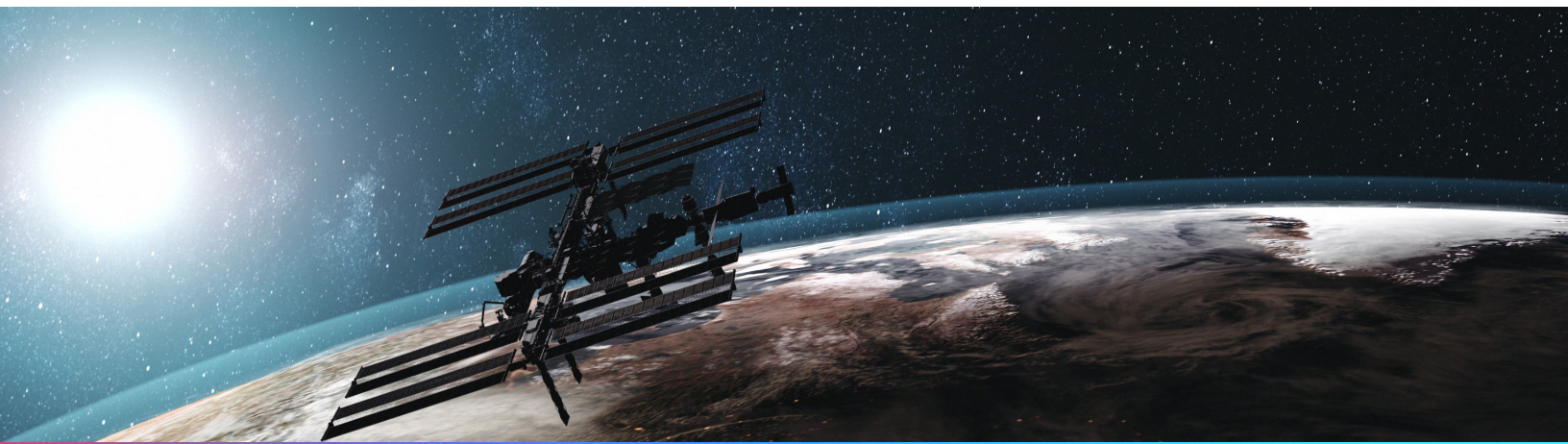




MT2000: Unlocking PA Efficiency Through 3rd Harmonic Load Pull

Application Note / 2026-05-03



Abstract

Recent advances in RF power amplifier (PA) design show that controlling only the fundamental and second harmonic impedances can limit achievable efficiency. Experimental GaN device data demonstrate that independent source and load tuning up to the third harmonic can yield measurable efficiency improvements, including under power back-off conditions. This application note explains the value of third harmonic Load Pull and shows how the Maury Microwave MT2000 system enables this advanced characterization in practical customer laboratory environments.

Why the 3rd Harmonic Matters

Harmonic terminations define the voltage and current waveforms at the device terminals. While second-harmonic control primarily shapes waveform flatness and symmetry, the third harmonic introduces an additional degree of freedom that sharpens waveform transitions. Appropriate third harmonic source and load terminations reduce voltage-current overlap, directly improving drain efficiency and power-added efficiency (PAE), as illustrated in Figure 1. Measured GaN devices show that third harmonic effects are significant rather than marginal: when optimized, third harmonic tuning delivers up to 6% absolute efficiency improvement compared to second harmonic-only optimization, with no measurable performance degradation observed when non-optimal third harmonic settings are applied.

