بنام خدا

H2 SpectIntrod 971127 Sat

Signal to Noise ratio

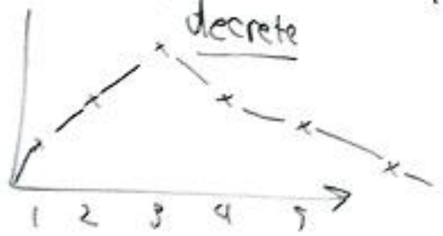
- Random
  - Fundam. : Shot → Inherent : $\frac{S}{N} = \frac{S}{\sqrt{S}} = \sqrt{S}$
  - Exeess : Flicker $= \frac{S}{N} = \frac{S}{S} = \text{Const.}$
- Non random

- White noise
- Pink noise (→ red noise)
- Interferance noise
- ⋮

Poisson Distribution

P(n)

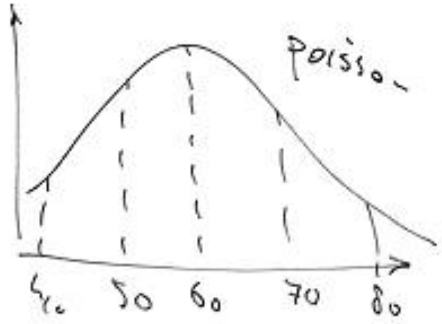
n↓ decrete



n↑ → Gaussian distrib. (Contiuous)

radioactive

$\bar{n} = 60\ \beta/\text{sec}$



Poisson Dist.

$\bar{n} = rt$

$\sigma_n = (rt)^{1/2} = \sqrt{\bar{n}}$ → $\frac{S}{N} = \frac{S}{\sqrt{S}}$ Shot noise

Analytical

↖ Related to Analyte

Amplifier readout noise

دقت اندازه گیری دستگاه تقویت کننده.

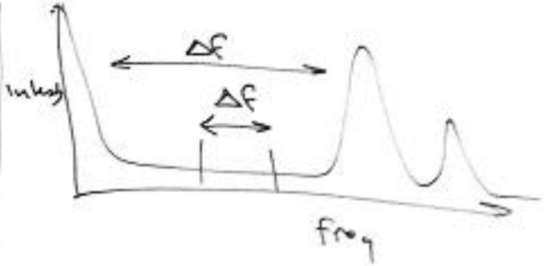
i_{inp} → i_{oup}

5.2 mA, 5.1 mA, 5.0 mA } higher amplf r. noise

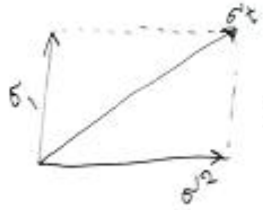
→ 5.124 mA, 5.128 mA, 5.126 mA } → lower amplf readout noise

Δf

noise equival. band pass



Summation of Indep noise



$\sigma_T = (\sigma_1^2 + \sigma_2^2)^{1/2}$

Flicker noise

Source flicker noise

- **Analytical** flicker noise (Related to analyte signal)
  Analytical flicker factor (ξ, ksi)
- **Background** flicker noise (Related to background sign.)
  Background flicker factor (χ, Kai)
- Transmission flicker noise (Cell, Flame)

Number of pulses per second

TABLE 5-4
Analytical and background flicker noise

Type of signal	Photon counting	Analog
Analytical	$(\sigma_S)_f = \xi n_S$	$(\sigma_S)_f = \xi E_S$
Background	$(\sigma_B)_f = \chi n_B$	$(\sigma_B)_f = \chi E_B$

Flicker noise ∝ signal ➔ if S↑ → no change in S/N

Other noise sources

- Excess **dark current noise**
- **Amplifier readout noise**
- Quantization noise ? $\sigma_q = \frac{q}{12^{1/2}} = 0.29q$

Johnson Noise

(Thermal; Brownian motion in resistor R)

