

# MICROWAVE TRANSISTOR AMPLIFIERS

*Analysis and Design*



SECOND EDITION

Guillermo Gonzalez

# Microwave Transistor Amplifiers Analysis And Design 2nd Edition International Edition

**George D. Vendelin,Anthony M.  
Pavio,Ulrich L. Rohde**



## **Microwave Transistor Amplifiers Analysis And Design 2nd Edition International Edition:**

*Practical RF Circuit Design for Modern Wireless Systems* Rowan Gilmore, Les Besser, 2003 A practical approach to RF circuit design this volume covers nonlinear circuits and modelling RF transistor amplifiers oscillators and mixers

*HF-Leistungsverstärker in modernen Silizium- und Verbindungshalbleitern-Technologien* Daniel Gruner, 2012-11-01  
Kurzbeschreibung Diese Dissertation beschäftigt sich mit HF Leistungsverstärkern auf Basis moderner Transistortechnologien und verfolgt aktuelle Trends im Bereich Silizium und III V Verbindungshalbleiter Dies umfasst den Entwurf von innovativen HF Leistungstransistoren und Verstärker Aspekten zur Charakterisierung und Aufbautechnik sowie den Vergleich zum aktuellen Stand von Wissenschaft und Technik Im ersten Teil richtet sich der Fokus auf MMIC Leistungsverstärker für 5,6 GHz WLAN Anwendungen Hierbei wird zunächst auf den Entwurf eines Push Pull PAs in einer 0,25 µm BiCMOS Technologie eingegangen Mit einer Betriebsspannung von lediglich 1,8 V zeigt dieser Verstärker ein breitbandiges Verhalten und erreicht im Frequenzbereich 5,6-6,2 GHz eine Sättigungsleistung von 24 dBm Der maximale Wirkungsgrad liegt bei 27 % PAE 18 % mit einer Verstärkung von typischerweise 9 dB Um diese Performance weiter zu verbessern wird eine innovative Transformer Combining Topologie vorgestellt Im Vergleich zum Push Pull Verstärker kann diese eine erhöhte Verstärkung 12 dB sowie einen exzellenten PAE Maximalwert von 23 % bei sonst ähnlichen Eigenschaften erzielen Als zweite Zielstellung wird die Steigerung der HF Leistungs Performance innerhalb moderner Bi CMOS Technologien verfolgt In diesem Rahmen stehen die Analyse der Entwurf und die Evaluierung von LDMOS Transistoren für Anwendungen bis in den 6 GHz Bereich im Mittelpunkt Der Einfluss von Transistorgröße und Geometrie sowie auch der Stabilitätsnetzwerke wird unter Verwendung HF optimierter LDMOS Strukturen untersucht Die Evaluierung der Source Load Load Pull Messungen wird mit Hilfe mehrerer hybrider Verstärkermodule durchgeführt Als eine der ersten Veröffentlichungen kann diese Arbeit eine 6 GHz LDMOS Implementation in einer Standard BiCMOS Technologie mit einer Ausgangsleistung von mehr als 1 W und einem Wirkungsgrad über 40 % demonstrieren Der dritte Teil beschäftigt sich mit GaN Doherty Verstärkern für das 6 GHz Band Die Kombination von Doherty Konzept mit Strategien zur Harmonischen Terminierung einem auf Device Referenzebene optimierten Entwurf und der entwickelten Chip Wire Aufbautechnik erlaubt die Realisierung von einem der ersten 6 GHz Doherty Verstärker mit exzellenter Wirkungsgrad Leistungs sowie Linearitäts Performance Unter Verwendung zweier GaN Chip Transistoren kann eine maximale Ausgangsleistung von 41,5 dBm mit einem maximalen Wirkungsgrad von 63 % erreicht werden Im 6 dB Backoff Punkt wird dabei ein exzellenter Wirkungsgrad von 49 % erzielt Description This work focuses on RF power amplifiers based on modern transistor technologies and investigates current trends in silicon as well as III V semiconductors This includes the design of innovative RF power devices and amplifiers characterization and assembling techniques as well as the comparison to other state of the art achievements The first part focuses on MMIC power amplifiers for WLAN applications in the 5,6 GHz range Based on a 0,25 µm BiCMOS technology a low voltage push pull power amplifier

