De-Embedding with Scalable Groundshield Teststructures

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Wolfgang Kraus

wolfgang.kraus@hno.atmel.com

Atmel Germany

Outline

- Overview on Calibration/De-Embedding
- Groundshields
- Why is scaling important?
- Results
- Work to do
- References
- and finally . . .

Overview

For Si-based devices RF-characterization is typically done by :

1. Calibrating the NWA up to the probe tips on calibration substrates available from several vendors, using one of several well-known methods like SOLT, TRL, LRM, . . .
2. Removing surplus parasitics, not belonging to the device proper, thru de-embedding, using one-way to four-way methods [1, 2, 3, 4].

Because of lacking accuracy Si-based calibration standards

are **not** normally used.

Why Groundshields?

Groundshields -

- were first used to create low-noise pads for LNA design [5].
- were used for teststructures in low substrate resistivity CMOS processes [6].
- their **objective** is to remove substrate coupling between signal leads.
- use the lower metal level(s) for shielding.
- tend to increase parallel capacitance

Comparison with std open

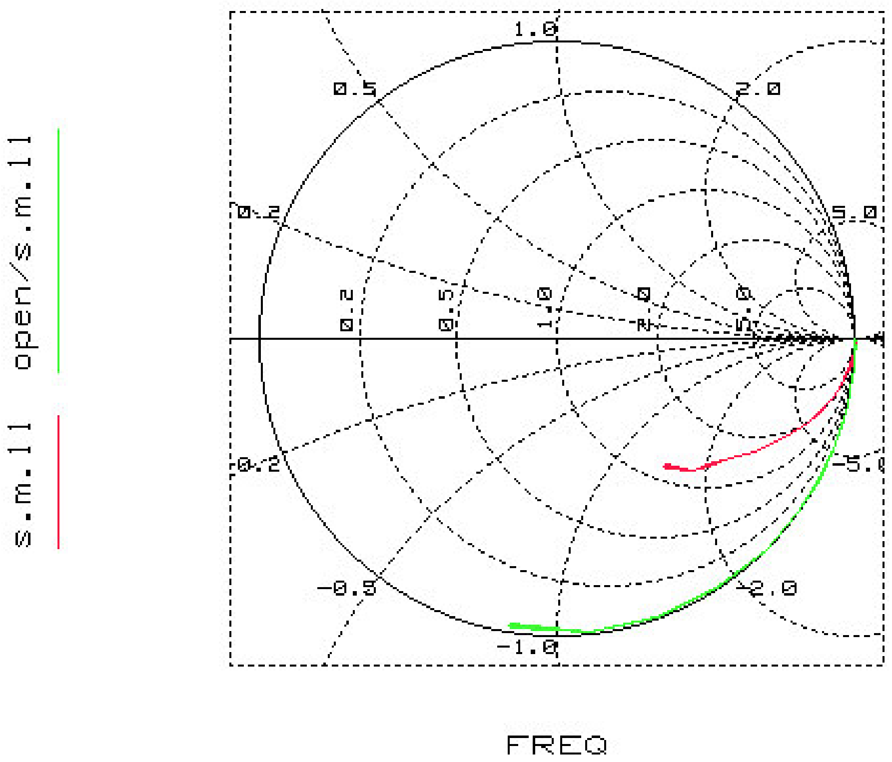


Figure 1: scattering parameter s_{11} of standard and groundshield open

Groundshield geometry

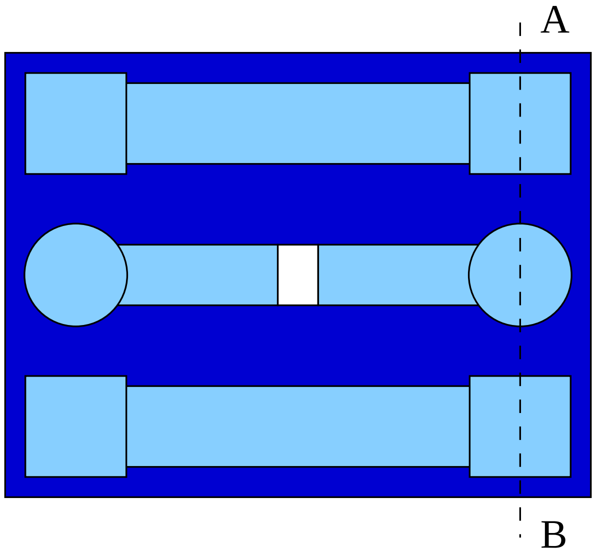


Figure 2: top view showing groundshield with extension, metallization and DUT gap

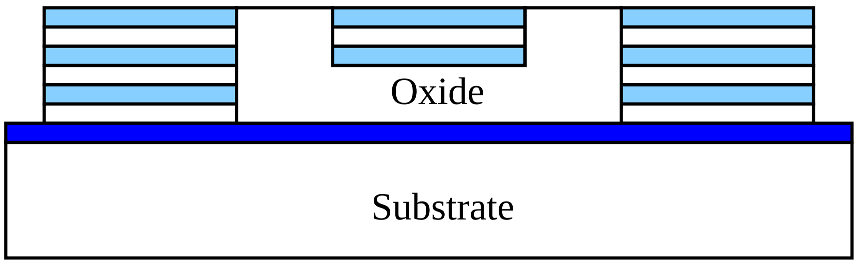


Figure 3: cross section along points A, B of figure 1

Why is scaling important?

De-embedding different sized DUT's can be done by :

- Keeping the length of the leads constant. This implies moving the pads and cabling with DUT size.
- Keeping the pad positions fixed. This implies changing the length of the leads.
- Depending on the method used, up to 4x chip space is needed for de-embedding structures.
- Often accuracy is sacrificed by using only a subset of the required de-embedding structures.

