Deembedding Effects
on
Cold S-parameter Measurements

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Outline

- **Cold S-parameter measurements**
- **Two Step Deembedding**
- **OPEN and SHORT subcircuit modeling**
- **Effect of OPEN and SHORT on extracted capacitances**
- **Summary**

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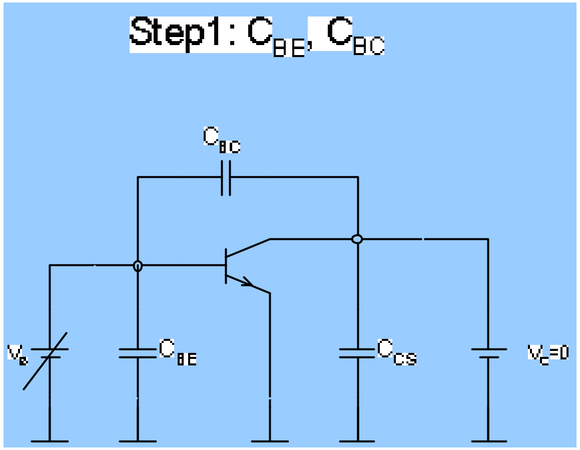
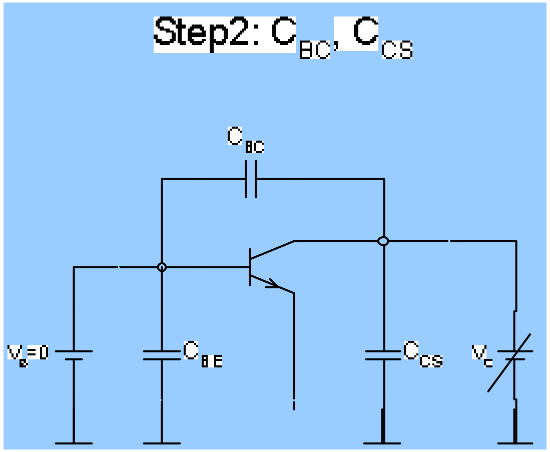
Deembedding effects ...
Cold S-Parameter Measurements (1)

- Cold S-parameter measurements are measurements for space charge capacitance determination, using an inactive transistor
- In a certain frequency range, a PI circuit assumption is valid for the DUT, and C_{BE}, C_{BC} and C_{CS} may be extracted





- Meas.1: C_{BE} (V) and C_{BC} (V)
- V_B is sweep

- Meas.2: C_{BC} (V) and C_{CS} (V)
- V_C is sweep

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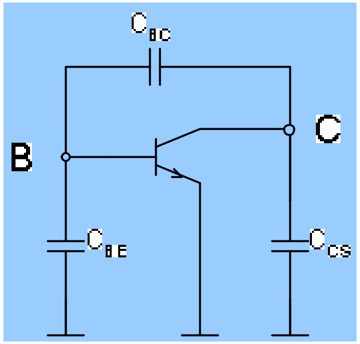
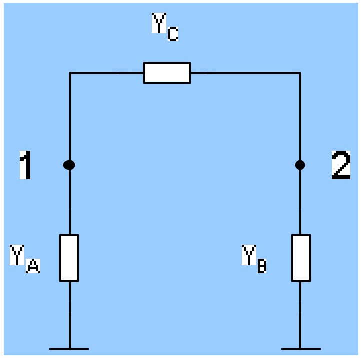
Cold S-Parameter Measurements (2)





- Assuming a PI circuit for the inactive DUT, we have the following Y – matrix:

$$Y_{PI} = \begin{bmatrix} Y_A + Y_C & -Y_C \\ -Y_C & Y_B + Y_C \end{bmatrix} \Rightarrow Y_{PI} = \begin{bmatrix} jw(C_A + C_C) & -jwC_C \\ -jwC_C & jw(C_B + C_C) \end{bmatrix}$$