using integrated transformers is presented. At a supply voltage of 1.8 V, this fully integrated amplifier achieves a wideband performance showing a maximum output power of 24 dBm across 5.6–2 GHz. A maximum efficiency of 27 % PAE, 18 % is obtained with a small signal gain of typically 9 dB. To further improve this performance, an innovative transformer combining topology is developed. Compared to the push-pull amplifier, this topology achieves an increased gain of 12 dB and an enhanced maximum PAE of up to 23 % with otherwise similar characteristics, showing state-of-the-art performance. The RF power enhancement of Bi-CMOS technologies is a second major aim of this work. In this context, the analysis, design, and evaluation of medium-voltage LDMOS FETs for wireless applications up to 6 GHz is presented. Using RF-optimized NLDMOS transistors, power devices of different sizes were fabricated in a standard 0.25- $\mu$ m BiCMOS technology. The influences of the finger geometry and the stabilization networks on the RF performance are studied. Power evaluation of the LDMOS transistors is carried out by means of hybrid power amplifier modules. As one of the first contributions, this work shows a 6 GHz LDMOS implementation in a standard BiCMOS technology that achieves an output power of greater than 1 W with a drain efficiency of more than 40 %. In the third part, a harmonically tuned GaN Doherty amplifier targeted for vehicular applications at 6 GHz is presented. The combination of the Doherty concept with harmonic tuning strategies, an optimized design approach, and the developed chip-wire assembly technology results in one of the first Doherty amplifiers implemented for the 6 GHz frequency range with excellent efficiency, output power, and linearity performance. Using two bare-die GaN devices, a maximum output power of 41.5 dBm with 63% peak drain efficiency is obtained. At 6 dB output power back-off, an excellent drain efficiency of still 49 % can be achieved.

**The Electrical Engineering Handbook, Second Edition**

Richard C. Dorf, 1997-09-26. In 1993, the first edition of *The Electrical Engineering Handbook* set a new standard for breadth and depth of coverage in an engineering reference work. Now, this classic has been substantially revised and updated to include the latest information on all the important topics in electrical engineering today. Every electrical engineer should have an opportunity to expand his expertise with this definitive guide. In a single volume, this handbook provides a complete reference to answer the questions encountered by practicing engineers in industry, government, or academia. This well-organized book is divided into 12 major sections that encompass the entire field of electrical engineering, including circuits, signal processing, electronics, electromagnetics, electrical effects and devices, and energy, and the emerging trends in the fields of communications, digital devices, computer engineering, systems, and biomedical engineering. A compendium of physical, chemical, material, and mathematical data completes this comprehensive resource. Every major topic is thoroughly covered, and every important concept is defined, described, and illustrated. Conceptually challenging but carefully explained articles are equally valuable to the practicing engineer, researchers, and students. A distinguished advisory board and contributors, including many of the leading authors, professors, and researchers in the field today, assist noted author and professor Richard Dorf in offering complete coverage of this rapidly expanding field. No other single volume available today offers this

combination of broad coverage and depth of exploration of the topics The Electrical Engineering Handbook will be an invaluable resource for electrical engineers for years to come     High Frequency and Microwave Engineering Ed da Silva,2001-03-15 With the increased use of mobile phones and computer wireless techniques a need has developed for a book which provides students and industry with expertise in radio and microwave engineering This important text has been written with these aims in mind Provides a comprehensive course in radio and microwave engineering Includes CD ROM containing the CAD package PUFF 2 1 for construction and evaluation of circuits and a comprehensive section on practical aspects of design Written by an experienced author in a clear and easy to follow style Contains a variety of examples and self test questions with model answers The material covers transmission lines scattering parameters couplers amplifiers oscillators and phase locked loops in a novel way by introducing examples from daily life prior to the introduction of the theory Microwave tools such as Smith charts scattering parameters and signal flow diagrams are dealt with thoroughly and are fully integrated in the numerous examples throughout the text and with PUFF High Frequency and Microwave Engineering is intended as an advanced undergraduate text for students of electrical and communication engineering and is also eminently suitable for self study and as a manual for those in the industry wishing to update their engineering skills Provides a comprehensive course in radio and microwave engineering Contains many examples and self test questions with model answers     **RF / Microwave Circuit Design for Wireless Applications** Ulrich L. Rohde,Matthias Rudolph,2013-01-07 Provides researchers and engineers with a complete set of modeling design and implementation tools for tackling the newest IC technologies Revised and completely updated RF Microwave Circuit Design for Wireless Applications Second Edition is a unique state of the art guide to wireless integrated circuit design that provides researchers and engineers with a complete set of modeling design and implementation tools for tackling even the newest IC technologies It emphasizes practical design solutions for high performance devices and circuitry incorporating ample examples of novel and clever circuits from high profile companies Complete with excellent appendices containing working models and CAD based applications this powerful one stop resource Covers the entire area of circuit design for wireless applications Discusses the complete system for which circuits are designed as well as the device technologies on which the devices and circuits are based Presents theory as well as practical issues Introduces wireless systems and modulation types Takes a systematic approach that differentiates between designing for battery operated devices and base station design RF Microwave Circuit Design for Wireless Applications Second Edition is an indispensable tool for circuit designers engineers who design wireless communications systems and researchers in semiconductor technologies telecommunications and wireless transmission systems     **Antennas and Propagation for Wireless Communication Systems** Simon R. Saunders,Alejandro A. Aragón-Zavala,2024-09-11 Comprehensive resource describing both fundamentals and practical industry applications of antennas and radio propagation employed in modern wireless communication systems The newly revised and thoroughly

