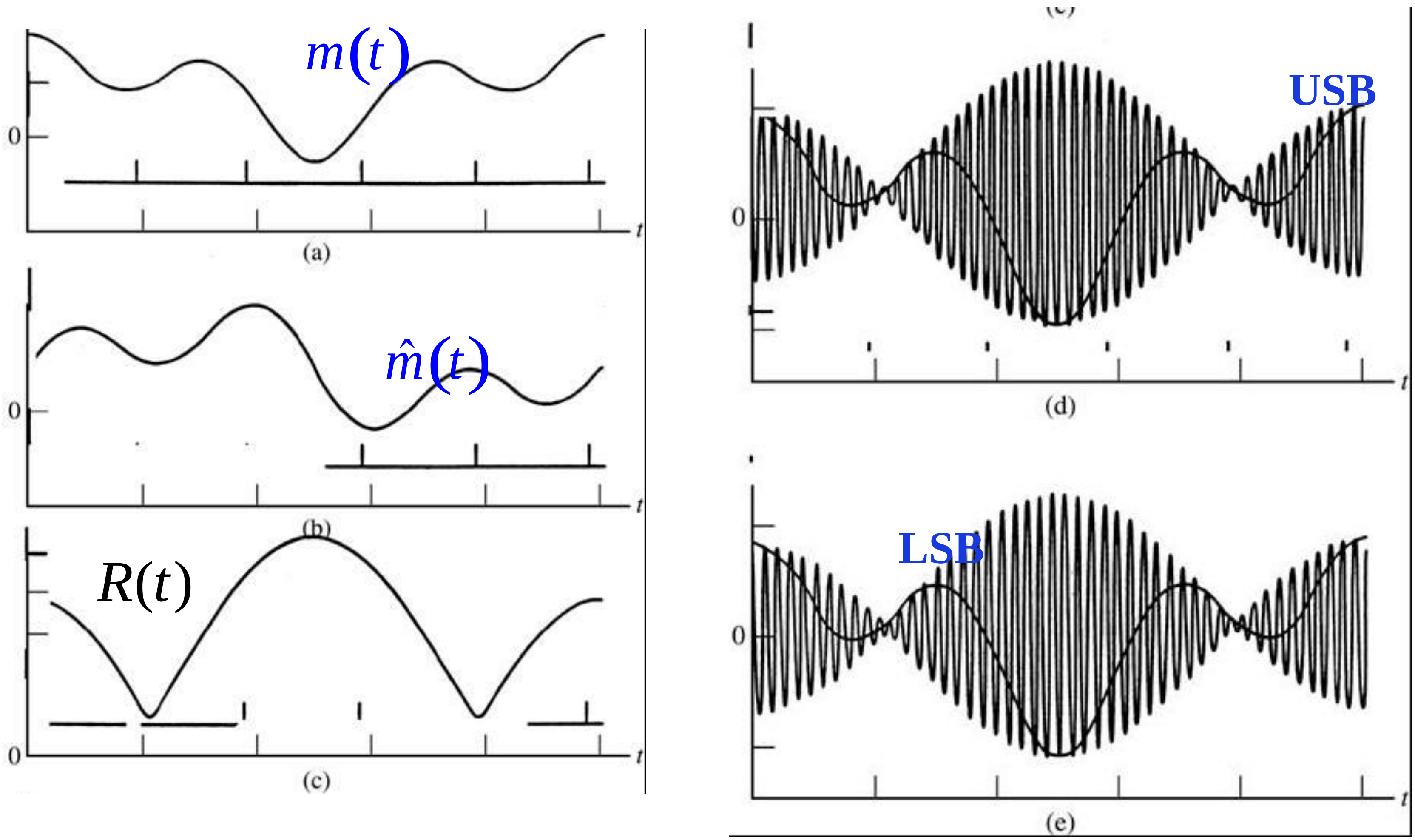
Envelope of the SSB Signal

- Recall: In DSB and AM the message signal only affects (modulates) the amplitude of the carrier.
- However, SSB changes both amplitude and phase of the carrier!

$$s_{ssb}(t) = \frac{A_c}{2}\left(m(t)\cos\left(2\pi f_c t\right) \mp \hat{m}(t)\sin\left(2\pi f_c t\right)\right) = R(t)\cos\left(2\pi f_c t \pm \theta(t)\right),$$

- In the above equation:
  - $R(t) =$ $\theta\,(t) =$
- R(t) is the envelope of SSB signal but it is **not** a linear function of m(t)! Thus, SSB signal **cannot** be demodulated with an envelope detector.
- It can be seen that SSB-USB and LSB have the same envelope

