ENSC327
Communications Systems
24: Ch. 9: Noise in Analog Systems
(Part 1)

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Outline

- Chap 9 studies noise performance of various analog modulations
- Definition: Signal to Noise Ratio (SNR) = $\frac{Power\ of\ the\ desired\ signal}{Power\ of\ noise}$
- Various SNRs in a system:
  - Pre-detection SNR
  - Post-detection SNR
  - Reference SNR (also known as Channel SNR)
  - Figure of Merit
- SNR in DSB
- SNR in AM
- SNR in SSB
- SNR in FM
- Main Conclusions:
  - DSB and SSB have the same noise performance as the baseband comm system.
  - AM has worse noise performance, but has simpler receiver (envelope detector)
  - FM has much better noise performance, at the price of the increased bandwidth.

System Model

- Channel model: Additive White Gaussian Noise (AWGN) with psd N0/2.
- Receiver model: ideal band-pass filters and ideal demodulator.

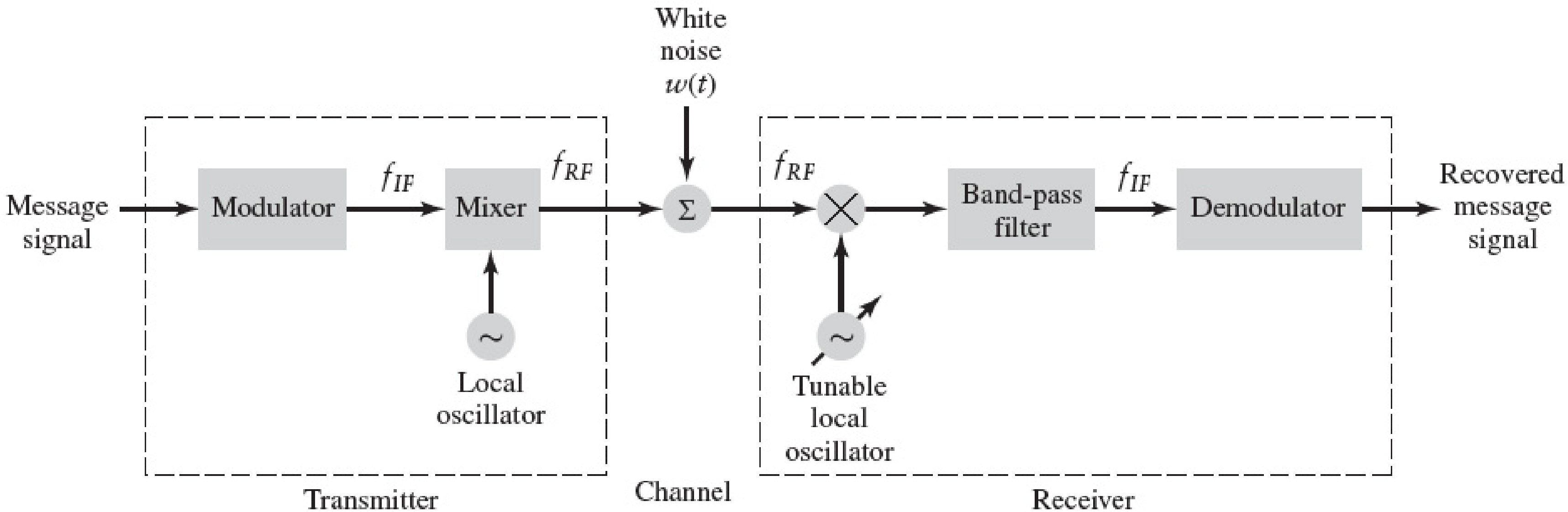
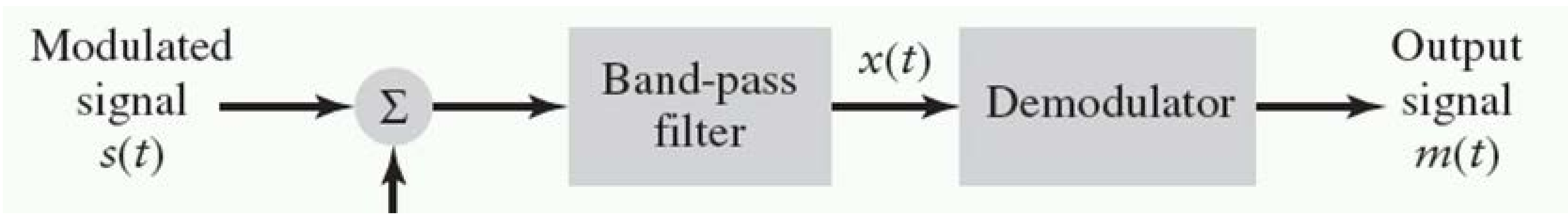