Answer : **economical & accuracy reasons**

Scaling experiment

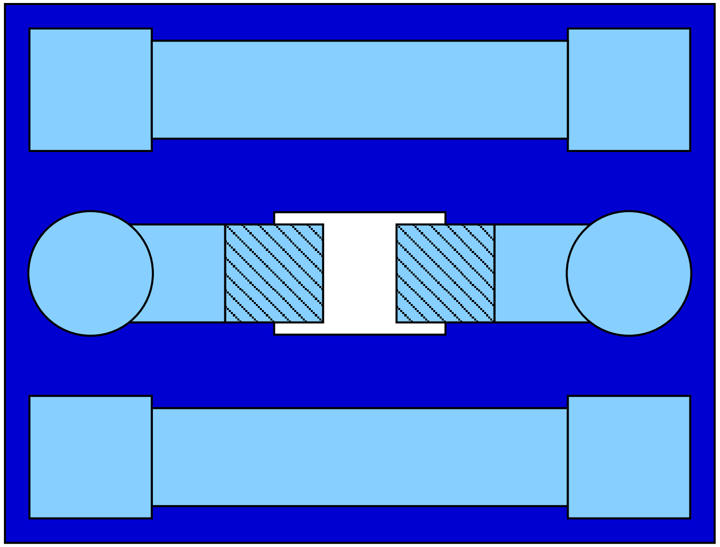
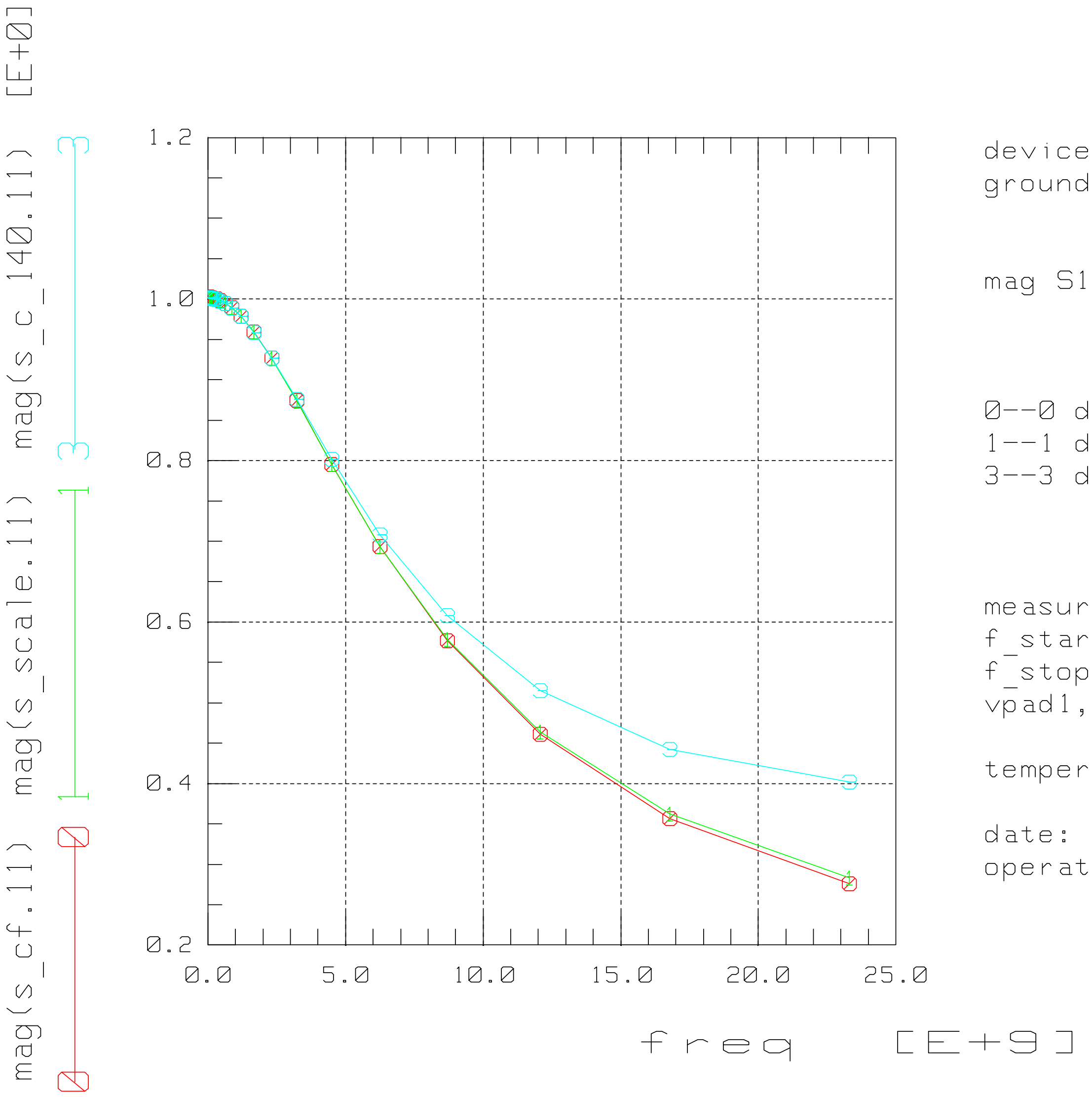


Figure 4: lead length is scaled, (crosshatched area)

DUT : Nitride capacitor
array of 5 different sizes with corre-ponding open de-embedding struc-tures

Results



device: nitride capacitor 10 x 20um2
groundshield gap: 50 x 50 um2

mag S11 versus freq[Hz]

