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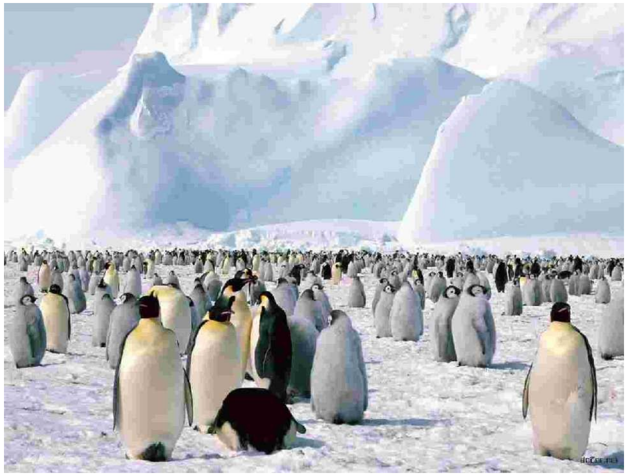
LEADING BEYOND S-PARAMETERS

HIP @ ICE

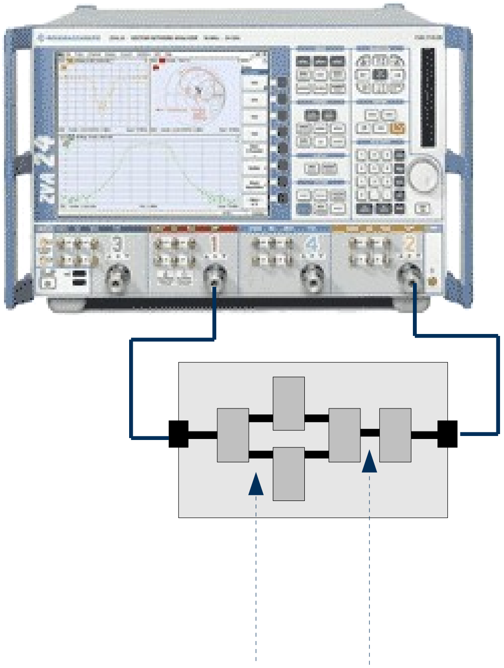
using high-impedance probes for in-circuit voltage time-domain measurements



2/2012

Summary

Goal: accurate in-circuit measurement of time-domain voltage using one or more high-impedance probes (HIP) within a large-signal network analysis context @ locations normally unreachable using a vector network analyzer



Supported:
- Multiple probes
- Probing on PCB
- Probing on wafer

What are the voltage waveforms in-between the components?

How to measure these accurately?	Apply proper calibration techniques
How to minimize their disturbance?	Use high-impedance probes

Outline

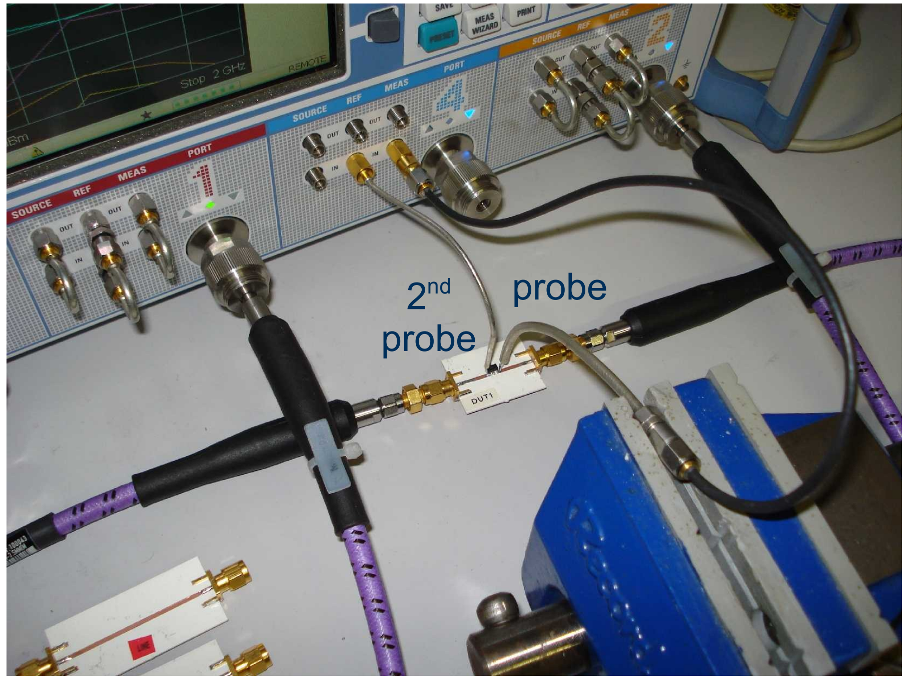
- Calibrated measurement using “home-made” HIP and ZVxPlus (*)
  - Measurement setup
  - Measurement results
  - Impact of high-impedance probing
  - Calibration

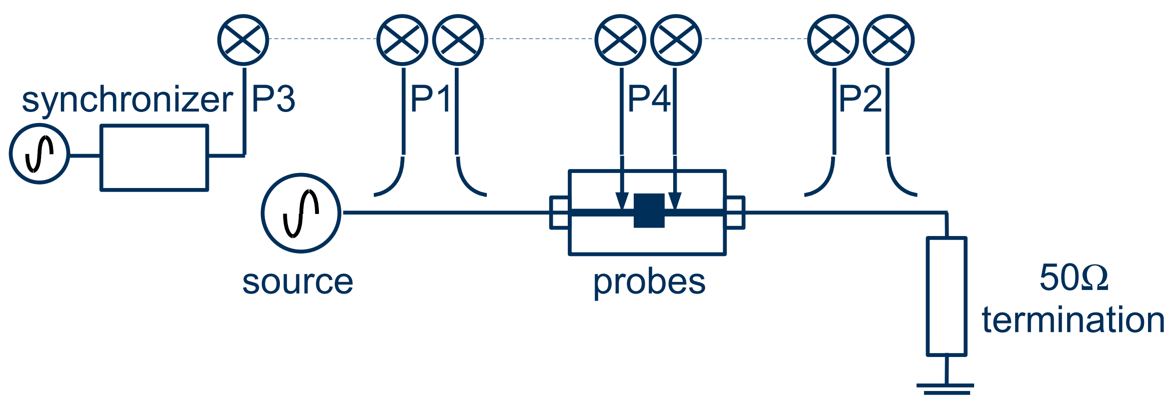
- Calibrated measurement using commercial Kelvin probe and real-time scope
  - Measurement setup
  - Measurement results
  - Impact of high-impedance probing
  - Calibration

(*) R&S ZVA24 VNA with nonlinear extensions to allow time-domain measurements

Measurement using calibrated HIP in practice (I)

