On the feasability of single touch on wafer calibration using HBT (on wafer ECAL)

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overview

- advantages of ecal
- methodology description
- results
- discussion

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advantages of electronic calibration on wafer (ecal)

- complete calibration with only one contact (compared to four with SOLT)
- improved repeatability
- simpler wafer handling and recalibration of the VNA
- reduced probe head contacts
- coaxial calibration with on wafer standards is also possible

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measurement procedure - part I

1 two-port self calibration procedure using ISS standards (e.g. TRL)

2 measurement and deembedding of the DUT (e.g. Transistor) test fixture e.g. [1]

3 one-port measurement with port1 of the base-emitter diode at three different operating points to have three different “non overlapping“ reflection coefficients.

4 repeat the reflection measurements with port 2 (same device and operating points, second contact)

5 calculation of the calibrated reflection coefficients

[1] K.H.Yau, et al., “A Transmission-Line Based Technique for De-Embedding Noise Parameters“, 2007 IEEE ICMTS, pp.237-243.

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measurement procedure - part II

6 perform uncalibrated measurements of steps 3 and 4

7 contacting an arbitrary DUT with the same test fixture as in 2 and measure a reciprocal operating point (unknown thru)

8 calculating 12-Term error coefficients with data from 6 and 7 with models from 5 (SOLR-Method [2])

9 measure the calibrated S-parameters of the DUT at the desired operating points.

10 for recalibration repeat only steps 6 to 8

[2] A.Ferrero, U. Pisani, "Two-Port Network Analyzer Calibration Using an Unknown "Thru"", 1992 IEEE MGWL,Vol.2, No 12, pp.505-506.

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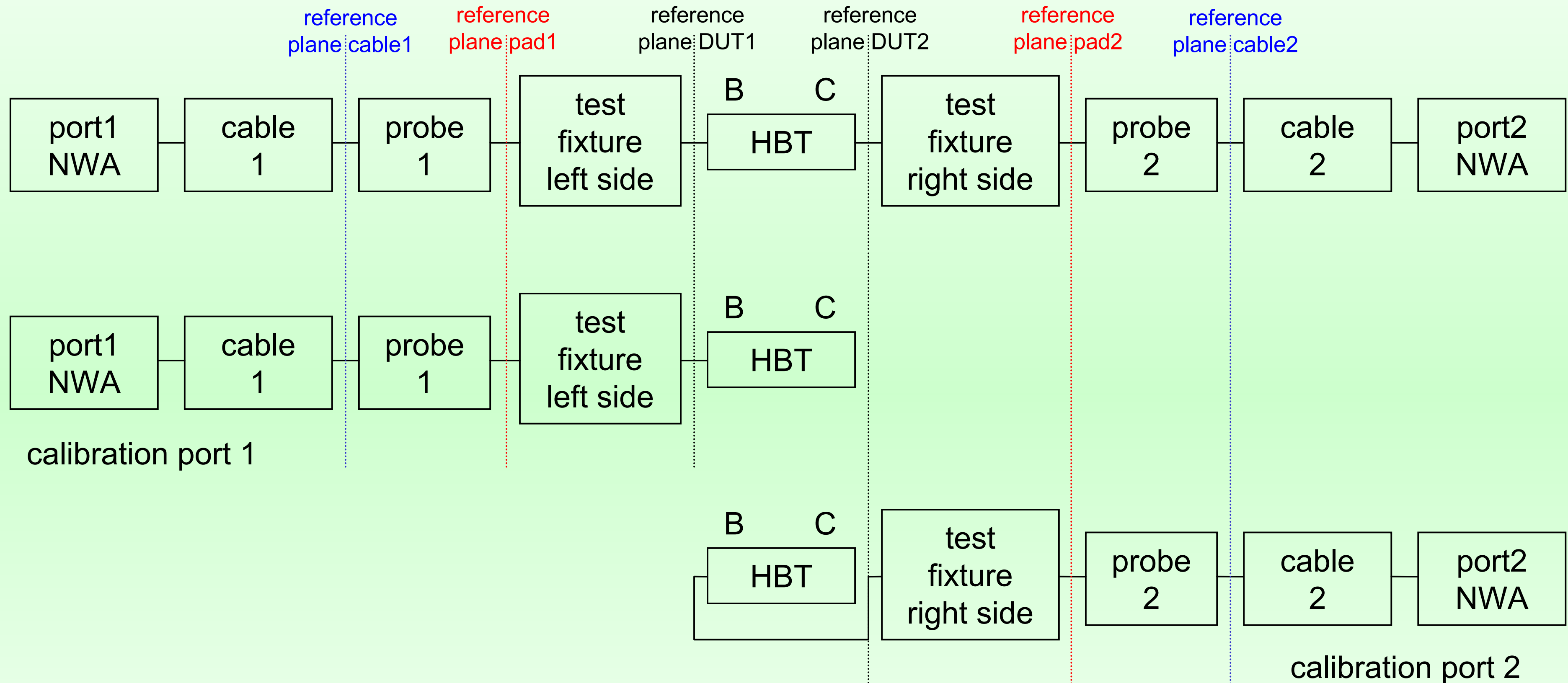
signal flow charts
two port and one port measurements