updated Third Edition of this classic and popular text *Antennas and Propagation for Wireless Communication Systems* addresses fundamentals and practical applications of antennas and radio propagation commonly used in modern wireless communication systems from the basic electromagnetic principles to the characteristics of the technology employed in the most recent systems deployed with an outlook of forthcoming developments in the field. Core topics include fundamental electromagnetic principles underlying propagation and antennas, basic concepts of antennas and their application to specific wireless systems, propagation measurement, modelling and prediction for fixed links, macrocells, microcells, femtocells, picocells, megacells and narrowband and wideband channel modelling with the effect of the channel on communication system performance. Worked examples and specific assignments for students are presented throughout the text with a solutions manual available for course tutors with a dedicated website containing online calculators and additional resources plus details of simple measurements that students can perform with off the shelf equipment such as their laptops and a Wi-Fi card. This Third Edition of *Antennas and Propagation for Wireless Communication Systems* has been thoroughly revised and updated, expanding on and adding brand new coverage of sample topics such as Maxwell's equations and EM theory, multiple reflections as propagation mechanisms and waveguiding, HAPS (High Altitude Platforms) propagation, design and noise considerations of earth stations, macrocell models and cellular base station site engineering, FSS (frequency selective surfaces), adaptive antenna theory, developments in massive and distributed MIMO in particular and how to process raw data related to channel measurements for mobile radio systems. The techniques used in mobile systems spanning the latest 4G, 5G and 6G technology generations. A wider range of frequencies extending from HF, VHF and UHF up to the latest millimetre wave and sub-terahertz bands. With comprehensive coverage of foundational subject matter as well as major recent advancements in the field, *Antennas and Propagation for Wireless Communication Systems* is an essential resource for undergraduate and postgraduate students, researchers and industry engineers in related disciplines.

*Hocheffiziente frequenzagile Mikrowellen-Leistungsverstärker auf Basis von Verbindungshalbleitern und Ferroelektrika* Sebastian Preis, 2019-05-28. Diese Arbeit beschäftigt sich mit dem Entwurf der Optimierung und Charakterisierung von GaN HEMT Leistungsverstärkern für Mobilfunkanwendungen. Der Fokus liegt hierbei auf steuerbaren Transformationsnetzwerken auf Basis elektronisch anpassbarer Barium Strontium Titanat (BST) Varaktoren. Dabei konnte die Leistungsverträglichkeit jener BST Varaktoren bis zu 50 W gesteigert werden verbunden mit einer guten Linearität und geringen Temperaturabhängigkeit. Dies zielte darauf den Wirkungsgrad von Leistungsverstärkern bei Leistungen deutlich unterhalb der Sättigung zu verbessern. Die so entwickelten steuerbaren Transformationsnetzwerke sind für hochintegrierte Transistormodule optimiert. Auf diese Weise lassen sich platzsparende und zuerst flexibel einsetzbare Komponenten für Hochfrequenzanwendungen realisieren. Die Transistormodule erreichen einen hohen Wirkungsgrad von bis zu 72% PAE in der Sättigung. Sie verbessern zudem die PAE bei reduzierter Leistung um mehrere Prozentpunkte gegenüber statisch angepassten Transistoren. Darüber hinaus sind sie über die Frequenz

