MT2000: Double Pulse Load Pull for Trapping Characterization of GaN Transistors

Application Note / 2026-05-01

Abstract

GaN HEMT power amplifiers used in radar, wireless infrastructure, and pulsed RF systems exhibit pronounced dynamic behavior driven by charge trapping effects. Conventional CW or single-pulse Load Pull techniques often fail to capture this behavior under realistic operating conditions. RF Double Pulse Load Pull separates RF stress conditioning from performance measurement by using an RF pre-pulse to define the large-signal operating point (LSOP), thereby establishing a controlled trapping and thermal state prior to RF characterization. This application note describes how the Maury Microwave MT2000 platform enables repeatable, trapping-aware Load Pull measurements that closely reflect real-world pulsed and high peak-to-average RF operation.

Background: Trapping Effects in GaN Devices

Charge trapping in GaN HEMTs leads to current collapse, dynamic on-resistance variation, and memory effects. Trap capture and emission time constants are typically much longer than the RF period and are often comparable to envelope variations in wideband or pulsed RF signals. As a result, PA performance immediately following large-signal RF stress can differ significantly from steady-state behavior, particularly with respect to gain, efficiency, and linearity.

Limitations of Conventional Load Pull

Conventional CW and single-pulse Load Pull techniques are effective for steady-state characterization but do not control the trapping state under realistic RF stress conditions. During impedance or power sweeps, the trapping state evolves continuously, causing each load point to be evaluated under a different device history. This limits correlation with real pulsed operation and can lead to overly optimistic estimates of performance.

Principle of MT2000 RF Double Pulse Load Pull

RF Double Pulse Load Pull overcomes these limitations by explicitly separating device conditioning from RF measurement. An RF pre-pulse establishes a defined LSOP, including input power level and load impedance representative of the target application, thereby setting a controlled trapping and thermal state. After a programmable interval time, a short RF measurement pulse captures output power, gain, efficiency, and waveform behavior before significant trap emission occurs. By repeating this sequence for every impedance condition, all Load Pull points are evaluated under identical device history, as illustrated in Figure 2.

MT2000 RF Double Pulse Implementation

As shown in Figure 1, the MT2000 platform integrates fast RF switching, programmable pulse timing, and multi-harmonic active Load Pull capability. Independent control of pulse width, duty cycle, and interval time enables precise definition of the trapping state prior to RF measurement. The system supports fixed or independent impedance control at the fundamental and harmonic frequencies during both the pre-pulse and measurement pulse, allowing realistic LSOP definition. High measurement speed minimizes self-heating and enables rapid exploration of impedance, bias, and timing dimensions.

Figure 1. Typical MT2000 configuration for RF Double Pulse Load Pull.

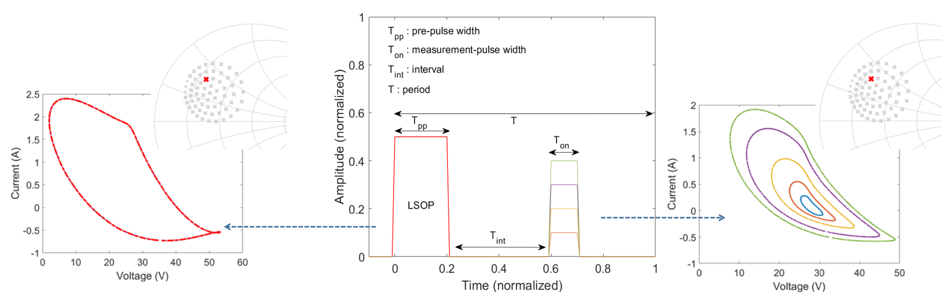


Figure 2. MT2000 timing sequence showing the LSOP-defining RF pre-pulse, interval time, RF measurement pulse, and recovery period.

Example MT2000 RF Double Pulse Load Pull Results

Measured results obtained using the MT2000 RF Double Pulse approach are presented in Figures 3 and 4. Two GaN HEMT technologies with identical layouts but different buffer designs were evaluated to assess trapping behavior. Measurements performed at 3.6 GHz and 50 V drain bias demonstrate that RF pre-pulse conditioning has a significant impact on gain compression, back-off behavior, and AM-PM distortion.