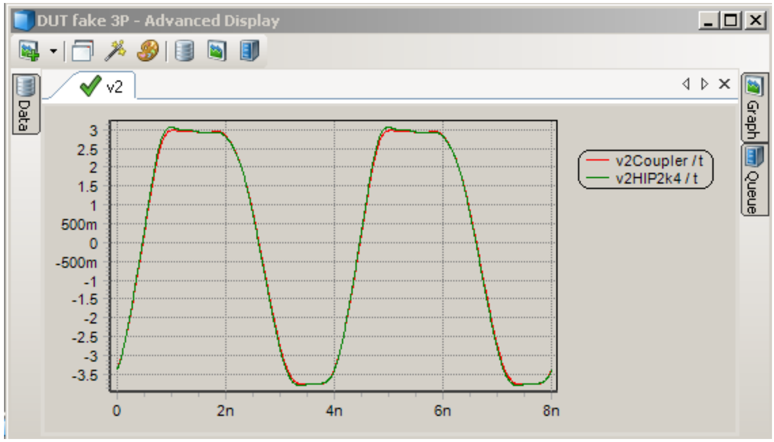
Sanity check measuring the output voltage of an E-pHEMT FET
-5 dBm input @ 250 MHz, Vgs = 0.4 V, Vds = 4 V





2nd calibrated HIP probe allows to measure the input voltage

Measurement using calibrated HIP in practice (II)



v2(t)

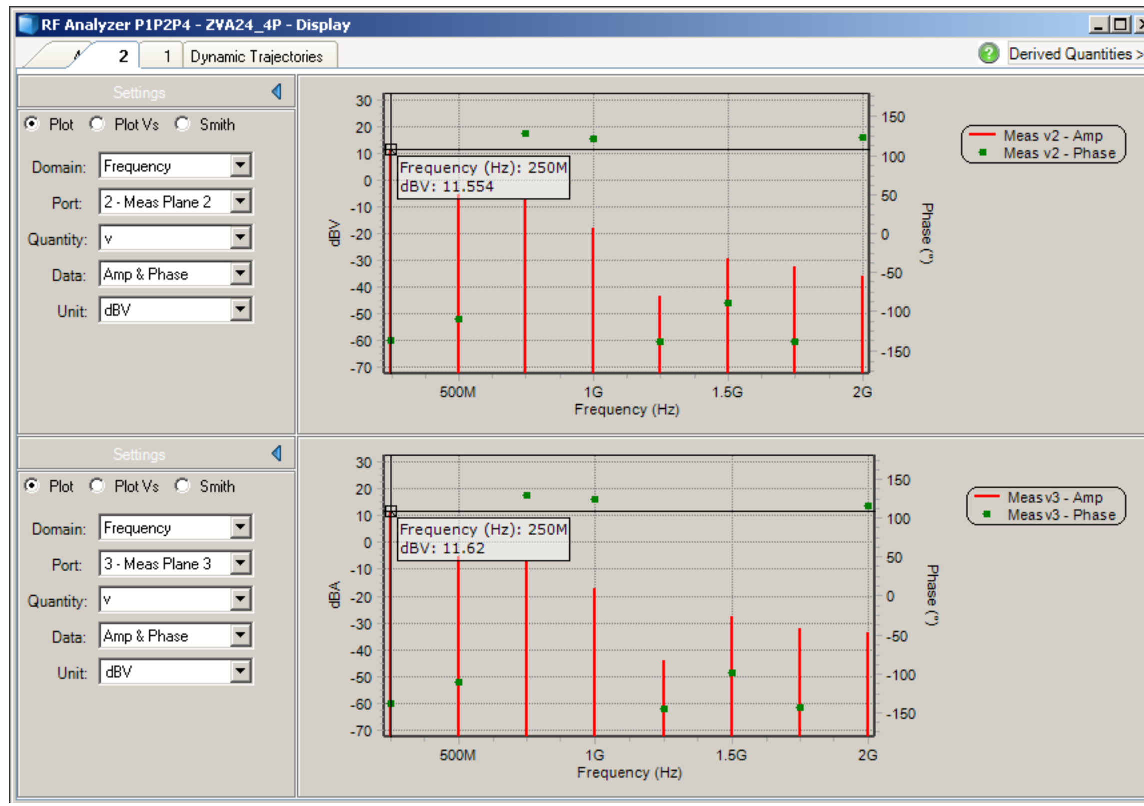
excellent agreement between output voltage (red) measured using the TRL-calibrated coupler-based two-port network analyzer and the voltage (green) measured by the calibrated high-impedance probe

v2(f)

