# Noise Analysis of the Opto-Electronic Microwave Oscillator (OEO)

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**This article is an extended abstract**

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***Abstract*— This article reports on the noise model of the OEO. The phase-noise and the amplitide-noise spectra can be predicted on the ground of the noise of the OEO internal components.**

## OEO Noise

The OEO is an oscillator in which the resonator is replaced with a long optical fiber of delay $\tau$ [1], [2]. Such a loop can sustain oscillation at a frequency multiple of $1/\tau$ in a wide range, for wide bandpass filter is needed to select the mode.

The OEO noise, which is quasi-cyclostationary, is best described as a slow-varying random process after freezing the periodic oscillation. In polar coordinates, the oscillator model splits into two subsystems, in which all signals are the amplitude and the phase of the main system, respectively. Since phase is not stretchable because it carries the time information, all the nonlinearity goes to the amplitude subsystem. In the phase representation, the delay line is a delay $\tau$, the mode selector is a low-pass filter, and the amplifier is an amplifier of gain exactly equal to one. More interestingly, phase noise is always additive regardless of the physical origin, as extensively discussed in [3]. The amplitude-noise model differs for a smooth nonlinearity in the amplifier. This theory ends up in a unified noise transfer function that predicts precisely the oscillator AM and PM noise if the noise of its components is known [4], extended to the OEO noise.

The analysis of phase noise spectra taken from the literature or measured on our prototypes reveals that the frequency flicker is chiefly the $1/f$ phase noise of the electronics, i.e., amplifier [5] and photodiodes [6], [7], [8], turned into $1/f^3$ via the Leeson effect, with likely a minor contribution of the optical fiber. The typical 'good' value is $b_{-3} \approx 10^{-3}$ (coefficient of the $1/f^3$ component of $S_\varphi$) for a 20 $\mu$s delay (4 km), which is equivalent to $\sigma_y \approx 3\times10^{-12}$ (Allan deviation).

A specific pattern is observed in a number of PM-noise spectra, where there are two different levels of $1/f^3$ noise, the higher at lower frequency. This phenomenon, which seems to be due to the coupling between AM and PM noise already observed in traditional oscillators (based on resonators), is being investigated. The same pattern has been observed in traditional oscillators (based on resonators) and related to the presence of two levels of $1/f$ AM noise, predicted and fully explained by the theory. The latter phenomenon is transposed to frequency noise, yielding two levels of $1/f^3$ PM noise, if AM and PM are coupled.

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