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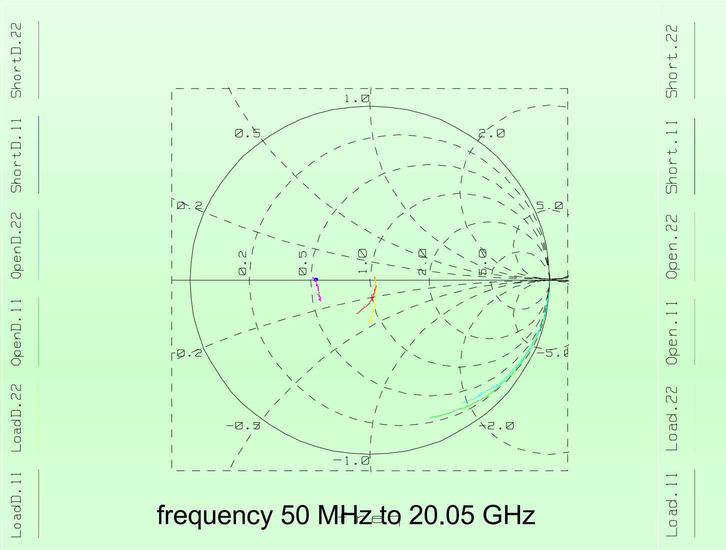
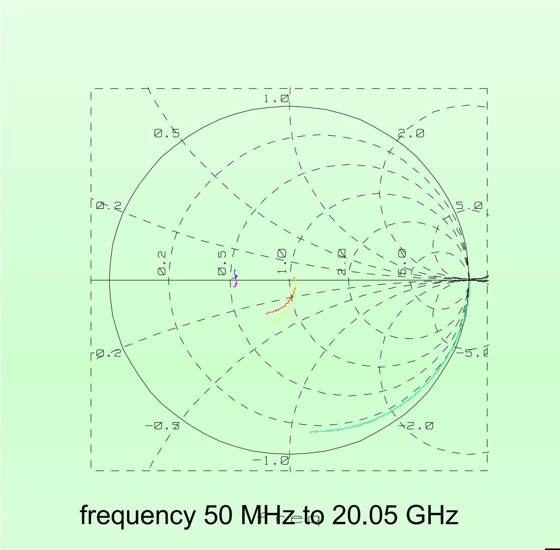
reflection coefficient comparison port 1 with port 2 data

