Optimization of a Local Oscillator to Achieve Minimum Impairment of the Receiver by Phase Noise

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The noise characteristics of a local oscillator have a major impact on the performance of practically every receiver in a communications system. In recent years, a comprehensive theory was developed describing the noise processes in an oscillating system. Our intention is to connect this theory of noise in the oscillator circuit with the concept of phase noise which is usually used in communications engineering.

Especially the fundamental work of Demir[1] built the basis to understand the stochastic differential equations describing the oscillator circuit. The author suggested an oblique decomposition of the noise into a component tangential to the system's steady-state trajectory and into a second component, called the orbital deviation of the system. The stochastic characteristic of the tangential perturbation is described by Demir whereas the orbital deviation was comprehensively discussed by Traversa and Bonani[2].

It is argued in this paper that the phenomenon of phase noise as it is observed in receivers of communications systems is not the same as the signal fluctuations caused by the tangential perturbation component. In fact, an appropriate weighted combination of both components has to be considered. Thus, it is shown how both components have an impact on the figures of merit in a receiver such as the bit error rate or the estimation of signal parameters.

Therefore, it is shown how to optimize the circuit of an oscillator (i.e. its parameters) to finally achieve minimum impairment of the receiver by phase noise. To do this, it is necessary to consider the components within the receiver having a direct impact on the power spectral density of the receiver, such as the frequency mixer and the phase-locked-loop (PLL). Here, it will become clear that optimization of the oscillator with respect to minimum tangential perturbation can lead to different results than its optimization with respect to minimum phase noise.

To illustrate our findings, we use the appealing oscillator model presented by Coram[3] which allows to solve the respective stochastic differential equations in an analytical manner. Furthermore, we exemplify our approach by discussing the consequences for a scenario where the oscillator is used as local oscillator within a PLL-synchronized communications receiver.

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1 A. Demir, A. Mehrotra, J. Roychowdhury, "Phase Noise in Oscillators: A Unifying Theory and Numerical Methods for Characterisation", IEEE Transactions on Circuits and Systems I, vol. 47, pp. 655-674, 2000.

2 F. L. Traversa, F. Bonani, "Oscillator Noise: A Nonlinear Perturbative Theory Including Orbital Fluctuations and Phase-Orbital Correlation", IEEE Transactions on Circuits and Systems I, vol. 58, pp. 2485-2497, 2011.

3 G. Coram, "A simple 2-D oscillator to determine the correct decomposition of perturbations into amplitude and phase noise", IEEE Transactions on Circuits and Systems I, vol. 48, pp. 896-898, 2001.