im S Band nicht nur gut steuerbar sondern lassen sich auch durch Änderung der Steuerspannung auf optimalen Wirkungsgrad oder Linearität bei verschiedenen Leistungspegeln anpassen Auch hybride Verstärker werden vorgestellt in denen diskret aufgebaute Varaktoren verbaut sind Dank der verwendeten Modulatoren für welche ebenfalls GaN Transistoren und Dioden genutzt werden bieten die Verstärker das Potenzial zur Lastmodulation Dadurch steigt die Effizienz beim Betrieb mit modulierten Signalen Für LTE äquivalente Signale lässt sich die mittlere PAE um mehrere Prozentpunkte erhöhen ohne die Linearität in einem System mit Vorverzerrung zu belasten

**Highly Efficient CMOS Power Amplifiers at C- and S-Band for Low Supply Voltages** Jörg Carls, 2009      **Fundamentals of RF and Microwave Transistor Amplifiers** Inder

Bahl, 2009-06-17 A Comprehensive and Up to Date Treatment of RF and Microwave Transistor Amplifiers This book provides state of the art coverage of RF and microwave transistor amplifiers including low noise narrowband broadband linear high power high efficiency and high voltage Topics covered include modeling analysis design packaging and thermal and fabrication considerations Through a unique integration of theory and practice readers will learn to solve amplifier related design problems ranging from matching networks to biasing and stability More than 240 problems are included to help readers test their basic amplifier and circuit design skills and more than half of the problems feature fully worked out solutions With an emphasis on theory design and everyday applications this book is geared toward students teachers scientists and practicing engineers who are interested in broadening their knowledge of RF and microwave transistor amplifier circuit design

*CMOS Front Ends for Millimeter Wave Wireless Communication Systems* Noël Defrem, Patrick Reynaert, 2015-03-23 This book focuses on the development of circuit and system design techniques for millimeter wave wireless communication systems above 90GHz and fabricated in nanometer scale CMOS technologies The authors demonstrate a hands on methodology that was applied to design six different chips in order to overcome a variety of design challenges Behavior of both actives and passives and how to design them to achieve high performance is discussed in detail This book serves as a valuable reference for millimeter wave designers working at both the transistor level and system level

**CMOS Low Noise Amplifiers for Single and Multiband Applications: A Comprehensive Design Approach** Norlaili Mohd Noh, Farshad Eshghabadi, Arjuna Marzuki, 2023-10-11 This book provides comprehensive knowledge aimed at practicing integrated circuit design engineer or researcher to learn and design a low noise amplifier LNA for single and multiband applications The content is structured in a way so that even a beginner can follow the design method easily This book features the following characteristics different types of LNA designs with key building blocks are discussed and detailed analysis is given for each LNA design which covers from the fundamental and principal knowledge to the justification of the design approach Detailed design approaches are using 180 nm and 130nm CMOS technologies purposely presented in this manner to give exposure to the design of LNA under different technologies The LNAs in this book are designed for GSM WCDMA and WLAN standards but the same method can be used for other frequencies of operation Comprehensive analyses

on the extreme or corner condition effects are highlighted Besides detailed derivation of equations relating to the parameters of the LNA s performance metrics help LNA designers in understanding how the performance metrics of the LNA can be optimized to meet the desired specification Electromagnetic analyses using Sonnet an electromagnetic tool able to replace the conventional post layout simulation with resistance and capacitance parasitic extraction for more accurate frequency performance prediction are presented The electromagnetic method is proposed to be used in the LNA design as it can accurately predict the LNA s performance before tape out for first pass fabrication MATLAB codes are provided to generate important S parameters and noise figure values

Compressive Sensing Based Algorithms for Electronic Defence Amit Kumar Mishra,Ryno Strauss Verster,2016-12-22 This book details some of the major developments in the implementation of compressive sensing in radio applications for electronic defense and warfare communication use It provides a comprehensive background to the subject and at the same time describes some novel algorithms It also investigates application value and performance related parameters of compressive sensing in scenarios such as direction finding spectrum monitoring detection and classification