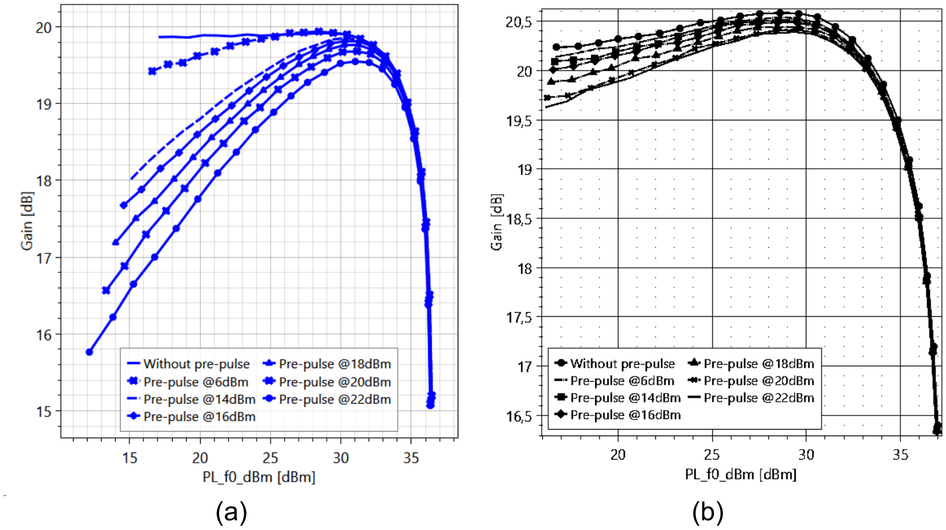


Figure 3. Measured gain versus output power for two GaN devices, comparing single-pulse and RF Double Pulse Load Pull measurements.

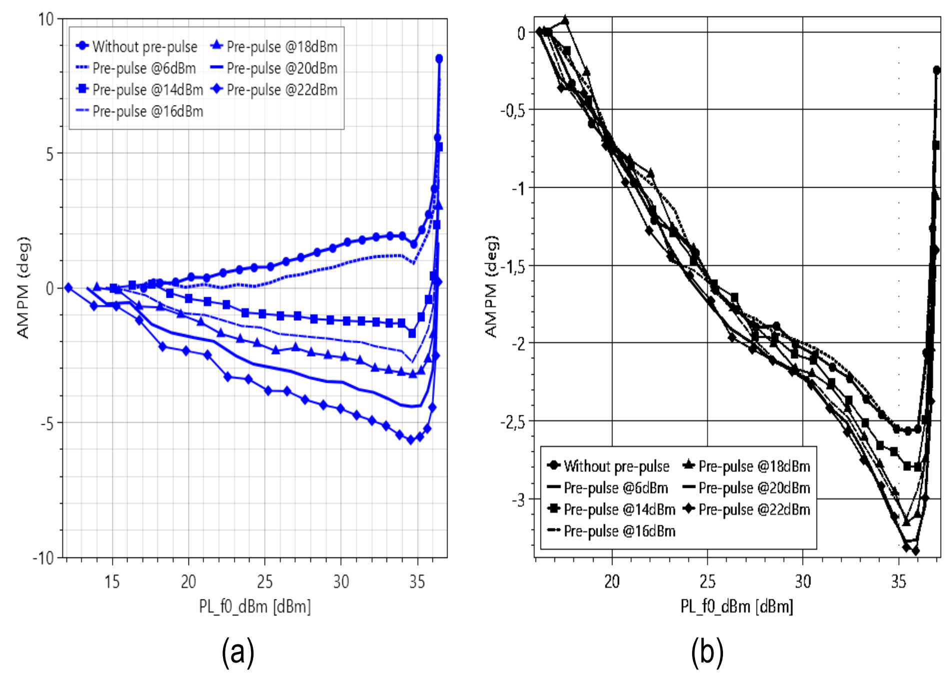


Figure 4. Measured AM-PM versus output power for two GaN devices under single-pulse and RF Double Pulse Load Pull conditions.

Pulse Profiling and Time-Domain Analysis

As shown in Figure 5, time domain drain current measurements reveal trapping induced Idq collapse following the RF pulse, load dependent p3dB compression behavior, and increased noise associated with Schottky diode conduction at high drive levels. Pulse profiling enables detailed analysis of the DUT's dynamic behavior during pulsed operation, which is not accessible using conventional Load Pull techniques.