Nyquist Eqn:

$$\sigma_J = (4kTR\,\Delta f)^{1/2}$$

$$25°C,\ \sigma_J = (1.6 \times 10^{-20} R\,\Delta f)^{1/2}$$

5-4 Signal-to-noise expressions for emission and luminescence measurement

$$E_{Lt} = E_L + E_{bgL} + E_{sc}$$
$$+ E_E + E_{bgE} + E_d$$

$$\sigma_t = (\sigma_1^2 + \sigma_2^2)^{1/2}$$

Independent sources

$$\sigma_t = (\sigma_1^2 + \sigma_2^2 + 2C\sigma_1\sigma_2)^{1/2}$$

Dependent sources

General Expressions

$$\sigma_t = (\sigma_S^2 + \sigma_{bk}^2)^{1/2}$$

Independent

$$\sigma_{bk} = (\sigma_B^2 + \sigma_{dt}^2)^{1/2}$$

Total dark noise

$$\sigma_B = [(\sigma_B)_s^2 + (\sigma_B)_f^2]^{1/2}$$

Backgournd shot noise

Background flicker noise

$$\sigma_{dt} = (\sigma_d^2 + \sigma_{ar}^2)^{1/2}$$

Noise in dark current signal

Amplifier read out noise

$$\sigma_d = [(\sigma_d)_s^2 + (\sigma_d)_{ex}^2]^{1/2}$$

dark excess noise

The analytical signal noise is due to the flicker and shot noise

$$\sigma_S = [(\sigma_S)_s^2 + (\sigma_S)_f^2]^{1/2}$$

analytical signal shot noise

analytical signal flicker noise

Combining mentioned noise sorts yields:

$$\sigma_t = [\sigma_S^2 + \sigma_B^2 + \sigma_{dt}^2]^{1/2}$$

$$\sigma_t = [(\sigma_S)_s^2 + (\sigma_S)_f^2 + (\sigma_B)_s^2 + (\sigma_B)_f^2 + \sigma_{dt}^2]^{1/2}$$

Total Noise Equation (as a function of E_{out} and i_{cath}):

$$\sigma_t = [mGK(E_S + E_B + E_d) + (\xi E_S)^2 + (\chi E_B)^2 + (\sigma_d)^2_{ex} + \sigma^2_{ar}]^{1/2}$$

In term of cathodic current ($E_{out} = mG\, i_{cath}$)

$$\sigma_t = (mG)\left\{ K(i_S + i_B + i_d) + (\xi i_S)^2 + (\chi i_B)^2 + \left[\frac{(\sigma_d)_{ex}}{mG}\right]^2 + \left(\frac{\sigma_{ar}}{mG}\right)^2 \right\}^{1/2}$$

Shot noise factor

Analytical signal noise factor

Background signal noise factor

Signal to total noise ratio equation:

$$\frac{S}{N} = \frac{E_S}{\sigma_t} = \frac{E_S}{(\sigma_S^2 + \sigma_{bk}^2)^{1/2}} = \frac{E_S}{(\sigma_S^2 + \sigma_B^2 + \sigma_{dt}^2)^{1/2}}$$

$$\frac{S}{N} = \frac{E_S}{[(\sigma_S)_s^2 + (\sigma_S)_f^2 + (\sigma_B)_s^2 + (\sigma_B)_f^2 + \sigma_{dt}^2]^{1/2}}$$

$$\frac{S}{N} = \frac{E_S}{[mGK(E_S + E_B + E_d) + (\xi E_S)^2 + (\chi E_B)^2 + (\sigma_d)_{ex}^2 + \sigma_{ar}^2]^{1/2}}$$

$$\frac{S}{N} = \frac{i_S}{\{K(i_S + i_B + i_d) + (\xi i_S)^2 + (\chi i_B)^2 + [(\sigma_d)_{ex}/mG]^2 + (\sigma_{ar}/mG)^2\}^{1/2}}$$

Noise in measurement can arise from several sources. But usually one these sources is dominate.