An example of SSB in the Time Domain



Example

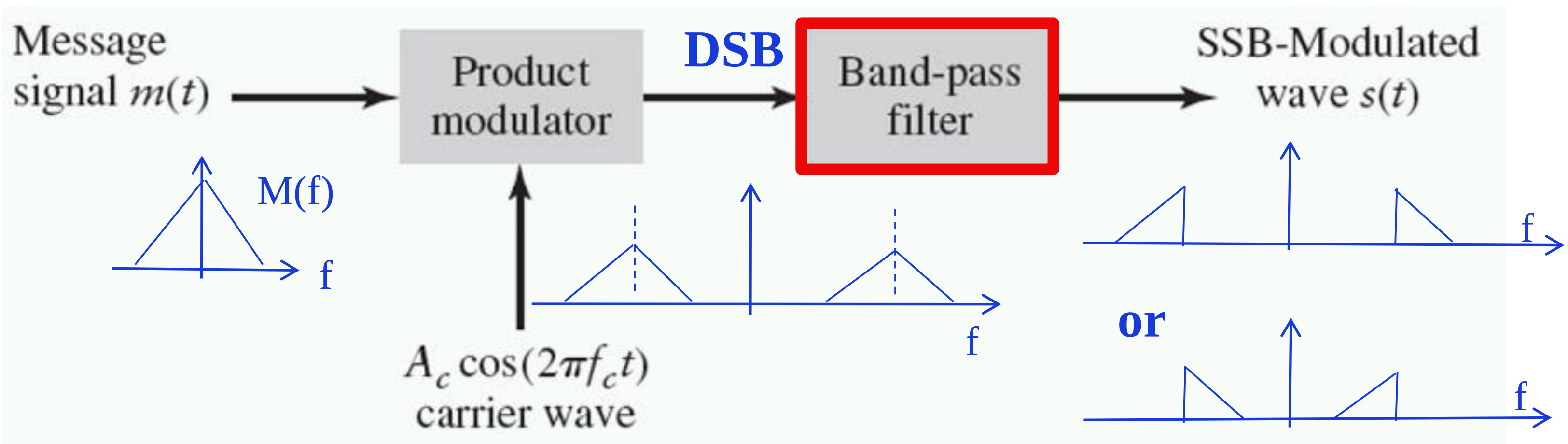
Find the SSB-USB waveform for

$$m(t) = \cos(2\pi f_0 t) - 0.4\cos(4\pi f_0 t) + 0.9\cos(6\pi f_0 t)$$

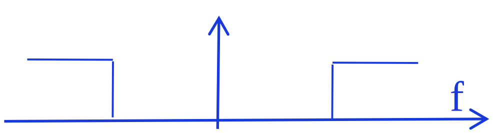
Solution:

Modulation Method 1: Generation of SSB using Frequency Discrimination

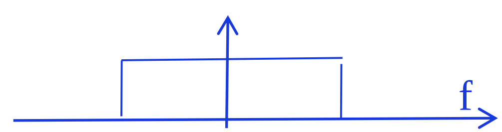
- Generate DSB first, then filter out the unnecessary sideband:



- Filter for USB:



Filter for LSB:



- Problems:
  - Only suitable for signals without low-freq contents (e.g., speech)
  - For other signals, need nearly ideal filters around fc
    ➔ Difficult, especially if fc needs to be tunable.

