Time-Domain Waveform Measurements under Large Signal RF Overdrive Stress in HEMT Technology

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1. Introduction

RF step stress is a technic for the investigation of RF of **space equipment**.
Knowledge of **actual operation conditions** and **lifetime** of the HEMT transistors in a RF power amplifier [1,2].

➡ **Advanced time-domain methodology** to investigate:

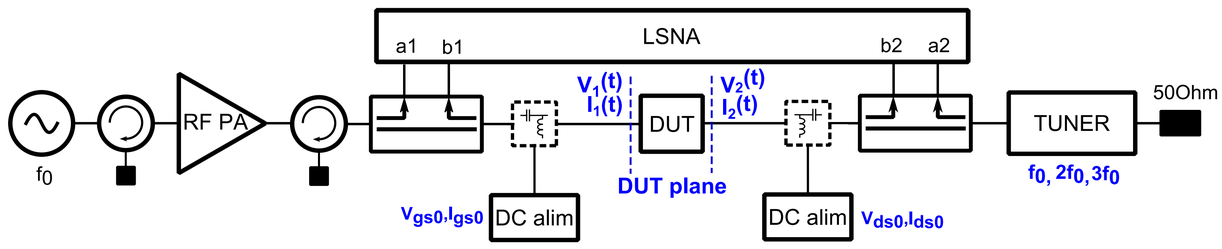
- ✓ **device reliability**
- ✓ **Safe Operating Area**

Test of two different HEMT Technologies:

- **GaAs** PPH25X 4x36 µm pHEMT transistor.
- **GaN** GH50-10 8x250µm transistor.

2. Time Domain System

The **DC parameters** (V_{gs0}, V_{ds0}, I_{gs0} and I_{ds0}) and **RF waveforms** ($V_1(t)$, $V_2(t)$, $I_1(t)$ and $I_2(t)$) are continuously recorded over 24 hours.

