High Power Load Pull Characterization of Scaled GaN High Electron Mobility Transistors in D-band

Weifeng Wu[#1], Lei Li[$*], Juncheng Xiong[#], James C. M. Hwang[$*], Patrick Fay[#]
[#]Department of Electrical Engineering, University of Notre Dame, USA
[$]School of Electrical and Computer Engineering, Cornell University, USA
[*]Department of Materials Science and Engineering, Cornell University, USA
[1]wwu9@nd.edu

The demand for high-performance power devices at D-band (110–170 GHz) is rapidly growing, driven by emerging high-speed wireless communication applications. While GaN-based HEMTs have shown excellent power capabilities at mm-wave frequencies, its viability at D-band requires further exploration. In this work, scaled GaN HEMTs are characterized at D-band using active load-pull, providing key insights into their potential for D-band applications.

The measurement system comprises a Keysight N5245B vector network analyzer, a Vertigo vector modulator, two VDI WR6.5VNATxRxM-4HP frequency extenders, and FormFactor I170-S-GSG-50-BT probes. To ensure accurate power leveling and control, a first-tier two-port TRL waveguide calibration at the frequency extender output flanges plane was applied, followed by waveguide port power calibration and leveling using a VDI Erickson PM5B power meter, and then the final measurement plane was moved to on-wafer device measurement plane by a second-tier two-port TRL calibration. The system can supply up to 22.9 dBm of input power to the device under test at the probe tip reference plane at 140 GHz. The measured transistors were fabricated in HRL Laboratories' "T3" 40-nm GaN-on-SiC HEMT technology, provides nominal f_t's of 200 GHz and f_{max}'s of 400 GHz.

The devices exhibit a maximum drain current (I_d) of approximately 900 mA/mm at a gate voltage of 1 V, a threshold voltage of -0.08 V, and peak transconductance of 609 mS/mm. Load pull was performed for $|\Gamma_{load}|$ up to ~0.9, which is impractical with passive tuners in D-band. The load-pull contours at 140 GHz were measured for quiescent I_d of 50, 100, and 200 mA/mm and a drain-source voltage of 12 V, covering deep Class AB to Class A operation. The load for peak PAE is ~ 0.7 + 0.5*j*, largely independent of bias. The load for maximum output power is ~ 0.5 + 0.5*j*, in close proximity to the peak PAE load. Power sweeps at the optimal Γ_{load} for peak PAE and output power were analyzed and compared. Under load conditions optimized for PAE, for a I_d of 100 mA/mm, a small-signal gain of 7 dB, with a peak PAE of 19.0% and saturated output power of 19.5 dBm were obtained at 140 GHz. The appreciable gain and efficiency suggests GaN is a viable transistor technology for mm-wave and sub-mm-wave applications.

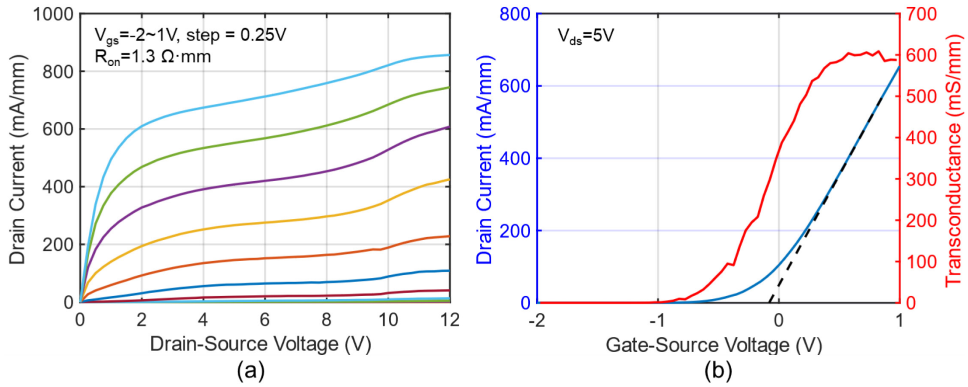

Fig. 1. (a) DC common-source output characteristics and (b) transfer characteristics and transconductance of the HEMT.

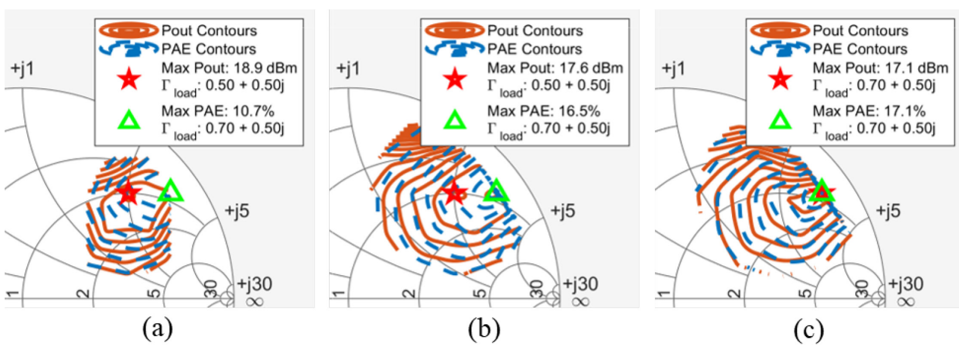

Fig. 2. Load pull contours at 3 dB compression of a 2x25 μm FET at 140 GHz with V_d of 12V: (a) I_d = 50 mA/mm; (b) I_d = 100 mA/mm; (c) I_d = 200 mA/mm.

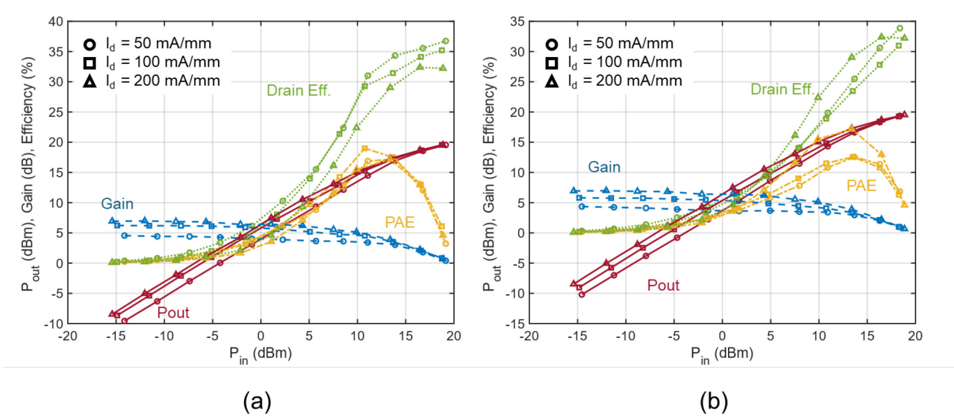

Fig. 3. Power Sweep of a 2x25 μm FET at 140 GHz with Γ_{Load} at (a) optimal PAE and (b) optimal Pout.