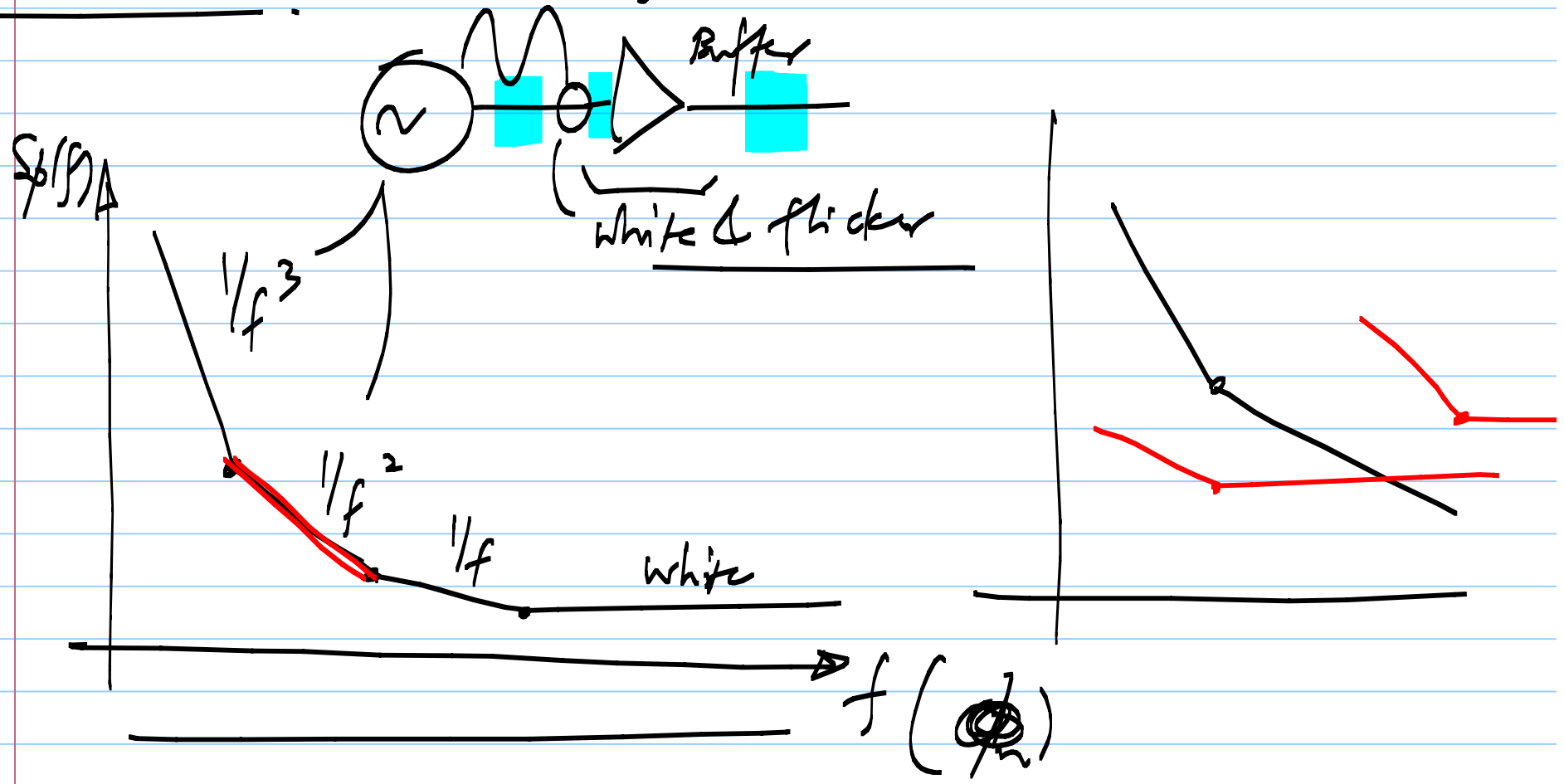
Lecture 22 Oscillator phase noise



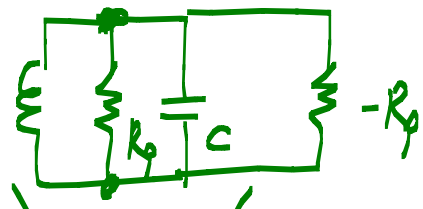
$$\propto \frac{f_0^2}{f^2} \cdot \frac{1}{P_{dc}}$$