reference plane DUT



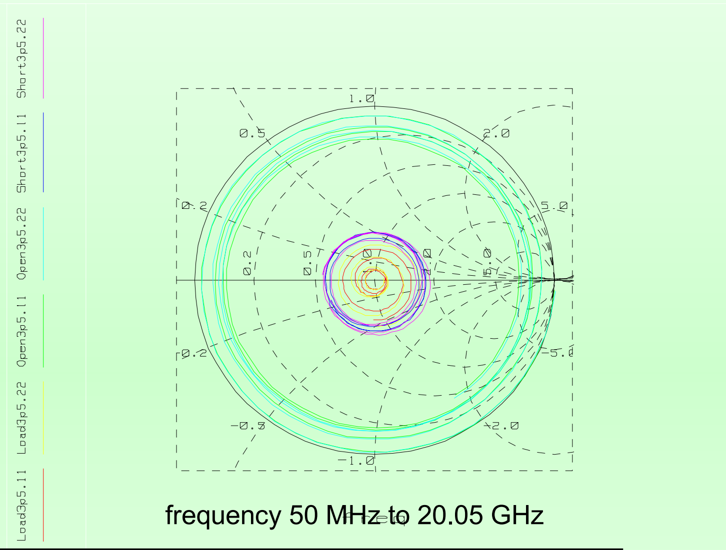
frequency 50 MHz to 20.05 GHz

reference plane pad



frequency 50 MHz to 20.05 GHz

reference plane cable



frequency 50 MHz to 20.05 GHz

GaAs HBT 8x1.5x1.5 μm^2 emitterarea

operating points: I (Open)=0 mA , I (Load)= 1 mA, I (Short)=6 mA

problem: difference between port1 and port2 calibration

reason: -probe positioning error? -different coupling of the probe to the substrate?

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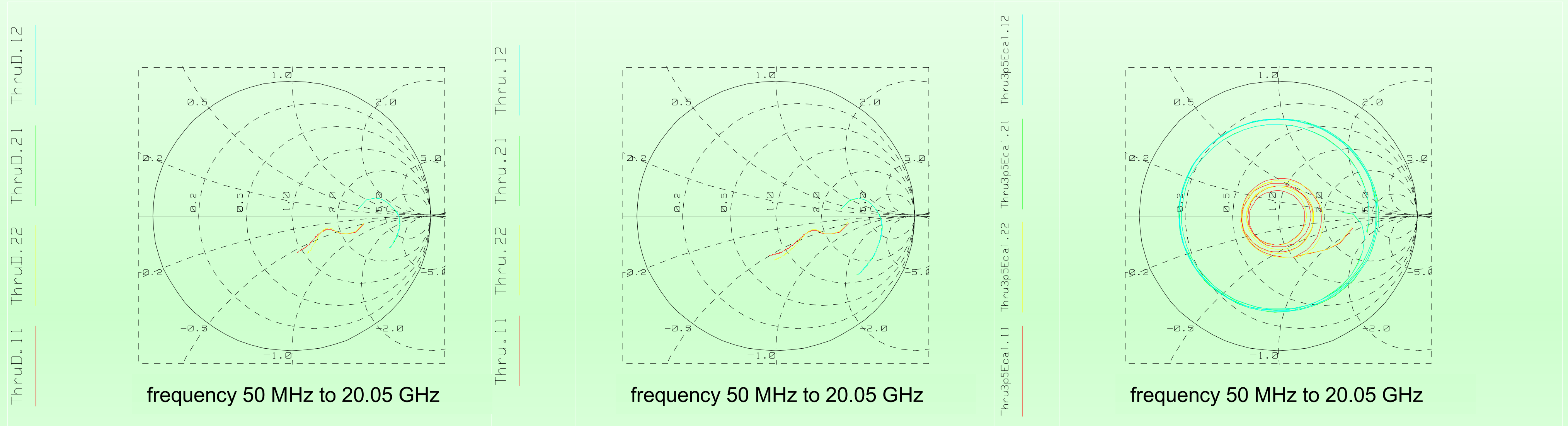
transmission coefficient



