



شبكة المعلومات الجامعية
التوثيق الإلكتروني والميكروفيلم

بسم الله الرحمن الرحيم



MONA MAGHRABY



شبكة المعلومات الجامعية
التوثيق الإلكتروني والميكرو فيلم



شبكة المعلومات الجامعية التوثيق الإلكتروني والميكرو فيلم



MONA MAGHRABY



شبكة المعلومات الجامعية
التوثيق الإلكتروني والميكروفيلم

جامعة عين شمس

التوثيق الإلكتروني والميكروفيلم

قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها
علي هذه الأقراص المدمجة قد أعدت دون أية تغيرات

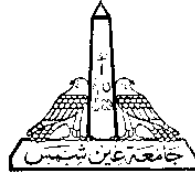


يجب أن

تحفظ هذه الأقراص المدمجة بعيدا عن الغبار



MONA MAGHRABY



AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Electronics Engineering and Electrical Communications

MILLIMETER-WAVE SILICON BASED FRONT-ENDS FOR WIRELESS COMMUNICATION

A Thesis submitted in partial fulfillment of the requirements of the degree of

Master of Science in Electrical Engineering

(Electronics Engineering and Electrical Communications)

by

Yousri Abozaid Mohamed Ahmed

Bachelor of Science in Electrical Engineering

(Electronics Engineering and Electrical Communications)

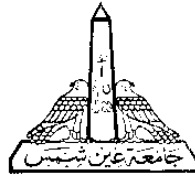
Faculty of Engineering, Ain Shams University, 2014

Supervised By

Prof. Mohamed Amin Ebrahim Dessouky

Dr. Mohamed Ahmed Mohamed El - Nozahi

Cairo - (2021)



AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Electronics and Communications

MILLIMETER-WAVE SILICON BASED FRONT-ENDS FOR WIRELESS COMMUNICATION

by

Yousri Abozaid Mohamed Ahmed

Bachelor of Science in Electrical Engineering

(Electronics Engineering and Electrical Communications)

Faculty of Engineering, Ain Shams University, 2014

Examiners' Committee

Name and Affiliation

Signature

Prof. Mohamed Amin Ebrahim Dessouky
Electronics Engineering and Electrical Communications
Faculty of Engineering, Ain Shams University

.....

Prof. Hani Fikry Ragai
Electronics Engineering and Electrical Communications
Faculty of Engineering, Ain Shams University

.....

Dr. Mohamed Ahmed Mohamed El – Nozahi
Electronics Engineering and Electrical Communications
Faculty of Engineering, Ain Shams University

.....

Prof. Ahmed Nader Mohieldin
Electronics Engineering and Electrical Communications
Faculty of Engineering, Cairo University

.....

Date: 29 August 2021

Statement

This thesis is submitted as a partial fulfilment of Master of Science in Electrical Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

Student name

Yousri Abozaid Mohamed Ahmed

Signature

.....

Date:29 August 2021

Researcher Data

Name	: Yousri Abozaid Mohamed Ahmed
Date of birth	: 02/11/1992
Place of birth	: Cairo, Egypt
Last academic degree	: B.Sc. in Electrical Engineering
Field of specialization	: IC Design
University issued the degree	: Ain Shams University
Date of issued degree	: 2014
Current job	: IC Design Engineer

Abstract

Fifth generation (5G) is the next mobile communication standard that will support higher data rates, higher spectrum efficiency, reliability, and lower latencies. Currently, demanding frequency bands for mm-wave 5G are at 24.25-27.5 GHz, 28 GHz, and 39 GHz. Building wideband beamformers/transceivers to cover the entire mm-wave 5G frequency bands from 24 GHz to 47 GHz is appealing for the next generation systems. Such wideband systems require the design and development of wideband or tunable components to achieve the desired performance. Those components include switches, low noise amplifiers, power amplifiers...etc.

The thesis presented a tunable resonant multiband T/R switch designed and fabricated in 45nm SOI CMOS to cover the frequency band from 24 GHz to 47 GHz allocated for 5G. The proposed tunable switch relied on changing the number of stacked devices that are on. The proposed switch was implemented and fabricated using 45 nm SOI technology and it consumed an area of 0.05 mm². Measurement results showed low insertion loss of minimum value of 0.8 dB with high linearity achieved in the TX path.

Also, the thesis presented a linearized low-noise amplifier (LNA) is proposed and fabricated in 45nm SOI CMOS. The LNA covers the frequency band from 32 GHz to 49 GHz. A linearization circuit is proposed to boost the Linearity IIP3. The LNA occupies an area of 0.25 mm². The LNA achieves a gain of 18.7 dB, noise figure in the range of 2.8-3.8 dB, a peak value of IIP3 at 3.5 dBm at 38.5 GHz. The LNA consumes 15 mW from a 1.25 V supply.

Thesis Summary

The thesis is divided to five chapters as listed below, Chapter 1

In this chapter, an introduction about the 5G communication system is presented. Finally, the organization of the thesis is briefly discussed.

Chapter 2

Chapter 2 gives a sufficient background of beamforming architectures with corresponding used blocks. Then, a prior art of the T/R switch and linearization techniques for LNA and the drawbacks of these topologies are presented. Finally, the used technology node is presented.