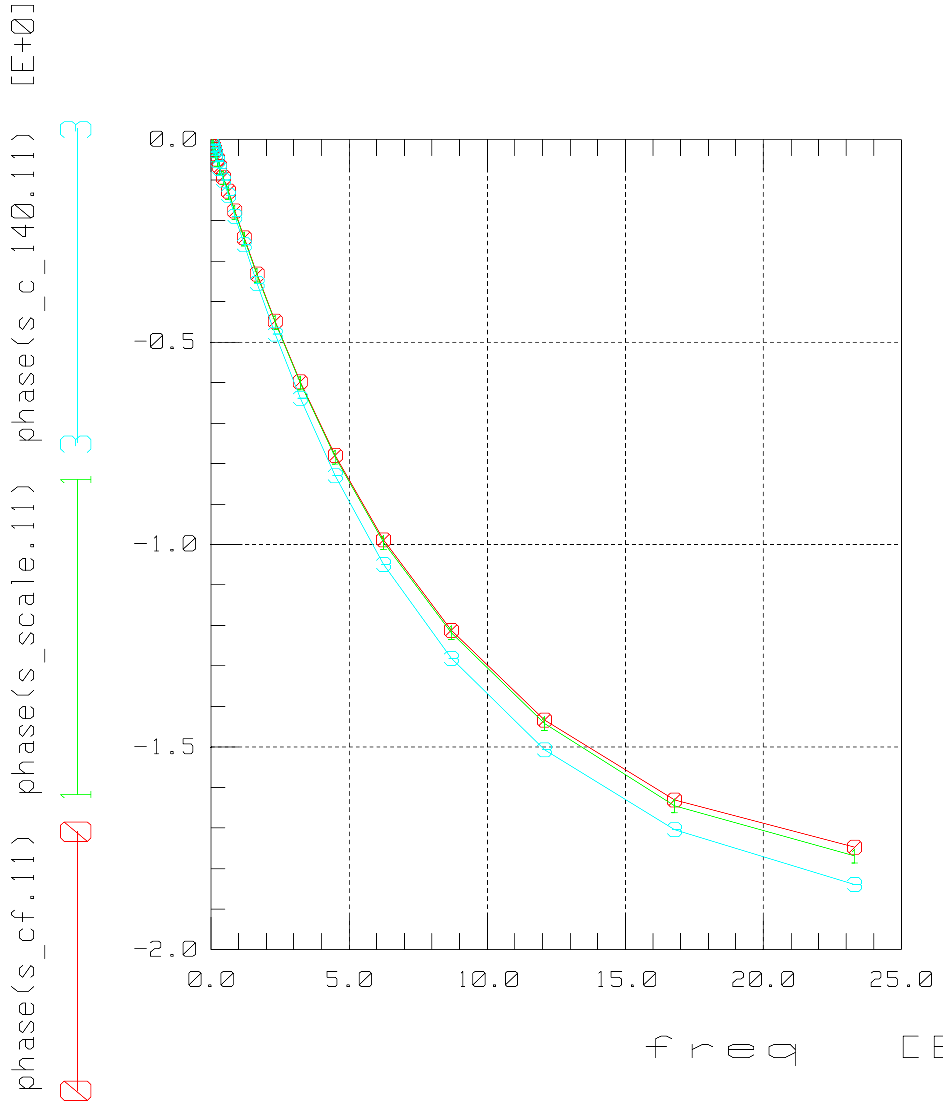
0--0 deembeeded with open gap 50x50um2
1--1 deembeeded with scaled open
3--3 deembeeded with open gap 140x140um2

measurement conditions:
f_start = 4.5E+07 Hz
f_stop = 2.33076E+10 Hz
vpad1, vpad2 =0 V

temperature = 27 ´C

date: 12/16/03
operator: Brigitte Kraus OP84

Results



device: nitride capacitor 10 x 20um2
groundshield gap: 50 x 50 um2

phase S11 versus freq[Hz]