GaAs HBT 8x1.5x1.5 μm^2 emitterarea

operating point: I (port1)=-I (port2)=0.5 mA

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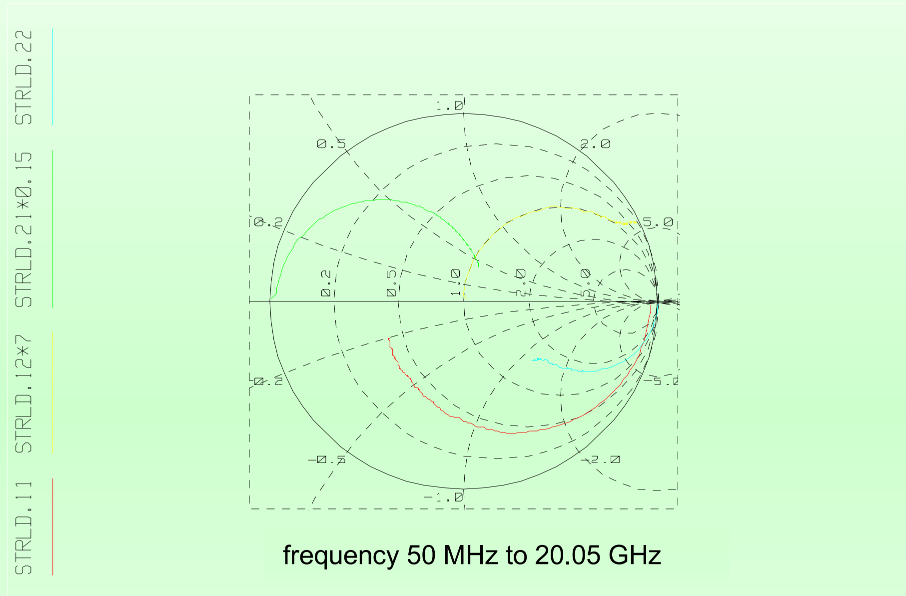
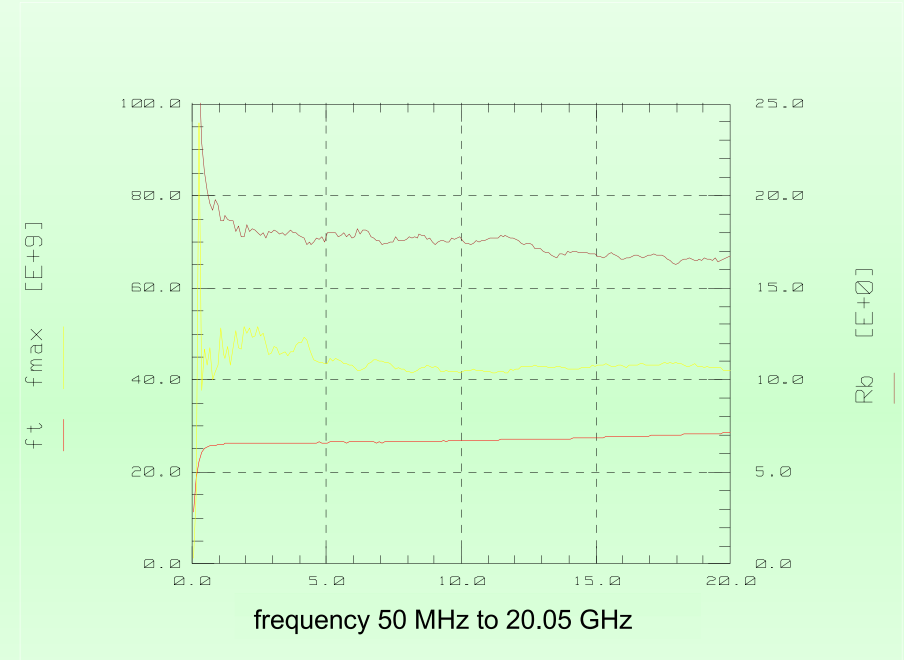
verification - transistor

