APPLIED SIGNAL PROCESSING

Part II: NOISE/
SIGNAL AVERAGING

Jan Westerholm, Spring 2011
In this chapter we assume that our desired signal is periodic with known period $T$.

In the measured values there will be
- samples of the signal, period $T$
- samples of noise with period $T' \neq T$
- samples of noise with period $T$

How can we utilize the fact that the signal is periodic?
SIGNAL AVERAGING

- Basic idea: Take measurements during several periods $T$ and add the measurements from the different periods.
  - The signal will be added coherently.
  - The noise will be added incoherently!

- Procedure:
  1. Take a set of samples during time $T$
  2. Repeatedly take another set of samples directly after this and add the corresponding measurements to each other
SIGNAL AVERAGING

- Example: suppose \( m(t) = s(t) + n(t) \) with typically \( s(t) = 10 \) and \( n(t) = 1000 \)
- The signal is buried in the noise!
  - For Gaussian noise \( n(t) \) will be \( 1000 \pm 33 \)
  - With one measurement \( s(t)/n(t) = 0.30 \)
- With 1000 measurements the signal will be \( 10000 \) and the noise \( 1000000 \pm 1000 \)
  - Now \( s(t)/n(t) = 10 \)
  - The signal emerges from the noise!
Case: Mössbauer spectroscopy

- $^{57}$Fe absorbs gamma rays with very high selectivity
- A gamma ray source is moved back and forth in front of a foil with $^{57}$Fe
- The gamma rays are Doppler shifted by the relative velocity
- Only a very small fraction of the gamma rays are absorbed by the $^{57}$Fe
Case: Mössbauer spectroscopy
SIGNAL AVERAGING

- What happened?
  - The signal \( s \) grows linearly with the number of samples \( N \)
  - The noise fluctuations grow like the square root of the number of samples, \( \sqrt{N} \)
  - The signal to noise ratio \( s/n \) grows as \( \sqrt{N} \)

- Another view of what happened:
  - Signal and noise of period \( T \) are added coherently
  - noise of period \( T' \neq T \) is added incoherently
SIGNAL AVERAGING

- Interesting case: the signal is periodic but we don’t know the period!
- Idea: Try different periods and see when you obtain a signal!
- Sample case: Pulsars
  - Slightly complicated by earth spinning around its axis
  - The earth moves around the sun
Pulsars

Figure 14.34
Crab nebula pulsar brightness versus time (light curve)
Crab nebula pulsar (NP0531)
Light curve
32 μs per point
SIGNAL AVERAGING

- Sometimes the signal can be made periodic.
- This is done in Mössbauer spectroscopy.
- Another case: radio amateurs send periodic signals (3 periods) towards the moon and other radio amateurs try to receive this signal knowing how long the period is and when the transmission is on.