corresponding excellent agreement of amplitude and phase in the frequency domain

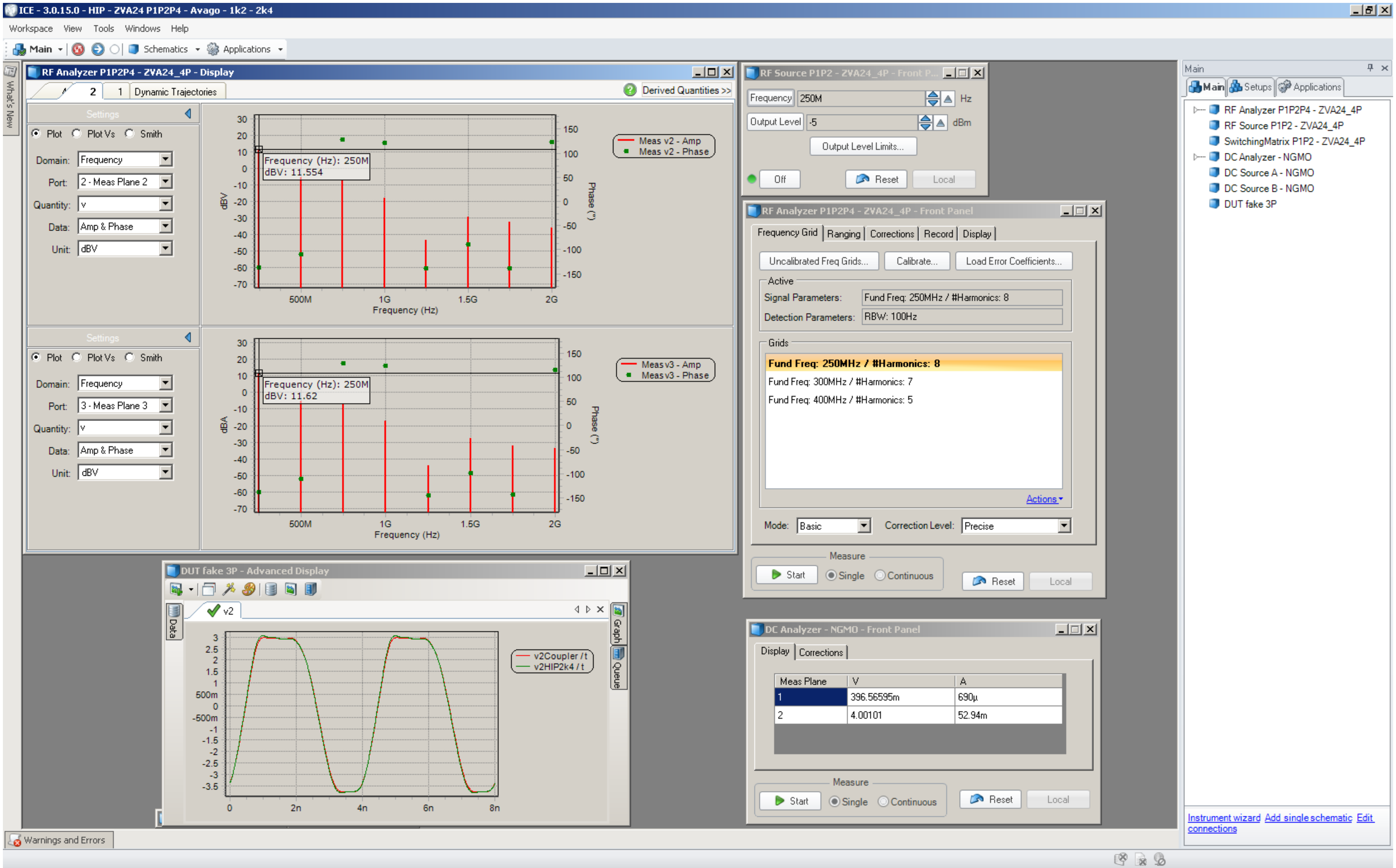
upper: coupler-based amp & phase

lower: calibrated HIP amp & phase



Measurement using calibrated HIP in practice (III)

"a global ICE perspective"



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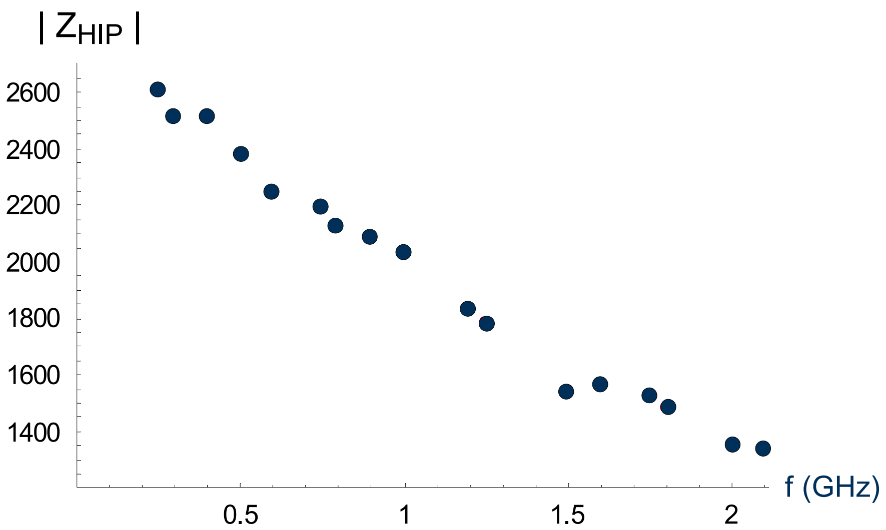
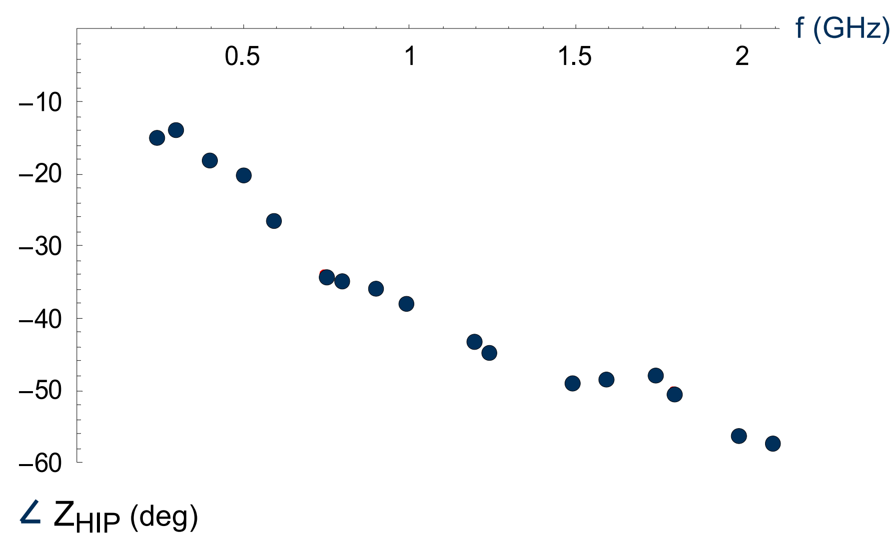
Impact of high-impedance probing(*)

