



بسم الله الرحمن الرحيم

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# **MM-WAVE POWER AMPLIFIERS FOR 5G APPLICATIONS AND DIFFERENT POWER COMBINING TECHNIQUES**

By

**Mohamed Alaa Elgamal**

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
in Partial Fulfillment of the  
Requirements for the Degree of  
**MASTER OF SCIENCE**  
in  
**Electronics and Communications Engineering**

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Under the Supervision of

**Dr. Mohamed A. Y. Abdalla**

Assistant Professor  
Electronics and Communications Engineering  
Faculty of Engineering , Cairo University

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Approved by the Examining Committee:

---

**Dr. Mohamed A. Y. Abdalla,**

**Thesis Main Advisor**

---

**Prof. Ahmed N. Mohieldin,**

**Internal Examiner**

---

**Prof. Mohamed A. El-Nozahi,**

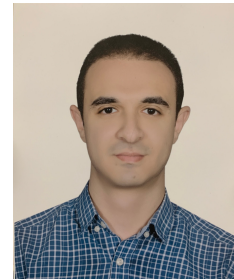
**External Examiner**

Associate Professor

Faculty of Engineering, Ain Shams University

FACULTY OF ENGINEERING ,CAIRO UNIVERSITY  
GIZA,EGYPT  
2022

**Engineer's Name:** Mohamed Alaa Elgamal  
**Date of Birth:** 21/12/1994  
**Nationality:** Egyptian  
**E-mail:** mohamed.alaa.elgamal@gmail.com  
**Phone:** +20 1119082892  
**Address:** 14 Mahmoud Zaky St., Helwan, Cairo  
**Registration Date:** 1/3/2018  
**Awarding Date:** --/2022  
**Degree:** Master of Science  
**Department:** Electronics and Communications Engineering



**Supervisors:**

**Dr. Mohamed A. Y. Abdalla**

**Examiners:**

**Dr. Mohamed A. Y. Abdalla** (Thesis main advisor)  
**Prof. Ahmed N. Mohieldin** (Internal examiner)  
**Prof. Mohamed A. El-Nozahi** (External examiner)  
Associate Professor  
Faculty of Engineering, Ain Shams University

**Title of Thesis:**

**mm-Wave Power Amplifiers for 5G Applications and Different Power Combining Techniques**

**Key Words:**

Power Amplifiers; Power combining; 5G; Beamformers

**Summary:**

Design trade-offs and challenges facing 5G power amplifiers are presented in this work. Different power amplifier classes are compared for 5G applications. Stacking transistors and Combining multiple power cells are discussed as a solution to achieve higher power levels without sacrificing efficiency or over-stressing the amplifier. Various properties of different power combining techniques like efficiency and impedance transformation are analyzed in depth and proper design guidelines are provided. The design of a fully differential two-stage two-way current combining power amplifier with an integrated transformer-based balun fabricated using CMOS technology to cover both n260 39GHz 5G (37G to 40GHz) and n259 41GHz 5G (39.5G to 43.5GHz) bands is discussed and the measurement results are presented.

# Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

Name: Mohamed Alaa Abdelaziz Mejahed Elgamal

Date:    /    / 2022

Signature:

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# List of Symbols and Abbreviations

| Abbreviation | Description                        |
|--------------|------------------------------------|
| 5G           | 5th Generation                     |
| FM           | Frequency Modulated                |
| FDMA         | Frequency Division Multiple Access |
| CDMA         | Code Division Multiple Access      |
| RF           | Radio Frequency                    |
| TX           | Transmitter                        |
| Rx           | Receiver                           |
| PA           | Power Amplifier                    |
| LNA          | Low Noise Amplifier                |
| VGA          | Variable Gain Amplifier            |
| VM           | Vector Modulator                   |
| TL           | Transmission Line                  |
| PS           | Phase Shifter                      |
| IL           | Insertion Loss                     |
| RL           | Return Loss                        |