

Chapter 6

RF–MEMS Based Oscillators

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ABSTRACT

Today's high-tech consumer market demand complex, portable personal wireless consumer devices that are low-cost and have small sizes. Creative methods of combining mature integrated circuit (IC) fabrication techniques with innovative radio-frequency micro-electro-mechanical systems (RF-MEMS) devices has given birth to wireless transceiver components, which operate at higher frequencies but are manufactured at the low-cost of standard ICs. Oscillators, RF bandpass filters, and low noise amplifiers are the most critical and important modules of any wireless transceiver. Their individual characteristics determine the overall performance of a transceiver. This chapter illustrates RF-oscillators that utilize MEMS devices such as resonators, varactors, and inductors for frequency generation. Emphasis will be given on state of the art RF-MEMS components such as film bulk acoustic wave, surface acoustic wave, flexural mode resonators, lateral and vertical varactors, and solenoid and planar inductors. The advantages and disadvantages of each device structure are described, with reference to the most recent work published in the field.

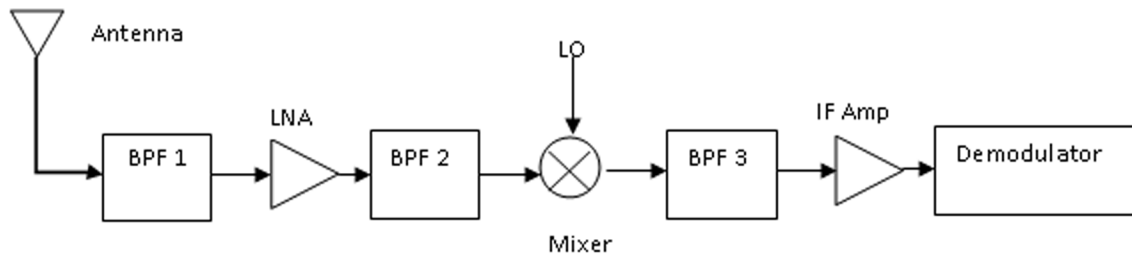
OSCILLATOR FUNDAMENTALS

The increasing demand for portable, small-sized, personal wireless consumer devices, wireless sensor nodes coupled with emerging field of radio-frequency micro-electro-mechanical systems (RF-MEMS) has fueled exciting research on the

complete integration of wireless transceivers (Deparis, 2008; Santos, 2004). Recent advancement of silicon based radio-frequency (RF) electronics have driven the innovation of CMOS-based, low-cost, high technology and portable consumer devices. The escalating need for more and more wireless circuits to be portable has highlighted the importance of low power consumption to enable long operating lifetime for such circuits (Tsung-

DOI: 10.4018/978-1-4666-0083-6.ch006

Figure 1. RF-front end receiver using a heterodyne architecture



Hsien et al., 2004). This chapter deals with the RF-MEMS oscillators, where RF-MEMS devices such as inductors, varactors and resonators are explained in detail. The focus of this chapter is how the usage of RF-MEMS components can benefit and greatly improve the performance of RF-circuits.

Wireless communication systems have evolved dramatically in the last few decades generating multi-standard wireless systems which have high speed data rates and a multitude of applications. Current trends require multi-standard wireless systems (WLAN, GSM, GPS, WCDMA, DCS and Bluetooth) to operate using multiple frequency bands. Such demands place stringent requirements on handheld mobile terminals to be able to switch from one standard to another and also simultaneously be capable of accessing different networks. Specifications for multi-band RF front-end transceiver devices are more complex since such capabilities also imply increase or reduction of current consumption to meet concurrent operational requirements (Tasic et al., 2007). Novel adaptive RF circuits are a popular solution to meet the stringent RF requirements such as high gain, low noise figure with the added variable power consumption (Tasic et al., 2007).

Modern wireless transceiver circuits can be categorized into either analog front-end circuits or digital baseband circuits. Figure 1 illustrates a typical RF front end receiver circuit. Analog front-ends basically perform three important functions namely: frequency selection, amplification and

frequency translation. Mixers with appropriate local oscillators typically perform frequency translation as required by the transceiver during signal transmission and reception. The challenge here is to design oscillators that meet the strict requirements imposed by different wireless standards. For example, the new IEEE 802.11a standard WLAN operates at 5.15 to 5.35 GHz and 5.725 to 5.875 GHz bands, with maximum data rates of 54 Mbps. Bluetooth on the other hand, operates at frequencies ranging from 2.4 to 2.4835GHz with data rates of 720 Kbps. On top of this are the general requirements for oscillators to be low cost, have low power consumption, small in size, multi-band (tunability) capabilities and silicon-compatible. This results in large chip area and high power requirement to allow multi-band/mode function. Area optimization and maximum block reusability for multiple mode of operation are the main challenges for System-on-Chip wireless transceiver designs (van Der Tang et al., 2003). One of the proposed solutions to this problem is to design an adaptive or reconfigurable RF circuit (Okada et al., 2005; Tasic et al., 2007; Yoshihara et al., 2004).

As shown in Figure 1, the local oscillator (LO) is a key component in a transceiver which generates a carrier signal (sinusoidal signal) as described in (1), from no input signal other than the dc bias. The LO input to the mixer allows the incoming RF signals to be downconverted to a lower frequency (kHz), which relaxes the complexity of

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