


17-22 January 2021
Virtual Conference

2021 IEEE Radio & Wireless Week
96th ARFTG Microwave Measurement Symposium

Friday, January 22, 2021
8:00 am – 12:00 am EST

Joint ARFTG-RWW 2021 Workshop

Modeling and Design Tools for Accelerated Design of 5G GaN Pas

Organizer: Nicholas C. Miller, AFRL, nicholas.miller.58@us.af.mil
Co-Organizer: Patrick Roblin, Ohio State University, roblin.1@osu.edu

Abstract: This workshop will review advances in the nonlinear device modeling and characterization of GaN HEMTs to support the accelerated design of 5G base stations. Both the extraction of ASM-HEMT and MIT Source based model will be discussed. Comparison of measurements with NVNA large-signal measurement results will be reported. Characterization and modeling of traps will be discussed. Finally, an embedding ASM-HEMT model for the accelerated design of GaN PAs will be presented.

Speakers:

1. **Shaloo Rakheja**, University of Illinois, rakheja@illinois.edu
   "Physics-based compact modeling of charge transport in ultra-scaled GaN HEMTs for RF applications"
2. **Sourabh Khandelwal**, University of South Florida, skhandelwal@usf.edu
   "From Poisson Equation to Power Amplifiers: Accurate Non-linear RF Models for GaN with Physics-based ASM-HEMT compact model"
3. **Ujwal Radhakrishna**, Texas Instruments, ujwal@ti.com
   "MVSG modeling framework to enable GaN device-circuit co-design for PA applications"
4. **Nicholas C. Miller**, Air Force Research Laboratory, nicholas.miller.58@us.af.mil
   "GaN HEMT Modeling for RF Applications using Advanced Circuit Extraction Tools and Fermi Kinetics Transport"
5. **Miles Lindquist**, P. Roblin and N. Miller, Ohio State University and AFRL, roblin.1@osu.edu
   "ASM-HEMT Embedding Model for Accelerated Design of PAs"

Schedule for ARFTG-RWW Workshop

Friday January 22, 2021, 8:00-12:00 am

8:00 am – 8:05 am
Nicholas C. Miller, Air Force Research Laboratory, nicholas.miller.58@us.af.mil
Introduction of "Modeling and design tools for accelerated design of 5G GaN PAs"

8:05 am – 8:45 am, ARFTG25

Shaloo Rakheja, University of Illinois, rakheja@illinois.edu

"Physics-based compact modeling of charge transport in ultra-scaled GaN HEMTs for RF applications"

8:45 am – 9:25 am, ARFTG26

Sourabh Khandelwal, University of South Florida, skhandelwal@usf.edu

"From Poisson Equation to Power Amplifiers: Accurate Non-linear RF Models for GaN with Physics-based ASM-HEMT compact model"

9:25 am – 10:05 am, ARFTG27

Ujwal Radhakrishna, Texas Instruments, ujwal@ti.com

"MVSG modeling framework to enable GaN device-circuit co-design for PA applications"

10:05 am – 10:45 am, ARFTG28

Nicholas C. Miller, Air Force Research Laboratory, nicholas.miller.58@us.af.mil

"GaN HEMT Modeling for RF Applications using Advanced Circuit Extraction Tools and Fermi Kinetics Transport"

10:45 am – 11:25 am, ARFTG29

Miles Lindquist, P. Roblin and N. Miller, Ohio State University and AFRL, roblin.1@osu.edu

"ASM-HEMT Embedding Model for Accelerated Design of PAs"

11:25 am – 12:00 pm

Panels with all Speakers

Abstracts & Bios

Shaloo Rakheja, University of Illinois, rakheja@illinois.edu

"Physics-based compact modeling of charge transport in ultra-scaled GaN HEMTs for RF applications"

Abstract: In this workshop presentation, I will focus on the static and dynamic modeling of ultra-scaled III-nitride high-electron mobility transistors (HEMTs) that operate in the quasi-ballistic regime. The model is inspired by the Landauer-Boltzmann approach to carrier transport and contains important physical extensions to cater to III-nitride HEMTs specific phenomena. I will discuss the model capability to capture transport in both short- and long-channel HEMTs and present examples of how incorrectly modeling transport in the device yields incorrect description of inter-nodal capacitances. I will demonstrate model validation against broad-bias and broad-temperature measured data of fabricated devices with gate lengths ranging from 40 nm to 150 nm. The model provides physical insight into the technology-device interaction and is used to elucidate the role of contact resistances, Joule heating, traps, gate leakage, and nodal capacitances on the circuit performance.