Ring osc.

$$\frac{32}{3} \frac{kT}{(V_{GS}-V_T) I_D} \cdot \frac{f_0^2}{f^2}$$

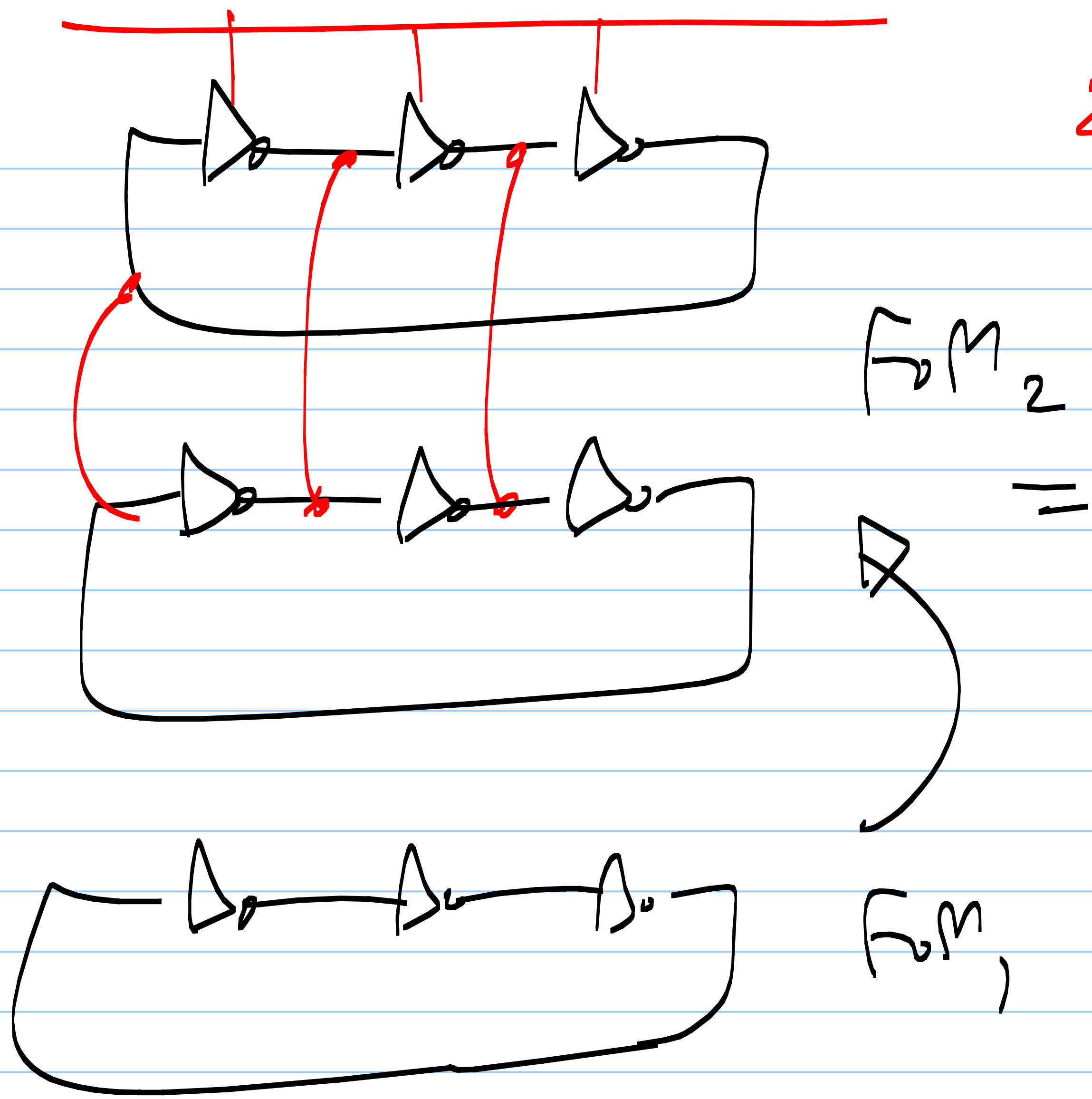
* Worse phase noise
  20–30dB worse than LC
* Compact

