Design of Miniaturized On-Chip Passive Circuits in Silicon-Based Technology for 5G Communications

by Zeyu Ge

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Certificate of Authorship/Originality

CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Zeyu Ge declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Faculty of Engineering & IT at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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Abstract

In any given wireless communication system, the RF filter is an indispensable device. This is especially true for the RF front-end module, which is designed to process the selecting frequency band for different RF signals, and reduce any spurious items in the transmitter and receiver chain and interference signals outside the whole transceiver system. As far as on-chip filtering solutions are concerned, recently devised solutions mainly concentrate on different types of semiconductor processes, namely gallium arsenide (GaAs), and silicon-based ones, such as CMOS and silicon germanium (SiGe). In this research, some fundamental design challenges, especially device miniaturization, will be fully addressed through some novel design methodologies. To explain the low-cost requirements for both prototyping and mass production, a silicon-based technology is used. Consequently, the designs presented in this thesis may be suitable for some high-performance on-chip transceiver systems. In this thesis, designed miniaturized on-chip passive filters in silicon-based technology will be presented. Both BSF and BPFs are implemented and characterized in the mm-wave frequency region. Three unique design approaches will be presented.

The first approach is used to design an on-chip absorptive BSF in a 0.13-μm complementary metal-oxide-semiconductor CMOS technology. Taking advantage of metal stack-up provided in this technology, this design utilizes a two-path transversal configuration in a multi-layer structure. It consists of a direct transmission line (TL) for the main path and two lossy edge-grounded spiral-shaped resonators. The TL is implemented in the top-most metal layer, namely TM2, while the resonators are implemented in a layer below TM2, known as TM1. They are coupled with each other through a broadside-coupled structure. Using this approach, a 24.5-GHz BSF is designed and it has a 10-dB-attenuation-referred absolute bandwidth of 1.54 GHz and maximum attenuation 23.1 dB. The maximum power attenuation level in the pass band region is 0.95 dB at 60 GHz and the size excluding pads is 0.316 × 0.12 mm^2. A good

agreement between simulated and measured results is obtained. The performance of this design can be considered for some systems which are isolator-less mm-wave transceivers.

The second approach serves to design a wideband BPF also based on a broadside-coupled structure. The design strategy for this work is that a highpass-type filtering response is obtained through a structure that is implemented by TM2, and an upper stopband frequency response is achieved by the bottom layer when the two structures are coupled. Consequently, a composite overall quasi-elliptic-type wide-band BPF functionality can be obtained. Using this approach for BPF design, a wideband 34.5-GHz BPF is devised. It has a 3-dB absolute bandwidth equal to 21.1 GHz and the minimum in-band insertion loss is 1.6 dB which is 0.264×0.124 mm^2 in size. This design is suitable for miniaturized broad-band RF transceivers when compared with previously published literature.

The final part of this work is an investigation of wideband BPF design using 3-D lumped inductors. In contrast to conventional studies that have been published in the literature, the approach presented here utilizes parasitic capacitances from the implemented 3-D inductor to introduce a transmission-zero (TZ) at upper stopband. For the purpose of proof-of-concept, a BPF prototype is designed and implemented. The on-wafer measurements show that the designed filter operates at center frequency with a 68.5% 3-dB bandwidth. Due to the proposed 3-D inductors, the overall size of the prototype excluding measurement pads is only 0.054 mm^2.