THREE DESIGNS OF RF OSCILLATORS OF IMPROVED PHASE NOISE IN 0.18μm CMOS PROCESS

シティ, アマリナ ビンティ エンチェ アブ ラヒム

出版情報：九州大学, 2016, 博士（工学）, 課程博士
バージョン：
権利関係：

（別紙様式 2）

氏　　名　：シテイ アマリナ ビンテイ エンチェ アブ ラヒム

論 文 名　：THREE DESIGNS OF RF OSCILLATORS OF IMPROVED PHASE NOISE IN 0.18 μm CMOS PROCESS

区　　分　：甲

論 文 内 容 の 要 旨

Being one of the most important building blocks of radiofrequency (RF) transceiver, a low phase noise, low power and compact VCO is required in order to realize a high performance CMOS RF transceiver. Despite its offers for low cost and high level of integration, CMOS technology suffers high substrate loss and thin metallization process. These drawbacks severely affect the performance of CMOS passive components, especially the spiral inductor. Usually, the quality factor (Q) is used to measure the performance of spiral inductor. High Q inductors are essential as they are used in almost every blocks in RF transceiver. However, the CMOS inductor has lower Q compared to the inductors of others technologies. Unfortunately, lossy inductors will severely degrade the phase noise performance of the oscillator. Consequently, the noisy signal in the RF receiver will significantly impact the Bit Error Rate (BER) performance during demodulation in digital transmission system, and thus causing distortion or complete loss of information. For this reason, a low phase noise (high spectral purity) oscillator is required in the wireless transceiver and it is a real challenge to design a CMOS oscillator with high purity signal at the output.

For VCO blocks, two type of CMOS oscillator are usually adopted: the ring oscillator and the inductor-capacitor (LC) oscillator. The ring oscillator is a sequence of inverters connected back-to-back, however, its phase noise is poorer than the one of LC oscillator. Accordingly, the LC oscillators is preferable. However, the low Q inductor limits its phase noise performance and usually inductor is the largest component in the RF circuits, which sees it occupies almost half of the area of the chip. The typical measured value of Q of inductors in silicon is less than 10. Research on how to improve the Q of the CMOS spiral inductors have been done which covers several techniques, however, most of these methods come with higher cost or additional complicated step in fabrication process. Besides of improving the Q of the inductor, the phase noise of the oscillator can be improved by improving the circuit topology. The most common topology that is used in LC oscillator is the cross-couple topology, due to its simple implementation and differential output. However, it operates in class-B, resulting a less power efficiency (≈30%). Therefore, studies on another operating class such as class-C, D F have been done in order to improve the circuit. Nonetheless, the class-D faces high supply pushing issue while in class-F, the number of inductor/transformer used in the circuit is doubled. On top of that, there is a fundamental trade-off between power consumption and the phase noise which need to be considered. On the other hand, another type of resonators have been proposed such as microelectromechanical system (MEMS) resonators which could be a better candidate than the LC tank resonator. These MEMS resonators have higher Q (more than 1000), and thus could provide lower phase noise.

This research work has for ultimate goal to investigate several methods or techniques in order to improve the phase noise of CMOS oscillator. Therefore some novel techniques are proposed. The thesis consists of six chapters. These chapters can be summarized as follows:

Chapter one is the introduction which contains the background and motivation of this research work, along with the research objectives.

In chapter two, a theoretical background about complementary cross-coupled oscillator are introduced. A literature review about the phase noise and the quality factor of the inductor are presented as well.

In chapter three, the methods on how to reduce the loss in silicon substrate in order to improve the Q of the inductor is investigated. For that, a new method is proposed, where a full depletion layer is created in the substrate below the inductor structure, which increase the substrate's resistance, and thus increase the Q. The proposed technique is verified experimentally. A complementary cross-coupled LC oscillator using this improved inductor is designed and measured. The comparison with the same oscillator but uses conventional inductor shows that there is an improvement of phase noise of about 1dB at 1MHz offset from the carrier.

In chapter four, a study on the defected ground structure (DGS) resonator on CMOS is carried out. A detailed study of square shape DGS structure is introduced. Based on this investigation, the DGS resonator gives higher Q than the previous method. The advantage of DGS resonator is it can be designed in CMOS, which makes it better candidate than the FBAR resonator. A complementary cross-coupled oscillator using DGS resonator is designed, where it sees an improvement of phase noise of 5.4dB at 1MHz offset from the carrier.

In chapter five, in order to benefits the high Q of FBAR resonator and the efficient current generation of class-C, a design of class-C film bulk acoustic resonator (FBAR) is proposed. It is the first design of FBAR oscillator in class-C that have been presented. In this chapter, the theoretical study on the FBAR resonator and class-C oscillator are discussed in details. Post layout simulation shows that there is improvement of around 3dB at 1MHz offset from the carrier compared to the same oscillator that operates in class-B.

Finally, the chapter six summarizes and compares the performances of these methods. In addition, the contribution of this research work and the expected future work are also highlighted.