ENSC327
Communications Systems
12: FM Demodulation: Frequency Discriminator

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Three FM Demodulation Methods

- Frequency discriminator (slope detector)
  - Balanced freq. discriminator
- Phase-locked loop (PLL) demodulator
- Quadrature detector (not covered in this course, but is used in our lab equipment, see Lab 4)

Overview of FM Demodulation

FM signals:

$$s(t) = A_c \cos(2\pi f_c t + 2\pi k_f \int_0^t m(\tau)d\tau)$$

- To recover the message m(t):
  - Need a circuit whose output is proportional to the difference of the instantaneous frequency from the carrier frequency:

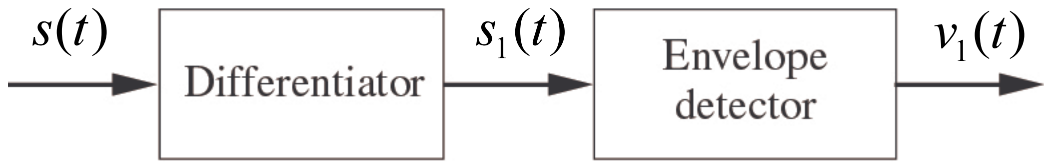
- Two methods:
  - Frequency discriminator (slope detector)
  - Phase locked loop

Ideal Freq. Discriminator

$$s(t) = A_c \cos(2\pi f_c t + 2\pi k_f \int_0^t m(\tau) d\tau)$$

- If we take the derivative of s(t):

Ideal Freq. Discriminator



- Recall: Freq response of the differentiator:

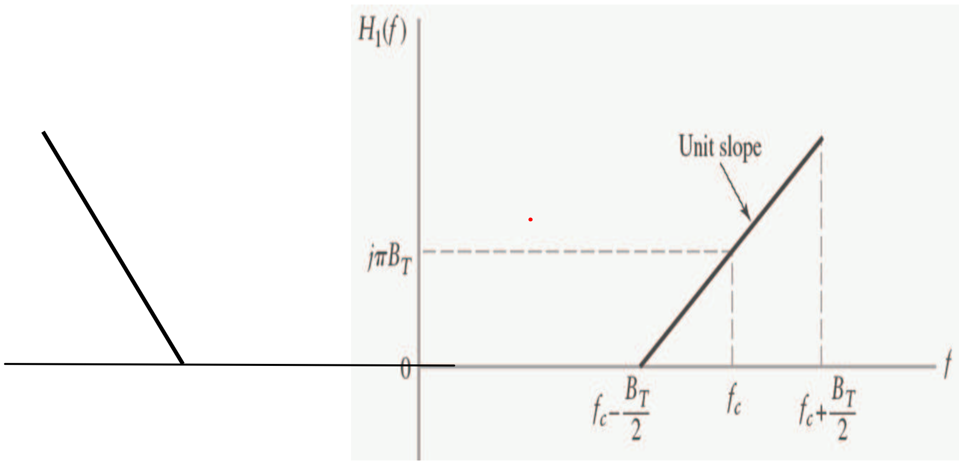
- ➔The differentiation operator corresponds to a filter

  - Problem:
  - Practical implementation:

Practical Freq. Discriminator

- Freq response of the differentiator (for f > 0):

- H1(f) for f < 0 is defined by using conj. symmetry.



- To find the output of this filter for the input s(t):

$$s(t) = A_c \cos(2\pi f_c t + 2\pi k_f \int_0^t m(\tau)d\tau)$$

Practical Freq. Discriminator

- We first find the complex envelope of s(t):

- We next find the complex envelope of the differentiator :

From $H_1(f) = \begin{cases} j2\pi\left(f - \left(f_c - B_T/2\right)\right), & f_c - B_T/2 \le f \le f_c + B_T/2, \\ 0, & \text{otherwise} \end{cases}$

Practical Freq. Discriminator

- complex envelope:

Note: Eq. (4.49) should be doubled, as in Eq. (3.44).

As a result, Eqs. (4.50) to (4.55) should be doubled too.

