PHYS 3360 / AEP 3630

Lecture 42

Detecting signal buried in noise

For poor S/N signal, recovery is often possible

- averaging if signal is repetitive

Q: what if not repetitive? A: can often make repetitive

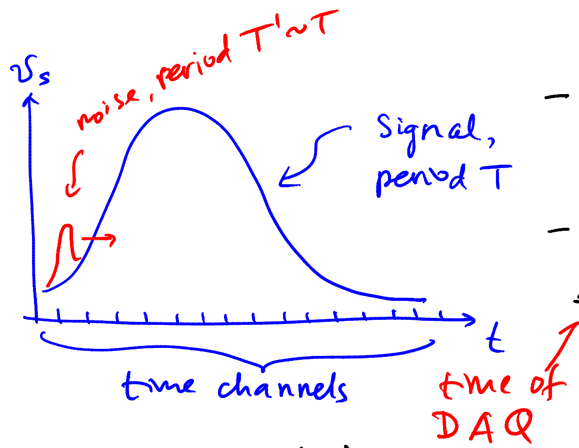
For N_s samples : $S \propto N_s$, $N \propto \sqrt{N_s}$

$$\Rightarrow SNR \propto \sqrt{N_s}$$

$\Rightarrow$ SNR can be made very large Q: limited by what?

signal averaging - example of bandwidth narrowing

Ex.



- noisy "bump" travels across various time channels

- after some time $\Delta t \Rightarrow$ avg. in all channels

$$\Delta t = \frac{1}{\Delta f} = \frac{1}{\left|\frac{1}{T} - \frac{1}{T'}\right|}$$

$f = \frac{1}{T}$; $f' = \frac{1}{T'}$

Δf - bandwidth of meas.

$$SNR_{dB} = 10 \log_{10}\left(\frac{P_s}{P_n}\right) = 10 \log_{10}\left(\frac{P_s}{\left(\frac{\partial P_n}{\partial f}\right) \cdot \Delta f}\right) = 10 \log_{10}\left(\frac{P_s \,\Delta t}{\left(\frac{\partial P_n}{\partial f}\right)}\right)$$

$[W/Hz]$

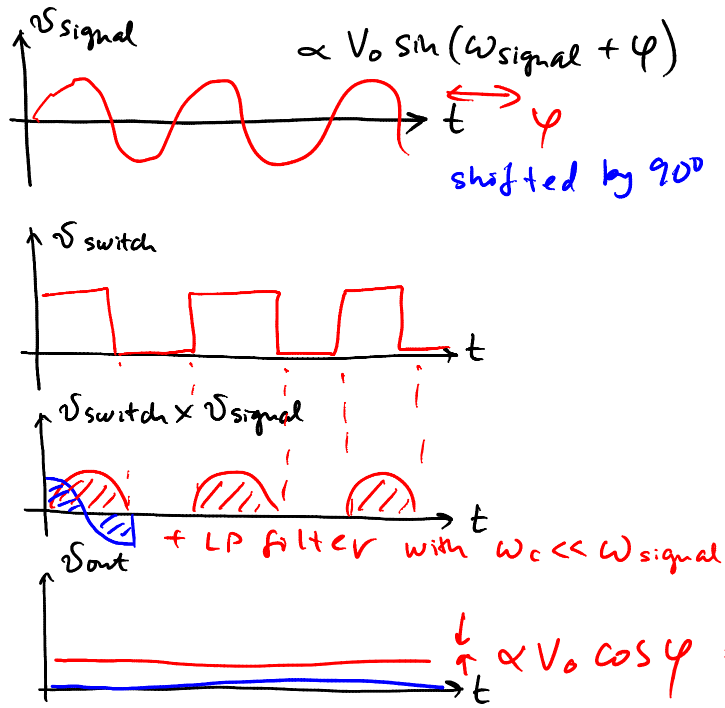
SNR increases 3dB for each doubling of DAQ time

Lock-in amplification

- most signals can be made repetitive (e.g. use chopper wheel, trigger, etc.)
- if signal can be add'l. made periodic, can use lock-in amp

ω_{switch}

Phase sensitive detector:



= output signal proportional to phase of the incoming signal

Lock-in amp

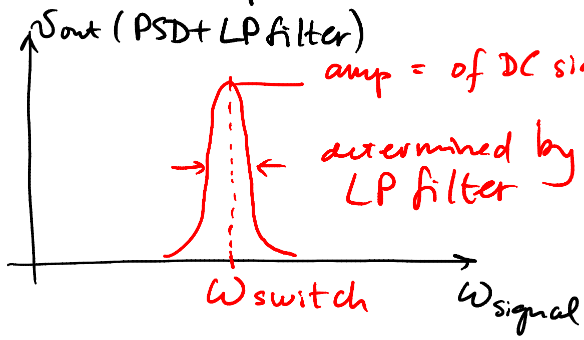
1) system response signal of interest V_0 is modulated at ω_{switch}

2) PSD: gives DC component $\propto V_0 \cos\varphi$ ← only if $\omega_{switch} = \omega_{signal}$

if $\Delta\omega = \omega_{signal} - \omega_{switch} \neq 0$,

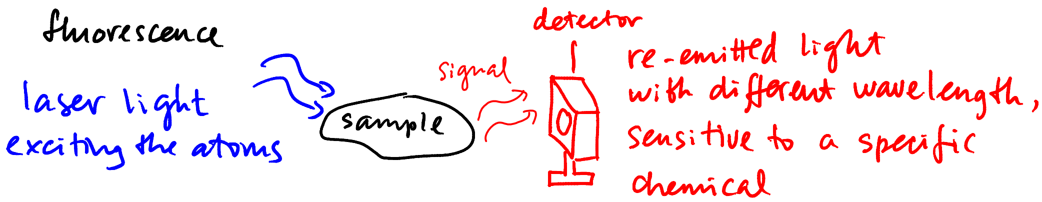
PSD output $\propto V_0 \cos(\Delta\omega t)$

3) LP filter after PSD defines $|\Delta\omega| \lesssim \frac{1}{RC}$ for which output is non-zero (and $\propto V_0$)



Application Example

you are measuring a very weak signal, e.g. fluorescence



Photodetector output is very noisy

e.g. SNR = -60 dB