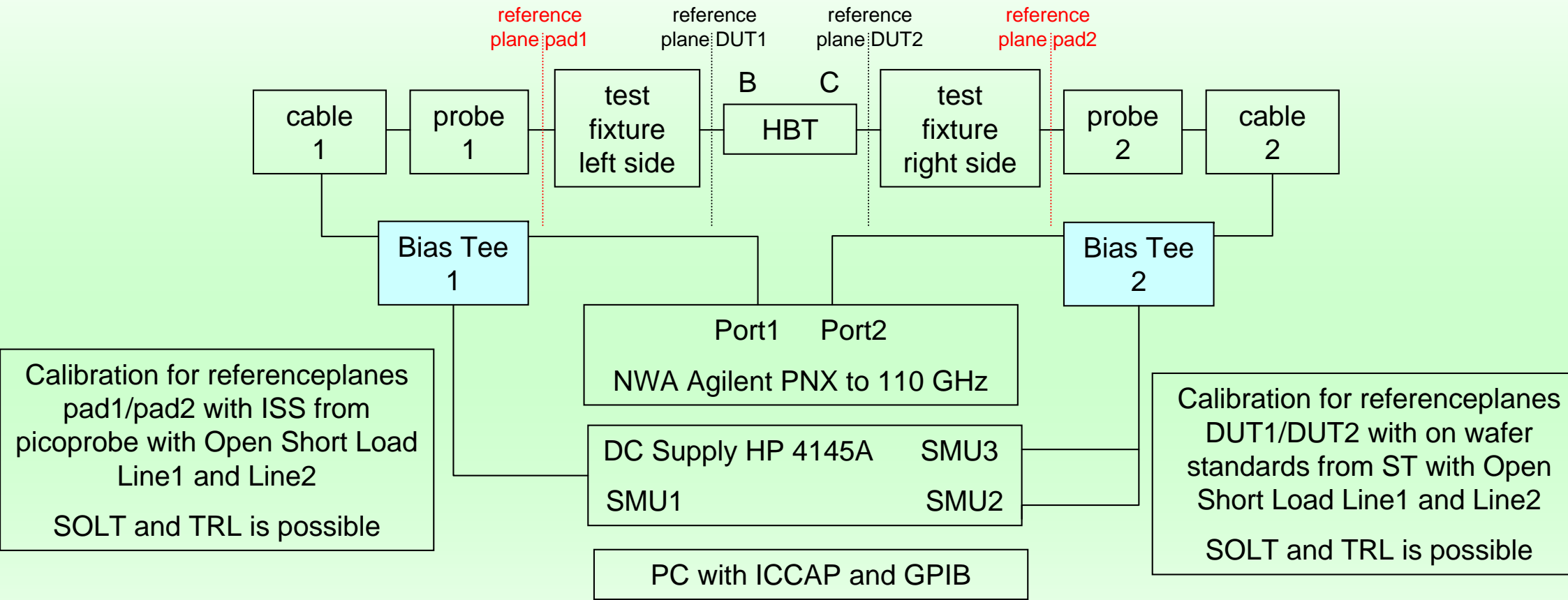


Deembedding of SiGe multifinger HBTs to 110 GHz - problems and solutions

- measurement setup
- ISS vs on wafer calibration
- open - short deembedding
- results small transistor
- ISS to on wafer adapter
- results large(multifinger) transistor
- discussion



- ISS cs5 from Picoprobe with Cascade Probe Tips to 110 GHz with reference plane probe tip
- + well known standards for SOLT calibration
 - + Au pads and even pad topology for reliable contacts
 - + usable to very high frequency (e.g. 350 GHz)
 - on wafer probe to dut adapter is not known
 - on wafer probe to dut adapter phase shift could not be treated as electrical small at high frequency

- on wafer standards from ST with Cascade Probe Tips to 110 GHz with reference plane near dut
- unknown standards for SOLT calibration
 - Au or Al pads but uneven pad topology - contact problems
 - usable to very high frequency (e.g. 350 GHz not yet shown)
 - + on wafer probe to dut adapter is known after TRL calibration
 - + calibrated dut adapter phase shift could be treated as electrical small at high frequency
-

```

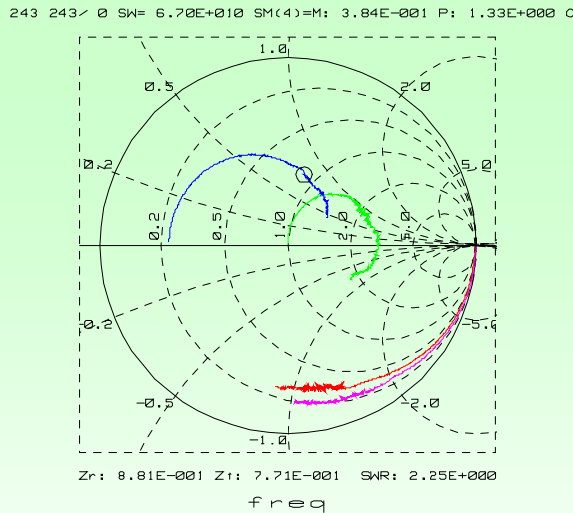
UPDATE_MANUAL
Ym=TwoPort(Sap,"S","Y")
Yo=TwoPort(Topen,"S","Y")
Zi=TwoPort(Ym-Yo,"Y","Z")
Zs=TwoPort(Tshort,"S","Z")
Sdeem=TwoPort(Zi-Zs,"Z","S")
return Sdeem
    
```