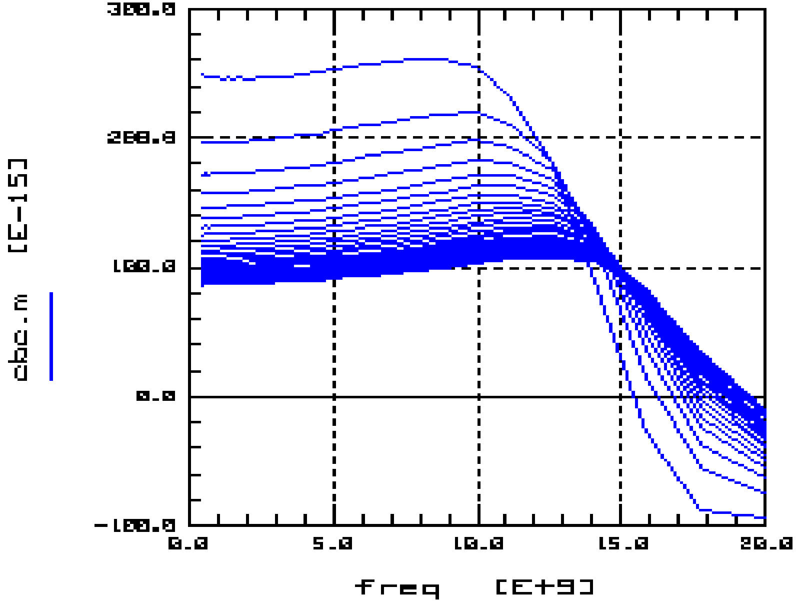
- The capacitances CBE, CBC and CCs may be calculated now as:

$$C_{BE} = C_A = IMAG(Y_{11} + Y_{12})/w \qquad C_{BC} = C_C = -IMAG(Y_{12} + Y_{21})/2w$$

$$C_{CS} = C_B = IMAG(Y_{22} + Y_{12})/w$$

Deembedding effects on Cold S-Parameter Meas.

- Example: Typical characteristic for CBC vs. f



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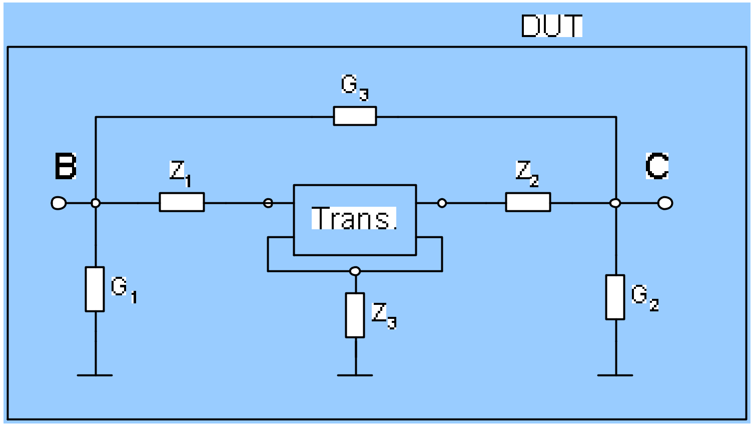
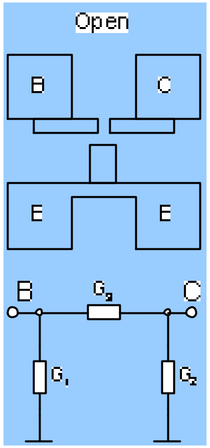
Deembedding effects ....
2 step deembedding (1)

- As for each S-parameter measurement, a deembedding is necessary for cold S-parameter measurements
- We used here the 2 step deembedding



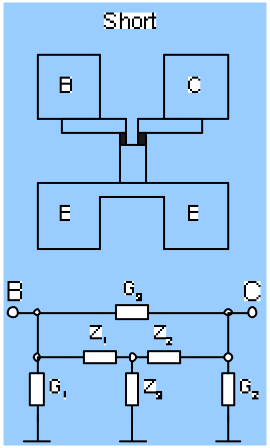
- 2 step deembedding is based on the assumption, that the DUT is surrounded by a PI-structure OPEN and a T-structure SHORT
- This presentation investigates the effect of the OPEN and SHORT on the extracted capacitance results

Deembedding effects ...
2 step deembedding (2)