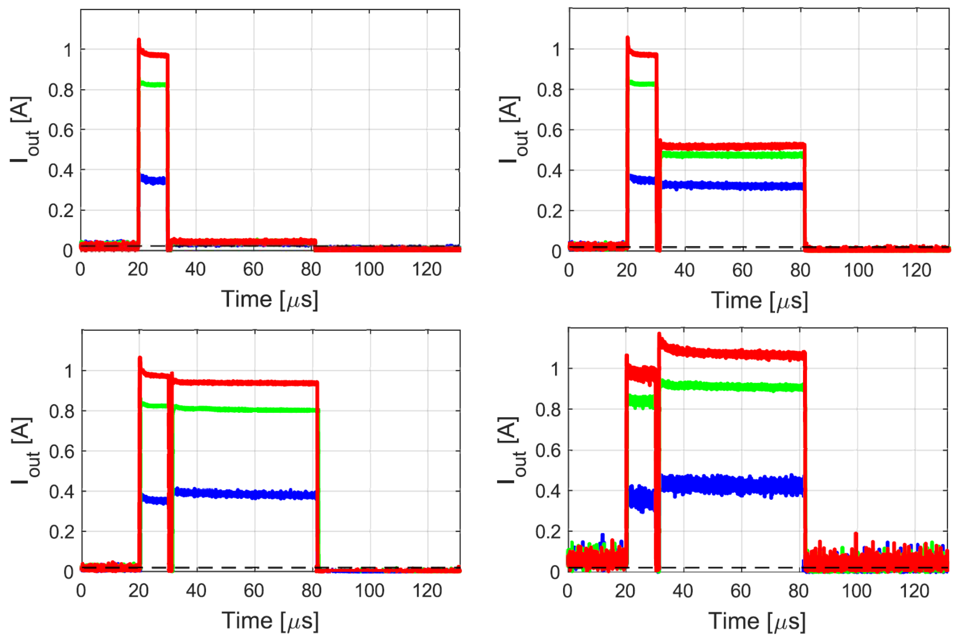


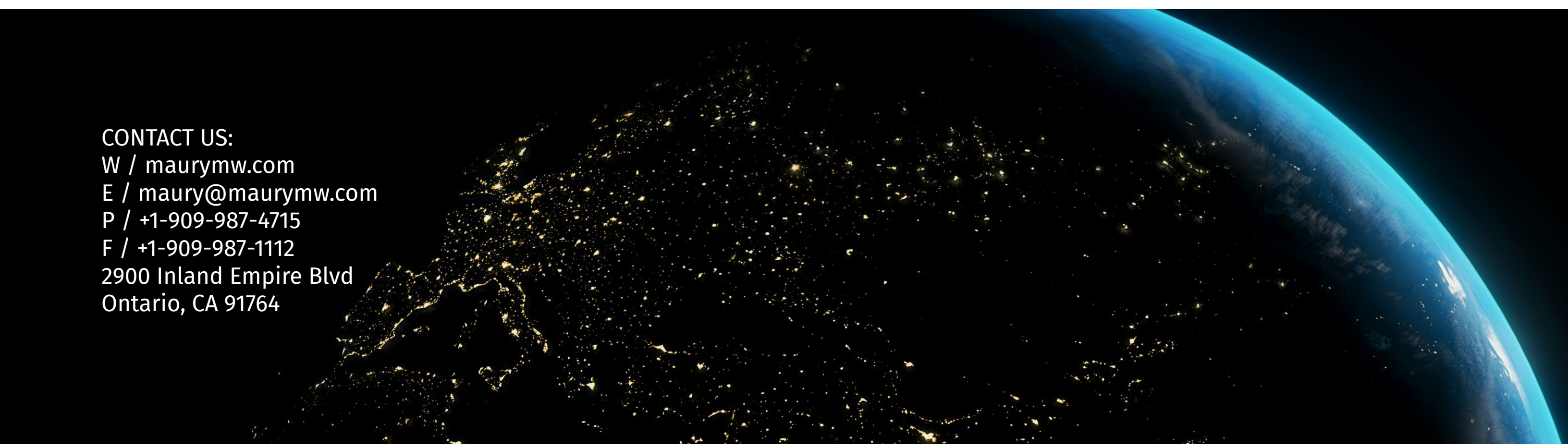
Figure 5. Time domain drain current waveforms at maximum power (red), maximum efficiency (blue), and trade off load impedances (green), illustrating trapping effects and dynamic compression behavior.

Impact on PA Design and Technology Development

By fixing the large-signal operating point prior to RF measurement, RF Double Pulse Load Pull provides a closer proxy to the peak-to-average behavior of modern modulated RF signals. As evidenced by Figures 3 through 5, the technique reveals performance shifts that would otherwise remain hidden, including back-off gain reduction, efficiency degradation, AM-PM distortion, and stress-dependent impedance changes. These insights are critical for technology selection, model validation, and high-confidence PA design.

Conclusion

The MT2000 transforms RF Double Pulse Load Pull into a practical, production ready measurement methodology. By enabling trapping aware LSOP definition, time domain analysis, and fast, repeatable impedance characterization, the MT2000 allows accurate evaluation of GaN power amplifiers under conditions that closely resemble real pulsed operation. This results in improved model accuracy, reduced design risk, and greater confidence in high power PA development.



CONTACT US:
W / maurymw.com
E / maury@maurymw.com
P / +1-909-987-4715
F / +1-909-987-1112
2900 Inland Empire Blvd
Ontario, CA 91764