MULTI-BAND / WIDE-BAND FREQUENCY GENERATORS FOR SPECTRUM-AGILE RADIO AND FUTURE MILLIMETER-WAVE APPLICATIONS

By

Burak Çatlı

An Abstract of a Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: ELECTRICAL ENGINEERING

The original of the complete thesis is on file
in the Rensselaer Polytechnic Institute Library

Examining Committee:

Mona Mostafa Hella, Thesis Adviser
Gary Saulnier, Member
Tong Zhang, Member
Diana-Andra Borca-Tasciuc, Member

Rensselaer Polytechnic Institute
Troy, New York

December 2009
(For Graduation December 2009)

ABSTRACT

System-on-chip (SOC) reconfigurable radio for multi-band/multi-mode operation has been a long term goal for consumer and military applications. The concept of Cognitive Radio (CR) has also recently emerged as an umbrella term for systems that can adapt to changing conditions to dynamically use the spectrum in an opportunistic manner. These future communication devices will not only support applications ranging from text, telephony, graphics, and video, but they will also have to maintain connections with many other devices in a variety of environments. The multiple functional requirements for next generation communication systems will require flexible, low power, and frequency-agile RF transceivers that are viewed as the foundation of future radios in its most extreme form of a radio that can jump in and out of any band and any operating mode. The expected wave of wireless standards and applications in the coming decade will focus on (1) mm-wave for ultra high data rate communication and (2) opportunistic communication devices or cognitive radio wave for efficient use of the spectrum rather than the current practice of licensed bands.

This thesis entails the investigation of new design techniques that enhance the performance (power consumption, size, functionality) of multi-band RF integrated circuits. The objective of this work is to address the challenges and limitations of frequency generation circuits in general, and develop new architectures targeting multi-band and very high speed standards. The techniques proposed within the context of this work would ultimately serve future spectrum-agile applications (software defined radio and cognitive radio) as well as mm-wave radios.

To address the challenges in the generation of multiband reference generation, two different multiband frequency generation techniques are proposed and demonstrated experimentally. The proposed transformed based dual band oscillator is implemented in a 0.25μm CMOS technology and covers the bands from 1.94 to 2.55 GHz at low-band and from 3.6 to 4.77 GHz at high-band, while the oscillator based on the band-limited negative resistance is implemented in a GaAs BiFET technology

operates at 2.1 GHz and 3.9 GHz. The main contribution of the proposed techniques is the elimination of the switch from band-switching mechanism, which extend the use of the proposed techniques to the mm-wave band.

In order to meet the wideband operation requirement of 60 GHz ISM band, a mm-wave frequency synthesizer architecture is proposed to address the limitations of narrow band mm-wave frequency synthesizers. Harmonic oscillators with the emphasis on n-push operation is investigated to support the proposed architecture and address various mm-wave design challenges such as low quality factor of integrated passives and strict LC budgets. A 30 GHz triple-push oscillator is implemented in a 0.13μm CMOS technology to test the feasibility of n-push oscillators on silicon with the highest harmonic rejection performance measured to the date among integrated n-push oscillators. The second triple-push oscillator is developed to cover the 60 GHz ISM band. The measured 60 GHz triple-push VCO covers a range from 55 GHz to 65 GHz leaving some margins at both ends of ISM band to guarantee the coverage of 7GHz ISM band over PVT variations. This study demonstrates a combined VCO/divider (C-VCO/D) and is important in terms of the feasibility of a frequency synthesizer architecture that does not employ an injection locked frequency divider, which is the major bottleneck in the realization of wide-band frequency synthesizer. Finally, in order to show the applicability of the C-VCO/D to a mm-wave frequency synthesizer, a 60 GHz CMOS frequency synthesizer example is given and simulation results are presented.