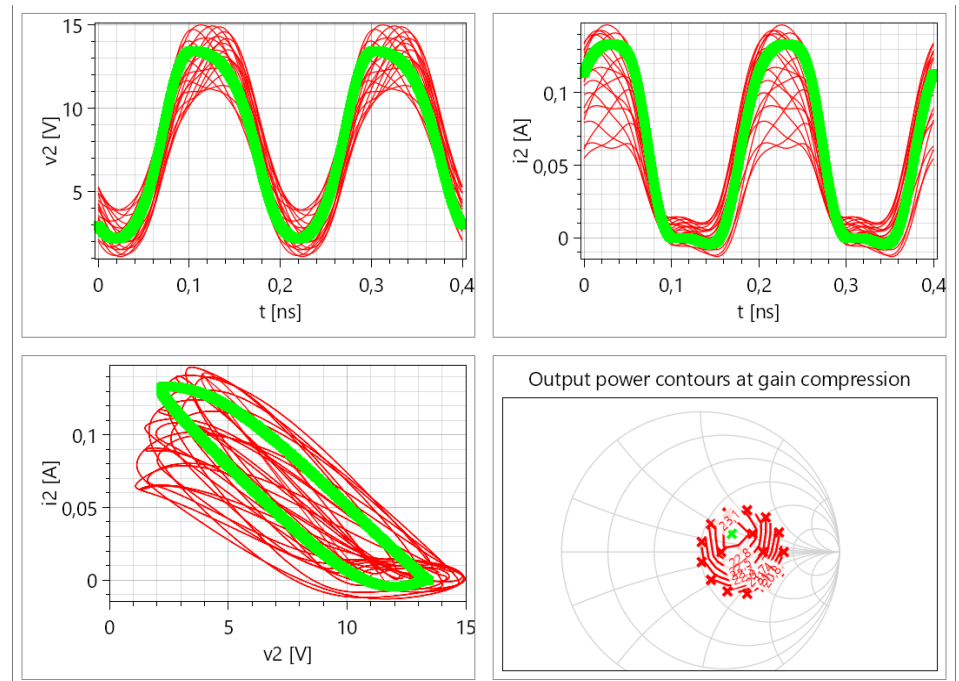


Figure 1. Measured time domain waveform shaping with 3rd harmonic Load Pull.

Experimental Results Summary

Key measured observations from this measurement example, as shown in Figure 2, include:

- > Up to 6% absolute efficiency improvement using full source and load third harmonic tuning.
- > Approximately 4% verified efficiency improvement using upgraded multi-harmonic MT2000 systems.
- > Efficiency gains maintained at 5 dB output power back-off.
- > Worst-case third harmonic tuning does not degrade performance relative to second harmonic-only optimization.

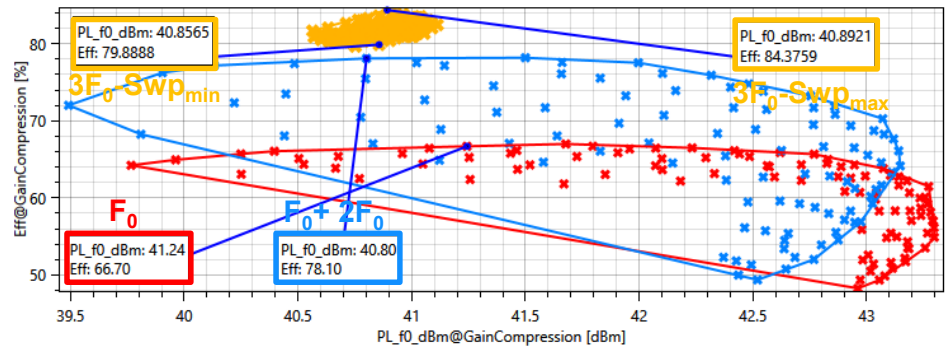
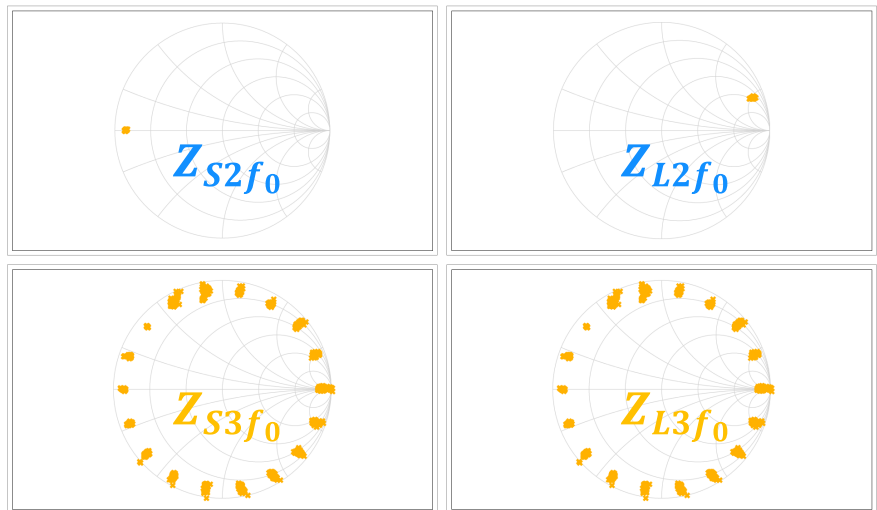


Figure 2. Measured drain efficiency comparison between fundamental only, second harmonic only, and optimized third harmonic tuning.

MT2000 System: Enabling Practical 3rd Harmonic Load Pull

The MT2000 architecture is designed to make advanced multi-harmonic Load Pull measurements practical within typical laboratory time constraints (Figure 3). By combining wideband receivers, parallel signal generation, and software-based convergence algorithms, the MT2000 dramatically reduces total measurement time compared to traditional VNA and tuner-based approaches. In representative measurements, more than 4,000 multi-harmonic Load Pull states, including independent fundamental, second, and third harmonic source and load conditions, can be completed in approximately 15 minutes, while comparable measurements using conventional techniques typically require hours. This high measurement speed enables rapid exploration of multi-dimensional impedance spaces during technology development, model validation, PA characterization, and optimization.

