Modeling of RTD-Gated GaN HEMTs at Terahertz Frequencies Using a Full-Wave Simulation Toolset Coupled with Particle-Based Equations

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Terahertz devices can be used for a variety of applications, including secure communications, imaging, radar, and radio astronomy. The demand for higher frequency devices has compelled designers to scale device dimensions down to a point where a trial-and-error approach in fabrication can no longer be used. Instead, device optimization via simulations has become vitally important to reduce time and production costs involved. Although many simulation models exist for microwave transistors, modeling them at terahertz frequencies comes with new challenges, as quantum and electromagnetic wave effects that could once be neglected become limiting factors in device performance. This requires the development of more complete toolsets that can describe the inherent electromagnetic nature and associated wave effects. Specifically, modeling of terahertz devices must include full wave electromagnetic modeling along with all relevant semiconductor device physics.

In this paper, we propose a model that couples full-wave Maxwell's equations with full-band particle-based Monte Carlo simulations. In addition, a Schrodinger-based solver that models quantum effects at the device channel is incorporated. This complete design toolset is used to evaluate power gain for a gallium-nitride (GaN) HEMT with a gate exhibiting negative differential conductance (NDC). The gate is realized using a resonant tunneling diode (RTD) structure, resulting in a RTD-gated HEMT. Our validated equivalent circuit of the HEMT is used within the developed toolset to show that a gain of 4 dB and fivefold increase in resonance can be achieved, when an RTD is integrated with a GaN HEMT. Specifically, the designed RTD-gated HEMT operates at 2.25GHz. For validation, a realistic and fully optimized device model will be shown. The details of the design methodology and equation sets employed in our modeling toolset will be described at the conference along with the specifics of the optimized device structures.