Design Of Cmos Millimeter Wave And Terahertz Integrated Circuits With Metamaterials

Build high-performance, energy-efficient circuits with this cutting-edge guide to designing, modeling, analysing, implementing and testing new mm-wave systems.

Design and Modeling of Millimeter-wave CMOS Circuits for Wireless Transceivers describes in detail some of the interesting developments in CMOS millimetre-wave circuit design. This includes the re-emergence of the slow-wave technique used on passive devices, the license-free 60GHz band circuit blocks and a 76GHz voltage-controlled oscillator suitable for vehicular radar applications. All circuit solutions described are suitable for digital CMOS technology. Digital CMOS technology developments driven by Moore's law make it an inevitable solution for low cost and high volume products in the marketplace. Explosion of the consumer wireless applications further makes this subject a hot topic of the day. The book begins with a brief history of millimetre-wave research and how the silicon transistor is born. Originally meant for different purposes, the two technologies converged and found its way into advanced chip designs. The second part of the book describes the most important passive devices used in millimetre-wave CMOS circuits. Part three uses these passive devices and builds circuit blocks for the wireless transceiver. The book completes with a comprehensive list of references for further readings. Design and Modeling of Millimeter-wave CMOS Circuits for Wireless Transceivers is useful to show the analogue IC designer the issues involved in making the leap to millimetre-wave circuit designs. The graduate student and researcher can also use it as a starting point to understand the subject or proceed to innovative from the works described herein.

Design and Analysis of Key Components for Manufacturable and Low-power CMOS Millimeter-wave Receiver Front End

Design of Millimeter-wave Power Amplifiers in SiGe (Bi) CMOS Technology

Beyond 100 GHz

Antennas, Packaging and Circuits

Design of CMOS Millimeter-Wave and Terahertz Integrated Circuits with Metamaterials

This dissertation presents the design and implementation of circuits and transceivers in CMOS technology to enable many new millimeter-wave applications. A simple approach is presented for accurately modeling the millimeter-wave characteristics of transistors that are not fully captured by contemporary parasitic extraction techniques. Next, the integration of a low-power 60-GHz CMOS on-off keying (OOK) receiver in 90-nm CMOS for use in multi-gigabit per second wireless communications is demonstrated. The use of non-coherent OOK demodulation by a novel demodulator enabled a data throughput of 3.5 Gbps and resulted in the lowest power budget (31pJ/bit) for integrated 60-GHz CMOS OOK receivers at the time of publication. Also presented is the design of a high-power, high-efficiency 45-GHz VCO in 45-nm SOI CMOS. The design is a class-E power amplifier placed in a positive feedback configuration. This circuit achieves the highest reported output power (8.2 dBm) and efficiency (15.64%) to date for monolithic silicon-based millimeter-wave VCOs. Results are provided for the

standalone VCO as well as after packaging in a liquid crystal polymer (LCP) substrate. In addition, a high-power high-efficiency (5.2 dBm/6.1%) injection locked oscillator is presented. Finally, the design of a 2-channel 45-GHz vector modulator in 45-nm SOI CMOS for LINC transmitters is presented. A zero-power passive IQ generation network and a low-power Gilbert cell modulator are used to enable continuous 360° vector generation. The IC is packaged with a Wilkinson power combiner on LCP and driven by external DACs to demonstrate the first ever 16-QAM generated by outphasing modulation in CMOS in the Q-band.

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.

Design of Millimeter-Wave CMOS K-band Quadrature Voltage-Controlled Oscillators

Cmos Millimeter-wave Integrated Circuits For Next Generation Wireless Communication Systems

Design and Analysis of Millimeter-wave CMOS Phase Shifter and Low Phase Variation Circuits

Millimeter-wave CMOS Power Amplifiers Design

Design of Microwave and Millimeter-wave CMOS VCOs

The objective of this dissertation is to develop key components of a CMOS heterodyne millimeter-wave receiver front end. Robust designs are necessary to overcome PVT variations as well as modeling inaccuracies, while with minimum power consumption overhead to facilitate low-power radio for portable applications. Heterodyne receiver topology is adopted because of its robust performances at millimeter-wave frequencies. Device models for both passive and active devices are developed and used in the circuit designs in this dissertation.\r : Two low-noise amplifiers (LNAs) are developed in this dissertation. The first LNA features a proposed temperature-compensation biasing technique, which confines the gain variation within 5 dB for temperature variation from -5 to 85 Celsius degree. The measured gain and NF are 21 and 6.5 dB, respectively, for 49-mW power dissipation. The second LNA reveals a design technique to tolerate a low-accuracy model at millimeter-wave frequencies. Both LNAs provide full coverage of the FCC 60-GHz band (57-64 GHz).\r : For the frequency generation circuits, both the IF QVCO and mm-wave VCO are investigated. The inherent bimodal oscillation of QVCOs is analyzed and, for the first time, a systematic measurement technique is proposed to intentionally control the oscillation mode. This technique is further utilized to extend the tuning range of the QVCO, which possesses dual tuning curves without penalty on phase noise. The measurement results of a 13-GHz QVCO in