LC osc



$$\frac{kT \cdot (1+\gamma)}{2 P_{tank} Q^2} \cdot \frac{f_0^2}{f^2}$$

* Better phase noise
* Improves with Q
* Large size



$2p_d \cdot \frac{S_\phi}{2}$

Figure of merit for an oscillator

$$S_\phi(f) \propto \frac{f_0^2}{f^2} \cdot \frac{1}{P_{dc}}$$

P_{dc}: Power drawn from the supply

$$FoM = 10\log_{10}\left(\frac{f_0^2}{f^2} \cdot \frac{1}{S_\phi(f)} \cdot \frac{1}{P_{dc}(mW)}\right)$$

LC osc: 190–195 dB

Ring osc: 165–175 dB (180 dB)

$$A\cos(\omega_0 t + \alpha\cos\omega_m t) \simeq A\cos(\omega_0 t) - \frac{A\alpha}{2}\sin(\omega_0 + \omega_m)t \pm \frac{A\alpha}{2}\sin(\omega_0 - \omega_m)t$$

$\alpha \ll 1$

$\frac{A^2}{2}$

$A/2\ (\frac{A^2}{4})$ $A/2\ (\frac{A^2}{4})$

$-\omega_0$ ω_0

$\frac{A^2\alpha^2}{8}$

$\alpha/2$ $\alpha/2$

$\alpha^2/4$ $\alpha^2/4$

$(A^2/4)$ $(A^2/4)$

$-\omega_m$ ω_m

$A\cos(\omega_1 t + \phi_m)$

$A/2$ $A/2$

$A\alpha/4$ $A\alpha/4$

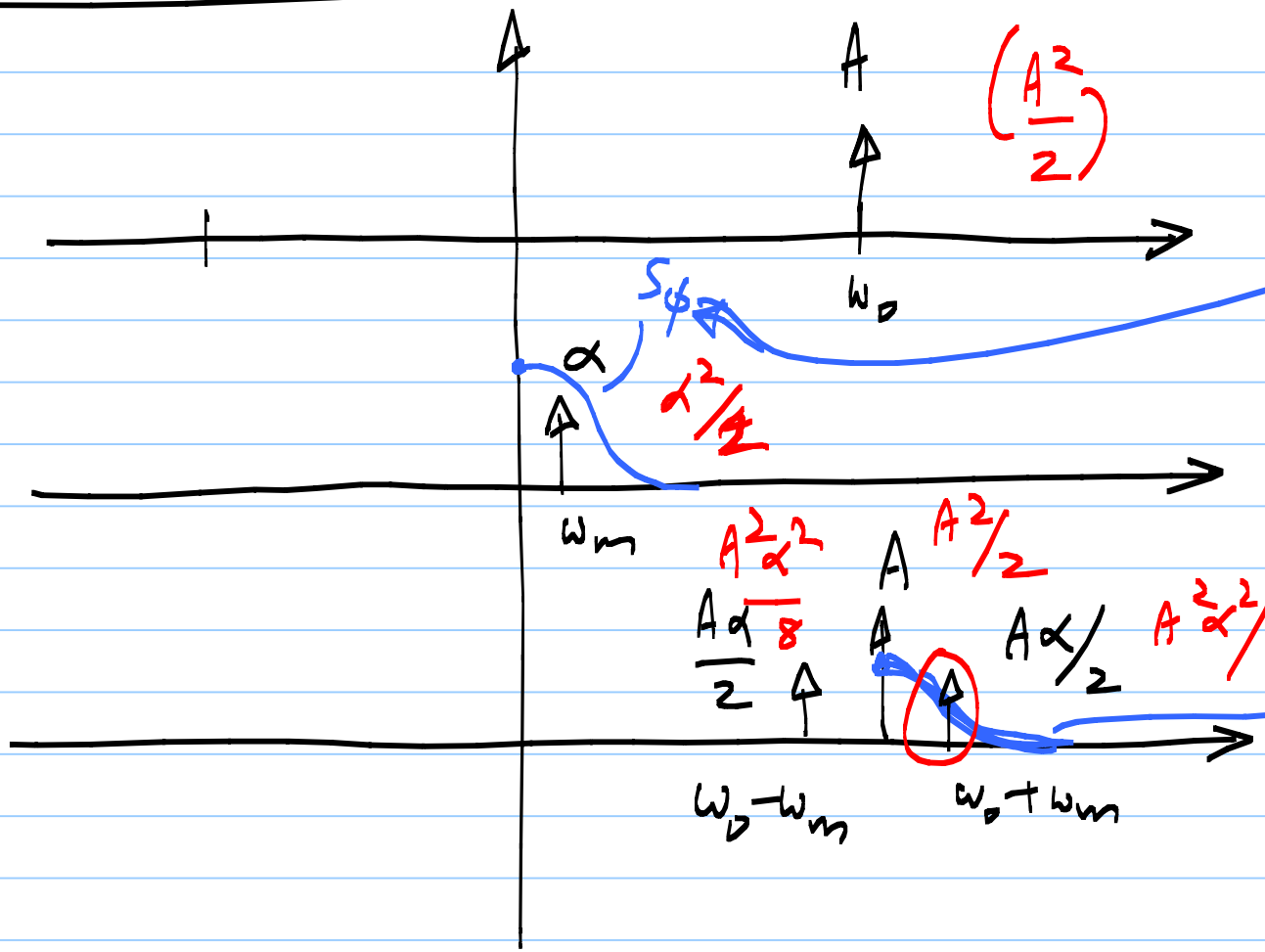
$\frac{A^2\alpha^2}{16}$ $\frac{A\alpha}{4}$ $\frac{A\alpha}{4}$ $\frac{A^2\alpha^2}{16}$