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1--1 deembeeded with scaled open
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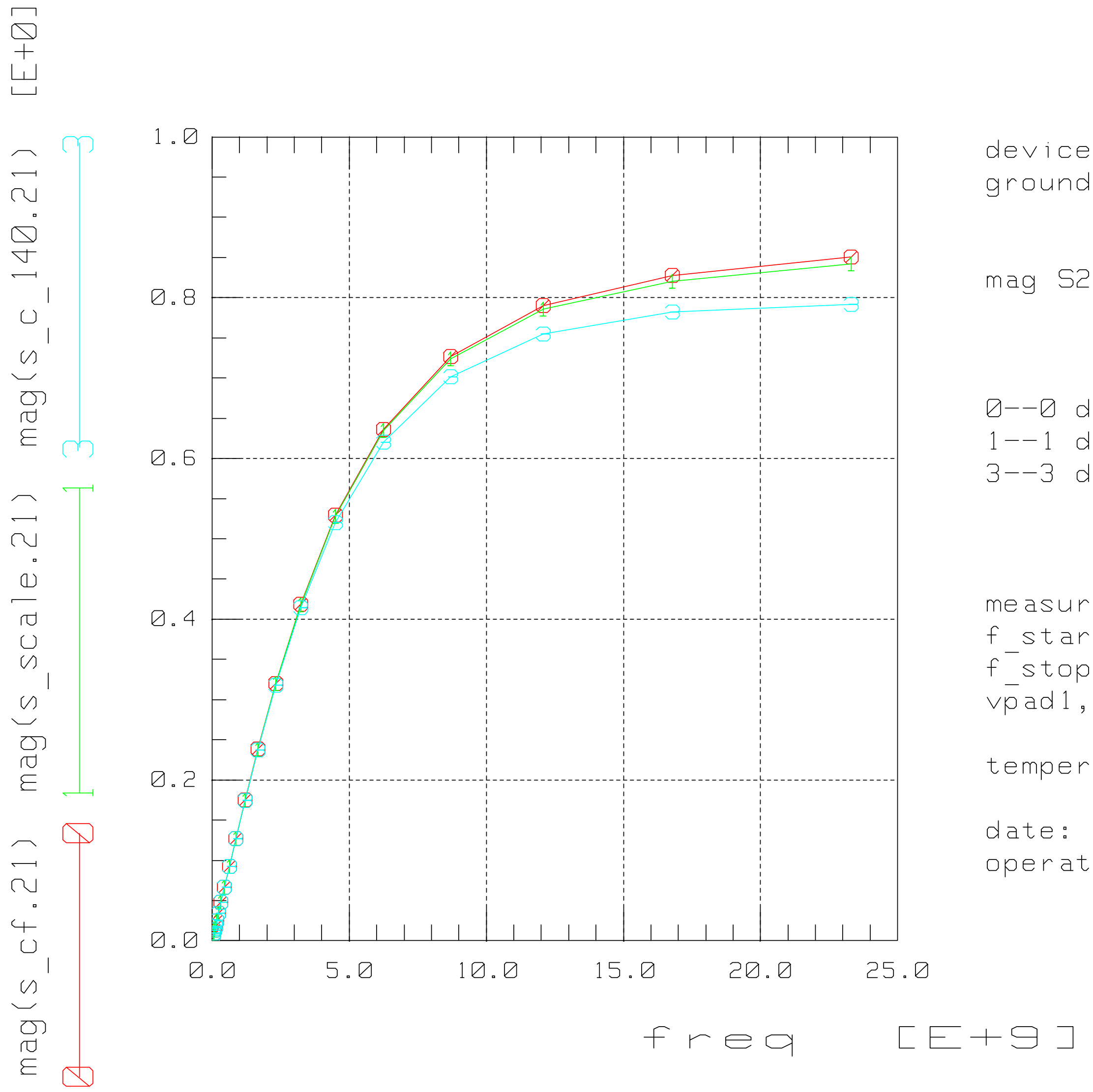


device: nitride capacitor 10 x 20um2
groundshield gap: 50 x 50 um2

mag S21 versus freq[Hz]