**RF and Microwave Circuits, Measurements, and Modeling** Mike Golio,Janet Golio,2018-10-08 Highlighting the challenges RF and microwave circuit designers face in their day to day tasks RF and Microwave Circuits Measurements and Modeling explores RF and microwave circuit designs in terms of performance and critical design specifications The book discusses transmitters and receivers first in terms of functional circuit block and then examines each block individually Separate articles consider fundamental amplifier issues low noise amplifiers power amplifiers for handset applications and high power power amplifiers Additional chapters cover other circuit functions including oscillators mixers modulators phase locked loops filters and multiplexers New chapters discuss high power PAs bit error rate testing and nonlinear modeling of heterojunction bipolar transistors while other chapters feature new and updated material that reflects recent progress in such areas as high volume testing transmitters and receivers and CAD tools The unique behavior and requirements associated with RF and microwave systems establishes a need for unique and complex models and simulation tools The required toolset for a microwave circuit designer includes unique device models both 2D and 3D electromagnetic simulators as well as frequency domain based small signal and large signal circuit and system simulators This unique suite of tools requires a design procedure that is also distinctive This book examines not only the distinct design tools of the microwave circuit designer but also the design procedures that must be followed to use them effectively

*Circuit Design for RF Transceivers* Domine Leenaerts,J. van der Tang,Cicero S. Vaucher,2007-05-08 Circuit Design for RF Transceivers covers key building blocks which are needed to make an integrated transceiver for wireless and cellular applications that is low noise amplifiers mixers voltage controlled oscillators RF power amplifiers and phase locked loop systems Starting from detailed RF concepts and specifications the authors discuss the circuits in detail and provide solutions to many design problems The circuits are implemented in a wide range of modern technology processes Production requirements are taken



into account and measurement results are presented and discussed Several of the presented circuits are used in IC products The text also includes several RF technologies for example double poly Silicon on Anything SiGe bipolar RF CMOS etc and microwave design techniques such as transmission line concepts In addition the problem of connecting the RF signals on chip to the PCB and to the antenna will be discussed including the influence of the package ESD and bond pads The contents of Circuit Design for RF Transceivers 2nd edition are based on research activities carried out at Philips Research Many internal and external publications contributed to make the presented material state of the art The book is written for people who have a basic knowledge of analogue IC design The second edition of this successful 2001 RF Circuit Design book has been updated latest technology reviews have been added as well as several actual case studies Due to the authors being active in industry as well as academia this should prove to be an essential guide on RF Transceiver Design for students and engineers

**Advanced Silicon MMICs for mm-Wave Automotive Radar Front-Ends** Alexander Kravets, 2015-06-12 This work presents a high linearity automotive radar front end at 77 GHz in 0.25  $\mu$ m SiGe technology The passive elements were realized using thin film microstrip lines A detailed transformer balun synthesis procedure was developed The realized passive baluns rat race and transformer show excellent commonmode rejection ratios exceeding 30 dB and low losses of 2.5 dB On the active side a low gain high linearity single stage common emitter LNA was realized The selected topology allowed finer trade off between linearity and sensitivity of the front end compared to multi stage LNA solutions For the mixer a low voltage supply high linearity low noise double balanced concept was employed It uses AC coupling between the two stages which allowed an independent optimization of transconductance core sizing and bias The transconductance was designed for best noise performance while the core was chosen for maximum linearity A high fidelity two channel receiver was realized using these circuit components which achieved a performance comparable to the published state of the art results in SiGe Single sideband noise figure better than 16.5 dB 1 dB compression point exceeding 12 dBm while consuming moderate 82 mA DC current from a 1.6 V supply for both channels

**Methoden und Techniken zur Integration von 122 GHz Antennen in miniaturisierte Radarsensoren** Stefan Beer, 2014-05-22 Die Dissertation beschreibt Methoden und Techniken zur Realisierung eines vollintegrierten Radarsensors im Frequenzbereich oberhalb von 100 GHz Der hohe Frequenzbereich ermoglicht die Integration von Antennen und einem Radar IC in ein gemeinsames Chip Geh use da die Antenne durch die Wellenlange im Millimeterbereich hnliche Abmessungen hat wie der IC selbst Durch diese Integration resultiert ein abgeschlossenes Hochfrequenzsystem innerhalb des Geh uses

