Signal, Noise, Sensitivity and Averaging

• Signal to Noise Ratio (S/N):

S/N = <average signal amplitude>/<average noise amplitude>

• Averaging a set of p experiments:

$S_{total}/N_{total} = (S \times p)/(N \times p^{1/2}) = p^{1/2} \times S/N$

• Methods of Signal Averaging:

Collating Multiple Scans, Boxcar Averaging, Lock-in Amplifiers

• Sources of Noise:

1. Environmental Noise (e.g., 60 Hz noise)

2. Flicker Noise - 1/f frequency dependence

3. Johnson/Thermal Noise:

$V_j = (4kT\ R\ \Delta f)^{1/2}$ Δf = frequency bandwidth

$i_j = (4kT\ \Delta f/R\ )^{1/2}$

4. Shot Noise:

$i_s = (2e\ I\ \Delta f\ )^{1/2}$

• Signal/Noise Parameters for Photon Detectors

Symbol	Name	Units
S	Radiant Sensitivity	amps/watt
id	Dark Current	amps
Q.E.	Quantum Efficiency Q. E. = 100 x S x 1240/λ	%
NEP	Noise Equivalent Power	watts/$(Hz)^{1/2}$
D*	Normalized Detectivity $D^* = A^{1/2}/NEP$	(cm x $(Hz)^{1/2}$)/watts A = detector area