The 2 step deembedding principle

- Step1: DUT is Deembedded from OPEN
- Step2: first the SHORT must be is deembedded from OPEN, then result from step1 is deembedded from SHORT



$$Y_A = Y_{DUT} - Y_{OPEN}$$

$$Y_{SHORT-OPEN} = Y_{SHORT} - Y_{OPEN}$$

$$Y_A \Rightarrow Z_A$$

$$Y_{SHORT-OPEN} \Rightarrow Z_{SHORT-OPEN}$$

$$Z_B = Z_A - Z_{SHORT-OPEN} = Z_{TRAN}$$

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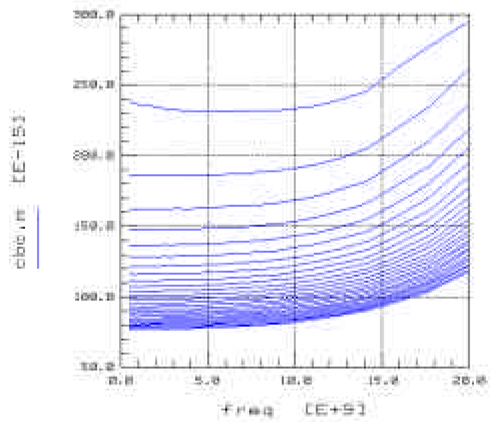
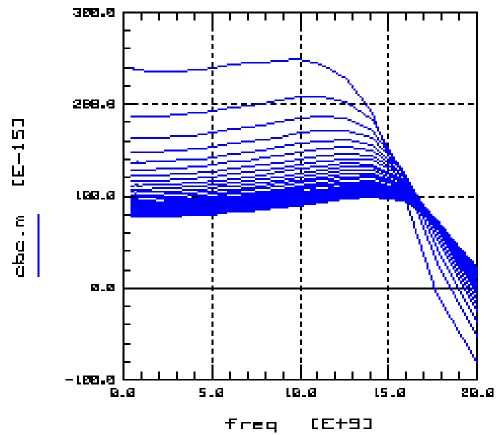
Deembedding effects ...
2 step deembedding (3)

The cold-S-Parameter were 2-step deembedded as described above. It were used OPEN- and SHORT-measured data of two different chips.

chip1



chip2



The Problem: the measured 2-step deemdedded CBC data for chip 1 and chip 2 differ significantly

Because of the differences between chip1 and chip2, the deembedding effects were investigated in detail

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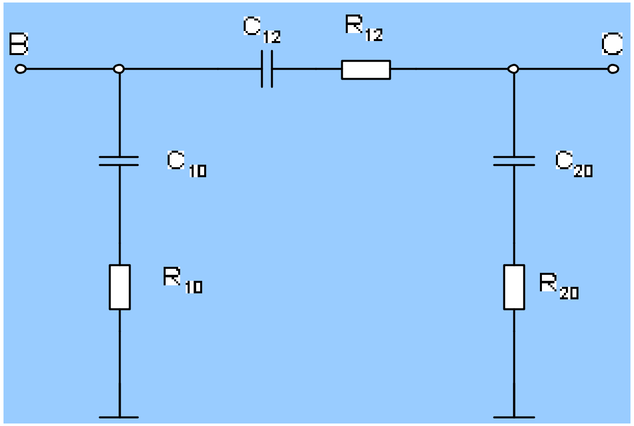
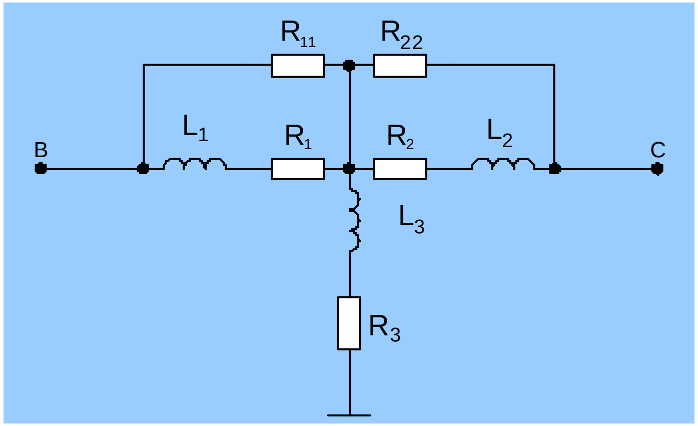
Deembedding effects ...
OPEN and SHORT subcircuit modeling (1)