Small Transistor S-Parameter with $V_{be}=V_{ce}=0.97\text{ V}$

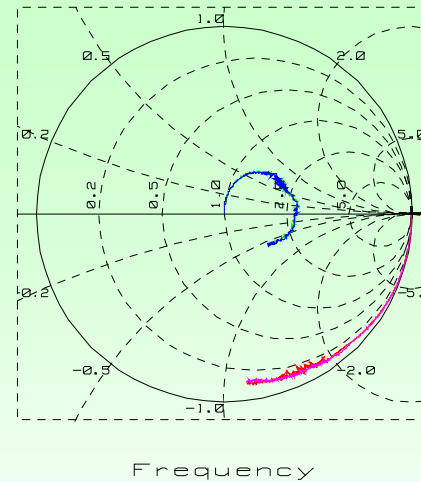
Transistor-Open

Transistor-Short

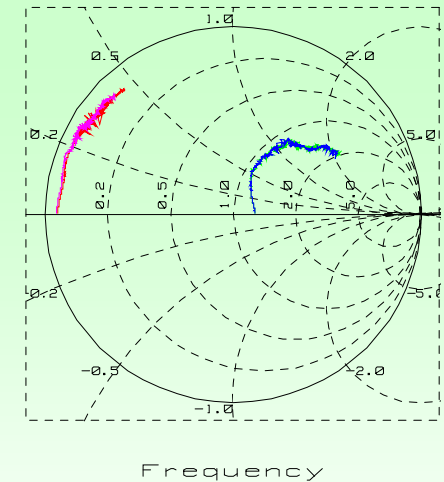
Sap.11 Sap.12*5 Sap.21*0.5 Sap.22



Topen.11 Topen.12*5 Topen.21*5 Topen.22



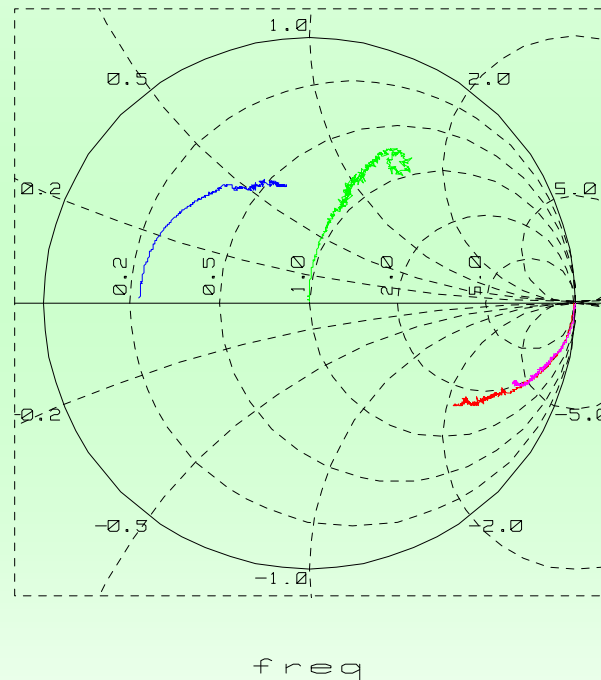
Tshort.11 Tshort.12*5 Tshort.21*5 Tshort.22