Blank noise limited S/N expression

If the analyte concentration is small

$$E_S << E_B + E_d \text{ or } E_t \approx E_{bk} \qquad \sigma_t = \sigma_{bk}$$

Then:

$$\frac{S}{N} = \frac{i_S}{\{K(\cancel{i_S} + i_B + i_d) + (\cancel{\xi i_S})^2 + (\chi i_B)^2 + [(\sigma_d)_{ex}/mG]^2 + (\sigma_{ar}/mG)^2\}^{1/2}}$$

$$\frac{S}{N} = \frac{i_S}{\{K(i_B + i_d) + (\chi i_B)^2 + [(\sigma_d)_{ex}/mG]^2 + (\sigma_{ar}/mG)^2\}^{1/2}}$$

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$$\frac{S}{N} = \frac{i_s}{\left\{K(i_s + i_B + i_d) + (\xi i_s)^2 + (\chi i_B)^2 + \left[(\sigma_d)_{ex}/mG\right]^2 + \left[\sigma_{ar}/mG\right]^2\right\}^{1/2}}$$

Blank noise limited cond.

$$E_t = E_L + E_{bgL} + E_s$$

$$E_E + E_{bge} + E_d$$

(low conc. of analyte)

3. Background limiting

$$\frac{S}{N} = \frac{i_s}{\left(K i_B + (\chi i_B)^2\right)^{1/2}} \xrightarrow[i_s \uparrow]{[\text{analyte}]\uparrow} \frac{S}{N} \propto s \uparrow$$

Blank noise limited S/N expression (Fluor or Emiss, low concn)

1. Shot-noise-limited case (Very high quality instrument)

$$\frac{S}{N} = \frac{i_S}{\{K(i_B + i_d) + (\chi i_B)^2 + [(\sigma_d)_{ex}/mG]^2 + (\sigma_{ar}/mG)^2\}^{1/2}}$$

Shot noise limited case: if background, excess dark current, and amplifier read out noise are negligible this represent the **best S/N obtainable**.to further improvement of this case we must reduce K.

$$\frac{S}{N} = \frac{i_S}{[K(i_B + i_d)]^{1/2}}$$

Blank noise limited S/N expression (Fluor or Emiss, low concn)

2. Non-fundamental Noise Limited case

(Moderate quality instrument)

$$\frac{S}{N} = \frac{i_S}{\{K(i_B + i_d) + (\chi i_B)^2 + [(\sigma_d)_{ex}/mG]^2 + (\sigma_{ar}/mG)^2\}^{1/2}}$$

(Flicker noise limited)

if shot noise is negligible then we have :

$$\frac{S}{N} = \frac{i_S}{\{(\chi i_B)^2 + [(\sigma_d)_{ex}/mG]^2 + (\sigma_{ar}/mG)^2\}^{1/2}}$$

The S/N can be improved by selecting higher quality PMT and amplifier readout system.but in general the improvement is less than for shot noise .

Blank noise limited S/N expression (Fluor or Emiss, low concn)

3. Background –Signal-Noise Limited case

(high background Fluorescence or emission)

$$\frac{S}{N} = \frac{i_S}{\{K(i_B + i_d) + (\chi i_B)^2 + [(\sigma_d)_{ex}/mG]^2 + (\sigma_{ar}/mG)^2\}^{1/2}}$$

In many emission and luminescence measurments the background noise is significant .S/N enhancement is achived by adjusting exqerimental variables and reduction of Δf which is most effective when background shot noise dominant.

$$\frac{S}{N} = \frac{i_S}{[Ki_B + (\chi i_B)^2]^{1/2}}$$

Blank noise limited S/N expression (Fluor or Emiss, low concn)

4. Detector-Noise-Limited case

(Very low background Fluorescence or emission)

$$\frac{S}{N} = \frac{i_S}{\{K(i_B + i_d) + (\chi i_B)^2 + [(\sigma_d)_{ex}/mG]^2 + (\sigma_{ar}/mG)^2\}^{1/2}}$$

if background and amplifier resdout noise are negligible then we have :

$$\frac{S}{N} = \frac{i_S}{\{Ki_d + [(\sigma_d)_{ex}/mG]^2\}^{1/2}}$$

The S/N improved by increasing is or reducing dark current.

Example: PMT

Limiting: Shot noise in dark current condition

(Low analyte concn, low background, high quality instrument)

NEP is usually defined as $\sigma_d/R(\lambda)$

$$\text{NEP} = (Ki_d)^{1/2}/R(\lambda) \qquad \sigma_d = (Ki_d)^{1/2}$$

D= 1/ NEP

$$D = R(\lambda)/(Ki_d)^{1/2}$$