FIGURE 9.5 Block diagram of band-pass transmission showing a superheterodyne receiver.

Simplified Receiver Model



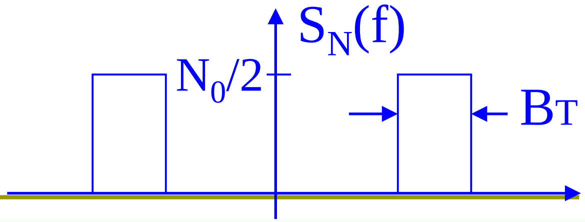
w(t): AWGN

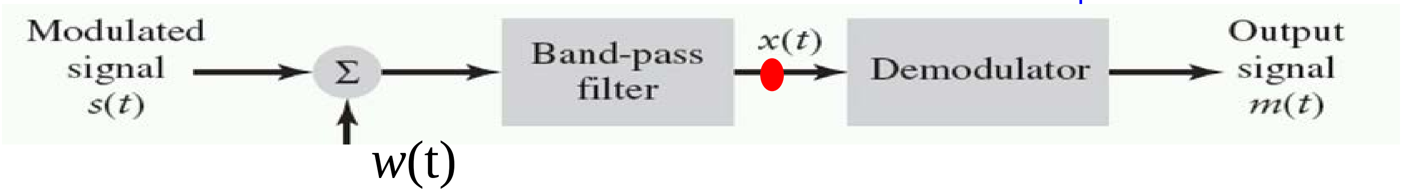
Bandwidth: B_T

- The BPF is usually a part of a mixer , e.g., in superhet receiver (Prev Slide).
- The output freq of the BPF is the intermediate frequency (IF) (455kHz in AM, 10.7MHz in FM). It's also denoted as fc in Chap 9.
- The bandwidth (BT) of the BPF is equal to the bandwidth of the modulated signal
- BT= in AM and DSB, in SSB, in FM, where W is message bandwidth
- The noise after the BPF (n(t)) is thus narrowband noise (Chap 8):

$$x(t)=s(t)+n(t), \quad n(t) = n_I(t)\cos(2\pi f_c t) - n_Q(t)\sin(2\pi f_c t)$$

Pre-detection SNR



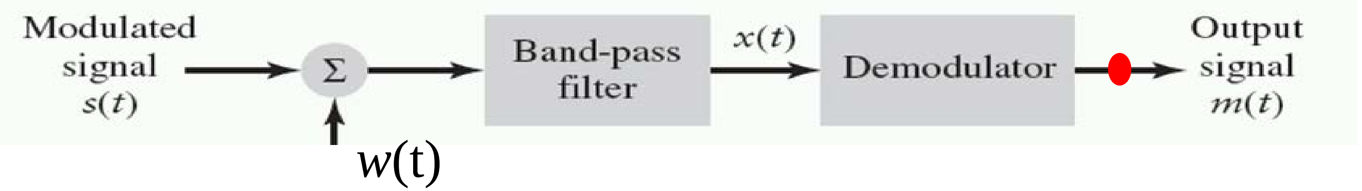


- Pre-detection Signal to Noise Ratio: The SNR at the demodulator input (after the bandpass filter):

$$\mathrm{SNR}_{pre} = \frac{\text{power of modulated signal}}{\text{power of the narrowband noise}}$$