Small Transistor S-Parameter with $V_{be}=V_{ce}=0.97\text{ V}$

f_t and f_{max} data with (ft,fmax) and without (ftF;fmaxF) deembedding

Bip.11 Bip.12x5 Bip.21x0.5 Bip.22



ftF ft fmax fmaxF

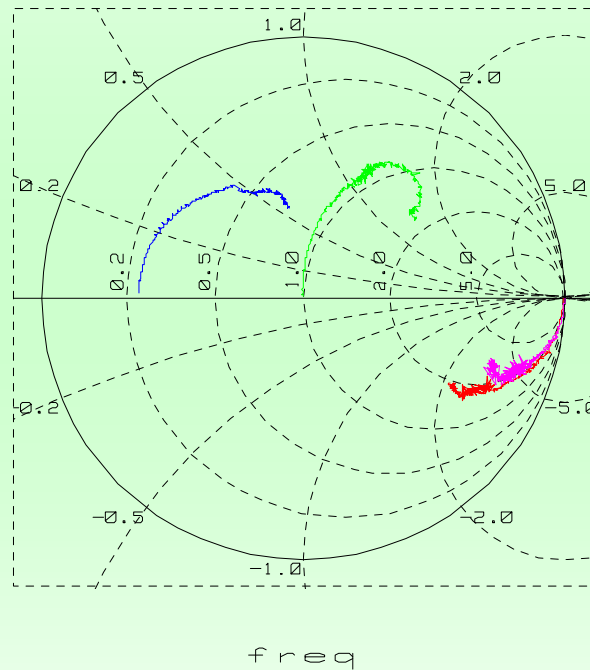


Small Transistor S-Parameter with $V_{be}=V_{ce}=0.97\text{ V}$

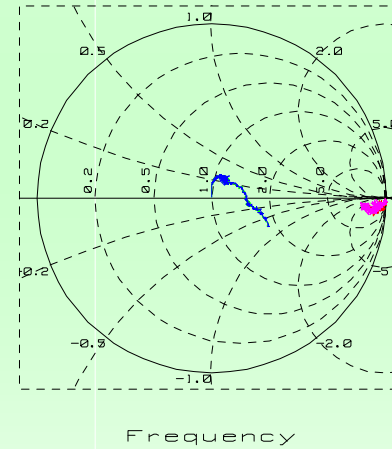
Transistor-Open

Transistor-Short

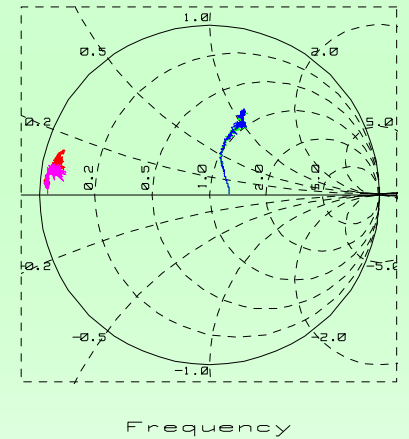