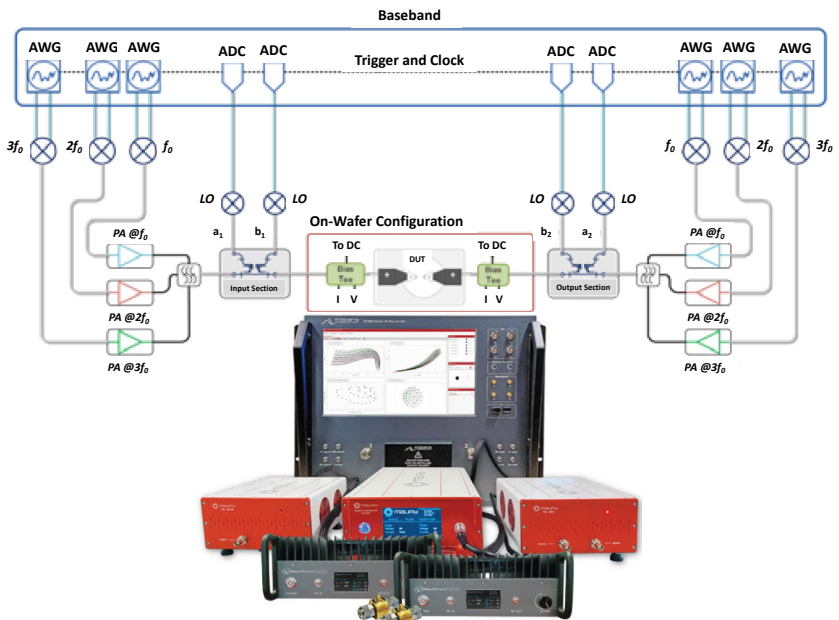


Figure 3. Typical MT2000 configuration for fundamental, second, and third harmonic Load Pull measurements.

Measurement Flow Using MT2000

A typical third harmonic Load Pull measurement flow using the MT2000 includes:

1. Calibrate the MT2000 to the DUT reference planes.
2. Optimize fundamental source and load impedances.
3. Fix fundamental source and load impedances at their optimum values.
4. Sweep second harmonic source and load impedances simultaneously.
5. Fix fundamental and second harmonic impedances at their optimum values.
6. Sweep third harmonic source and load impedances simultaneously.
7. Fix second and third harmonic impedances at their optimum values.
8. Re-sweep fundamental load impedance to extract final efficiency and power contours.
9. Evaluate peak efficiency, output power, and back-off performance.

Figure 4 shows an example efficiency nose plot generated using this measurement approach.

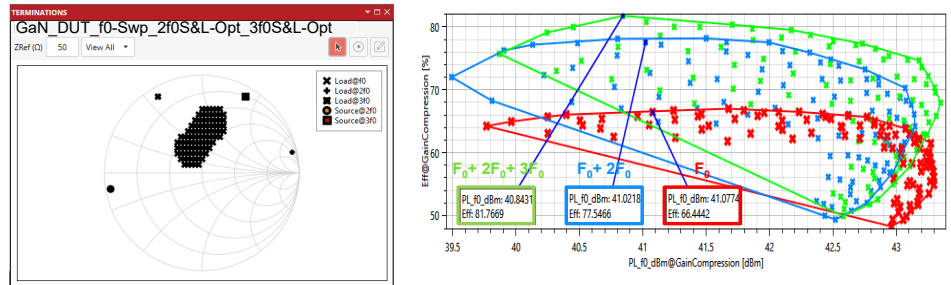


Figure 4. Example efficiency nose plot illustrating the benefit of optimized third harmonic tuning.

Customer Benefits

By enabling practical third harmonic Load Pull characterization, the MT2000 helps engineers improve amplifier efficiency while accelerating development and validation workflows. Key benefits include:

- > Higher peak and back-off efficiency for GaN power amplifiers.
- > Improved insight into waveform-driven PA behavior.
- > More accurate device models and faster PA design cycles.
- > Risk-free exploration of advanced harmonic tuning techniques.

Conclusion

Third harmonic Load Pull is no longer a theoretical curiosity or a technique limited by excessive measurement complexity. It is a proven and repeatable approach for increasing power amplifier efficiency. The MT2000 platform transforms advanced multi harmonic Load Pull from a research exercise into a practical design tool that enables fast and accurate device characterization. Its high measurement speed supports rapid exploration of multi dimensional impedance spaces during technology development, allowing engineers to identify optimal operating conditions and efficiency tradeoffs early in the design cycle. As a result, technology development, model validation, PA characterization, and optimization can be performed faster and with greater insight, shortening development cycles while supporting more competitive and energy efficient RF designs.



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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