- At the demodulator input:
  - The desired signal power is:
  - The noise (unwanted signal) power is:
  - Thus:

Post-detection SNR



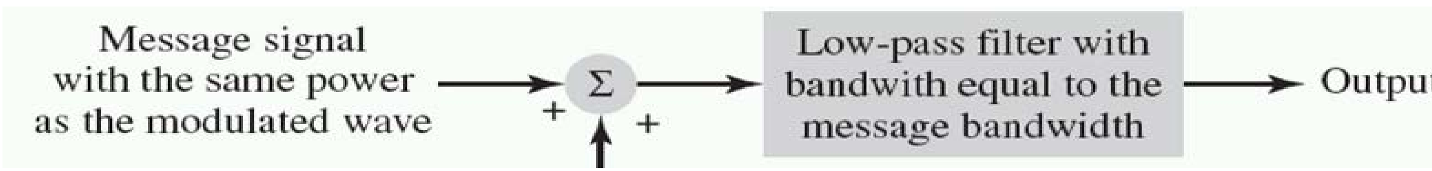
- Post-detection Signal to Noise Ratio: The SNR at the output of the demodulator

$$\mathrm{SNR}_{\mathrm{post}} = \frac{\text{Power of the demodulated}}{\text{Power of noise at demodulator's output}}$$

- At the demodulator output:
  - The desired signal is:
  - The output noise psd depends on the modulation/demodulation scheme.
  - SNR_{post} is what is important to the end user.

Reference SNR

- To compare the performances of different modulation systems, we need a reference model as a bench mark.
- This reference model is a baseband transmission, i.e., a communication system where the signal is transmitted directly without any modulation.
- For fair comparison, the transmitted power should be the same as that in a modulation system.
- The bandwidth of the LPF at the receiver equals to the message bandwidth



AWGN Noise

- The Reference SNR is thus defined as:

$$\mathrm{SNR}_{\mathrm{ref}} = \frac{\text{Average power of modulated signal}}{\text{Average noise power in the message bandwidth}} =$$

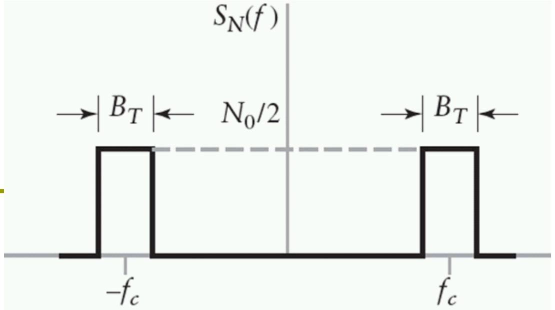
Figure of Merit

- Figure of Merit: The ratio of post-detection SNR to Reference SNR:

$$\text{Figure of Merit} = \frac{\text{Postdetection SNR}}{\text{Reference SNR}}$$

- It shows whether a modulation system has better or worse noise performance than the baseband reference model.

SNR in DSB-SC (9.4)