The impedance of the probe is measured during calibration

↓

The impact of the high-impedance probe can be taken into account

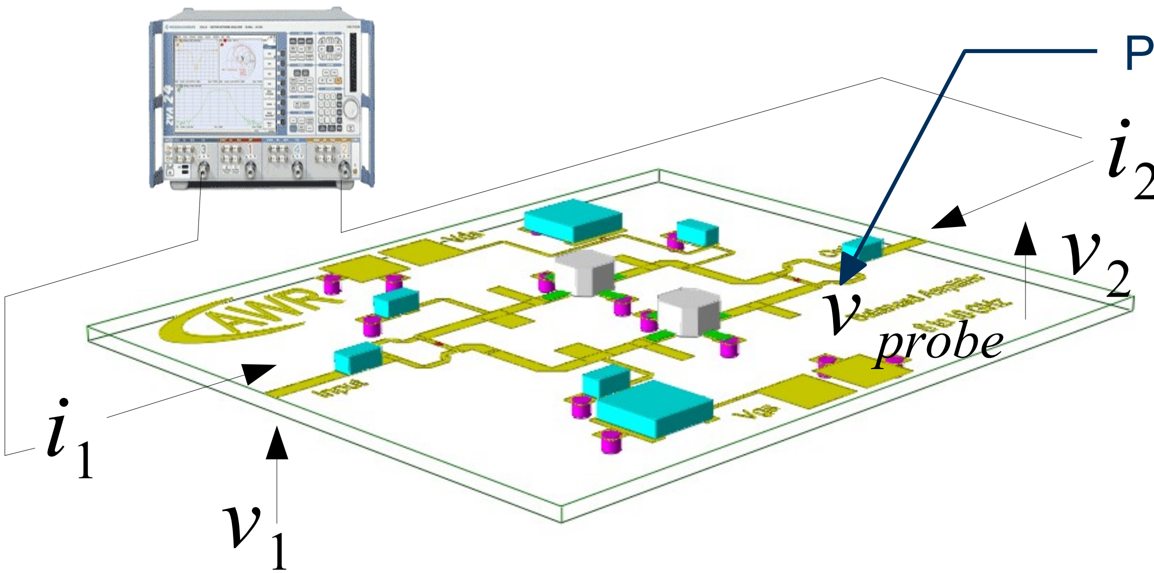


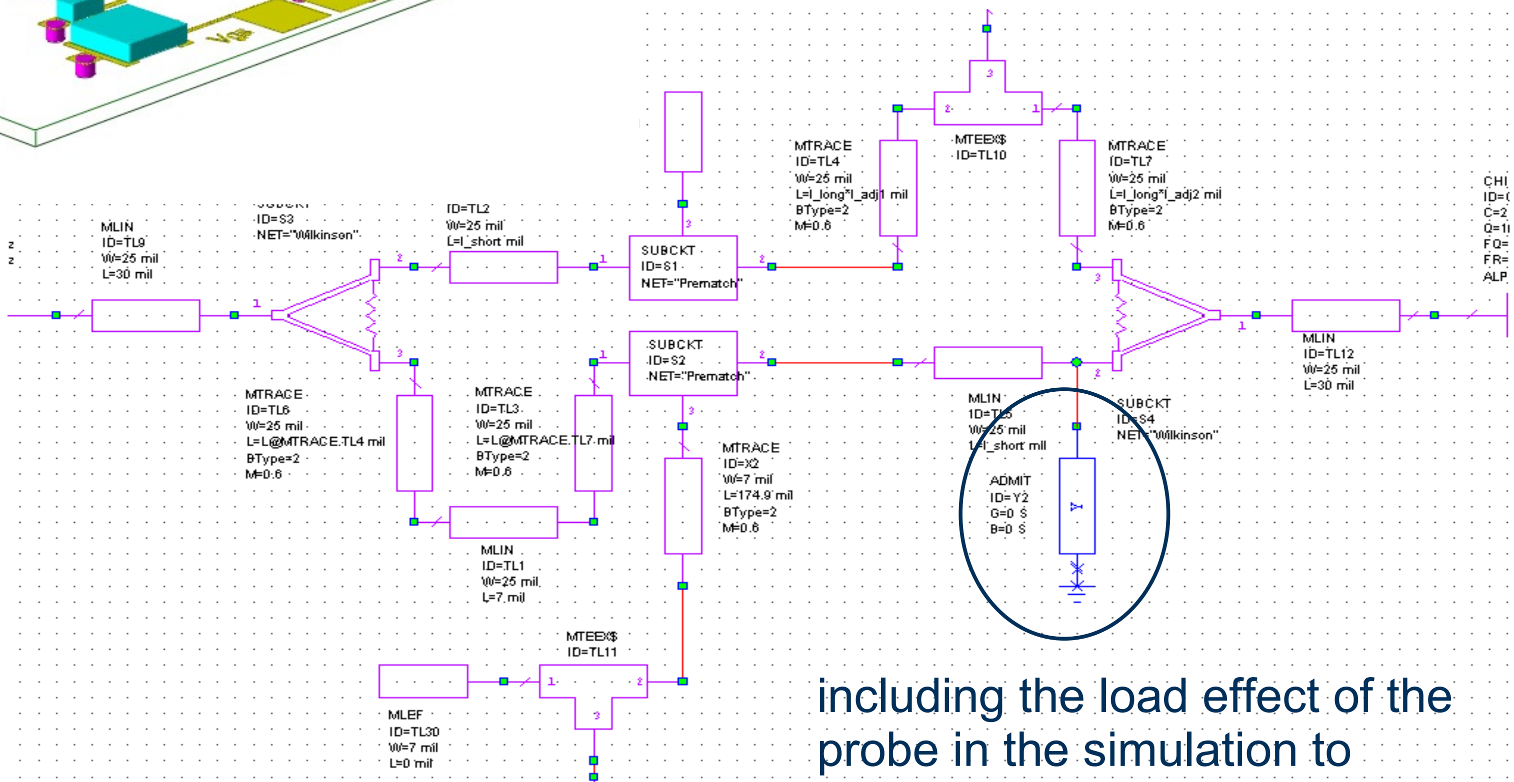


Estimated impedance of “home-made” (2k4) HIP

(*) in fact the combination of the probe, cable and receiver input

Including impact of high-impedance probe during simulation





including the load effect of the probe in the simulation to compare measurements with simulations

Figure and schematic courtesy of AWR

Calibration process

- **Step 1:** perform a “standard” one-port or two-port VNA calibration, extended with power and phase calibration to measure time-domain information
- **Step 2:** use the calibrated system resulting from step 1 to calibrate the high-impedance probe
- **Step 3:** use the calibrated high-impedance probe to measure the time-domain voltage in-circuit

Calibration of high-impedance probe (step 2)

Different options are possible, such as :

- Starting from an absolute TRL-based two-port calibration :
  - Connect the HIP to the open of the TRL calibration kit (fig. 1)
  - Connect the HIP to the thru of the TRL calibration kit (fig. 2)
- Starting from an absolute on-wafer one-port calibration :
  - Connect the HIP to the open of the on-wafer calibration kit
- Starting from an absolute coaxial one-port (or two-port) calibration :
  - Connect the HIP to the open on a microstrip or coplanar waveguide PCB provided by NMDG
  - De-embedding information provided with PCB allows to move the absolute calibration from the coaxial plane to the open on the PCB