90-nm CMOS reveals a 21.4% tuning range for continuously tuning from 11.7 to 14.5 GHz. The measured phase noise is -108 dBc/Hz at 1 MHz offset with a core power consumption of 10.8 mW. A millimeter-wave VCO is designed and fabricated in 65-nm CMOS. The VCO is fully characterized under voltage stress to examine the hot-carrier injection effects affecting the performance of a millimeter-wave VCO. The 41.6-47.4 GHz VCO is further integrated into a millimeter-wave down converter. The power-hungry buffer amplifiers are neglected by proper floor planning. Conversion loss of 1.4 dB is obtained with total power consumption of 72.5 mW.\r : Lastly, a power management system consisting of low-dropout (LDO) regulators is designed and integrated in a 90-nm CMOS millimeter-wave transceiver to provide stable and low-noise supply voltages. Voltage variation issues are alleviated by the LDOs.

ABSTRACT: The improvement of high frequency capability for silicon devices has made implementation of millimeter-wave (mm-wave) silicon integrated circuits operating at 60 GHz, 77 GHz and even higher feasible. This had led to the proposal of a low-cost 77-GHz CMOS transceiver for automobile radar application and a 60-GHz wireless inter-chip interconnect system. This Ph. D work demonstrated an 80-GHz mm-wave receiver chain integrated with a frequency synthesizer fabricated using low leakage transistors of a low cost 65-nm bulk CMOS technology. An 80-GHz single-ended low noise amplifier (LNA), a 77-GHz down-conversion mixer and a 94-GHz voltage-controlled oscillator (VCO) have been separately demonstrated. A 1.2-V supply, the single-ended LNA exhibits 12-dB gain and 9-dB noise figure (NF) consuming 32- mW power. The mixer has -8-dB conversion gain and 17 dB NF while consuming only 6-mW power. With a 1.5 V supply, the VCO achieves 5.8% tuning range around 94 GHz and - 87dBc/Hz phase noise at 1 MHz offset while consuming 14-mW power. These designs demonstrate that the low-cost, low leakage CMOS process can be used for the design of mmwave circuit blocks and potentially larger integrated system despite the challenges of using the technology such as low voltage headroom, moderate metallization performance and strict metal density filling requirements.

Design and Implementation of Millimeter-wave Power Amplifiers on CMOS

CMOS Millimeter-wave Receiver Front-end Circuits and Their Applications

Research Project

Low-power, High-efficiency, and High-linearity CMOS Millimeter-wave Circuits and Transceivers for Wireless Communications

Design of Millimeter-Wave CMOS Power Ampli "fi"ers with Multi-Mode Power Combining Techniques

Millimeter-wave CMOS power amplifiers design.

Discover the concepts and techniques needed to design millimeter-wave circuits for current and emerging wireless system applications.

Selected Topics in Power, RF, and Mixed-Signal ICs

Millimeter-wave CMOS Power Amplifier and Transceiver Circuit Design
Millimeter-Wave Voltage-Controlled Oscillators in 0.13-micrometer CMOS Technology
Analysis and Design of CMOS Mixers Millimeter-wave Direct-conversion Transceivers
Design and Reliability Studies of CMOS RF/Millimeter Wave Circuits

This book explains one of the hottest topics in wireless and electronic devices community, namely the wireless communication at mmWave frequencies, especially at the 60 GHz ISM band. It provides the reader with knowledge and techniques for mmWave antenna design, evaluation, antenna and chip packaging. Addresses practical engineering issues such as RF material evaluation and selection, antenna and packaging requirements, manufacturing tolerances, antenna and system interconnections, and antenna One of the first books to discuss the emerging research and application areas, particularly chip packages with integrated antennas, wafer scale mmWave phased arrays and imaging Contains a good number of case studies to aid understanding Provides the antenna and packaging technologies for the latest and emerging applications with the emphases on antenna integrations for practical applications such as wireless USB, wireless video, phase array, automobile collision avoidance radar, and imaging
The book covers the CMOS-based millimeter wave circuits and devices and presents methods and design techniques to use CMOS technology for circuits operating beyond 100 GHz. Coverage includes a detailed description of both active and passive devices, including modeling techniques and performance optimization. Various mm-wave circuit blocks are discussed, emphasizing their design distinctions from low-frequency design methodologies. This book also covers a device-oriented circuit design technique that is essential for ultra high speed circuits and gives some examples of device/circuit co-design that can be used for mm-wave technology.