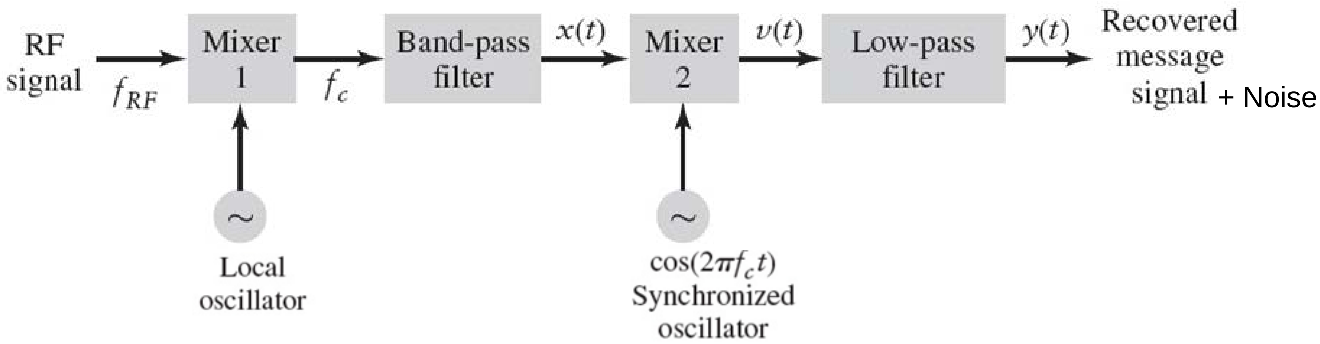


- The modulated DSB-SC signal at the transmitter:

$$s(t) = A_c m(t)\cos(2\pi f_c t)$$

- Linear DSB-SC receiver using coherent demodulation:

Superheterodine Receiver:



- Notes:
  - The BPF's bandwidth B_T is 2W, the BW of the modulated DSB signal.
  - The LPF's bandwidth is W, the message bandwidth.

Pre-detection SNR of DSB-SC

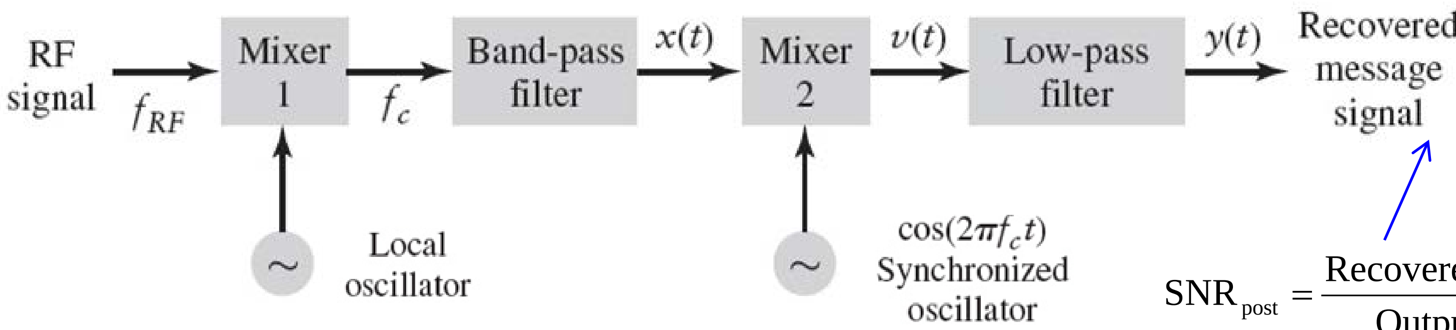
- The pre-detection SNR is defined as: $\mathrm{SNR}_{\mathrm{pre}} = \dfrac{\text{power of modulated signal}}{\text{power of the narrowband noise}}$

- Power of the modulated signal:

- Power of Pre-detection noise (After BPF):

- ➔ Pre-Detection SNR:

Post Detection SNR in DSB-SC



$$\mathrm{SNR}_{\text{post}} = \frac{\text{Recovered message power}}{\text{Output noise power}}.$$

- The signal after the bandpass filter:

Post Detection SNR in DSB-SC (Cont.)

- After multiplying by the carrier:
- After low-pass filter with BW= W , the output is:
- The recovered message power is:
- The noise power is:
- => Post detection SNR =

SNR of DSB-SC -Summarized

- Pre-detection SNR:
- Post-detection SNR:
- The post SNR is twice of the pre SNR.
- This is because the quadrature noise component is removed by the LPF.
- To get Figure of Merit, we need the reference SNR:

$$\mathrm{SNR}_{ref}^{\mathrm{DSB}} = \frac{Ps}{N_0 W} =$$

$$\Rightarrow \quad \text{Figure of Merit} = \frac{\text{Post SNR}}{\text{Ref SNR}} =$$

➔ DSB modulation has the same efficiency as the baseband modulation system.