- In a first step we extracted model parameters for the measured OPEN and SHORT, using the following subcircuit models





- OPEN was modelled using a PI – equivalent circuit with non-ideal capacitances
- SHORT was modelled using a T – equivalent circuit with non-ideal inductances

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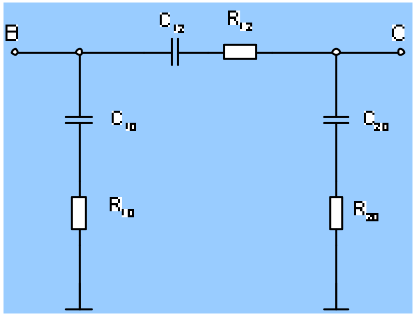
Deembedding effects ...
OPEN and SHORT subcircuit modeling (2)

	Chip1	Chip2	Chip1/Chip2
C10[fF]	72.01	67.4	107%
R10[O]	16.05	13.26	121%
C20[fF]	70.56	70.74	100%
R20[O]	9.372	12.79	73%
C12[fF]	10.23	9.767	105%
R12[mO]	31.28	17.48	179%



- Extracted subcircuit-model parameters for the OPEN
- Except R12, the differences are lower than 20 %

Deembedding effects ...
OPEN and SHORT subcircuit modeling (3)

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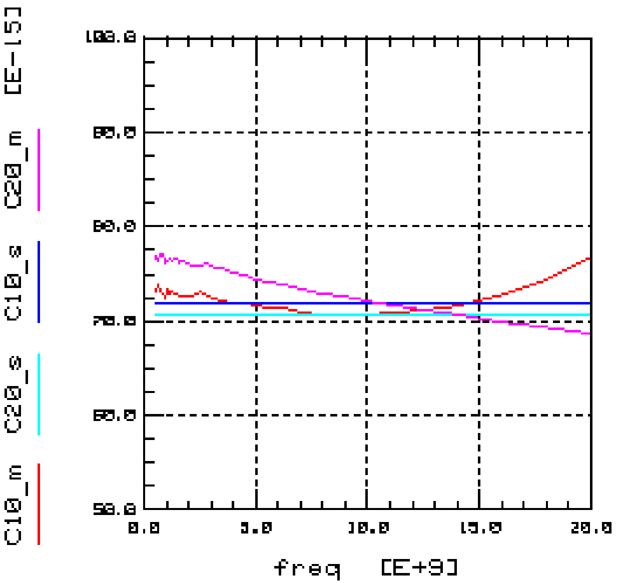
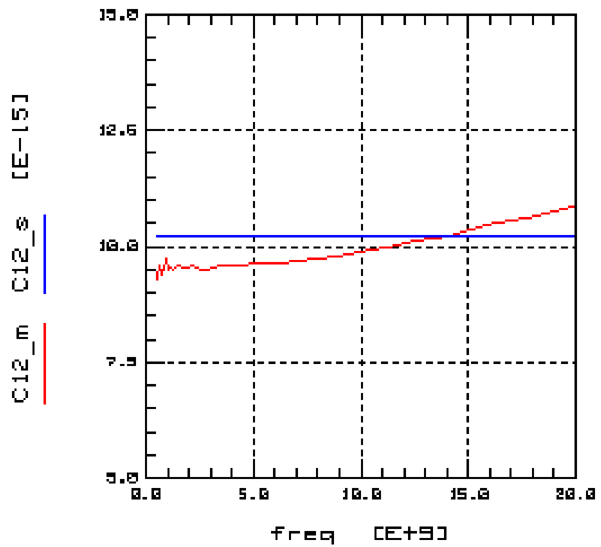
C10, C20



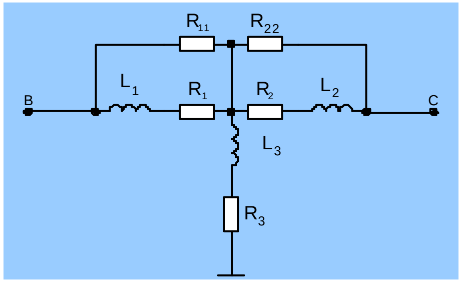
C12



- Open capacitance vs. f, comparison of measurement and model for chip1
- The used subcircuit model delivers a sufficient fit to measured data