reference plane DUT



frequency 50 MHz to 20.05 GHz



frequency 50 MHz to 20.05 GHz

GaAs HBT 8x1.5x1.5 µm² emitterarea

operating point: I (port1)=50 µA, V (port2)=3 V

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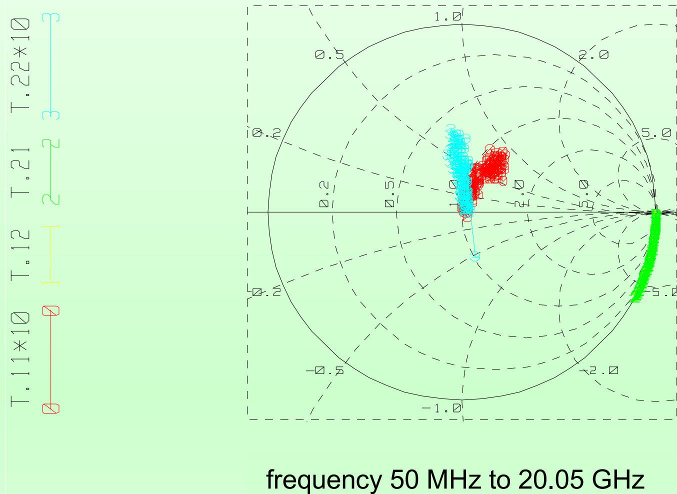
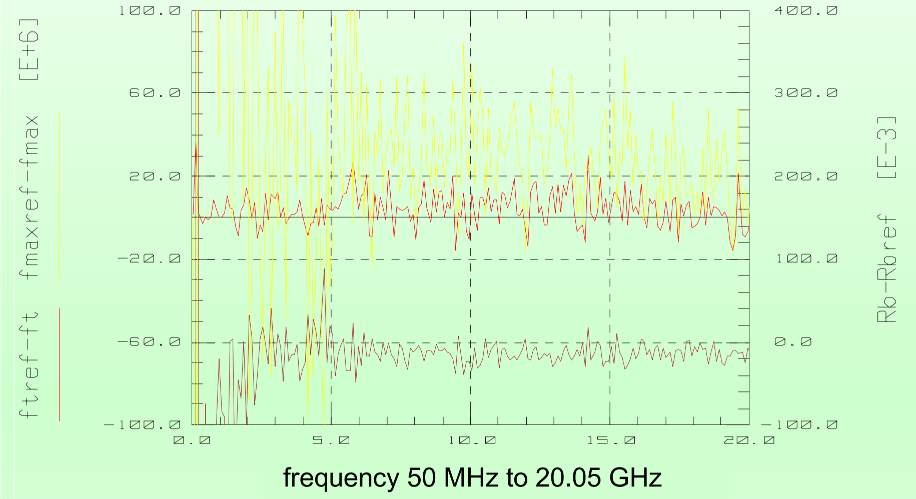
verification - transistor using nearly ideal reciprocal standard