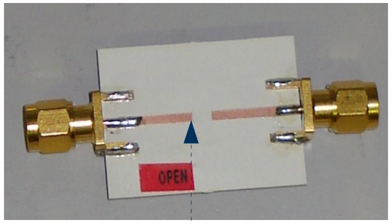


fig. 1

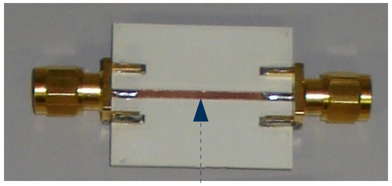
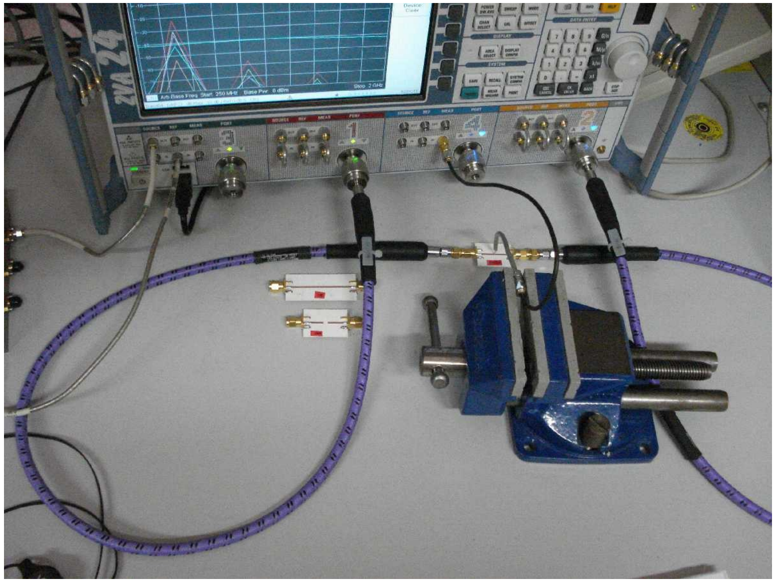
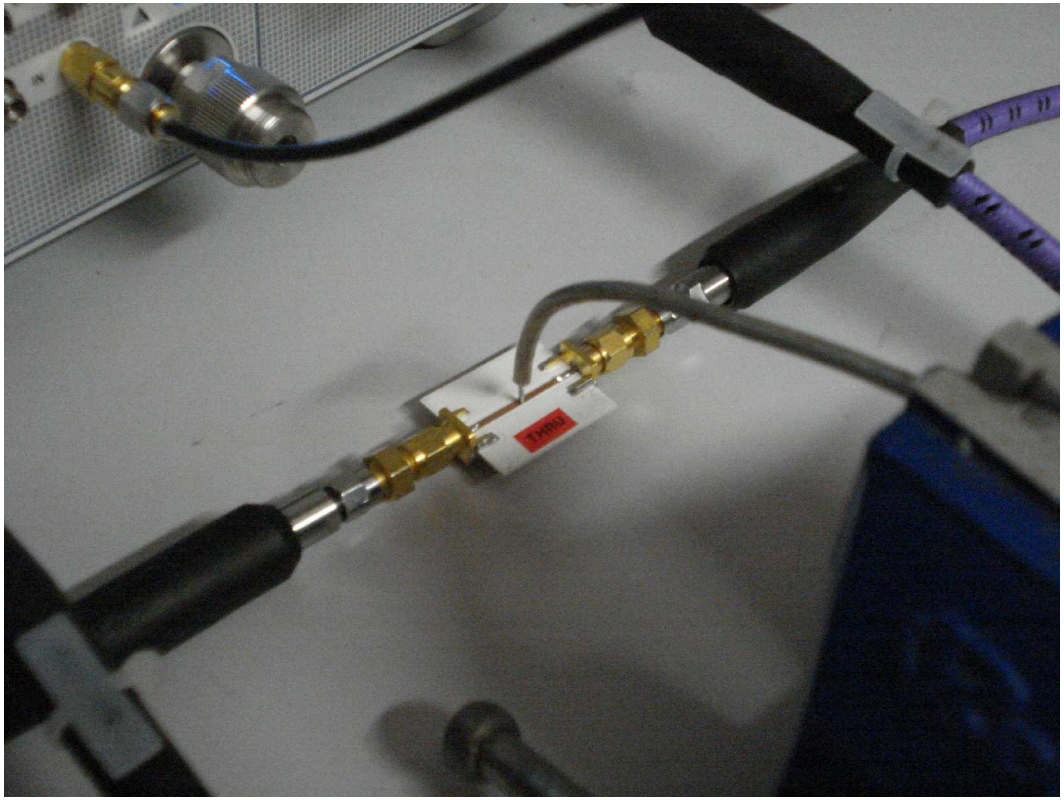


fig. 2

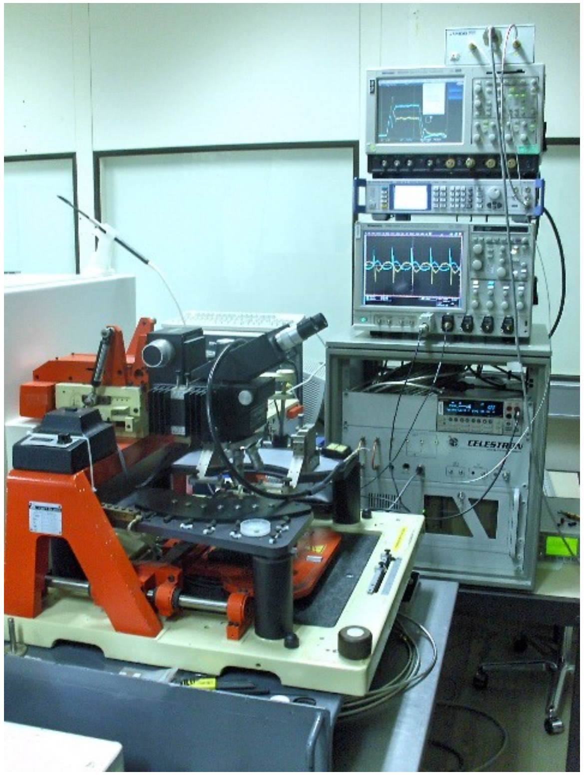
High-impedance probe calibration in practice (step 2)