Deembedding effects ...
OPEN and SHORT subcircuit modeling (4)

	Chip 1	Chip 2	Chip1/ Chip2
R1[O]	3.42	1.16	295%
L1[pH]	119.4	42.51	281%
R11[O]	26.3	36.55	72%
R2[mO]	330.3	301	110%
L2[pH]	41	34.24	120%
R22[kO]	34.21	26.6	129%
R3[mO]	75.76	73.69	103%
L3[pH]	6.775	6.881	98%



- Extracted subcircuit-model parameters for the SHORT
- Model parameters R1 and L1 show largest difference

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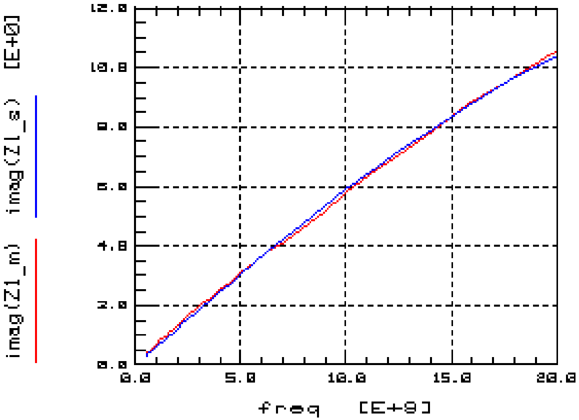
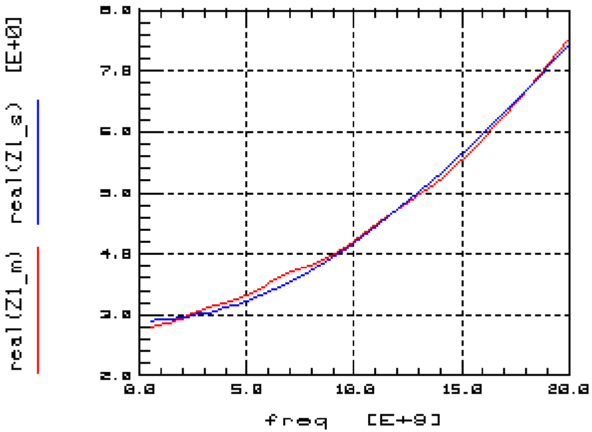
Deembedding effects ...
OPEN and SHORT subcircuit modeling (5)

Imag(Z1)



Real(Z1)



- Short Imag(Z1) and Real(Z1) vs. f, comparison of measurement and model
- Again, the used subcircuit model delivers a sufficient fit to measured data

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Deembedding effects ...
Effect of OPEN and SHORT (1)

- To investigate the effect of OPEN and SHORT on the extracted capacitance values, we created synthetic data first
- In this way it was possible to find out, which model parameters of the OPEN and the SHORT are most important for the deembedding of cold S-parameter measurements

- The procedure in detail:

1. Simulation of OPEN and SHORT using certain model parameters
2. Conversion of simulated data into measured data (= synthetic data)
3. Deembedding of cold S-parameter measurements using the synthetic data

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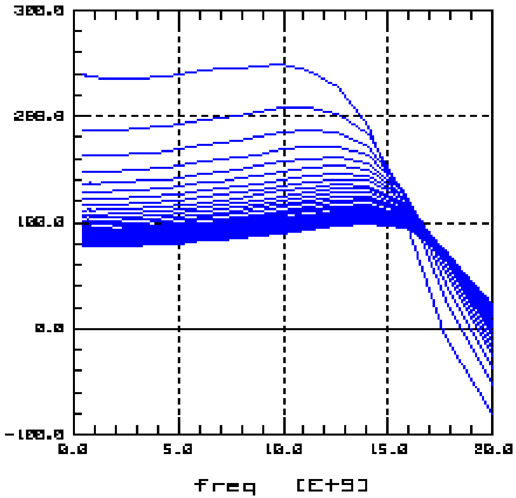
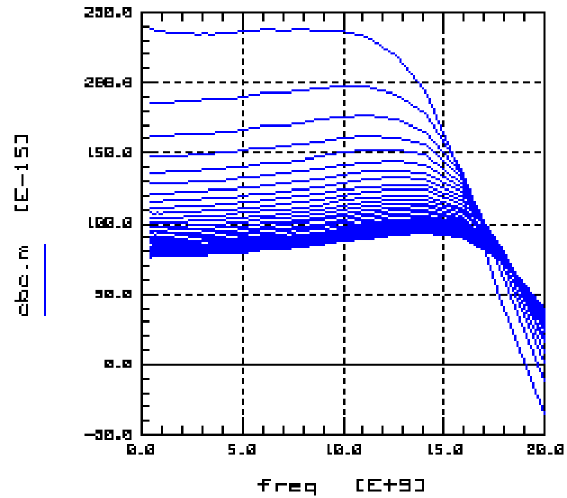
Deembedding effects ...
Effect of OPEN and SHORT (2)