Sap.11 Sap.12*5 Sap.21*0.5 Sap.22



Topen.11 Topen.12*5 Topen.21*5 Topen.22



Tshort.11 Tshort.12*5 Tshort.21*5 Tshort.22

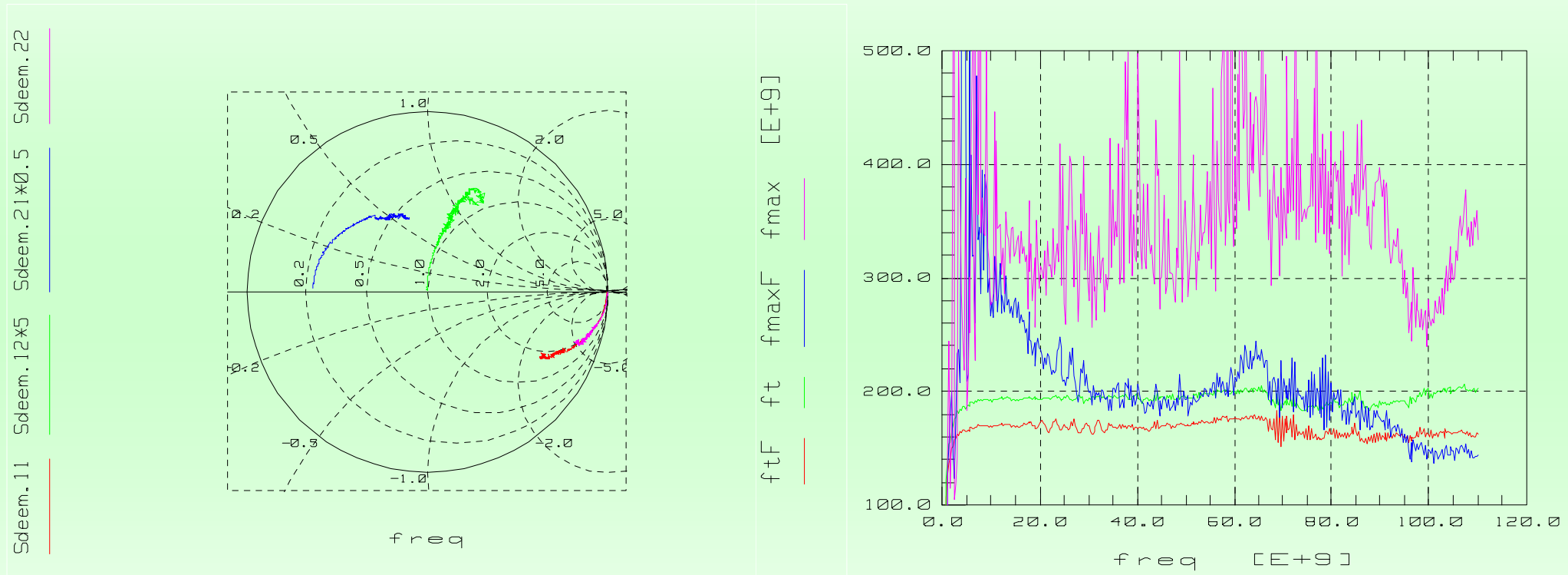


Open-Short Deembedding to 110 GHz with on wafer cal small transistor results

AK Bipolarmodellierung

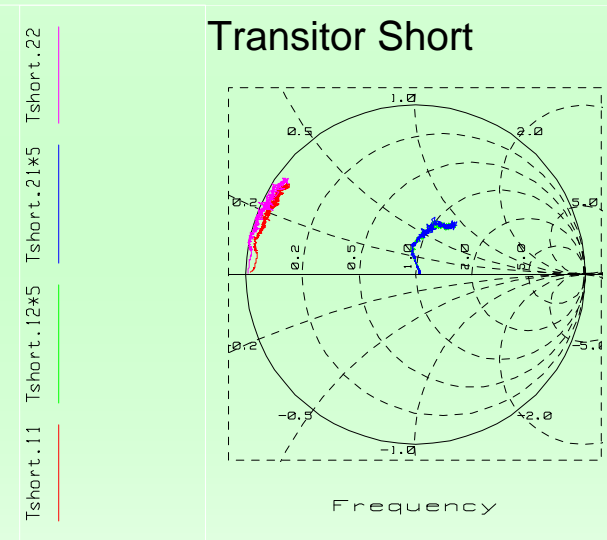
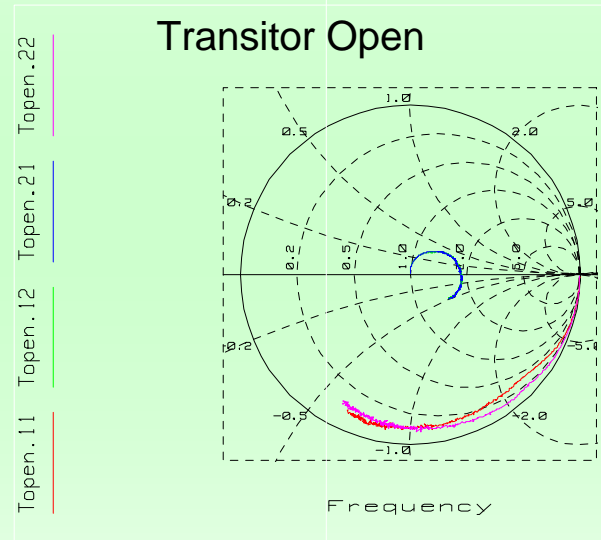
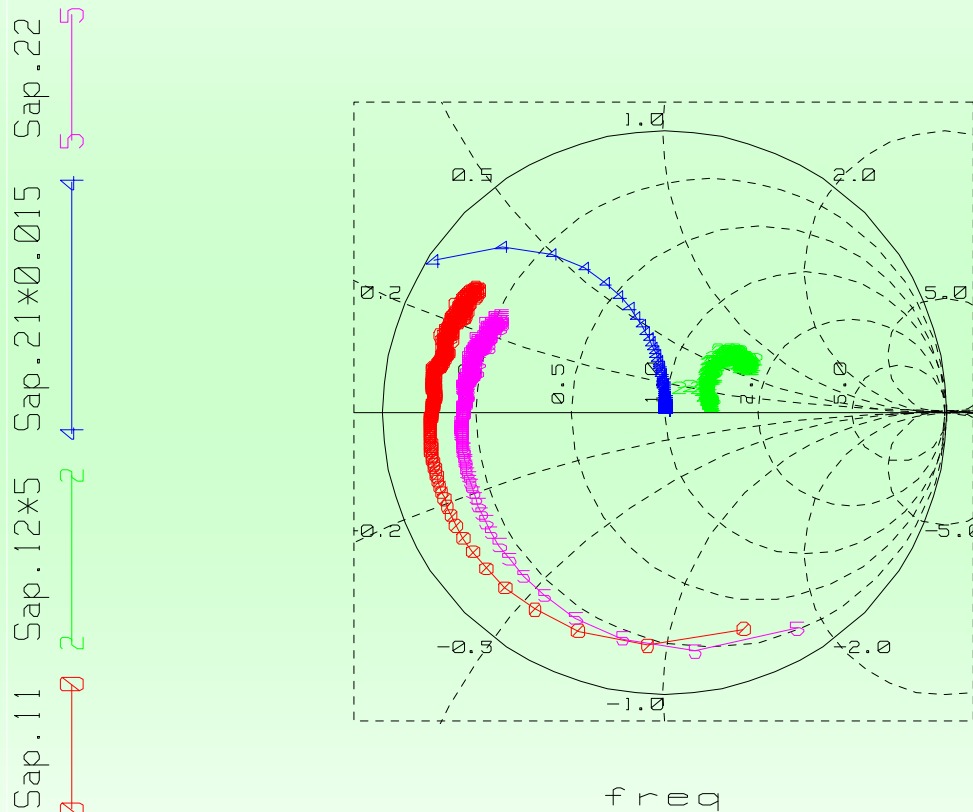
2013

