

Millimeter-Wave On-Wafer Large Signal Characterization System for Harmonic Source/Load Pull and Waveform Measurements.

A. Baddeley, S. Woodington, D. Gecan, A. Sheikh,
A. J. Lunn, P. Tasker, R. Quaglia

STATUS QUO

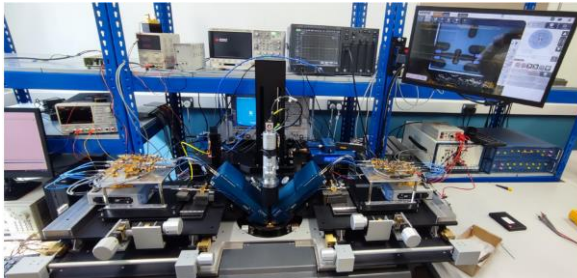
Purpose

- Large signal measurement of mm-wave transistors up to 110 GHz for device modelling and design.

State of the art

- Fundamental load-pull demonstrated >135 GHz [1,2]
- Waveform measurement and impedance control shown < 67 GHz [3].
- Systems are typically active implementations, due to losses at mm-wave, limiting the maximum achievable $|\Gamma_L|$.

NEW INSIGHTS



Developments

First demonstrated system to perform :

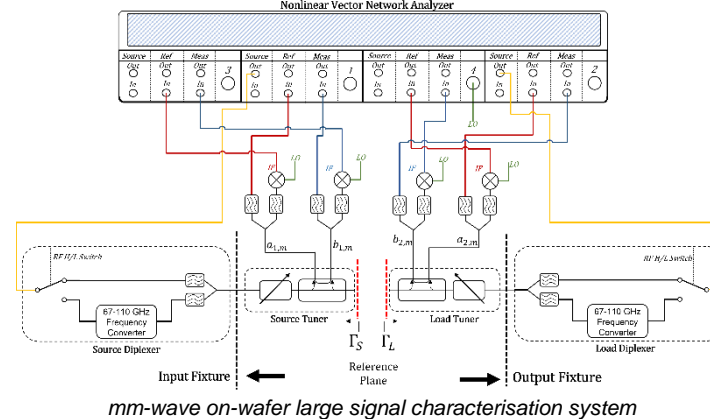
- Large signal single-sweep measurements.
- Waveform measurements and harmonic impedance control up to 100 GHz.

Practical applications

- Waveform engineering of Ka-band devices to maximize PAE.

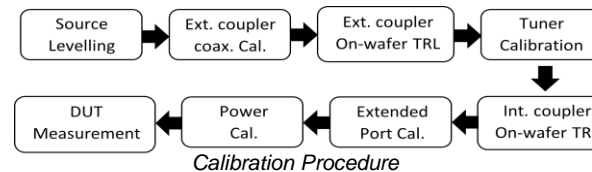
[1] V. Teppati et al., "A W-band On-Wafer Active Load-Pull System Based on Down-Conversion Techniques," IEEE Trans. Microw. Theory Techn., vol. 62, no. 1, pp. 148–153, 2014.
[2] C. De Martino et al., "Hardware and Software Solutions for Active Frequency Scalable (Sub)mm-Wave Load-Pull," IEEE Trans. Microw. Theory Techn., vol. 68, no. 9, pp. 3769–3775, 2020.

DESCRIPTION



System Overview

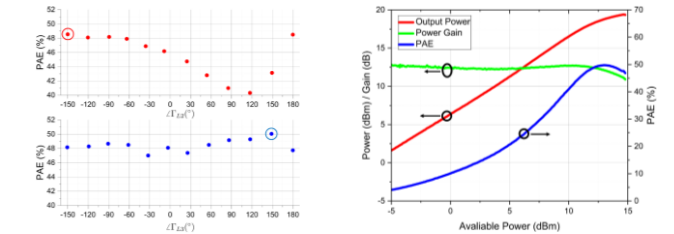
- On-wafer measurement system
 - 67 GHz NVNA
- Source and load passive tuner with triple slug for harmonic impedance control.
- Use of frequency conversion techniques to measure frequencies > 67 GHz.
- A 100 GHz wide bandwidth scope used as a phase meter.



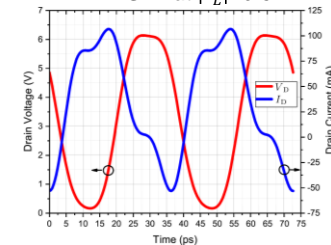
Performance

- Max $|\Gamma_L| = 0.8$ at 30 GHz.
- Max $|\Gamma_L| = 0.7$ at 90 GHz
- Calibrated/Measured impedance error vector < 2.8%

QUANTITATIVE IMPACT



Harmonic Tuning for 27.5 GHz at $|\Gamma_L|=0.6$



Measured waveforms up to third harmonic

Power Sweep of harmonically tuned device

- Qorvo GaAs 90 nm pHEMT
- $V_D = 3.5$ V $I_{DQ} = 50$ mA/mm
- Measured at 27.5 GHz up to 3rd harmonic, 82.5 GHz
- Harmonically tuned
- 8% variation of PAE for $|\Gamma_L|=0.6$ for 2nd harmonic tuning.

PROPOSED CONCEPT GOALS

- Allows for a greater understanding of the performance of mm-wave transistors from a waveform engineering viewpoint.
- Improved dataset to model mm-wave devices – harmonic data points.
- Opens up the possibility for future investigations into optimization of mm-wave devices.

3] R. Quaglia et al., "Source/Load-Pull Characterisation of GaN on Si HEMTs with Data Analysis Targeting Doherty Design," in 2020 IEEE Topical Conference PAWR, 2020, pp. 5–8.