Bio: Dr. Shaloo Rakheja started as an Assistant Professor in the Electrical and Computer Engineering (ECE) department at the University of Illinois at Urbana-Champaign in Oct. 2019. From 2015-2019, Shaloo was an Assistant Professor in ECE at New York University. Prior to joining NYU, she was a postdoctoral associate at the Microsystems Technology Laboratories at Massachusetts Institute of Technology. Shaloo received her M.S. and Ph.D. degrees in electrical and computer engineering from the Georgia Institute of Technology in 2009 and 2012, respectively. Shaloo's research interests are in understanding, predicting, and modeling physical phenomena in materials that drive their functional behavior and enable applications such as low-power logic and memory, sensing, and wireless communication.

Sourabh Khandelwal, University of South Florida, skhandelwal@usf.edu

"From Poisson Equation to Power Amplifiers: Accurate Non-linear RF Models for GaN with Physics-based ASM-HEMT compact model"

Abstract: ASM-HEMT is a new industry standard physics-based compact model for GaN HEMTs. This model is derived from a consistent solution of Schrodinger's and Poisson's formulations in the quantum well of GaN HEMT. This talk will present the basics of ASM-HEMT model. Core of the ASM-HEMT model, as well as the plethora of physical effects relevant for practical GaN devices included in this model will be discussed. The talk will also show non-linear model successes with ASM-HEMT for several commercial GaN technologies, covering multiple voltage and frequency ranges.

Bio: Dr. Sourabh Khandelwal is a Research Faculty at the University of South Florida. His research areas are the characterization and modeling of semiconductor devices and circuits with a focus on the ASM-GaN-HEMT model.

Ujwal Radhakrishna, Texas Instruments, ujwal@ti.com

"MVSG modeling framework to enable GaN device-circuit co-design for PA applications"

Abstract: GaN technologies are rapidly gaining ground in HF-RF markets. The MIT Virtual Source GaNFET (MVSG) model is an industry-standard charge-based physical model for GaNFETs suited for GaN-circuit design. The model adopts a self-consistent current and charge formulation that describes both HV- and HF-GaN devices. Example circuits for RF-frontend that use MVSG device-model for their design will be illustrated. Using an RF-frontend MMIC as an example, the speaker will show how the device parasitics, charge-trapping effects impact saturated power gains, power-added efficiencies, losses etc. in power-amplifiers and oscillators. The speaker will also illustrate how device-models can be used as a link between device-design and circuit-design. Using high-linearity requirement in RF-power amplifiers as a design challenge, we will see how both device-level and circuit level techniques can be used to meet the linearity spec.

Bio: Ujwal Radhakrishna works as an analog design engineer at Kilby research labs, Texas Instruments. At TI, he investigates device-circuit co-design solutions for automotive and load-switch applications and is a roadmap-developer for next-gen power-device technologies. He has Ph.D. (2016) and Masters (2013) from MIT on the development of GaN-HEMT models, RF- and HV-circuit design. His research interests are: device-physics and modeling, WBG semiconductor technologies, RF- and HV device-circuit design, MEMS-based energy harvesting and interface power-electronics.

Nicholas C. Miller, Air Force Research Laboratory, nicholas.miller.58@us.af.mil

"GaN HEMT Modeling for RF Applications using Advanced Circuit Extraction Tools and Fermi Kinetics Transport"

Abstract: Rapid design and prototyping of next-generation RF and mm-wave GaN technology requires reliable and accurate models of the underlying transistors. The speed of model extraction must also be fast to enable design success. In this talk, a thorough presentation of AFRL's physics-based GaN HEMT modeling capabilities will be presented. Accelerated linear and non-linear compact model extraction tools will be discussed. This talk will also present an overview of AFRL's custom large-signal RF TCAD simulator called Fermi kinetics transport.

Bio: Dr. Nicholas C. Miller is a Research Electronics Engineer at the Air Force Research Laboratory Sensors Directorate. His research interests include full-wave EM TCAD simulations, nonlinear RF compact modeling, and nonlinear RF characterization techniques.

Miles Lindquist, P. Roblin and N. Miller, Ohio State University and AFRL, roblin.1@osu.edu

"ASM-HEMT Embedding Model for Accelerated Design of PAs"

Abstract: In the process of PA design a nonlinear embedding model is invaluable, allowing the designer to simulate from the current source reference plane then individually account for parasitic effects from the device's internal resistance, contacts, and packaging. In this talk, a nonlinear embedding model for the industry standard ASM-HEMT model for GaN HEMTs will be presented. This presentation will show the design and operation of the embedding model and will include a comparison of the embedding model's simulations to measurements of a fabricated GaN HEMT.

Bio: Miles Lindquist is a PhD student studying with Dr. Patrick Roblin at The Ohio State University in Columbus, Ohio. His current research is focused on the characterization and modeling of GaN HEMTs by the use of novel measurement techniques. He has previously worked at the United States Air Force Research lab as a process engineer, fabricating GaN MMICs and other cutting-edge semiconductor devices and circuits.