Chapter 3*

Chapter 3 discusses the RF T/R switches. A new proposed tunable multiband T/R switch design is proposed in order to mitigate the drawbacks and achieve wideband operation. The theory is carried to design a T/R switch operating at 24-47 GHz band using 45nm SOI CMOS technology. A comparison is performed with the state-of-the-art switches.

Chapter 4

Chapter 4 discusses the linearization of low noise amplifier (LNA). A new proposed linearized LNA design is proposed to mitigate the drawbacks. The theory is carried to design a LNA operating at 32-49 GHz band using 45nm SOI CMOS technology. A comparison is performed with the state-of-the-art LNAs.

Chapter 5

In chapter 5, the thesis is summarized where the main contributions are high-

lighted. In addition, possible future research directions are suggested.

Key words: Millimeter-wave; Front-Ends; Wireless Communication; Satellite; 5G Mobile Communication; RF switches; Linearization; LNA.

* The proposed tunable multiband T/R switch was published in IEEE microwave and wireless components letters (2021).

Acknowledgements

First of all, I thank GOD for granting me the patience, strength and ability to complete this work. I wish to express my sincere gratitude to my supervisors, Dr. Mohamed El-Nozahi and Prof. Mohamed Dessouky, for their encouragement, and useful discussions. Dr. Mohamed El-Nozahi deserves many special thanks. Without his guidance, and advice, this work wouldn't have been possible. I have learnt from him not only on the technical level but also on the personal one and he changed my thinking to a higher level. I would like to thank Prof. Mohamed Dessouky, who has taught me devotion to work. Special thanks to all my colleagues and friends for the many fruitful discussions. Many thanks goes to Professor Hany Fekri and Professor Ahmed Nader for serving as my defense committee members and taking parts from their valuable time to read and judge my thesis work. Many thanks goes to Ahmed Aboalseoud for helping me out with testing the fabricated parts. Thanks to ADI for supporting the fabrication of the designed blocks. Finally, I would like to thank my wife for her long patience and support. Also want to thank my mother, family for their patience, care, and love that guided me through the whole journey.

Yousri Abozaid Mohamed Ahmed

July 2021

Table of Contents

Abstract	i
Thesis Summary	ii
Acknowledgements	iv
Table of Contents	v
List of Tables	ix
List of Figures	x
List of Abbreviations	xvi
List of Symbols	xvii
1 INTRODUCTION	1
1.1 Evolution Of Wireless Communication	1
1.1.1 Fifth Generation (5G)	1
1.2 Thesis Challenges	5
1.3 Thesis Contributions	5
1.4 Thesis Organization	5
2 LITERATURE REVIEW	7

2.1	The Concept of Beamforming	7
2.1.1	Different Beamforming Techniques	7
2.1.1.1	Analog Beamformers	8
2.1.1.2	Digital Beamformers.....	10
2.1.1.3	Hybrid Beamformers	11
2.1.2	Antenna Array Size	11
2.2	T/R Switches	13
2.2.1	T/R Switches Prior Art	15
2.2.1.1	Series-Shunt T/R SPDT Switch Topology	15
2.2.1.2	Resonant T/R SPDT Switch Topology	15
2.2.1.3	$\lambda/4$ Transmission Line Based SPDT T/R Switch Topology.	16
2.2.1.4	Asymmetric SPDT T/R Switch Topology.....	17
2.3	Linearization Techniques of LNA	20
2.3.1	LNA Linearization Techniques Prior Art	21
2.3.1.1	Feedback.....	21
2.3.1.2	Harmonic Termination Technique.....	25
2.3.1.3	Optimal Biasing	27
2.3.1.4	Feedforward	28
2.3.1.5	Derivative Superposition (DS).....	30
2.3.1.6	IM2 Injection	31
2.3.1.7	Noise/Distortion Cancellation	32

2.3.1.8	Post Distortion.....	33
2.4	45RFSOI Technology Node Selection	36
2.5	Summary.....	37
3	24-47 GHZ MULTIBAND T/R SWITCH	38
3.1	Basic Principles in T/R Switch Design.....	39
3.1.1	NMOS Device Model	39
3.1.2	Insertion Loss	41
3.1.3	Device Linearity (IP3).....	41
3.2	Proposed 24-47 GHz Multiband T/R Switch Design	43
3.3	Multiband T/R Switch Schematics and Layouts.....	45
3.3.1	Schematics.....	45
3.3.2	Layouts.....	51
3.4	Simulated And Measured Results.....	52
3.5	Summary.....	60
4	32-49 GHZ LINEARIZED LNA	61
4.1	LNA Main Performance Parameters.....	61
4.2	Current Density Of The Device	62
4.3	Proposed 32-49 GHz Linearized LNA	64
4.4	Analysis Of The Propsed LNA.....	64
4.4.1	Input Matching.....	64

4.4.2	Gain Qualitative Analysis.....	68
4.4.3	Noise Figure.....	69
4.4.4	Proposed Linearizer Circuit	70
4.5	32-49 GHz Linearized LNA Layouts	72
4.6	Post-layout Simulations	75
4.7	Simulated And Measured Results.....	77
4.8	Summary.....	80
5	CONCLUSION AND FUTURE WORK	81
5.1	Conclusion	81
5.1.1	24-47 GHz Resonant Multiband T/R switch	81
5.1.2	32-49 GHz Linearized LNA	82
5.2	Future Work	82
5.3	Summary.....	82
	List of Publications	83
	References	85