Millimeter-Wave Circuits for 5G and Radar
Design Of Millimeter-Wave Reconfigurable Front-End Circuits Using The Standard CMOS-MEMS Technology
Design and Characterization of MMIC IF VGA and Small Signal CMOS Millimeter Wave Amplifiers
Millimeter Wave CMOS VCO and PLL Design and Phase Noise Mitigation Techniques
Design and Modeling of Millimeter-wave CMOS Circuits for Wireless Transceivers

Along with numerous opportunities in communication and imaging applications, the design of emerging millimeter-wave (mm-wave) and terahertz (THz) electronic circuits and systems in CMOS technology faces new challenges and requires new devices. Design of CMOS Millimeter-Wave and Terahertz Integrated Circuits with Metamaterials provides alternative solutions using CMOS on-chip metamaterials. Unlike conventional metamaterial devices on printed circuit boards (PCBs), the presented CMOS metamaterials can be utilized to build many mm-wave and THz circuits and systems on chip. Leveraging the authors' extensive expertise and experience with CMOS on-chip metamaterials, this book shows that with the use of metamaterials, one can realize coherent THz signal generation, amplification, transmission, and detection of phase-arrayed CMOS transistors with significantly improved performance. Offering detailed coverage from device to system, the book hereby: Describes integrated *circuit design with application of metamaterials in CMOS technology Includes real CMOS integrated circuit examples and chip demonstrations with measurement results Evaluates novel mm-wave and THz communication and imaging systems under CMOS-based system-on-chip integration Design of CMOS Millimeter-Wave and Terahertz Integrated Circuits with Metamaterials reflects the latest research progress and provides a state-of-the-art reference on CMOS-based metamaterial devices and mm-wave and THz systems.*

Selected Topic in Power, RF, and Mixed-Signal ICs provides a practical overview and state-of-the-art advancements on several selected topics in the areas of power, RF, and mixed-signal integrated circuits and systems

CMOS Millimeter-Wave Amplifier Design

Design of Microwave and Millimeter-wave CMOS VCOS and Frequency Dividers

Design of Microwave and Millimeter-wave Wideband CMOS VCOs

Design of Wide-IF-Band CMOS Mixers for Millimeter Wave Receiver Application

Advanced Millimeter-wave Technologies

This book focuses on the development of design techniques and methodologies for 60-GHz and E-band power amplifiers and transmitters at device, circuit and layout levels. The authors show the recent development of millimeter-wave design techniques, especially of power amplifiers and transmitters, and presents novel design concepts, such as "power transistor layout" and "4-way parallel-series power combiner", that can enhance the output power and efficiency of power amplifiers in a compact silicon area. Five state-of-the-art 60-GHz and E-band designs with measured results are demonstrated to prove the effectiveness of the design concepts and hands-on methodologies presented. This book serves as a valuable reference for circuit designers to develop millimeter-wave building blocks for future 5G applications.

This paper describes the design of CMOS millimeter-wave voltage controlled oscillators. Varactor, transistor, and inductor designs are optimized to reduce the parasitic capacitances. An investigation of tradeoff between quality factor and tuning range for MOS varactors at 24 GHz has shown that the polysilicon gate lengths between 0.18 and 0.24 micrometer result in both good quality factor (>12) and Cmax/Cmin ratio (~3) in the 0.13-micrometer CMOS process used for the study. The components were utilized to realize a VCO operating around 60 GHz with a tuning range of 5.8 GHz. A 99-GHz VCO with a tuning range of 2.5 GHz, phase noise of --102.7 dBc/Hz at 10-MHz offset and power consumption of 7-15 mW from a 1.5-V supply and a 105-GHz VCO are also demonstrated. This is the CMOS circuit with the highest fundamental operating frequency. The lumped element approach can be used even for VCOs operating near 100-GHz and it results in a smaller circuit area.

mm-Wave Silicon Power Amplifiers and Transmitters

Microwave and Millimeter Wave CMOS Characterization, Modeling and Design

CMOS Front Ends for Millimeter Wave Wireless Communication Systems
Design of a FinFET Static Frequency Divider and a Millimeter-wave CMOS Push-push VCO
Era of Sub-100nm Technology

This book addresses in-depth technical issues, limitations, considerations and challenges facing millimeter-wave (MMW) integrated circuit and system designers in designing MMW wireless communication systems from the complementary metal-oxide semiconductor (CMOS) perspective. It offers both a comprehensive explanation of fundamental theories and a broad coverage of MMW integrated circuits and systems.CMOS Millimeter-Wave Integrated Circuits for Next Generation Wireless Communication Systems is an excellent reference for faculty, researchers and students working in electrical and electronic engineering, wireless communication, integrated circuit design and circuits and systems. While primarily written for upper-level undergraduate courses, it is also an excellent introduction to the subject for instructors, graduate students, researchers, integrated circuit designers and practicing engineers. Advanced readers could also benefit from this book as it includes many recent state-of-the-art MMW circuits.

Design of CMOS Voltage-Controlled Oscillator and Mixer for 60GHz Millimeter-Wave Applications
CMOS Millimeter-wave Circuits and Architecture Design Techniques for High Date Rate Receiver
CMOS 60-GHz and E-band Power Amplifiers and Transmitters
Design and Implementation of Millimeter-wave Transceivers on CMOS
Ultra High-Speed CMOS Circuits