a)



b)



Comparison of CBC data with deembedding using

a) measured data and

b) simulated (= synthetic) data

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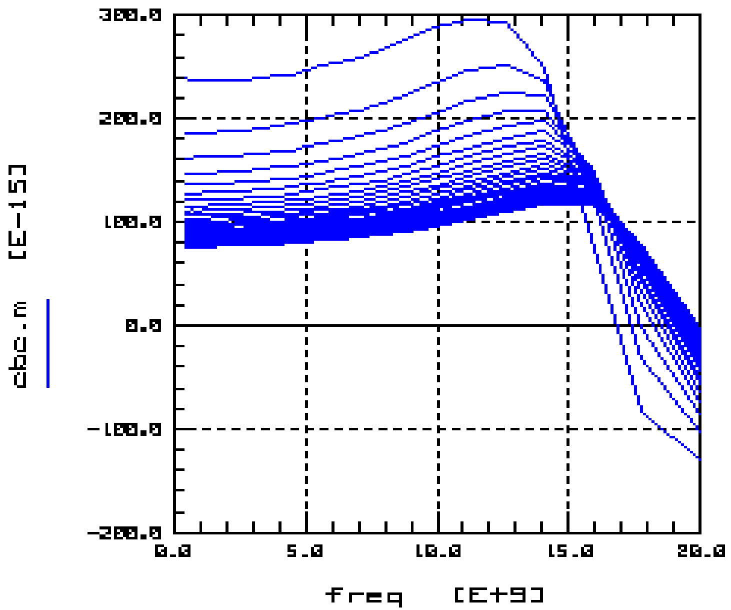
Deembedding effects ...
Effect of OPEN and SHORT (3)

The influence of L1_short on the Cold S-Parameter deembedding is investigated further

The parameter L1-short was chosen, because it is the model parameter, which differs most between chip1 and chip2 and probably causes the different characteristics

Based on the extracted parameters for chip 1 **L1_short** was varied between **10pH and 160pH**

Deembedding effects ...
Effect of OPEN and SHORT (4)



- CBE vs. f
- Deembedding with L1_short=10pH

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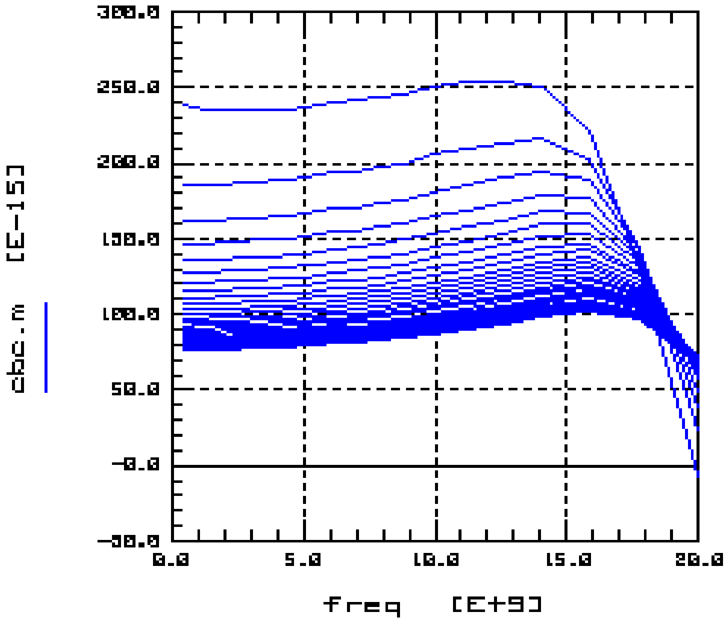
Deembedding effects ...
Effect of OPEN and SHORT (5)