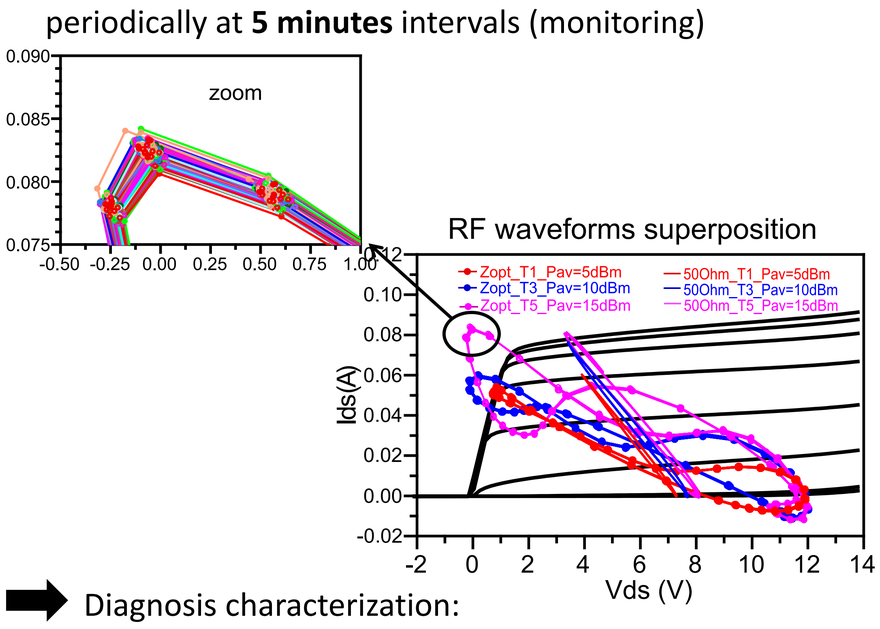


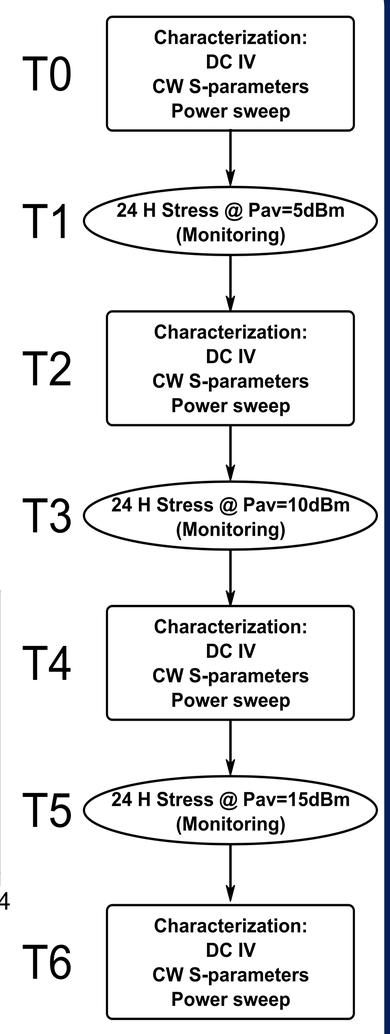
RF stress under overdrive condition consists on recording the calibrated time domain voltage and current waveforms [3,4] at both ports of the DUT driven by a CW large signal f_0 and loaded with fixed impedances at fundamental and harmonic frequencies (f_0, $2f_0$, $3f_0$).

3. Time domain RF Step stress in GaAs Technology

Time domain stress condition:

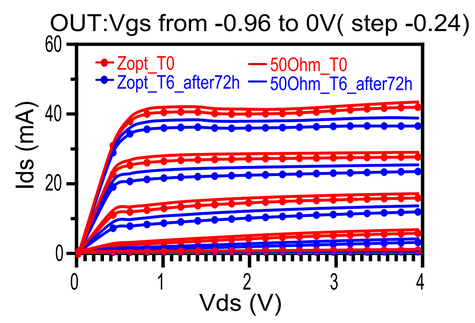
- 3 **different available power levels** at 4 GHz (5dBm, 10dBm and 15dBm)
- Two different load impedances: **optimal** PAE (Z_{OPT}=200Ω) and **output mismatching impedance** (Z_L=50Ω)
- **Class A** operation mode (Ids=15mA @ Vds=6V)
- **DC parameters** and **RF waveforms** were measured periodically at **5 minutes** intervals (monitoring)

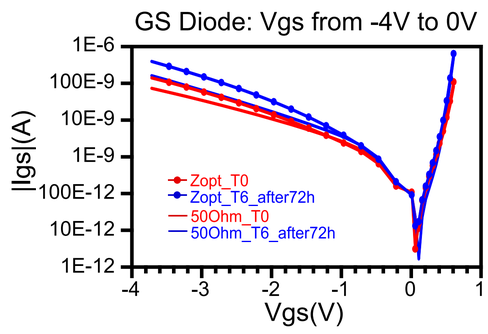


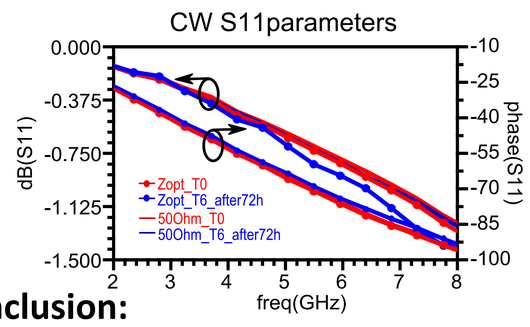


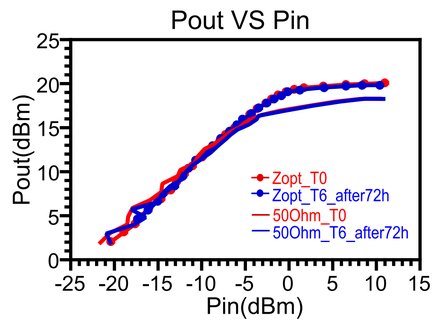
➡ Diagnosis characterization:

- **DC I-V** measurements (GS Diode, Id-Vg, Id-Vd)
- **CW S-parameters** measurements (2-8GHz)
- RF **power sweeps**









