ENSC327 Communications Systems 12: FM Demodulation: Frequency Discriminator

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Outline

- Required Background
- Overview of FM Demodulation methods
- Ideal Frequency Discriminator
- Practical Frequency Discriminator

Required Background

- FM Signal: $s(t) = A_c \cos(2\pi f_c t + 2\pi k_f \int_0^t m(\tau) d\tau)$
  - To recover the message m(t) we need a circuit whose output is proportional to the difference of the instantaneous frequency from the carrier frequency:
- Differentiation property of FT:
- Application of "Complex envelope" concept in LTI systems:

Overview of FM Demodulation Methods

- Frequency discriminator (slope detector)
  - Balanced freq. discriminator
- Phase-locked loop (PLL) demodulator
- Quadrature detector (Not covered in this course)
  http://en.wikipedia.org/wiki/Detector_%28radio%29#Quadrature_detector

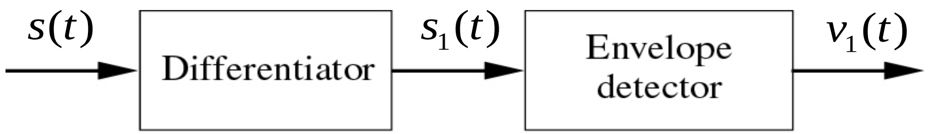
Ideal Freq. Discriminator

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

- Take the derivative of s(t):

- Where does $m(t)$ show up?

Ideal Freq. Discriminator (cont.)



- What is the frequency response of the "Differentiator"?

- Practical problem with this system?

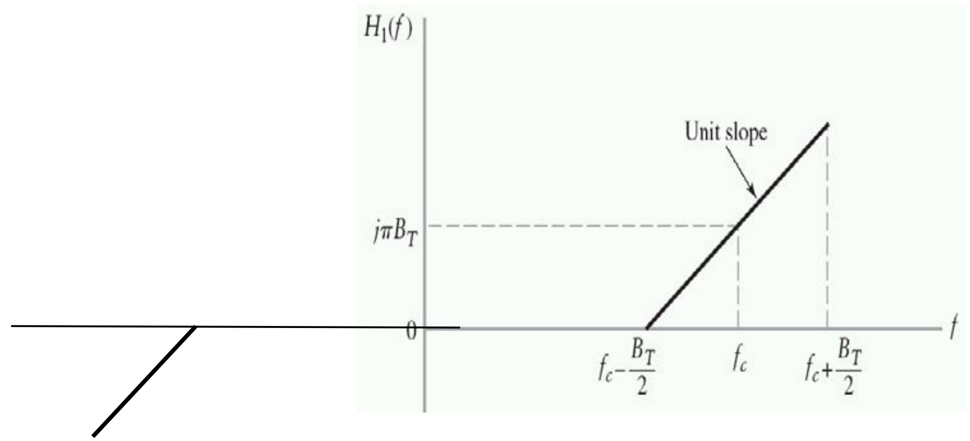
- Practical solution?

Practical Freq. Discriminator

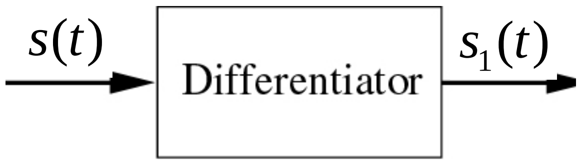
- For Positive f

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

($H_1(f)$ for f < 0 is defined using the conjugate symmetry property.)



- In order to find the output of this filter for the input s(t), we convert the system to baseband using the concept of complex envelope



Practical Freq. Discriminator (cont.)

- Complex envelope of s(t):

- Complex envelope of the differentiator :

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

Note: Eqs. 4.49 to 4.55 of text are missing a factor of 2!

Practical Freq. Discriminator (cont.)

- The complex envelope of the output is
  - Frequency Domain:

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

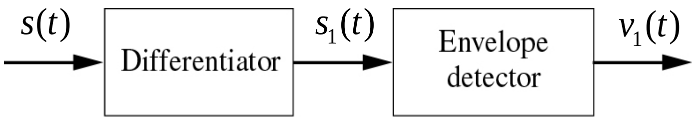
  - Time Domain:

Practical Freq. Discriminator (cont.)

- From previous page, we get:

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

- Finally we can find $s_1(t)$:



- Envelope detection can be used if:

- Output of the envelope detector:

Practical Freq. Discriminator

- A DC offset remover is required to remove the DC component of $v_1(t) = \pi A_c B_T \left[1 + \frac{2k_f}{B_T} m(t) \right]$
- In commercial FM radio receivers, however, another filter, this time with a negative slope, is used to generate a second signal:
$$v_2(t) = \pi A_c B_T \left[1 - \frac{2k_f}{B_T} m(t) \right]$$
- The two signals are subtracted to result in the final output $4\,\pi\, A_c k_f$m(t).

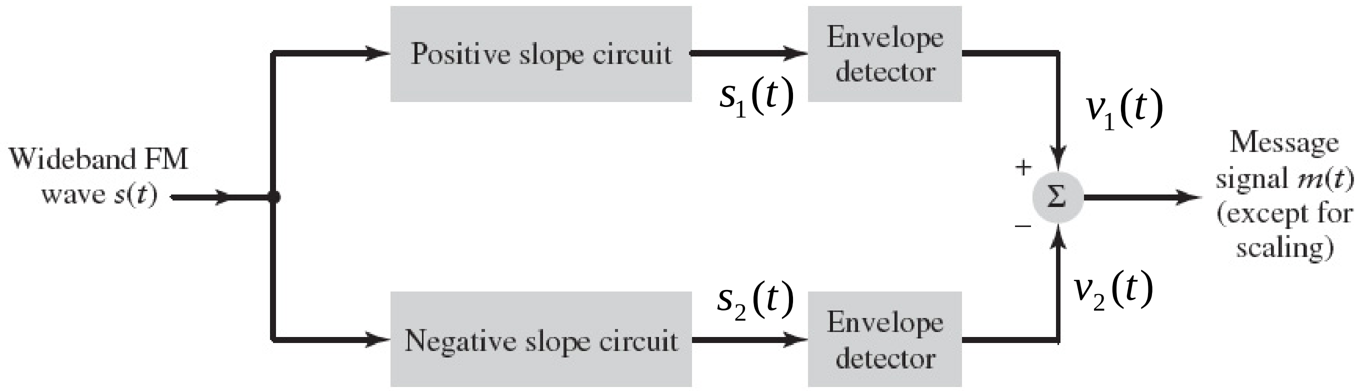


FIGURE 4.13 Block diagram of balanced frequency discriminator.

- This is a "balanced frequency discriminator" and is very similar to the FM demodulator commonly used in FM radio receivers referred to as Foster-Seeley Discriminator.