MINIATURIZED ON-CHIP PASSIVE DEVICES FOR MILLIMETRE-WAVE APPLICATIONS IN BI-CMOS TECHNOLOGY

by
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Dissertation submitted in fulfilment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

under the supervision of

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January 2019

ABSTRACT

Recent advances in silicon-based integrated circuits (ICs) have successfully demonstrated promising system-on-chip (SoC) solutions to support micro- and millimeter-wave (mm-wave) applications. As the end of Moore's Law is approaching, the full potential of active devices is eventually going to be reached. The technical advancement of these emerging technologies can further push through the introduction of alternative equivalent scaling techniques such as the implementation of new design geometries. As the interest in the mm-wave band grows, circuit miniaturization is faced with a unique set of challenges and constraints. In this work, we looked at the growing potential of monolithic integration to design high-performance transceiver system building blocks.

This thesis presents a passive inspired implementation of resonator and bandpass filters designed, and fabricated using IHP 0.13 μm SiGe Bi-CMOS process. Two unique miniaturization design methodologies are presented in this work. In order to fully demonstrate the insight of this approach, a simplified equivalent LC-circuit model is used for theoretical analysis. Using the analyzed results as a guideline along with a full-wave electromagnetic (EM) simulator, two compact bandpass filters (BPFs) are implemented and designed for mm-wave applications.

The first design methodology is a folded-strip-line-based design. The proposed method is based on a planar structure in which neither broadside coupling nor crossover between metals is required. Only a single metal layer is used to implement a compact resonator. To demonstrate its flexibility a

BPF is designed. The 1st BPF has one transmission zero at 58 GHz with a peak attenuation of 23 dB. The center frequency of this filter is 27 GHz with an insertion loss of 2.5 dB, while the S_{11} is better than 10 dB from 26 to 31 GHz. The 2nd BPF has two transmission zeros, and a minimum insertion loss of 3.5 dB is found at 29 GHz. The S_{11} is better than 10 dB from 26 GHz to 34 GHz. Also, more than 20 dB stop-band attenuation is achieved from DC to 20.5 GHz and from 48 GHz to 67 GHz. The chip sizes of these two BPFs, excluding the pads, are only 0.023 mm^2 and 0.028 mm^2, respectively.

The second methodology is designed with ultra-wideband and low insertion loss. The proposed approach uses merely a combination of meander-line structures with metal-insulator-metal (MIM) capacitors. For the 1st BPF, the return loss is better than 10 dB from 13.5 to 32 GHz, which indicates a fractional bandwidth of more than 78%. Also, the minimum insertion loss of 2.3 dB is achieved within the frequency range from 17 GHz to 27 GHz, and the in-band magnitude ripple is less than 0.1 dB. The chip size of this design, excluding the pads, is 0.148 mm^2. To demonstrate a miniaturized design, a 2nd design example is given. The return loss is better than 10 dB from 17.3 to 35.9 GHz, which indicates a fractional bandwidth of more than 70%. Also, the minimum insertion loss of 2.6 dB is achieved within the frequency range from 21.4 GHz to 27.7 GHz, and the in-band magnitude ripple is less than 0.1 dB. The chip size of the 2nd design, excluding the pads, is only 0.066 mm^2.

The overall performances of both proposed structures are suitable for miniaturizing design in silicon-based technology. The presented design can be useful to co-design with active devices. As compared to the previously published literature, the presented design in this thesis offer a promising solution in scaling down the physical size of the passive component.

CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This research is supported by Endeavour Postgraduate Scholarship.

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Date: May 10, 2019

ACKNOWLEDGMENTS

First, I would like to acknowledge the Endeavour Postgraduate Scholarship administered by the Australian Government Department of Education and Training for the generous support throughout my Ph.D. program.

I would like to express my sincere gratitude to my supervisor Prof. Eryk Dutkiewicz, who has been very supportive of all my endeavors in research-related and professional/social involvements. For the motivation, and providing me with the opportunity to expand my knowledge in a significant way and allowing me to grow as a researcher. My sincere appreciation also to my co-supervisor Dr. Forest Zhu, for his insightful comments, valuable inputs, and encouragement. For sharing his knowledge and expertise. I could not have imagined having a better supervisor/co-supervisor and mentors for my Ph.D. program.

I would like to thank my case managers from Scopeglobal for the monthly updates and for making sure that I can achieve the professional and academic objectives of my program.

Special thank you to all my wonderful colleagues and friends for their warm encouragement and beautiful friendship.

Also, my deepest gratitude to my family. My beloved parents, Francisco, and Myrle Bautista, my two loving sisters, Melanie Giselle and Mylene Grace, my brother-in-law Julius and my niece Juliene Kate for their unconditional love and support throughout my studies and life in general.

And above all, to Almighty God for the guidance and wisdom.

Dedicated to My Beloved Parents

Francisco and Myrle Bautista

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- **Meriam Gay Bautista**, , He Zhu, Xi Zhu, Yang Yang, Yichuang Sun, and Eryk Dutkiewicz "Compact Millimeter-Wave Bandpass Filter Using Quasi-lumped Elements in 0.13μm (Bi)-CMOS Technology for 5G Wireless Systems," in *IEEE Transactions on Microwave Theory and Techniques: Special Issue on 5G Hardware and System Technologies* (recently accepted - 4th-Jan.2019) (Corresponding to Chapter 3 and 4)

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