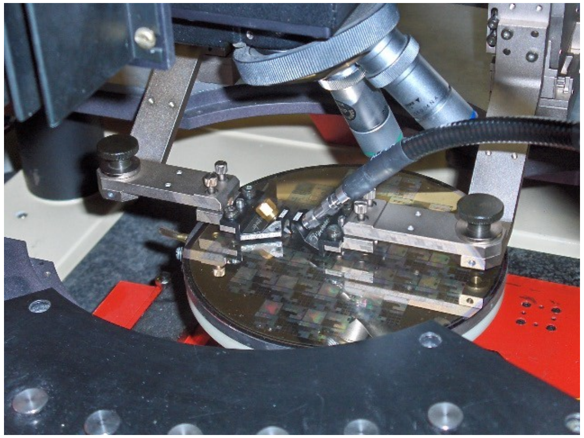


Connecting the “home-made” (2k4) HIP
to the thru of the TRL calibration kit

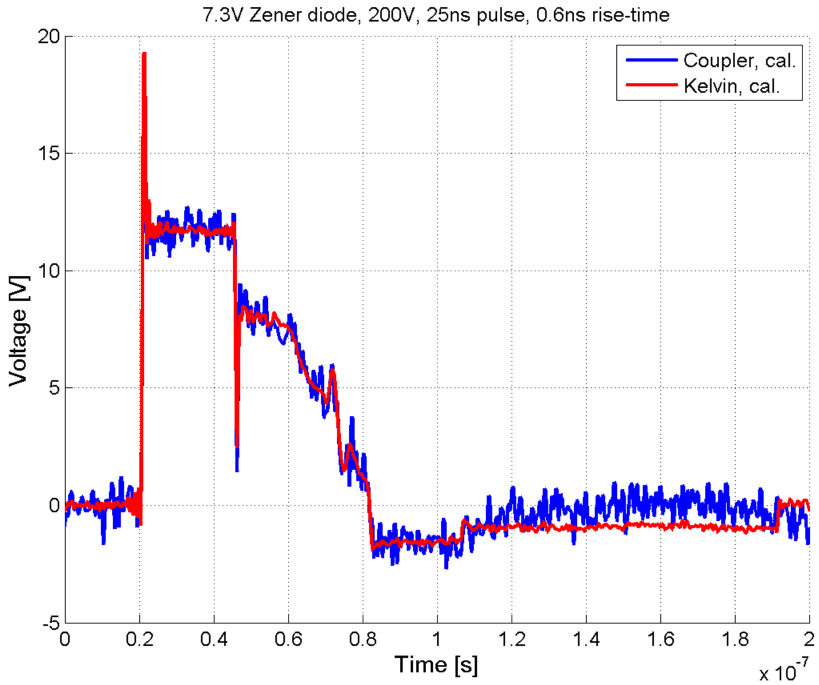


HIP and real-time scope : ESD (TLP) @ OnSemi





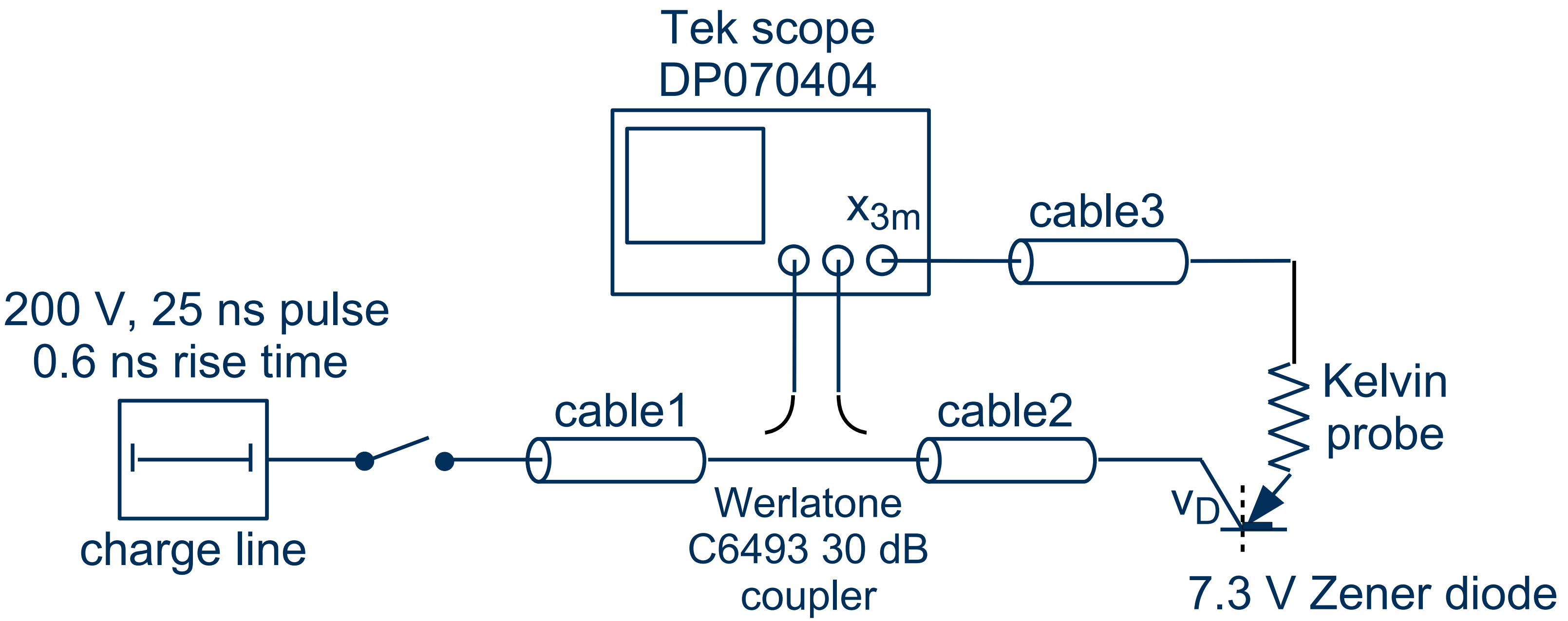
Using a **calibrated Kelvin probe** as part of a **transmission line pulse (TLP) system** to re-construct **dynamic voltage waveforms** on **low-impedance devices** subjected to **high currents** with a **very significant improvement in the signal-to-noise ratio**



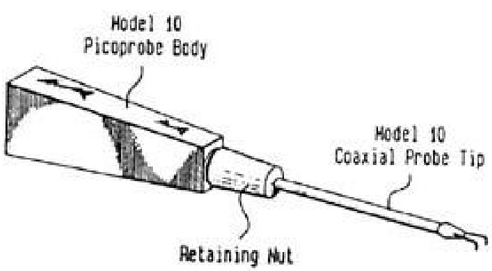
Comparing reconstructed voltage waveforms at the DUT, measured on a 7.3V Zener diode, subjected to a 200V TLP pulse. Blue : reconstructed using data from the directional couplers. Red : corrected data from Kelvin-probe.

Photos and figure courtesy of Renaud Gillon (OnSemi, Oudenaarde, Belgium)