$\frac{A^2}{2}$

$\omega_0 - \omega_m$ $\omega_0 + \omega_m$

Single sided spectral density

$A \cos(2\pi f_0 t + \phi_n)$

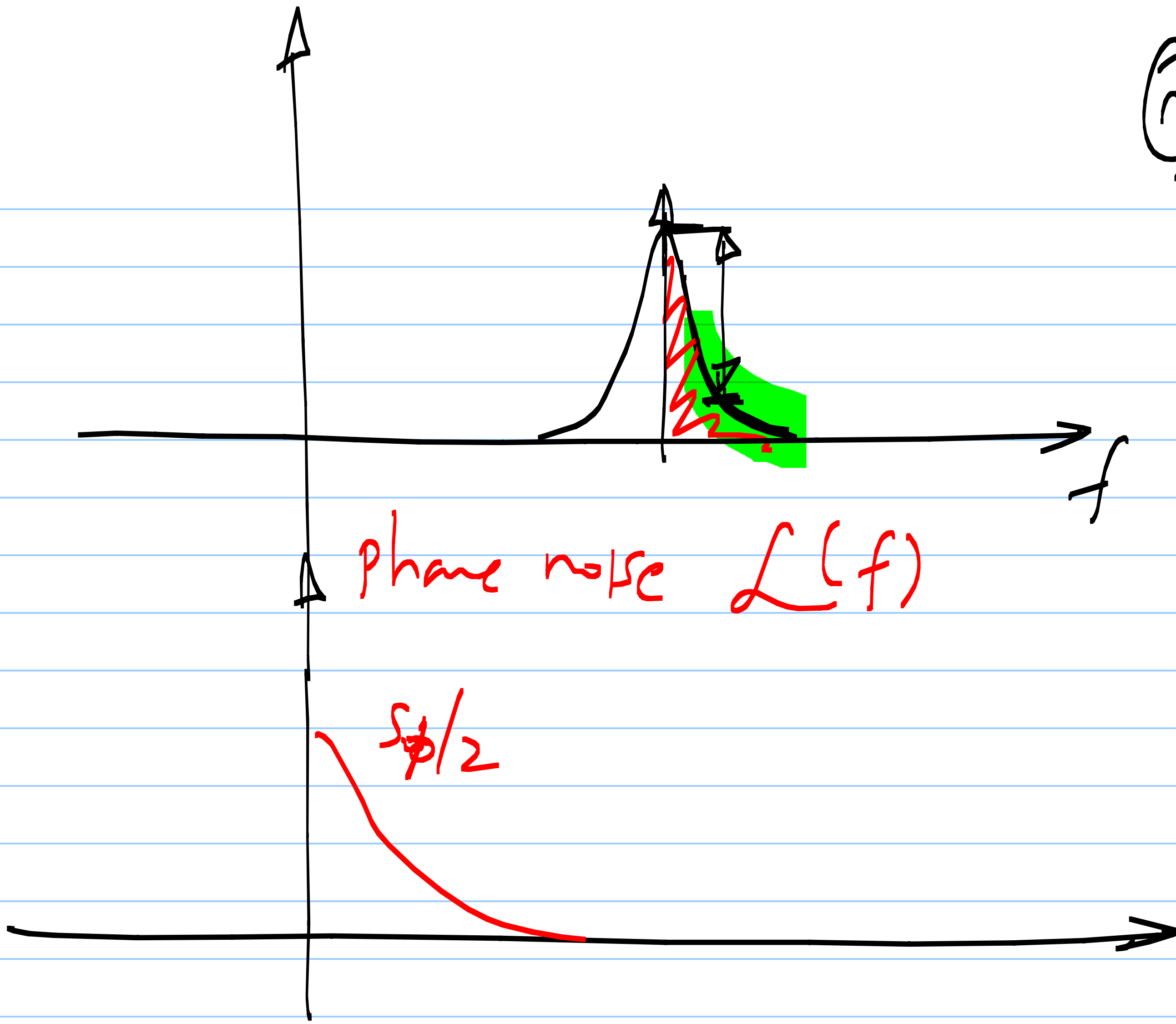


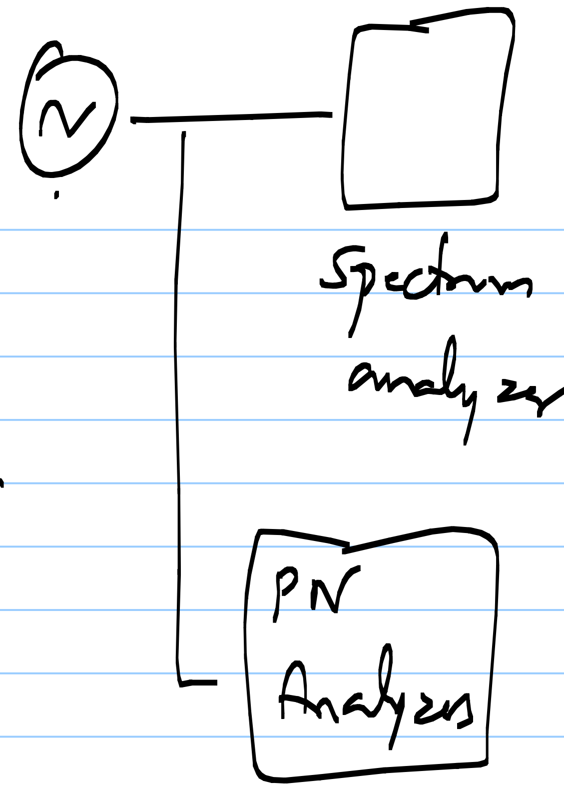
$$\overline{\phi_n^2} = \int_0^\infty S_\phi \, df$$

