Methods and Techniques for Improving Figure of Merit for Wide Tuning Range Quadrature Voltage Controlled Oscillators

ABSTRACT

Next generation wireless devices will be required to support a wide variety of commercial standards and operate over a wide range of frequency bands. Two examples that are already receiving a lot of attention are software-defined and cognitive radios. Therefore, components that are capable of operating over ultra-wide frequency ranges are required. Quadrature oscillators are a major component in any communication system. They are often needed in RF transceivers to support spectrally efficient modulation techniques. Furthermore, modern telecommunication standards require very low phase noise oscillators and because of their outstanding noise performance, *LC*-oscillators are a popular choice. Hence, a lot of effort has been invested in studying and improving the figure of merit (FOM) of wide tuning range *LC*-Quadrature voltage controlled oscillators (QVCO). So far this effort has been primarily focused on three areas, expanding the tuning range, improving phase noise performance, and reducing the power consumption. Although many techniques have been proposed and used successfully in the literature, a lot of them lack sufficient theoretical analysis.

First, the recently proposed, inductive current tuning methodology for expanding the tuning range of QVCOs beyond capacitive-tuning-only is fully analyzed. In addition, a new low phase noise architecture that employs a current tuning technique is proposed. The phase noise, tuning range, and power consumption of two existing architectures and the proposed one are compared. The three designs are simulated and their FOMs are calculated and compared to identify the highest FOM architecture.

Next, a popular architecture that is being utilized in the recent literature for the purpose of improving phase noise and expanding the tuning range, the transformer-based (T-based) oscillator, is analyzed. Linear time variant analysis is used to derive a new $1/f^2$ phase noise expression for the T-based oscillators that is distinct from the commonly used expression for the inductor-based (L-based) oscillators. The new analysis allows for new techniques to optimize the FOM of T-based oscillators through improving the phase noise performance. An oscillator that is implemented in a commercially available 130 nm technology is used to demonstrate these techniques.

Finally, the FOM of an optimized QVCO that combines the use of transformer and inductive current tuning is compared to an inductively tuned L-based QVCO. In addition to the higher FOM, T-based QVCO proves to be more stable than L-based QVCO. A full analysis of stability and tuning range of both oscillators is presented and verified through simulations using inductor models extracted using ADS momentum.