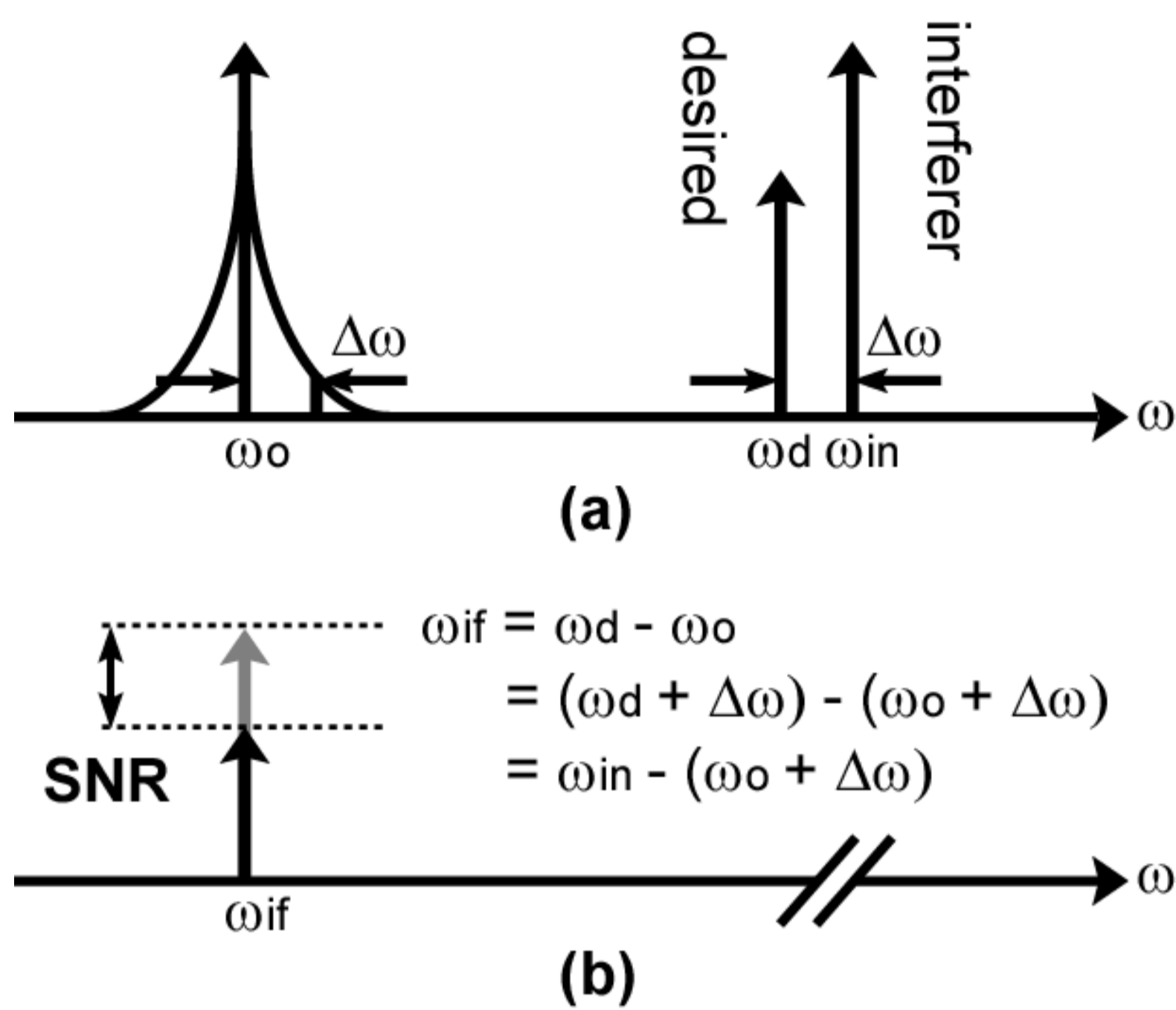


R5-1 A Design Optimization of Low-Phase-Noise LC-VCO Using Multiple-Divide Technique

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1. Background

The local oscillator has phase noise. The local signal brings noise spectrum and it is modeled by this noise tone.