- CBC vs. f
- Deembedding with L1_short = 60pH

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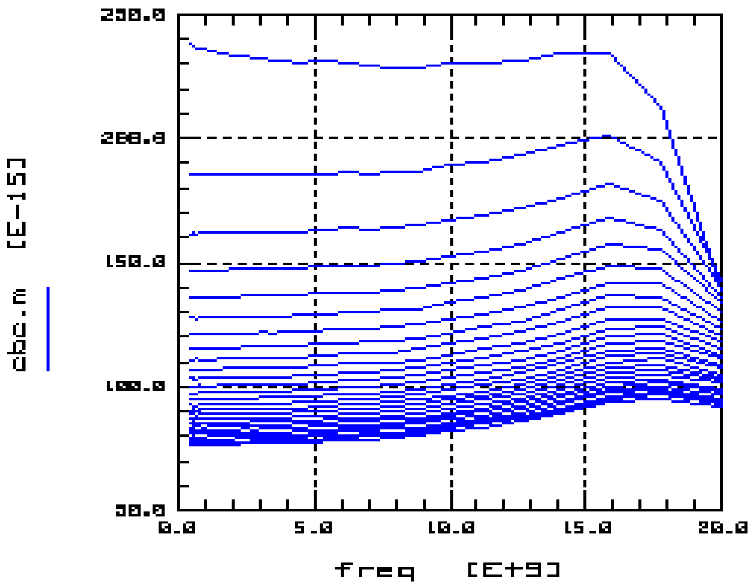
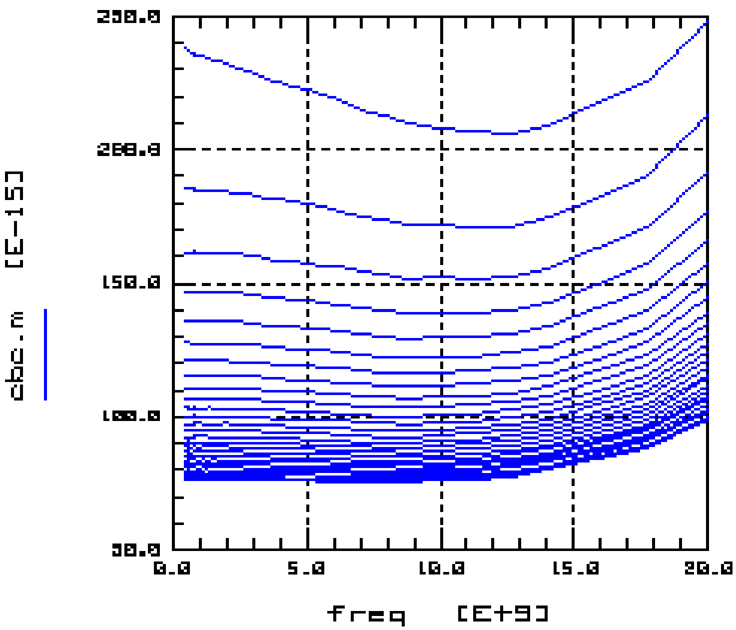
Deembedding effects ...
Effect of OPEN and SHORT (6)



- CBC vs. f
- Deembedding with L1_short = 100pH

Deembedding effects ...
Effect of OPEN and SHORT (7)



- CBC vs. f
- Deembedding with L1_short = 160 pH

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Summary

- **The OPEN and SHORT measured data were simulated using subcircuit PI- / T- models**
- **Based on the extracted parameters, synthetic measured data were generated and used for deembedding the cold S-Parameters**
- **This method was used to investigate the influence of the extracted parameters on the deembedding**
- **Using the synthetic data we were able to reproduce the different characteristics of chip 1 and chip 2**
- **We found out, that L1_short has biggest influence on the deembedding of the cold S-Parameters**