TLP measurement setup



Kelvin probe

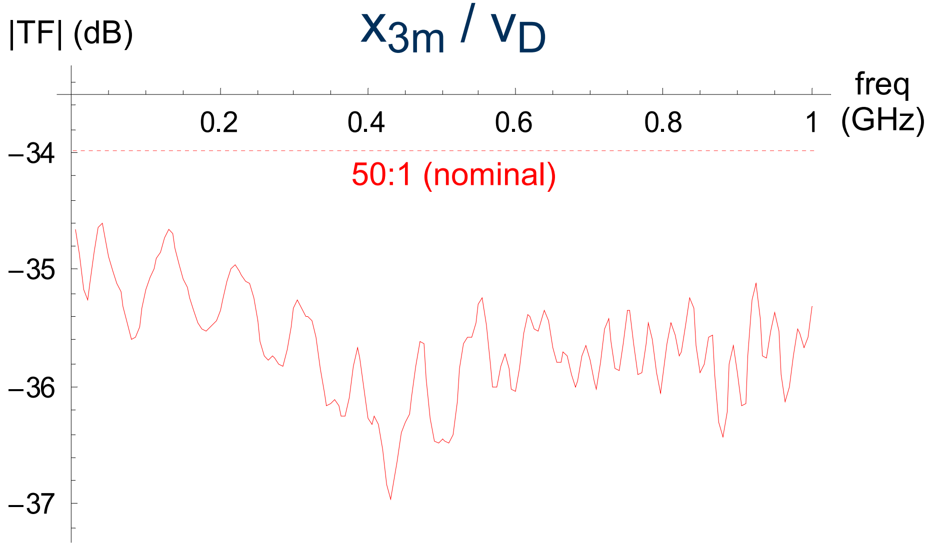


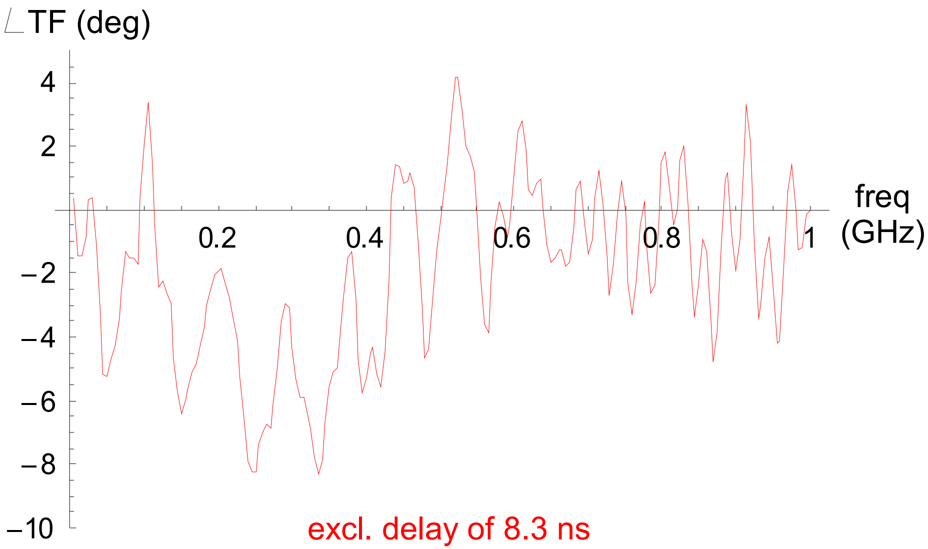
http://www.ggb.com/10.html

Combined impact of Kelvin probe(*), cable3 and scope

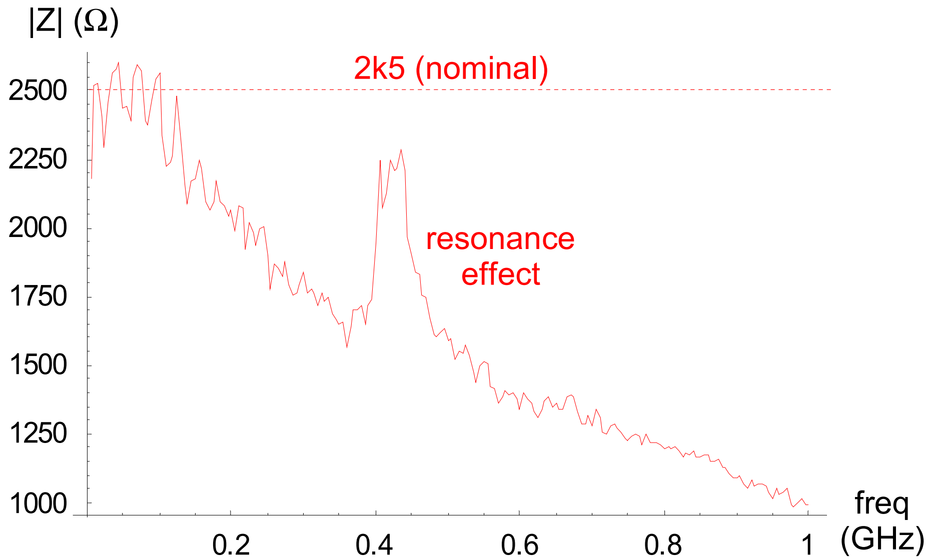
transfer function

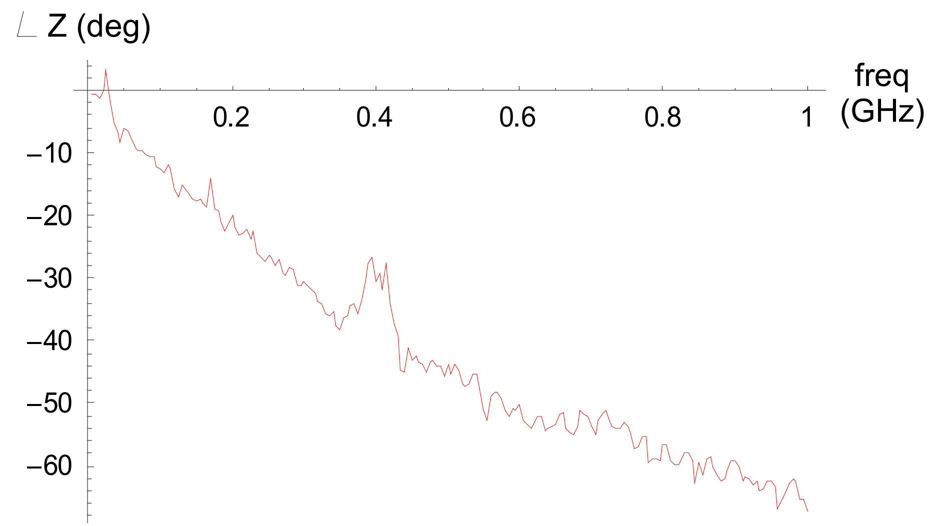
x_{3m} / v_D





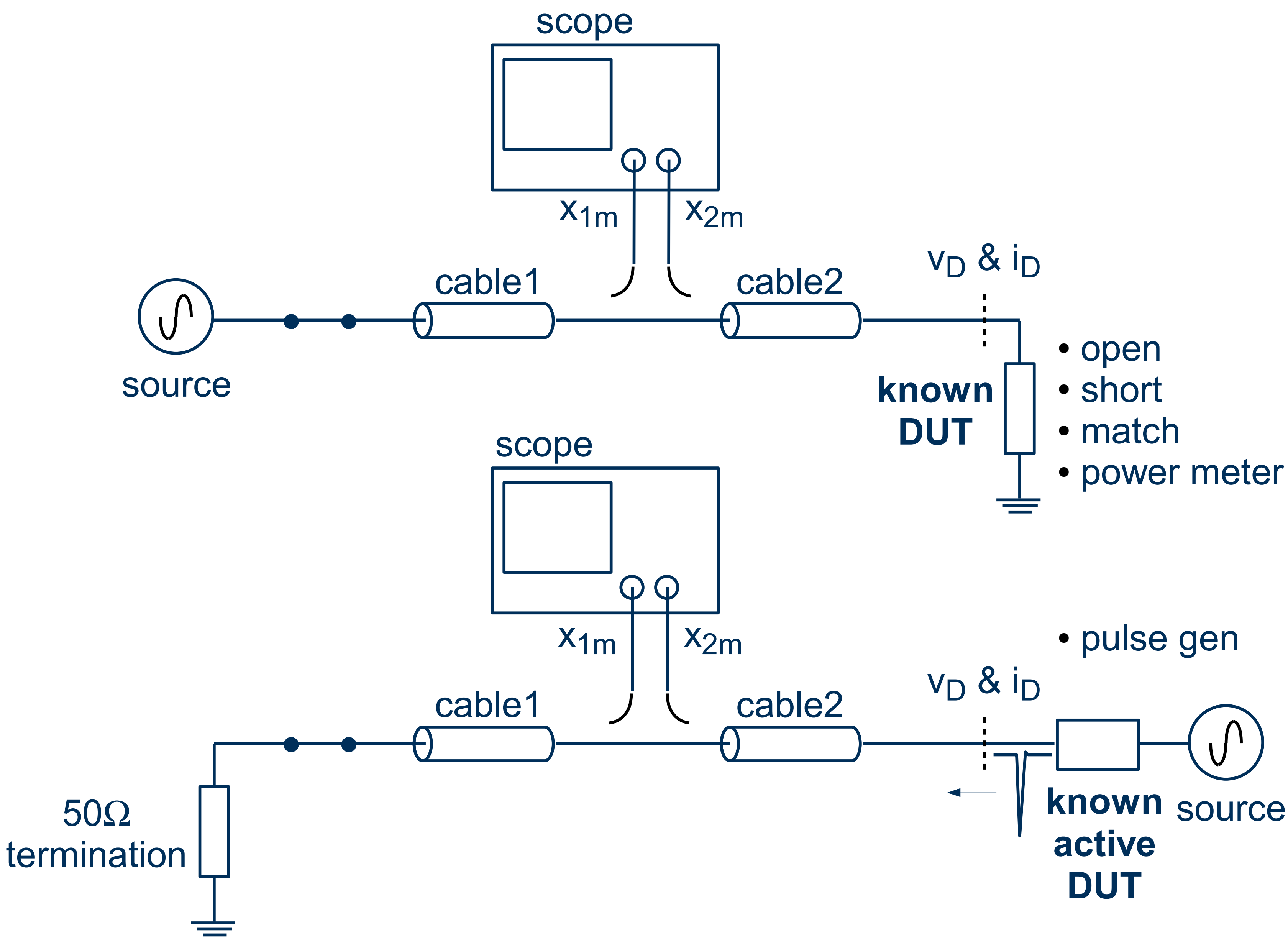
impedance





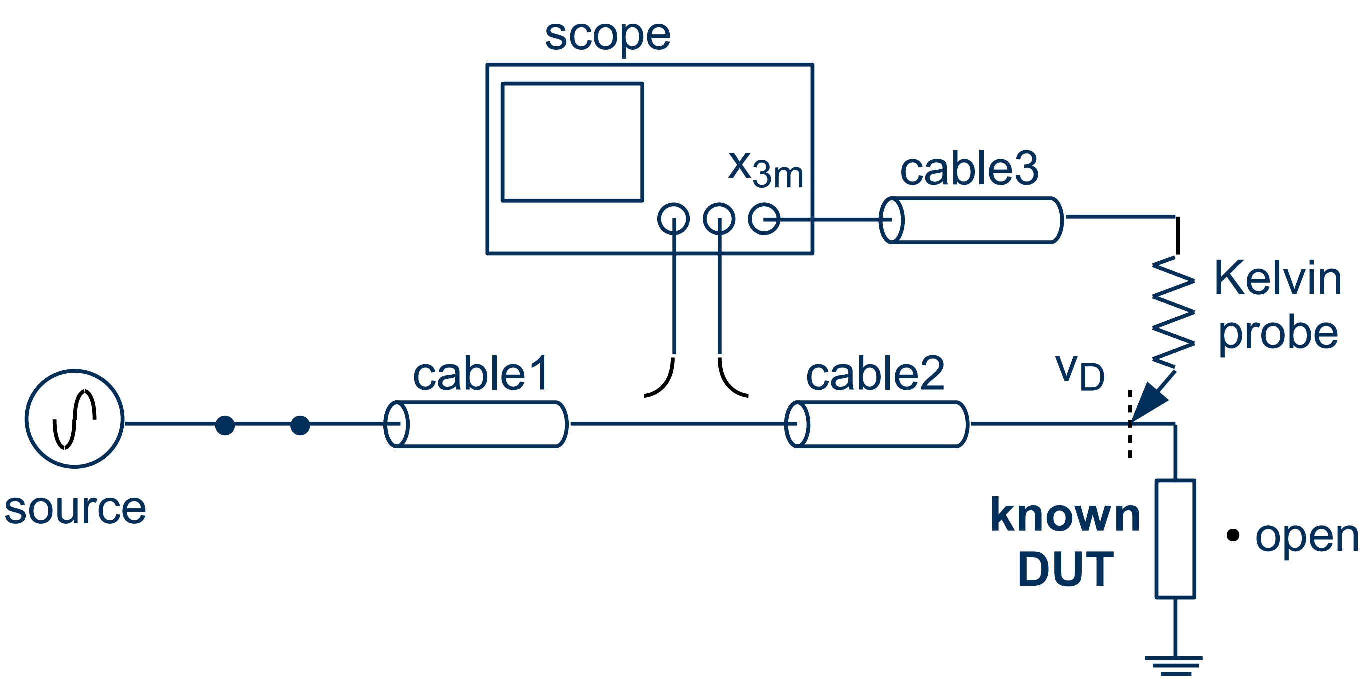
(*) GGB – Model 10 - 2k5

Primary calibration of TLP system



in case of on-wafer the absolute calibration is performed at an “Auxiliary” coaxial calibration plane

Additional calibration of TLP system



- Compare x_{3m} to calibrated coupler-based v_D while measuring an open
  Transfer function: $TF = 1 / e_{33} = x_{3m} / v_D$
- Measure impedance of Kelvin probe during calibration (using i_D)
- Allows to take effect of finite impedance into account during simulation

Acknowledgements and References

- NMDG wants to thank Rohde & Schwarz and OnSemi for their support

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  IEEE Microwave and Wireless Components Letters,
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Contact info

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