**Microwave Circuit Design Using Linear and Nonlinear Techniques** George D. Vendelin, Anthony M. Pavio, Ulrich L. Rohde, 2005-10-03 The ultimate handbook on microwave circuit design with CAD Full of tips and insights from seasoned industry veterans Microwave Circuit Design offers practical proven advice on improving the design quality of microwave passive and active circuits while cutting costs and time Covering all levels of microwave circuit design from the elementary to the very advanced the book systematically presents

computer aided methods for linear and nonlinear designs used in the design and manufacture of microwave amplifiers oscillators and mixers Using the newest CAD tools the book shows how to design transistor and diode circuits and also details CAD s usefulness in microwave integrated circuit MIC and monolithic microwave integrated circuit MMIC technology Applications of nonlinear SPICE programs now available for microwave CAD are described State of the art coverage includes microwave transistors HEMTs MODFETs MESFETs HBTs and more high power amplifier design oscillator design including feedback topologies phase noise and examples and more The techniques presented are illustrated with several MMIC designs including a wideband amplifier a low noise amplifier and an MMIC mixer This unique one stop handbook also features a major case study of an actual anticollision radar transceiver which is compared in detail against CAD predictions examples of actual circuit designs with photographs of completed circuits and tables of design formulae

Analog Circuit Design Willy M.C. Sansen,Johan Huijsing,Rudy J. van de Plassche,2013-03-09 This new book on Analog Circuit Design contains the revised contributions of all the tutorial speakers of the eight workshop AACD Advances in Analog Circuit Design which was held at Nice France on March 23 25 1999 The workshop was organized by Yves Leduc of TI Nice France The program committee consisted of Willy Sansen K U Leuven Belgium Han Huijsing T U Delft The Netherlands and Rudy van de Plassche T U Eindhoven The Netherlands The aim of these AACD workshops is to bring together a restricted group of about 100 people who are personally advancing the frontiers of analog circuit design to brainstorm on new possibilities and future developments in a restricted number of fields They are concentrated around three topics In each topic six speakers give a tutorial presentation Eighteen papers are thus included in this book The topics of 1999 are X DSL and other communication systems RF MOST models Integrated filters and oscillators The other topics which have been covered before are 1992 Operational amplifiers A D Converters Analog CAD 1993 Mixed mode A D design Sensor interfaces Communication circuits 1994 Low power low voltage design Integrated filters Smart power 1995 Low noise low power low voltage design Mixed mode design with CAD tools Voltage current and time references vii viii 1996 RF CMOS circuit design Bandpass sigma delta and other data converters Translinear circuits 1997 RF A D Converters Sensor and actuator interfaces Low noise oscillators PLL s and synthesizers 1998 I Volt electronics Design and implementation of mixed mode systems Low noise amplifiers and RF power amplifiers for telecommunications

**Intermodulation Distortion in Microwave and Wireless Circuits** José Carlos Pedro,Nuno Borges Carvalho,2003 This unique new book is your single resource for all issues related to intermodulation and multi tone distortion in microwave and wireless circuits Beginning with an overview of the general concepts of distortion in microwave and wireless devices it delves into the theory and practical aspects of nonlinear distortion tools for nonlinear analysis mathematical representations of wireless circuits and devices and design methods for minimizing distortion

Microwave Active Devices and Circuits for Communication Subhash Chandra Bera,2018-12-11 The book discusses active devices and circuits for microwave communications It begins with the basics of device physics and then

explores the design of microwave communication systems including analysis and the implementation of different circuits. In addition to classic topics in microwave active devices such as p-n diodes, Schottky diodes, step recovery diodes, BJT, HBT, MESFET, HFET, and various microwave circuits like switch, phase shifter, attenuator, detector, amplifier, multiplier, and mixer, the book also covers modern areas such as Class F power amplifiers, direct frequency modulators, linearizers, and equalizers. Most of the examples are based on practical devices available in commercial markets, and the circuits presented are operational. The book uses analytical methods to derive values of circuit components without the need for any circuit design tools in order to explain the theory of the circuits. All the given analytical expressions are also cross-verified using commercially available microwave circuit design tools, and each chapter includes relevant diagrams and solved problems. It is intended for scholars in the field of electronics and communication engineering.

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