small transistor S-Parameter with $V_{be}=V_{ce}=0.97\text{ V}$ f_t and f_{max} data with (ft,fmax) and without (ftF;fmaxF) deembedding



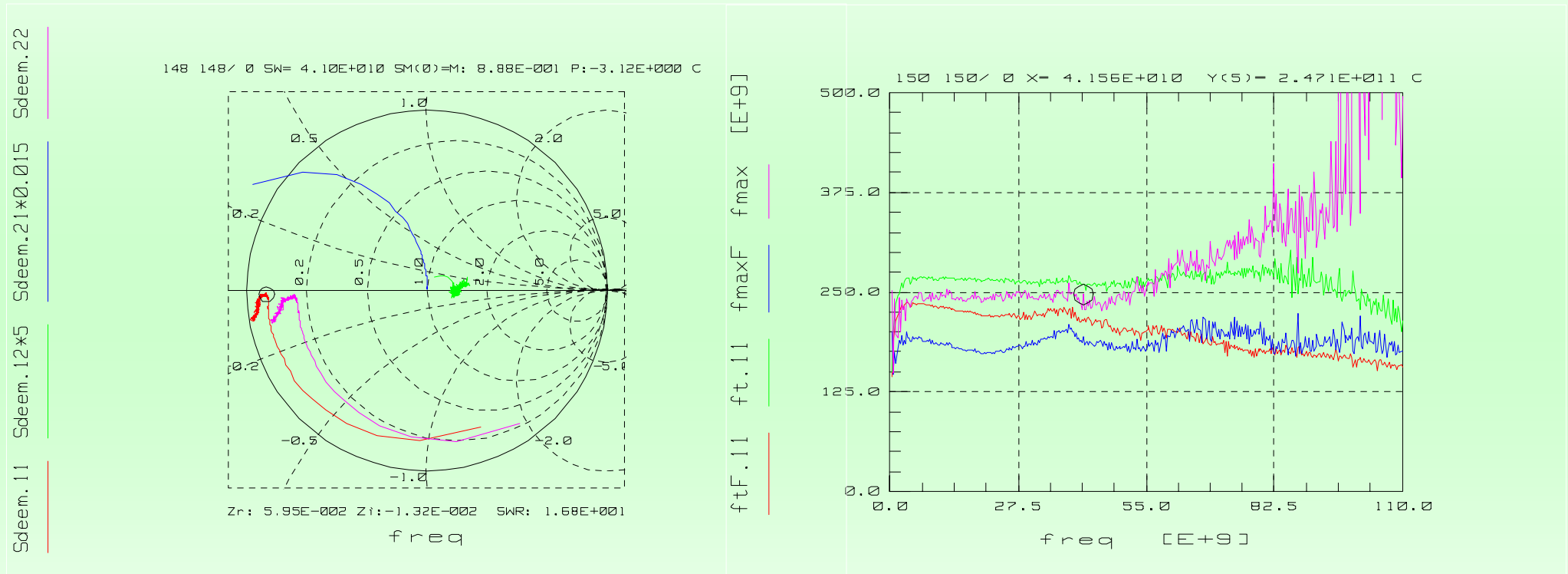
$f_t \approx 200\text{ GHz}; f_{max} \approx 300\text{ GHz}$