frequency 50 MHz to 20.05 GHz



frequency 50 MHz to 20.05 GHz

3.7 ps transmission line as reciprocal standard for SOLR

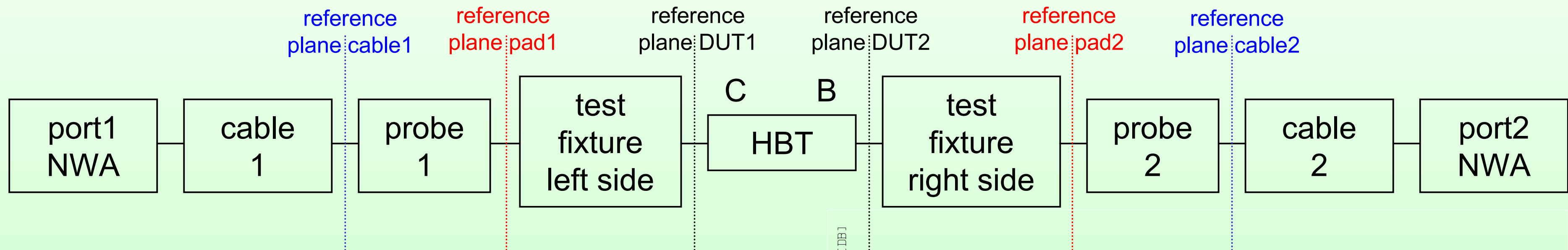
reference plane DUT

GaAs HBT 8x1.5x1.5 μm^2 emitterarea

operating point:

I (port1)=50 µA, V (port2)=3 V

verification - transistor turned 180°



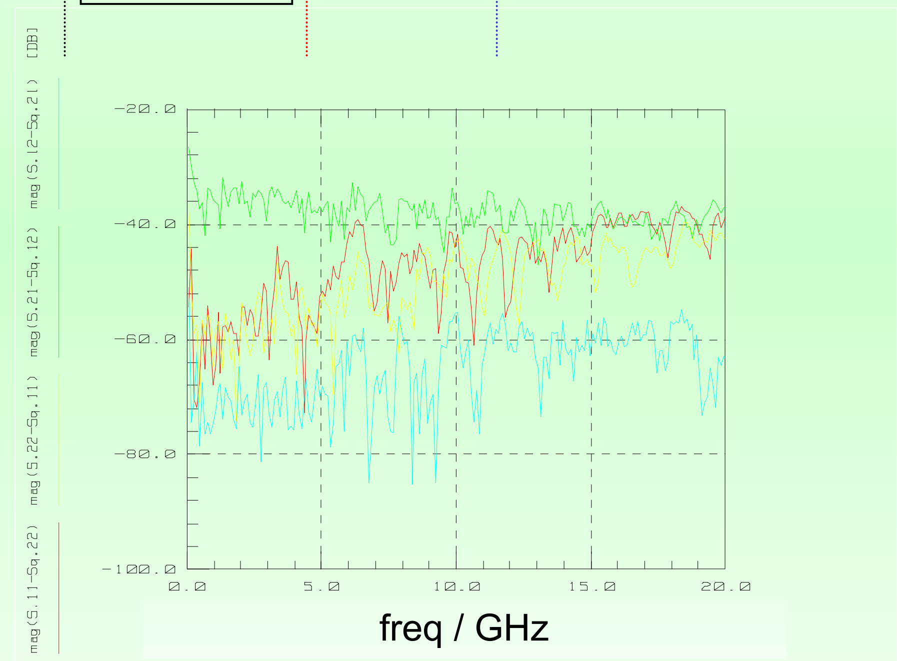
reference plane DUT

GaAs HBT 8x1.5x1.5 μm² emitterarea

operating points:

S: I (port1)=50 μA, V (port2)=3 V

Sq: I (port2)=50 μA, V (port1)=3 V



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verification - repeatability of steps 1-9