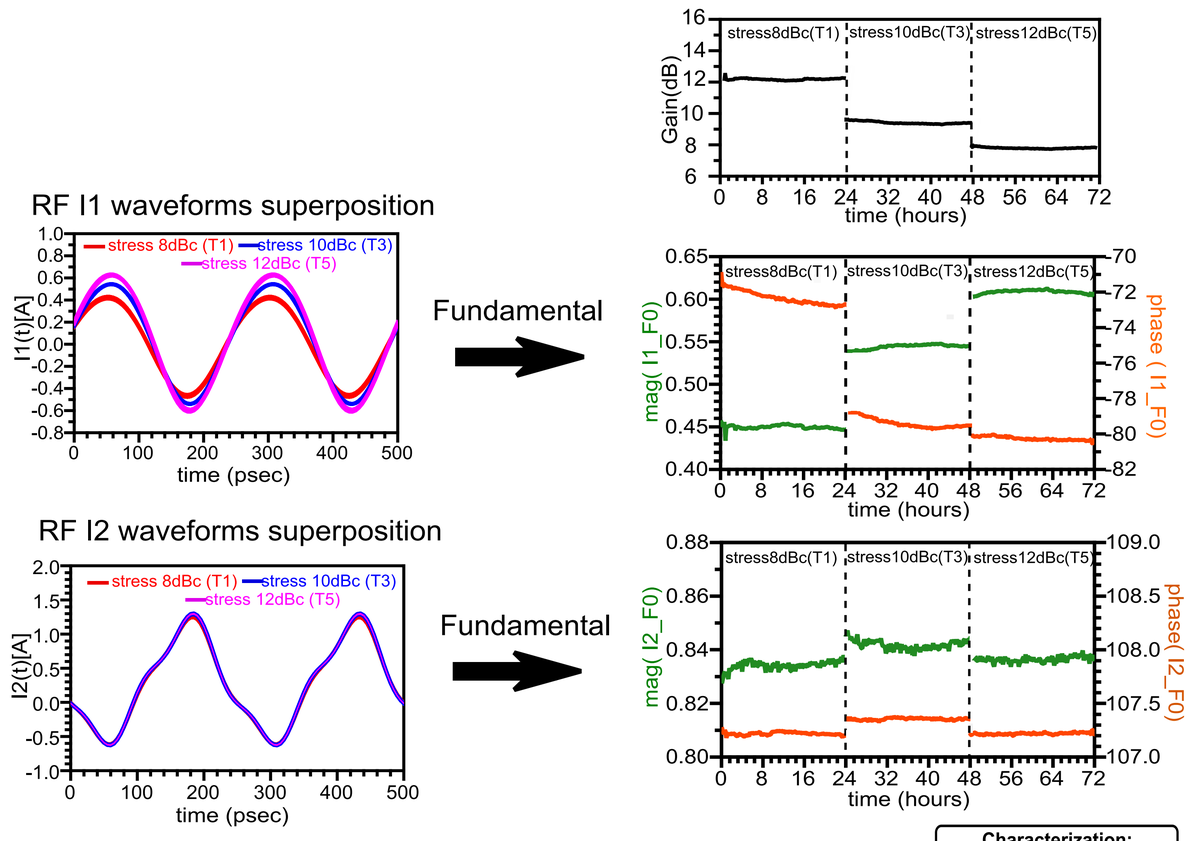
Conclusion:

- Variation of Gate current with RF power stress levels (variation S11 amplitude).
- No significant variation of large signal performances are induced by the RF stress.

4. Time domain RF Step stress in GaN Technology

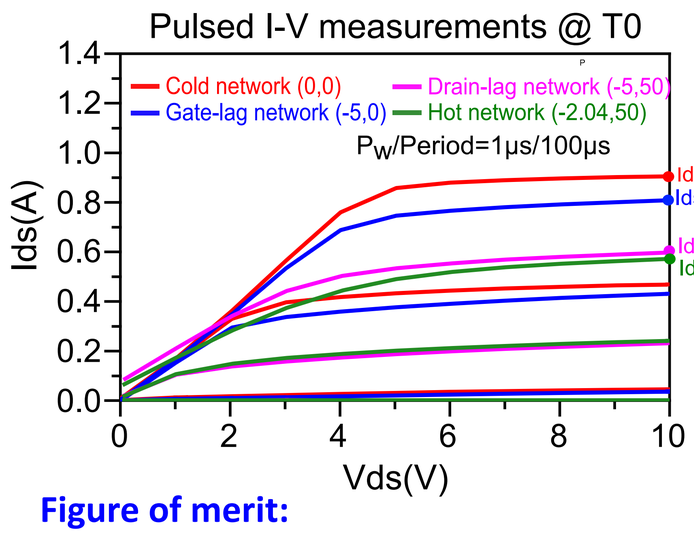
Time domain stress condition:

- 3 **different Gain compression** at 4 GHz (8dBc, 10dBc, 12dBc)
- Load impedance: **optimal PAE** (Z_{OPT}=19,12+j52,75Ω)
- **Class AB** operation mode (Ids=50mA @ Vds=50V)
- **DC parameters** and **RF waveforms** were measured periodically at **10 minutes** intervals



➡ NEW diagnosis characterization method (allows the extraction of the **electrothermal model** during the RF step stress [5]):

- **DC I-V** measurements (GS Diode, Id-Vg, Id-Vd)
- **Pulsed I-V** measurements:
  - ➢ **Cold** network (V_{Gbl}=0V, V_{Dbl}=0V)
  - ➢ **Gate-lag** network (V_{Gbl}=-5V, V_{Dbl}=0V)
  - ➢ **Drain-lag** network (V_{Gbl}=-5V, V_{Dbl}=50V)
  - ➢ **Hot** network (V_{Gbl}=-1,81V, V_{Dbl}=50V)
- **Pulsed S-parameters** measurements along working load line (0.5GHz-20 GHz) @(V_{Gbl}=-1,81V, V_{Dbl}=50V)
- RF **power sweeps**



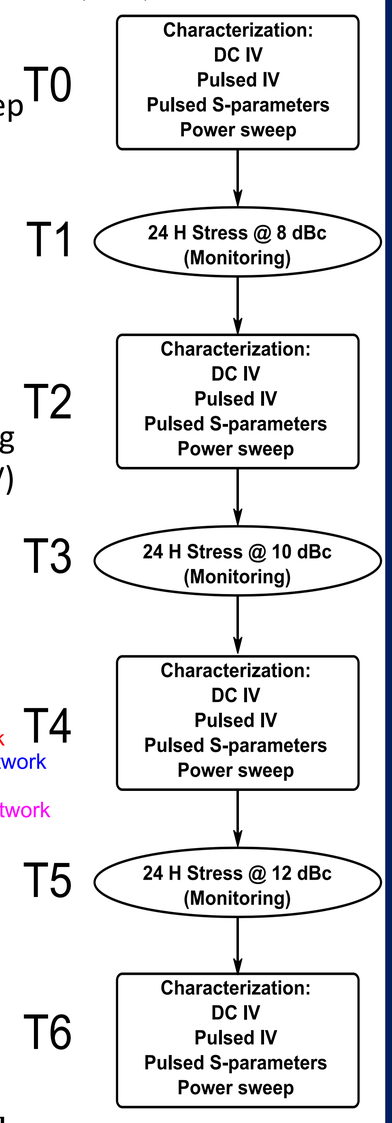


Figure of merit:

$$\text{current dispersion stress} = \left[1 - \frac{I_{ds_{Tn}}(V_{gs}=0V, V_{ds}=10V)}{I_{ds_{T0}}(V_{gs}=0V, V_{ds}=10V)}\right] \text{x}100 \quad \text{where n=2,4,6}$$

Current dispersion stress [%]	DC	Cold network	Gate-lag network	Drain-lag network	Hot network
After 8dBc (T2)	9	6	3	4	3
After 10dBc (T4)	10	4	3	4	2
After 12dBc (T6)	9	5	4	4	2

Preliminary Conclusion:

- Drop Ids current after first stress (10% in DC - <5% Pulsed IV).
- No significant variation of small & large signal performances are induced by the RF stress.

Perspectives:

- Increase **Time step stress (10 days)** & **Gain compression (16dBc)**

References:

[1] J. Joh et al., *ROCS Workshop*, p. 185–194, 2008.
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[5] O. Jardel et al., *IEEE Trans.*, vol. 55, n° 12, p. 2660-2669, 2007.