Multifinger-transistor S-Parameter with $V_{be}=V_{ce}=0.9\text{ V}$



Open-Short Deembedding to 110 GHz with ISS-cal

Multifinger-transistor S-Parameter with $V_{be}=V_{ce}=0.9\text{ V}$ f_t and f_{max} data with (ft,fmax) and without (ftF;fmaxF) deembedding



unphysical behavior at frequencies > 40 GHz

UPDATE_MANUAL

S1=AuswertungwaferfuerFixture/daten/K1S

S2=AuswertungwaferfuerFixture/daten/K2S

Sm=Sap

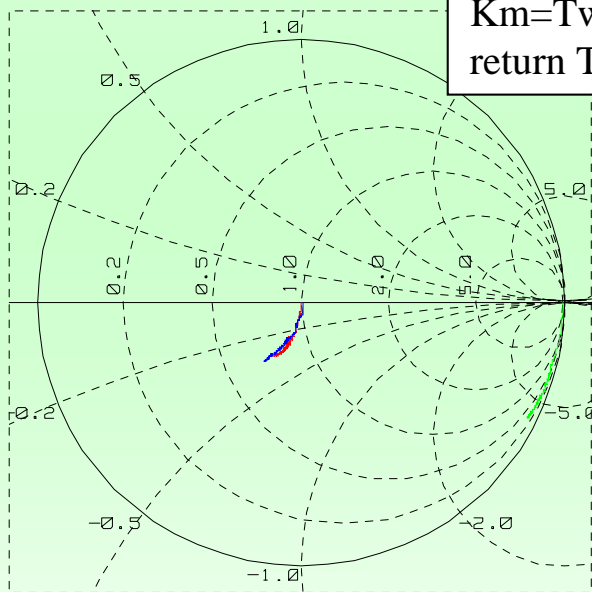
K1=TwoPort(S1,"S","K")

K2=TwoPort(S2,"S","K")

Km=TwoPort(Sm,"S","K")

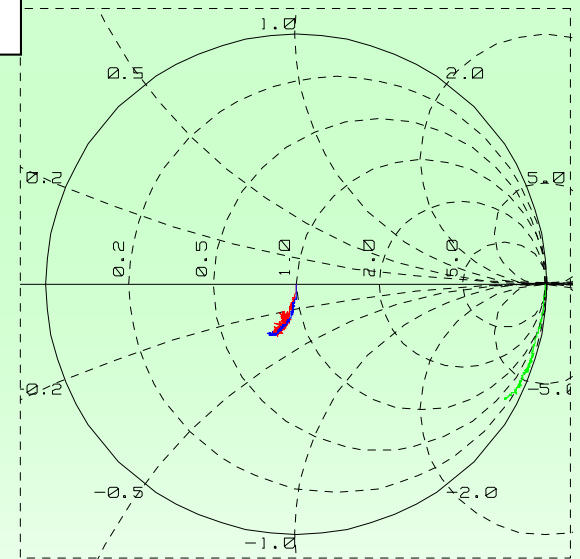
return TwoPort(K1**-1*Km*K2**-1,"K","S")