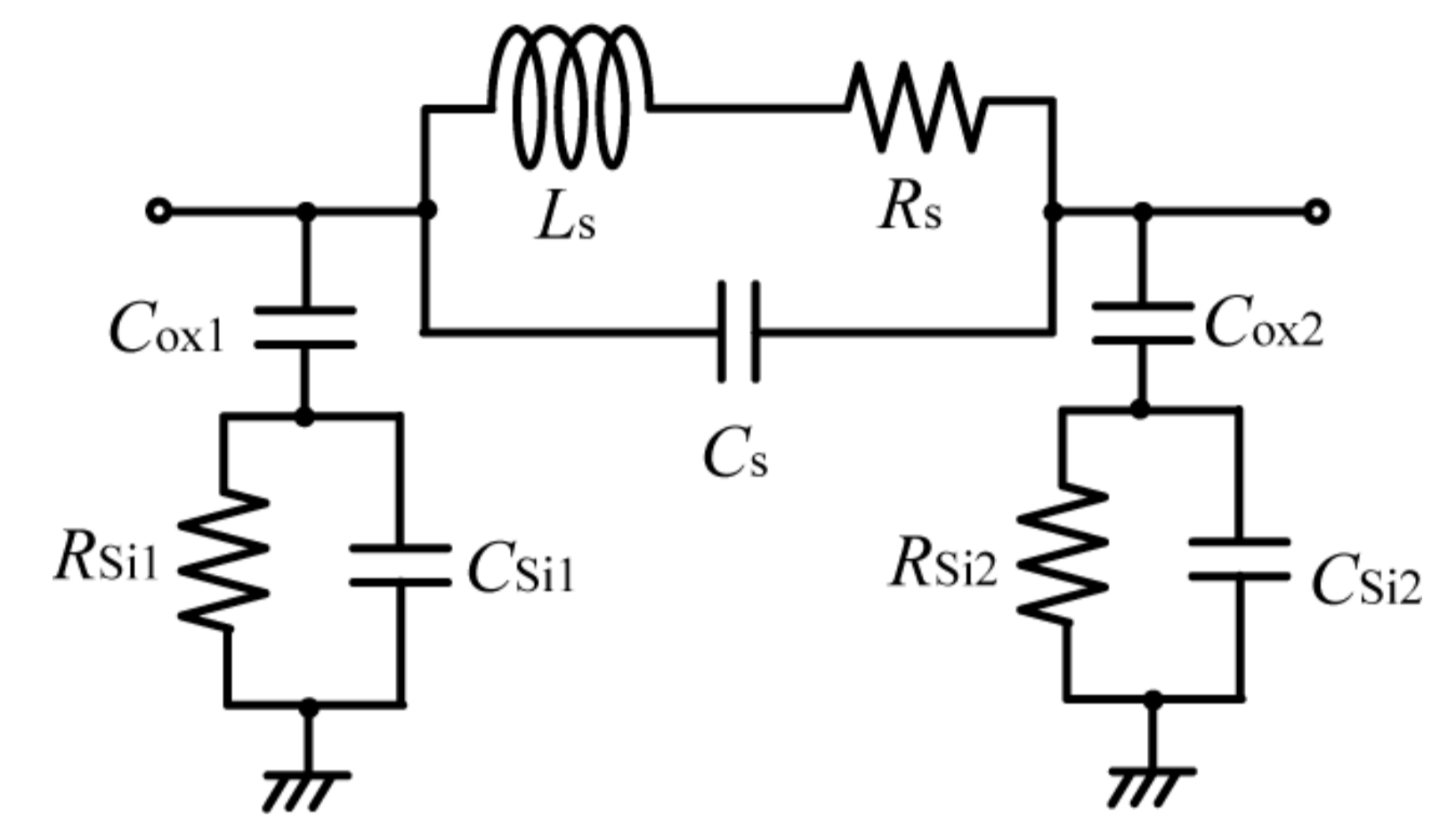