- The complex envelope of the output is:

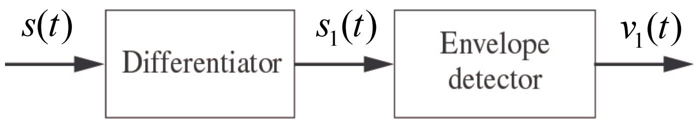
$$\tilde{s}(t) \longrightarrow \boxed{\tilde{h}_1(t)} \longrightarrow 2\tilde{s}_1(t)$$

Practical Freq. Discriminator

- Taking inverse FT:

Practical Freq. Discriminator

$$\tilde{s}_1(t) = j\pi A_c B_T \left[1 + \frac{2k_f}{B_T} m(t)\right] e^{j2\pi k_f \int_0^t m(\tau)d\tau}$$



- From $\tilde{s}_1(t)$ we can find $s_1(t)$:

Practical Freq. Discriminator

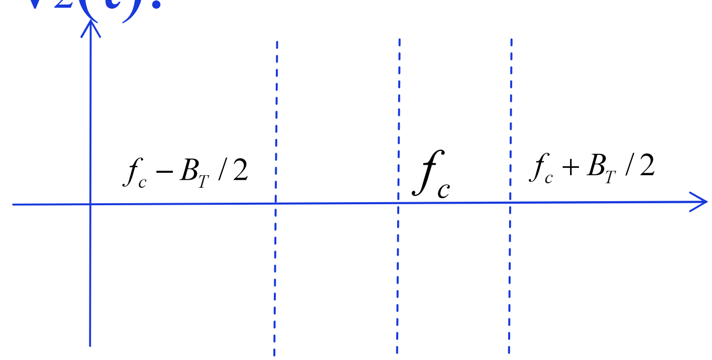
- How to remove the bias in $v_1(t) = \pi A_c B_T \left[1 + \frac{2k_f}{B_T} m(t) \right]$?

- If we can get another signal: $$v_2(t) = \pi A_c B_T \left[1 - \frac{2k_f}{B_T} m(t) \right]$$

  Then the bias can be cancelled by:

- This requires another filter for v2(t):

$$H_2(f) = j2\pi\left(f - \left(f_c + B_T/2\right)\right),$$
$$\text{for } f_c - B_T/2 \le f \le f_c + B_T/2,$$



Practical Freq. Discriminator

- To verify:

$$H_2(f) = j2\pi\left(f - \left(f_c + B_T/2\right)\right), \text{ for } f_c - B_T/2 \le f \le f_c + B_T/2,$$

- Taking inverse FT:

Practical Freq. Discriminator

$$\tilde{s}_2(t) = j\pi A_c B_T \left[-1 + \frac{2k_f}{B_T} m(t) \right] e^{j2\pi k_f \int_0^t m(\tau)d\tau} \quad \Rightarrow$$

Practical Freq. Discriminator

- The previous derivation means that we need the following circuit, which is called balanced frequency discriminator:

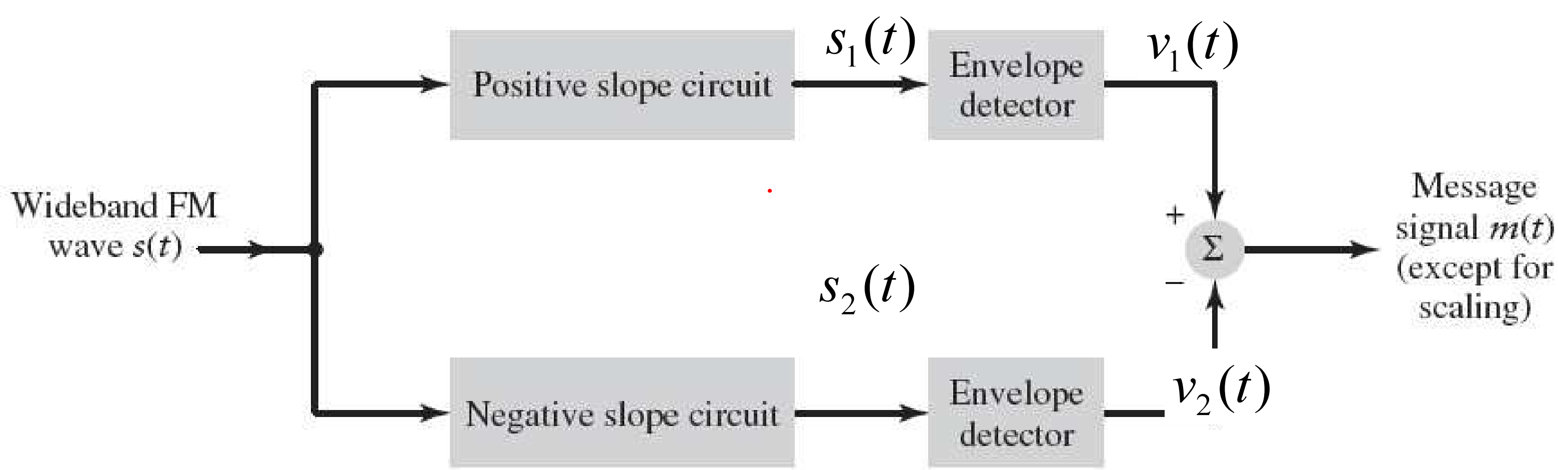


FIGURE 4.13 Block diagram of balanced frequency discriminator.