K1S is adapter for port1



freq

K2S is adapter for port2

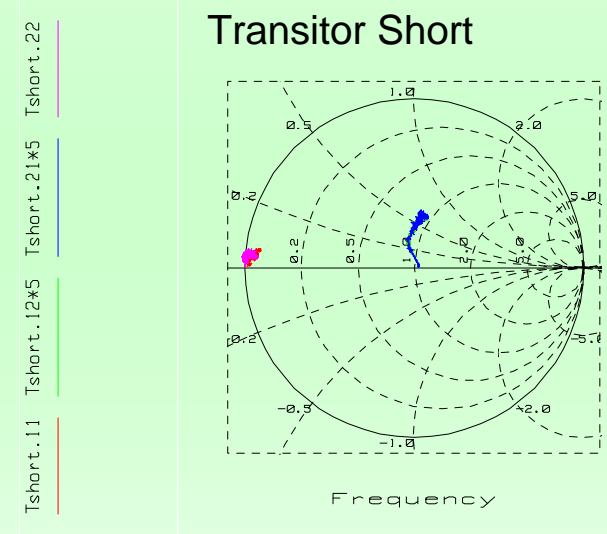
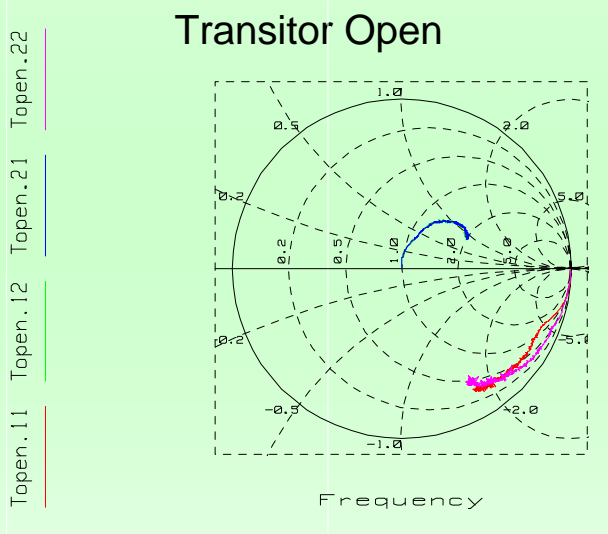
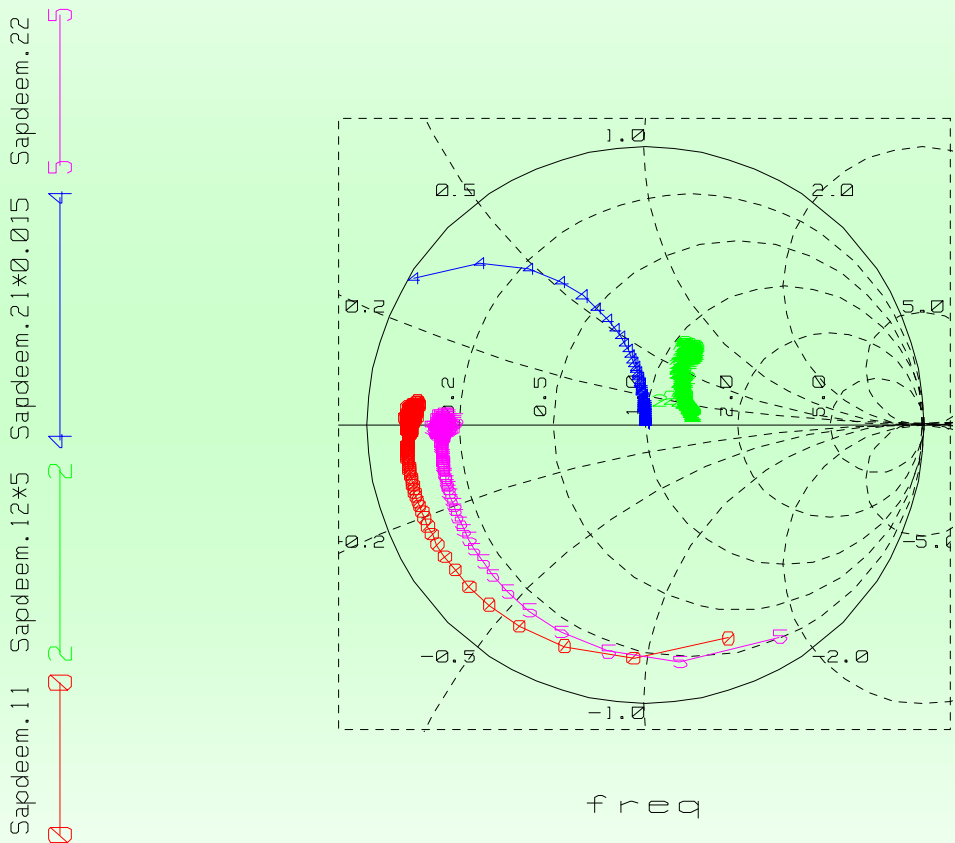


