Normalized *phase−noise spectral density*

$\log L(\Delta f)$ [dBc/Hz]

Saturation removes amplitude noise $P_\phi = P_{Nout}/2$

$$\frac{dP_{Nin}}{df} = N_0 = k_B(T_R + T_G) \approx k_B T_0 F$$

$$L(\Delta f) = \frac{1}{P_0} \cdot \frac{dP_\phi}{df} = \frac{1}{2} \cdot \left[1 + \left(\frac{f_0}{2Q_L \Delta f}\right)^2\right] \cdot \frac{k_B T_0 F}{P_0} \cdot \left(1 + \frac{f_C}{|\Delta f|}\right) \ [\text{Hz}^{-1}]$$

Valid at $L(\Delta f) \cdot \Delta f \ll 1$

Phase noise only

$P_0 \equiv carrier \ power$

1/f noise

$\alpha(\Delta f)^{-3}$

$$L(\Delta f)_{\text{dBc/Hz}} = 10\log_{10} \frac{1}{2} \cdot \left[1 + \left(\frac{f_0}{2Q_L \Delta f}\right)^2\right] \cdot \frac{k_B T_0 F}{P_0} \cdot \left(1 + \frac{f_C}{|\Delta f|}\right) \cdot 1\text{Hz}$$

1/ f noise

Simplified phase noise

$$L(\Delta f) \approx \frac{1}{8} \cdot \left(\frac{f_0}{Q_L \Delta f}\right)^2 \cdot \frac{k_B T_0 F}{P_0}$$

$\alpha(\Delta f)^{-2}$

f_C

$\frac{f_0}{2Q_L}$

Thermal noise

Offset from carrier $\log|\Delta f|$