7 Design for Low Flicker Phase Noise

1 Introduction

Despite numerous papers on oscillators, flicker noise has not received much attention. In part, this is because until recently RF oscillators were usually built using the bipolar junction transistors, which have relatively little flicker noise. The need for low flicker noise oscillators became apparent only in CMOS implementations that date to around 10 years ago. Today, almost all integrated LC oscillators are CMOS. This is true even when implementing the RF system in BiCMOS. The fundamental reason is that MOS devices can handle a larger signal swing, which is the most effective means of lowering phase noise.

Flicker noise's behavior in oscillators and mixers is quite distinct from that of thermal noise. Flicker noise is localized in the low frequency portion of the noise spectrum. To affect the phase of a multi-gigahertz oscillator, a frequency translation mechanism must be involved. However, it was shown in an earlier chapter that mixer-based up-conversion of flicker noise can only result in amplitude noise [1]. Flicker noise can only become phase noise through frequency modulation mechanisms. Frequency noise is indistinguishable from phase noise and corrupts communication systems in the same manner. Concepts like noise folding seldom apply to flicker noise in oscillators because, unlike thermal noise, its power is localized in low frequencies.

In a current-biased LC oscillator, the three sources of flicker noise are the current source, the varactor, and the switching pair transistors. Minimization of flicker noise makes use of a variety of techniques discussed in earlier chapters. In this chapter, we will re-visit these techniques from the perspective of minimizing flicker noise.

2 Flicker Noise Minimization

In Chapter 6, the mechanisms by which flicker noise disturbs the oscillator phase were discussed in detail. It is important to recall that while flicker noise of MOS transistors can be lowered by using larger transistors, the amount of frequency noise created by flicker is not a linear function of the transistor's flicker noise. While this might seem a little surprising, it is simply because of the nonlinearity of frequency modulation mechanisms responsible for flicker noise.

Consider the case where only the current source transistor has flicker noise and ignore the nonlinearity of junction capacitances associated with the output transistor. Consider also that the oscillator has no varactor to tune it. In this case, the flicker in the current source transistor does not modulate the frequency of the oscillator output. This is simply because the fluctuation in the bias current only disturbs the amplitude of oscillation, creating amplitude noise. Combined with a nonlinear varactor, the same fluctuation in the source current can disturb the bias point of the varactor, which modulates the frequency of oscillation creating frequency noise as discussed in detail in our varactor treatment in Chapter 8 [2].

Consider a different scenario where the bias current has no flicker noise while the switching pair transistors do. This is a practical case where the bias transistor is replaced with a fixed resistor for example. Assume the common mode point is capacitance-free, including the devices' self-capacitance. In this case, regardless of the amount of flicker noise present in the transistors, the frequency of oscillation is flicker-free. This should be obvious from the discussion in Chapter 6 where the switching FETs flicker noise was shown to modulate the effective capacitance of the active circuit built using the switching pair and the current source. The effective capacitance was shown to depend on the amount of capacitance at the common mode point.

Thermal noise is present in the entire frequency spectrum. Therefore, thermally generated phase noise in an oscillator cannot be eliminated. With clever design, this type of phase noise can be lowered, possibly to its topology-dependent lower bound. Flicker noise on the other hand can be eliminated altogether by intelligently attacking the mechanisms responsible for its up conversion.