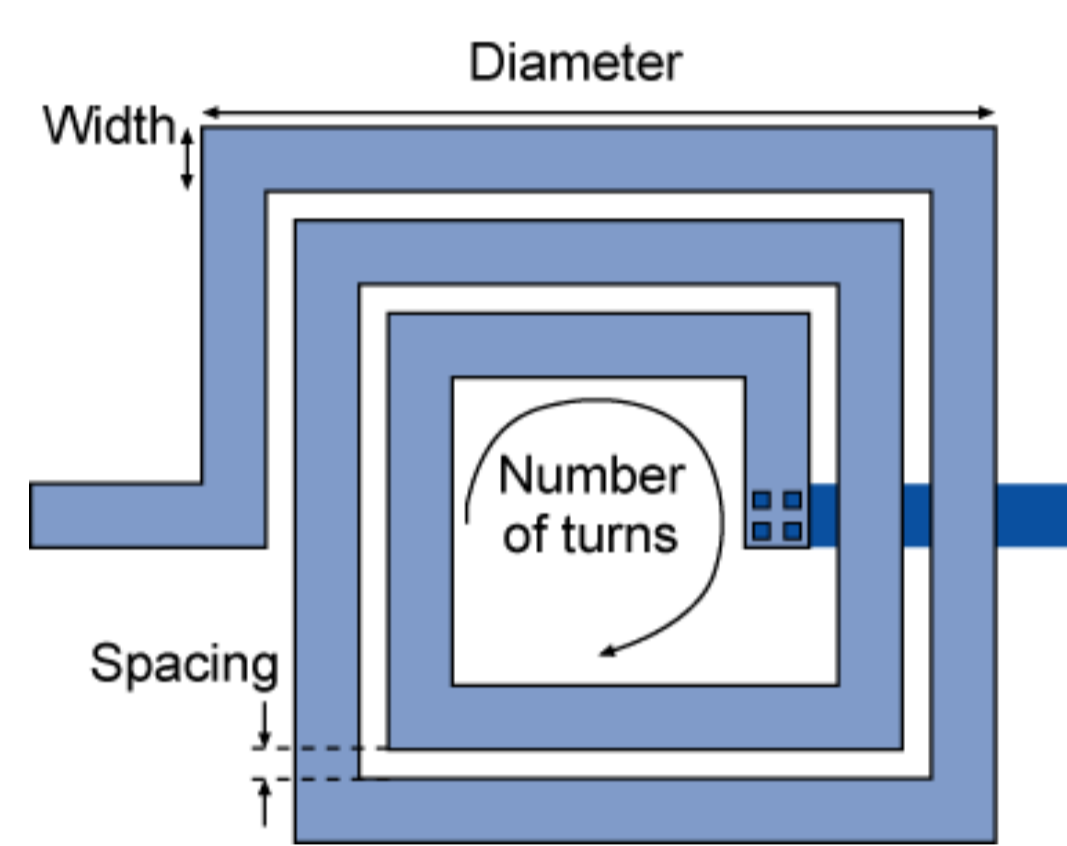