reference plane DUT

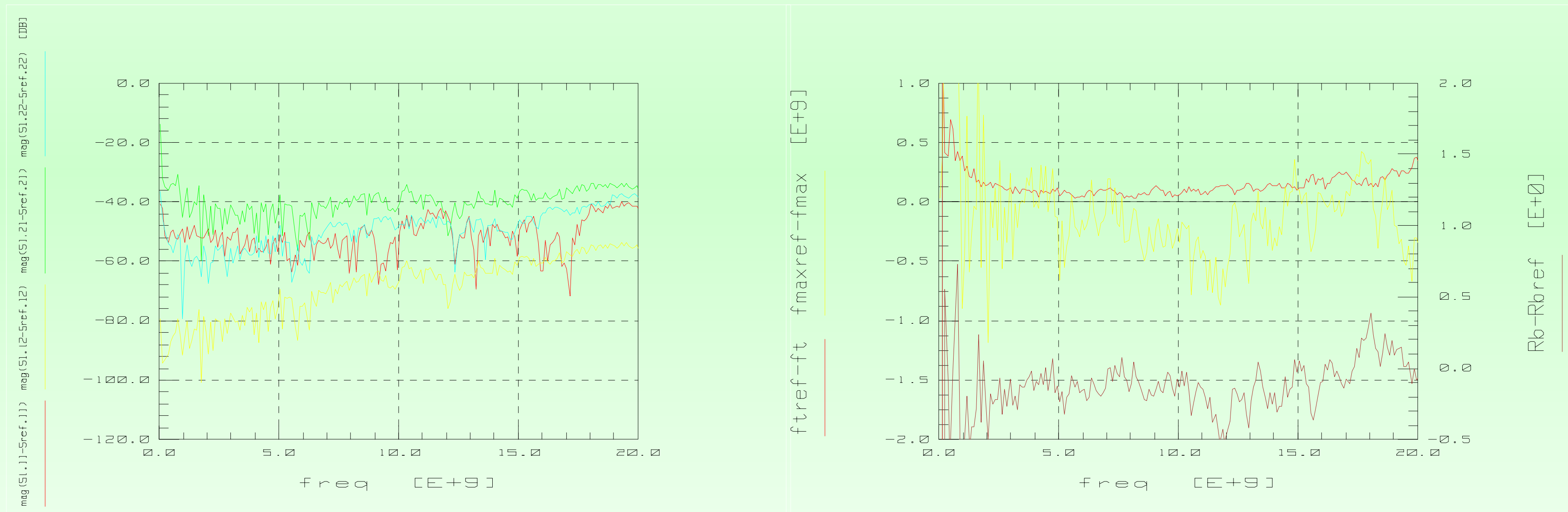
GaAs HBT 8x1.5x1.5 µm² emitterarea

operating point:

I (port1)=50 µA, V (port2)=3 V

Sref: reference measurement

S1:repeating steps 1-9 three weeks later



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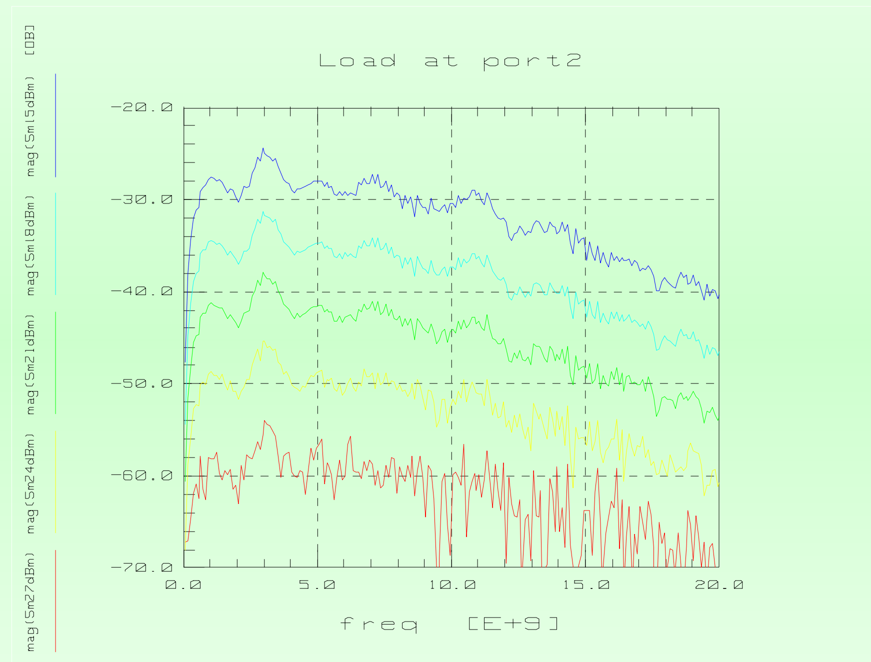
verification - linearity of uncalibrated data

reference plane DUT

GaAs HBT 8x1.5x1.5 µm² emitterarea

vector difference of data from -27 dBm to -15 dBm in 3dB steps with data at -30 dBm