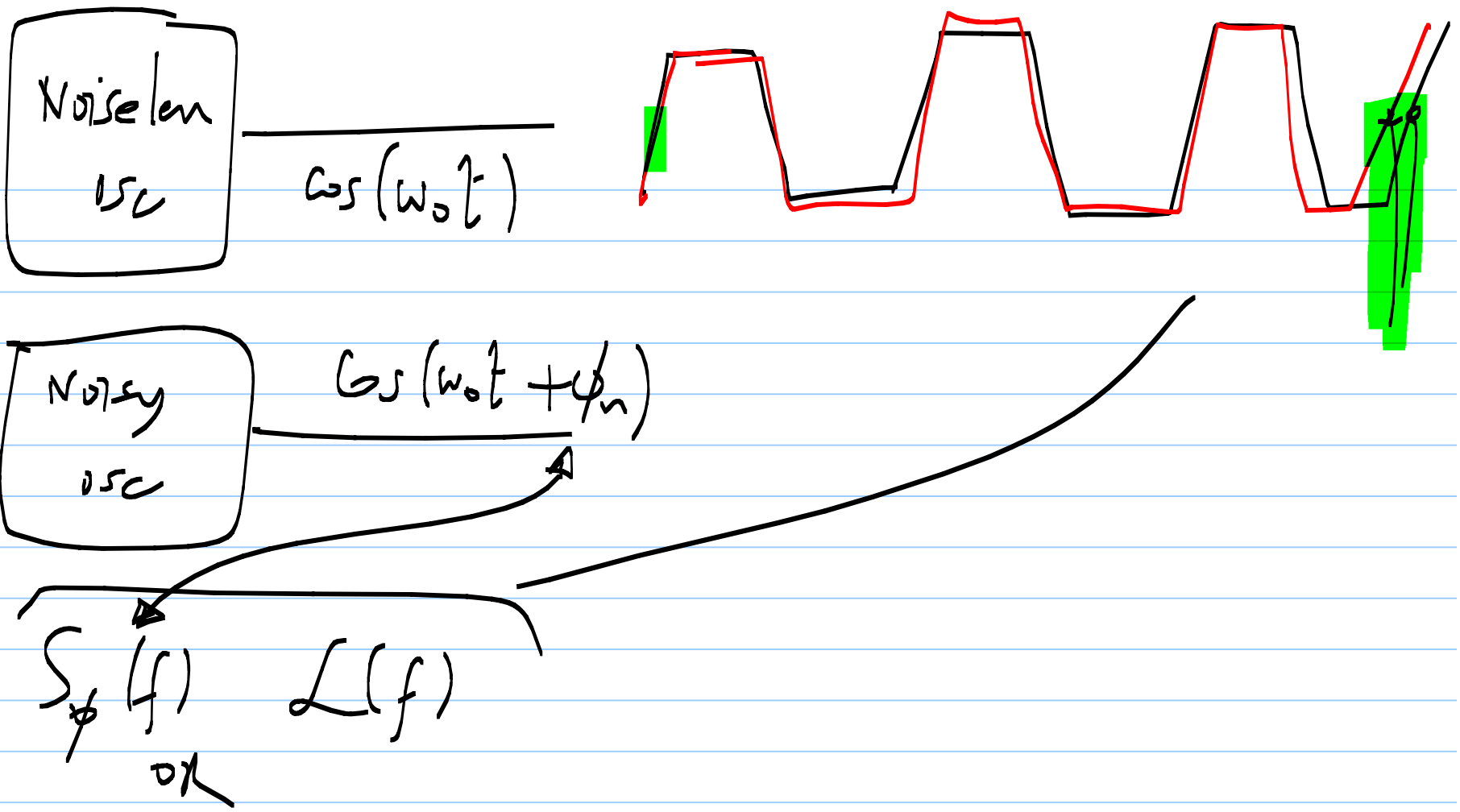
$$= 2\mathcal{L}(f)$$

$$\left(\frac{A^2}{2}\right)\left(\frac{S_\phi}{2}\right) =$$

Carrier power = 1


f
phase noise $\mathcal{L}(f)$
$S_\phi/2$


Spectrum analyzer
PN Analyzers


Noiseless
osc
cos(ω₀t)
Noisy
osc
cos(ω₀t + φₙ)
S_φ(f)
OK
ℒ(f)