2. Characteristic of Inductors

In Si CMOS technology, quality factor of inductor is almost equal to the effective quality factor of LC-tank. Low Q inductor causes a poor VCO phase noise characteristics

$$\mathcal{L}(\omega) = 10 \log \left[\frac{2kT}{P_{sig}} \left(\frac{f_0}{2Q_{tank} \Delta f} \right)^2 \right]$$

$$Q_{tank} = \frac{Q_L \cdot Q_C}{Q_L + Q_C}$$

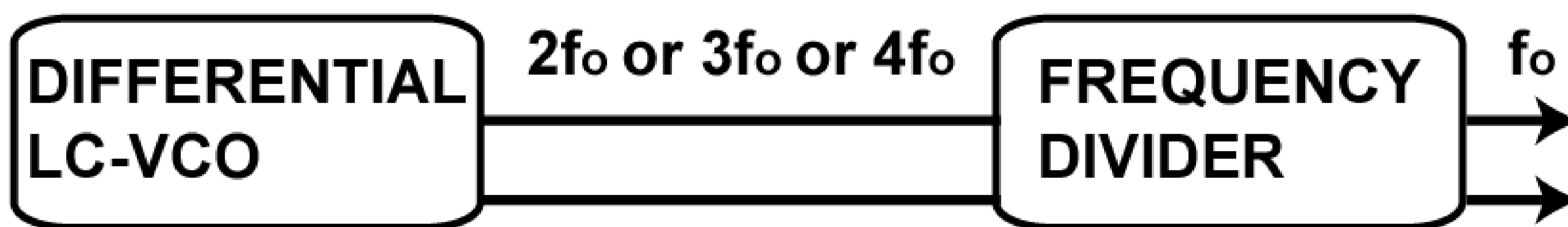


3. Multiple-Divide Technique

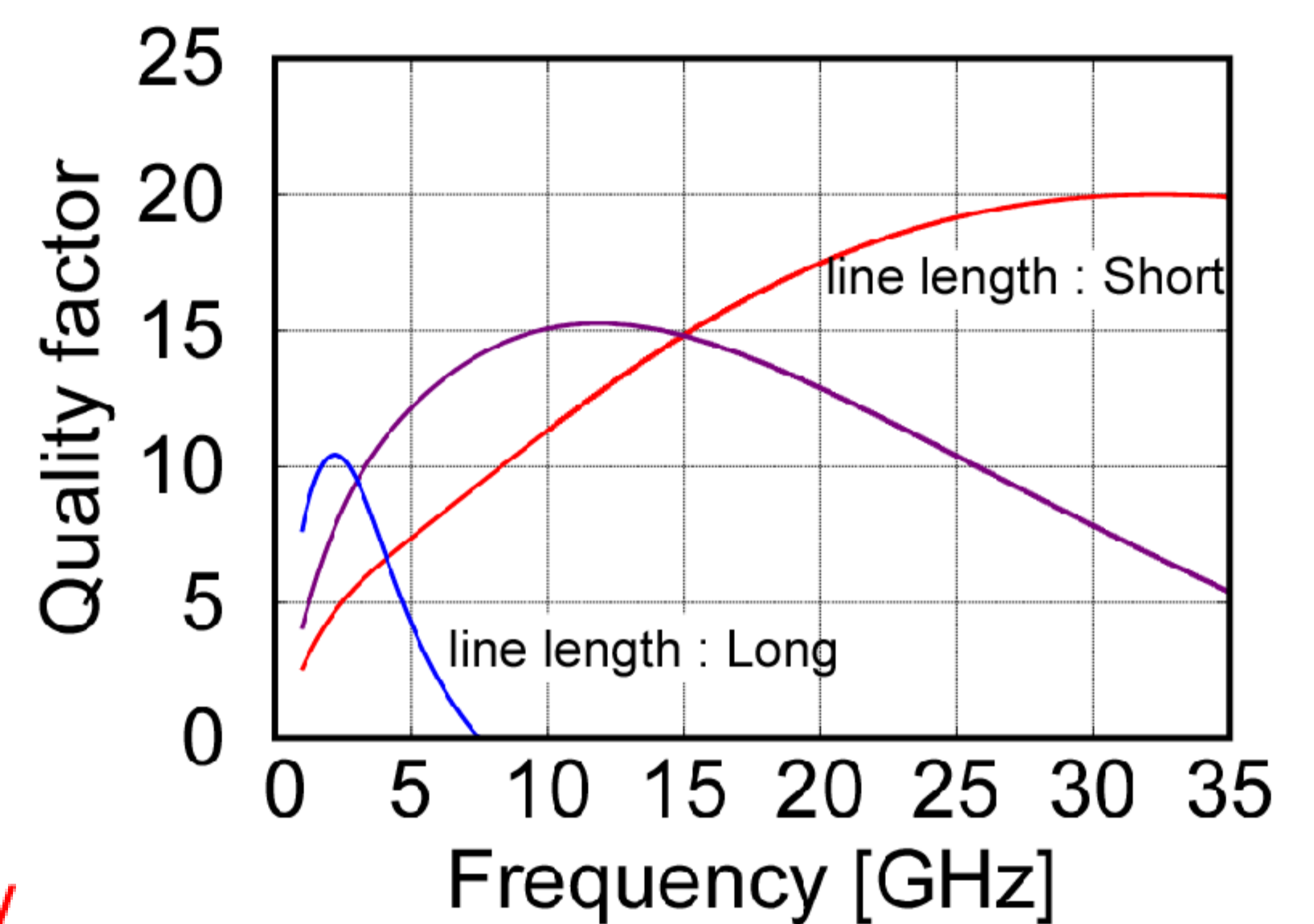
The Quality factor of inductor is higher at higher frequency. To generate oscillation signal, VCO oscillates at the optimal frequency for phase noise, and it is divided by frequency divider to obtain the desired signal.

