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

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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 power-added efficiency (PAE) is ~ $0.7 + 0.5j$, largely independent of bias. The load that maximizes output power (P_{out}) varies with the bias conditions but remains in close proximity to the load corresponding to peak PAE. Power sweeps at the optimal Γ_{load} for peak PAE and P_{out} were analyzed and compared. Under load conditions optimized for PAE, for an I_d of 100 mA/mm, a small-signal gain of 7 dB, with a peak PAE of 19.0% and saturated P_{out} of 19.5 dBm were obtained at 140 GHz. The appreciable gain and efficiency suggest GaN is a viable transistor technology for mm-wave and sub-mm-wave applications.