freq

K1S.11 K1S.21 K1S.22

K2S.11 K2S.21 K2S.22

Multifinger-transistor S-Parameter with $V_{be}=V_{ce}=0.9\text{ V}$



Open-Short Deembedding to 110 GHz with on-wafer adapter cal

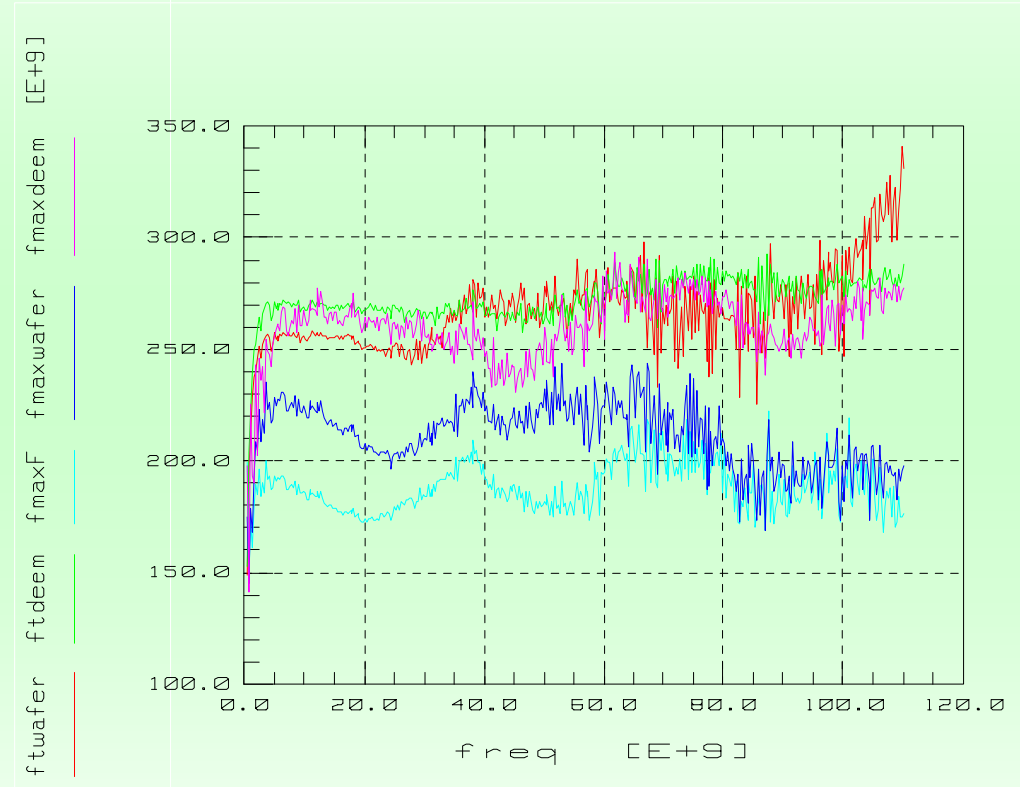
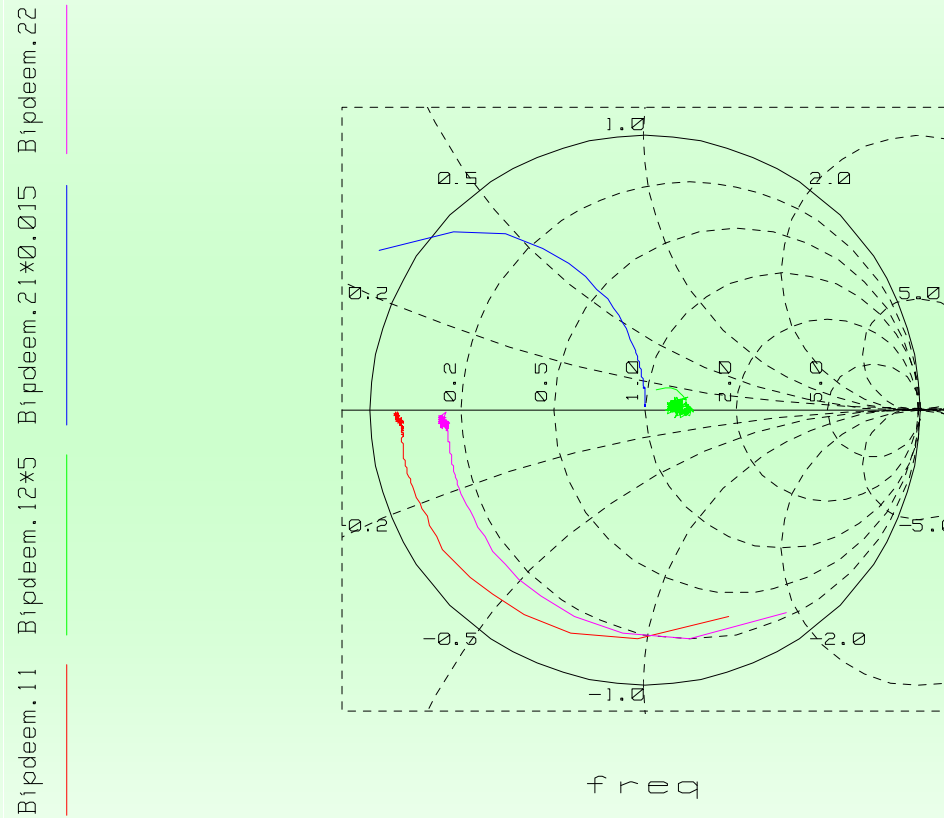
Multifinger-transistor results

AK Bipolarmodellierung

2013

Multifinger-transistor S-Parameter with $V_{be}=V_{ce}=0.9\text{ V}$

f_t and f_{max} data with (ftdeem,fmaxdeem) and without (ftwafer;fmaxwafer) deembedding



reasonable physical behavior at frequencies > 40 GHz

- for single finger transistors ISS calibration with O-S deembedding is sufficient
- in multifinger devices this technique gives unphysical results at higher frequencies and on wafer calibration is necessary to set the reference plane as near as possible to the DUT
- to combine both calibrations it is possible to make measurements with ISS calibration and shift the reference plane with an adapter model. Advantage: on wafer calibration has to be done only once with NWA-settings to have enough power to optimize S/N ratio.
- future work : ecal for adapter models (to 350GHz?)

This work has been done during an invitation to IMS in Bordeaux this year.

Thank You very much Thomas Zimmer, to You and Your stuff at IMS for this opportunity.

The paper is now open for discussions.