Ring VCO: Tuning range : **Very wide**, Phase noise : **Not good**

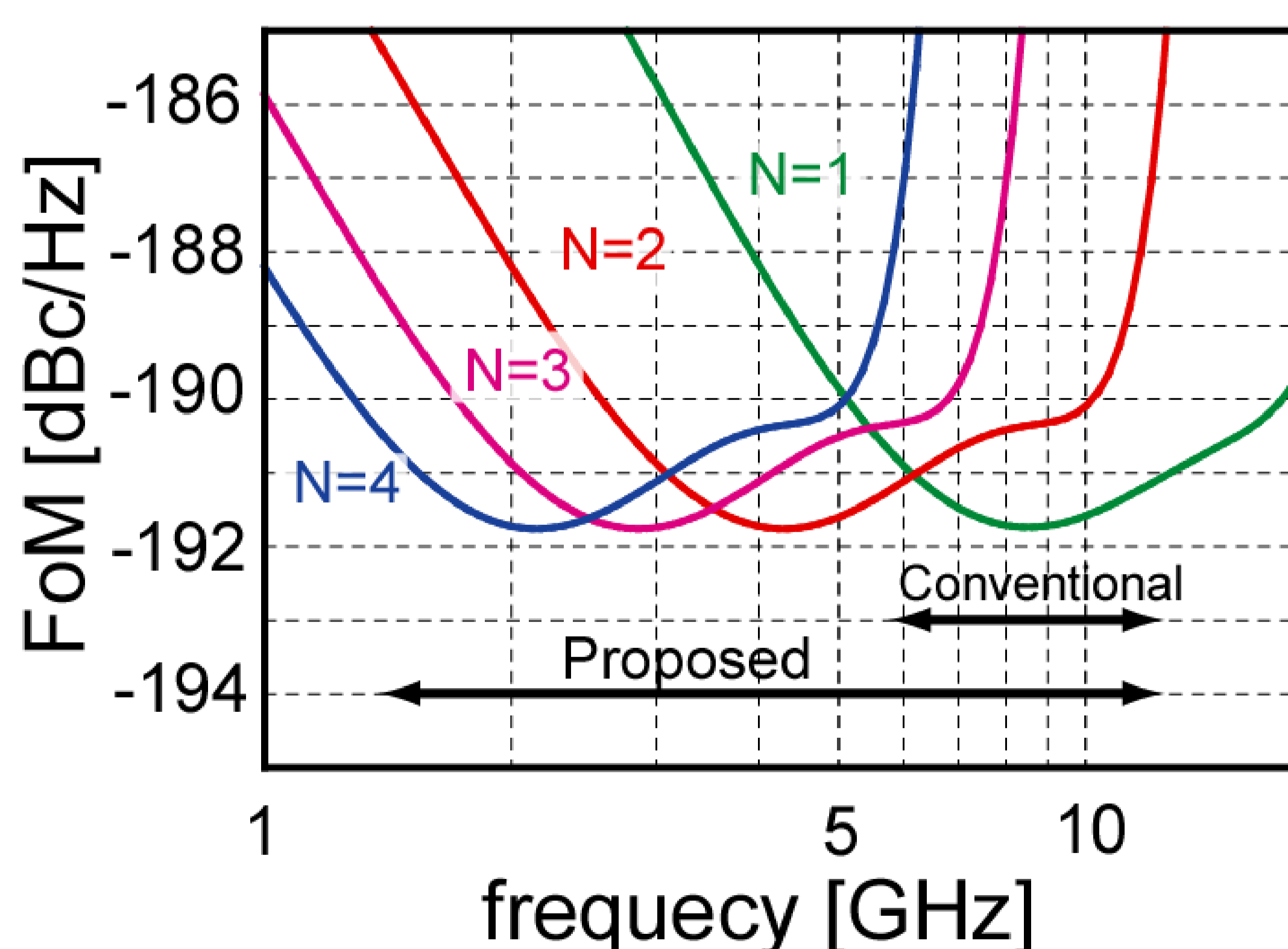
LC-VCO: Tuning range : **Narrow**, Phase noise : **Good**
The phase noise performance depends on quality factor of inductor.



Oscillation at the best FoM frequency Oscillation at desired frequency



4. Performance Improvement



Final output signal is 3GHz.

divide-by-#	conventional	2	3	4
oscillation frequency [GHz]	3.0	6.0	9.0	12.0
phase noise at oscillation frequency [dBc/Hz]	-126.1	-123.0	-119.1	-114.9
phase noise at 3GHz [dBc/Hz]	-126.1	-129.0	-128.6	-127.0
20logN [dBc/Hz]	+0	+6	+9	+12
P_{VCO} [mW]	4.0	5.3	4.2	3.5
$P_{divider}$ [mW]	0	0.2	0.2	0.2
FoM [dBc/Hz]	-189.9	-191.4	-191.9	-191.1

5. Summary

- This study proposes the multiple-divide technique using by-2, by-3, and by-4 frequency dividers to realize a lower phase noise LC-VCO.
- the optimum frequency range, achieving better than -191 dBc/Hz of FoM, can be extended from 6 GHz-12 GHz to 1.5 GHz-12 GHz.