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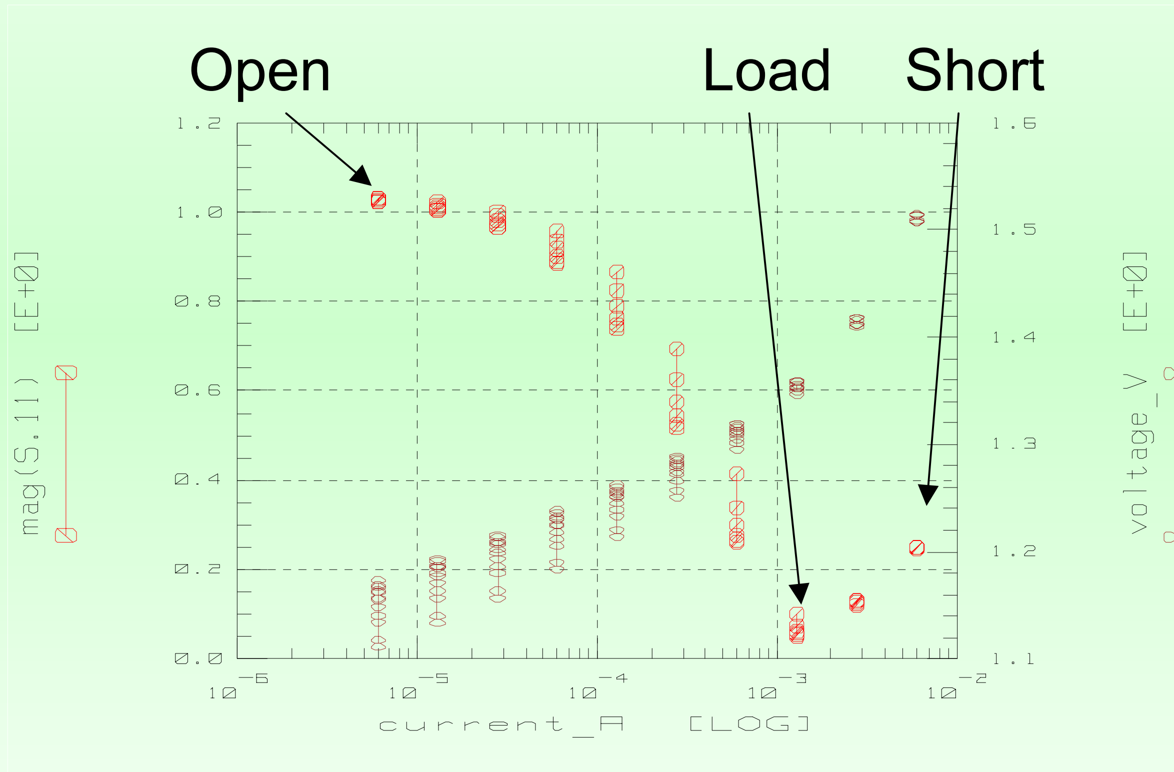
verification - linearity of uncalibrated data

reference plane DUT

GaAs HBT 8x1.5x1.5 µm[2] emitterarea

Reflection factor at 3 GHz from -30 dBm to -15 dBm source power in 3dB steps together with resulting voltage (right axis)



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conclusions

- calibration using HBT as calibration standard is possible

- one touch calibration should be possible if using appropriate test- structure with two transistors

- the method can be equally used deembedding other test fixtures

(coaxial calibration (e.g. 3.5 mm...1mm) with on wafer standards, or different on wafer test fixtures)

- further developments (remove ISS, improve “load“ standards linearity, comparing FET and Bipolar as calibration standard, extending frequency range)

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