Modulation Method 2: Generation of SSB using Phase Discrimination

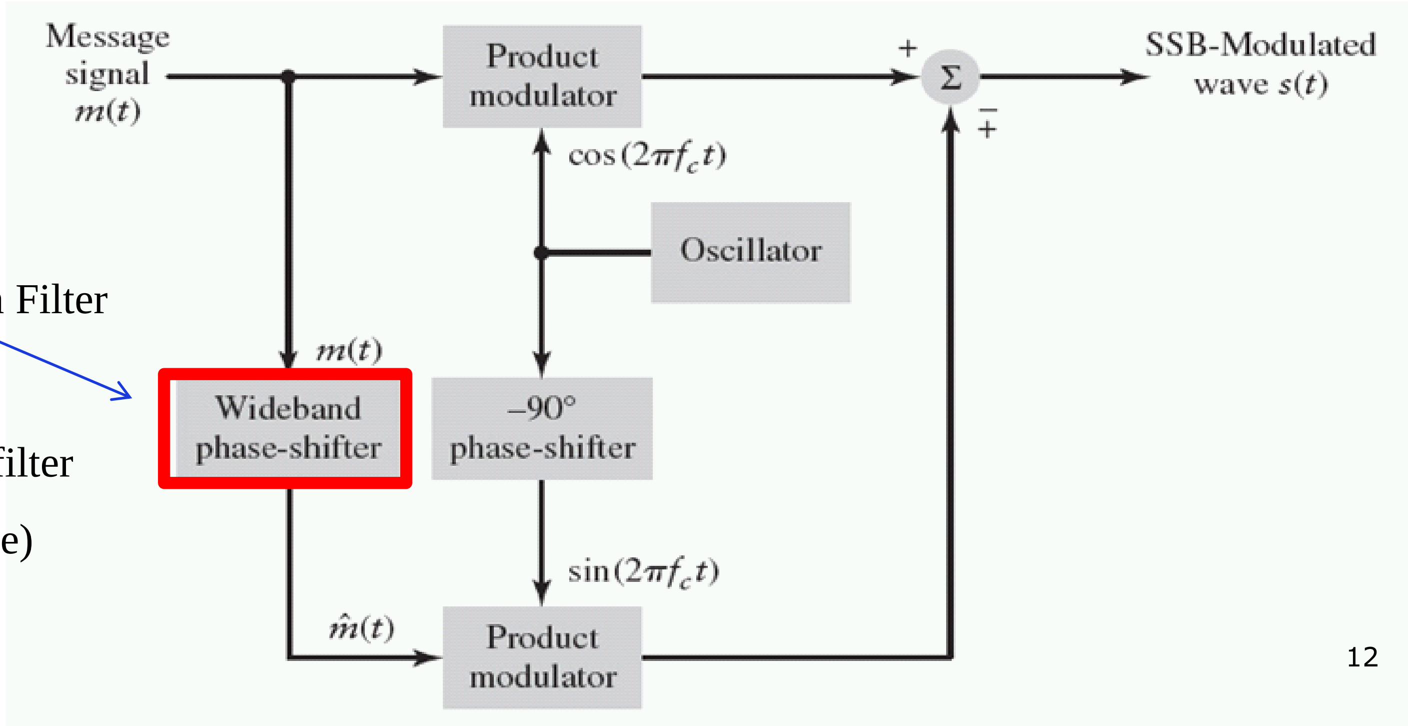
- Follow the Time domain expression to implement the modulation:

$$s_{ssb}(t) = \frac{A_c}{2}\left(m(t)\cos\left(2\pi f_c t\right) \mp \hat{m}(t)\sin\left(2\pi f_c t\right)\right)$$

Hilbert Transform Filter

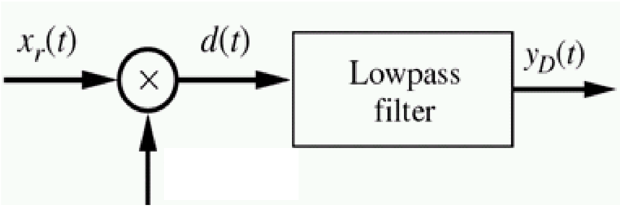
Easier than ideal filter

around fc (variable)



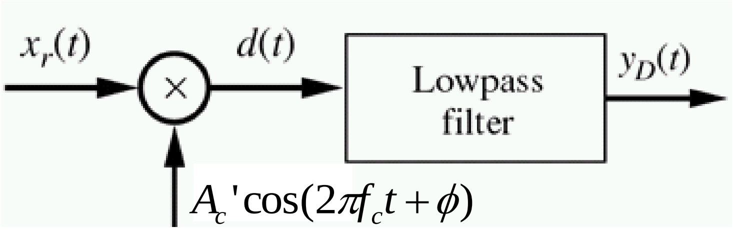
Coherent Detection of SSB

- SSB signal can be demodulated using coherent detection.
  - multiply with carrier, then LPF



$A_c'\cos(2\pi f_c t + \phi)$

Effect of Phase Error in Demodulation of SSB



Summary and Applications SSB

- Advantage: More bandwidth-efficient than DSB,
- Disadvantage: Cannot be used in signals with DC (Need near-ideal filters to avoid distortion), generation of SSB is more complicated than AM or DSB.
- Applications of SSB: Two way radio, HAM (Amateur) Radio
- Variation of SSB: Vestigial sideband modulation (VSB)
  - Send one sideband plus a small part of the other sideband
  - Achieved by a filter after the DSB signal
  - The filter can be designed so that the message can still be recovered by the coherent DSB demodulator.
  - Application: Used in analog TV modulation for video broadcast.