
SSB Noise Modeling in SysCalc

The SSB noise of an LO is typically specified at a few points, often at decade intervals (.1,1,10 etc.). The noise pdf (Power Spectral Density) is usually shown as straight line segments (log-log scale) because of $1/(f^3)$, $1/(f^2)$, $1/(f^m)$ noise characteristics. Assuming these characteristics, the pdf can be integrated as follows:

The log-log slope is given by

$$m = \frac{\log(P_{i+1}) - \log(P_i)}{\log(f_{i+1}) - \log(f_i)} = \frac{\log(P_{i+1} / P_i)}{\log(f_{i+1} / f_i)}$$

where P_i and P_{i+1} are points on the segment with units, Watts/Hz.

The pdf at any point, f , on the segment relative to P_i (also on the segment) is given by

$$\log(P / P_i) = m \cdot \log(f / f_i), \text{ or}$$

$$P(f) = P_i \left(\frac{f}{f_i} \right)^m \quad (\text{Watts/Hz})$$

The SSB phase noise (Watts) integrated over any portion of the segment is then

For $m \neq -1$,

$$P_{SSB} = \int_{f_1}^{f_2} P(f) df = \frac{P_i}{f_i^m (m+1)} \left[f^{m+1} \right]_{f_1}^{f_2} = \frac{P_i}{f_i^m (m+1)} \left[f_2^{m+1} - f_1^{m+1} \right]$$

For $m = -1$,

$$P_{SSB} = \int_{f_1}^{f_2} P(f) df = f_i P_i \left[\ln(f) \right]_{f_1}^{f_2}$$

The residual Phase Modulation is given by

$$\theta_{rms} = \sqrt{2 \int_{f_1}^{f_2} P(f) df}, \text{ valid for } \theta_{rms}^2 < 1 \text{ rad}^2$$

In like manner, the residual Frequency Modulation is given by

$$\Delta F_{rms} = \sqrt{2 \int_{f_1}^{f_2} f^2 P(f) df}, \text{ valid for } \theta_{rms}^2 < 1 \text{ rad}^2$$

Deemphasis Calculations (FM detection only)

When deemphasis is being applied in the post-detection process (FM only), the pdf shown above is multiplied by a single pole filter whose cutoff characteristics are given by

$$\frac{1}{1 + \left(\frac{f}{f_c}\right)^2} \quad \text{where, } f_c = \frac{1}{2\pi t_c} \quad f_c \text{ is defined by the deemphasis time constant supplied in the LO Phase Noise report (FM detection)}$$

Thus, the post-detection pdf is given by

$$P(f) = \frac{P_i}{1 + \left(\frac{f}{f_c}\right)^2} \left(\frac{f}{f_i}\right)^m$$

Hum and Noise

The LO Phase Noise Report computes Hum and Noise for FM detection relative to a reference deviation (usually 8 kHz) as

$$\text{Hum and Noise (dB)} = 20 \text{Log} \left(\frac{f_{Dev}}{\sqrt{2} \Delta F_{rms}} \right), \quad \text{where } f_{Dev} \text{ is in Hz and valid for } \theta_{rms}^2 < 1 \text{ rad}^2$$

Error Vector Magnitude Calculations

For digital detection, the Error Vector Magnitude is related to the residual phase noise and defined by

$$EVM_{\%} = \sqrt{2(1 - \cos(\sqrt{2}\theta))} \cdot 100$$