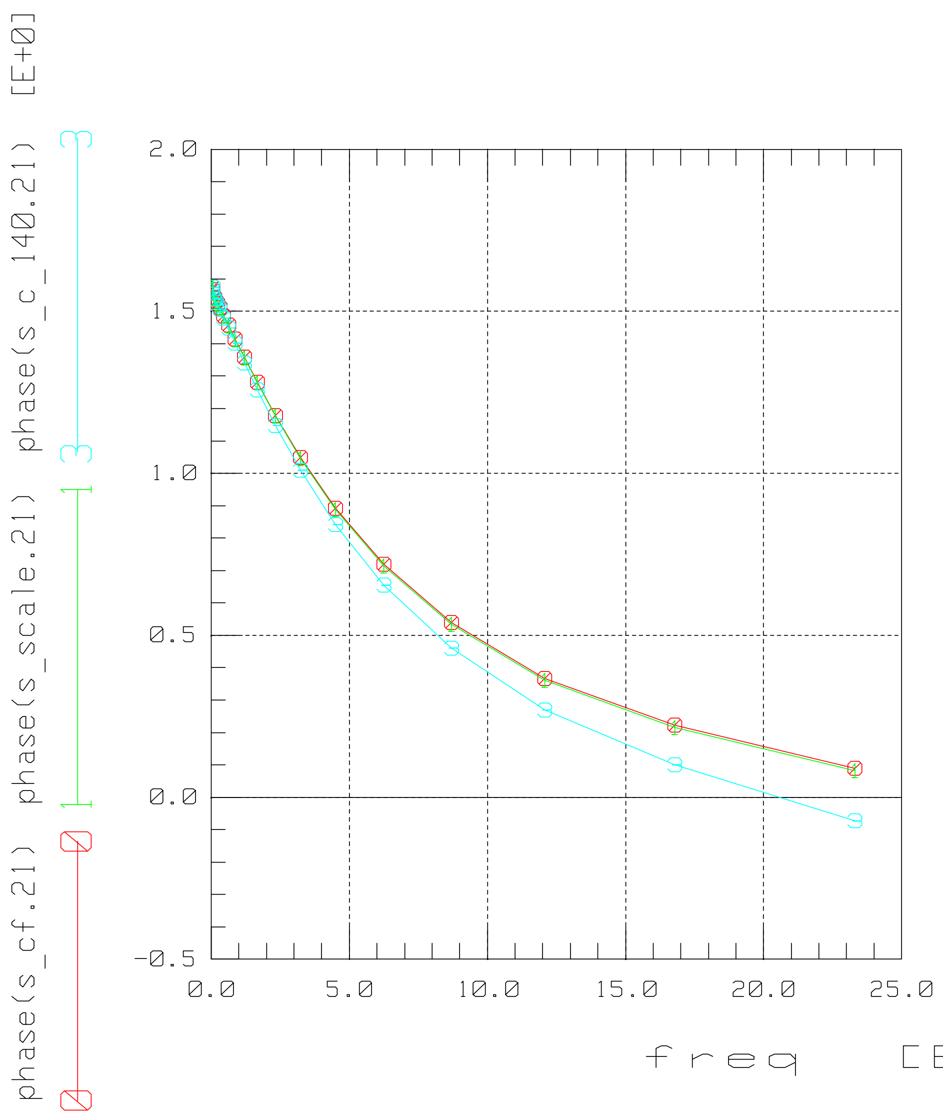
0--0 deembeeded with open gap 50x50um2
1--1 deembeeded with scaled open
3--3 deembeeded with open gap 140x140um2

measurement conditions:
f_start = 4.5E+07 Hz
f_stop = 2.33076E+10 Hz
vpad1, vpad2 =0 V

temperature = 27 ´C

date: 12/16/03
operator: Brigitte Kraus OP84

Results



device: nitride capacitor 10 x 20um2
groundshield gap: 50 x 50 um2

phase S21 versus freq[Hz]

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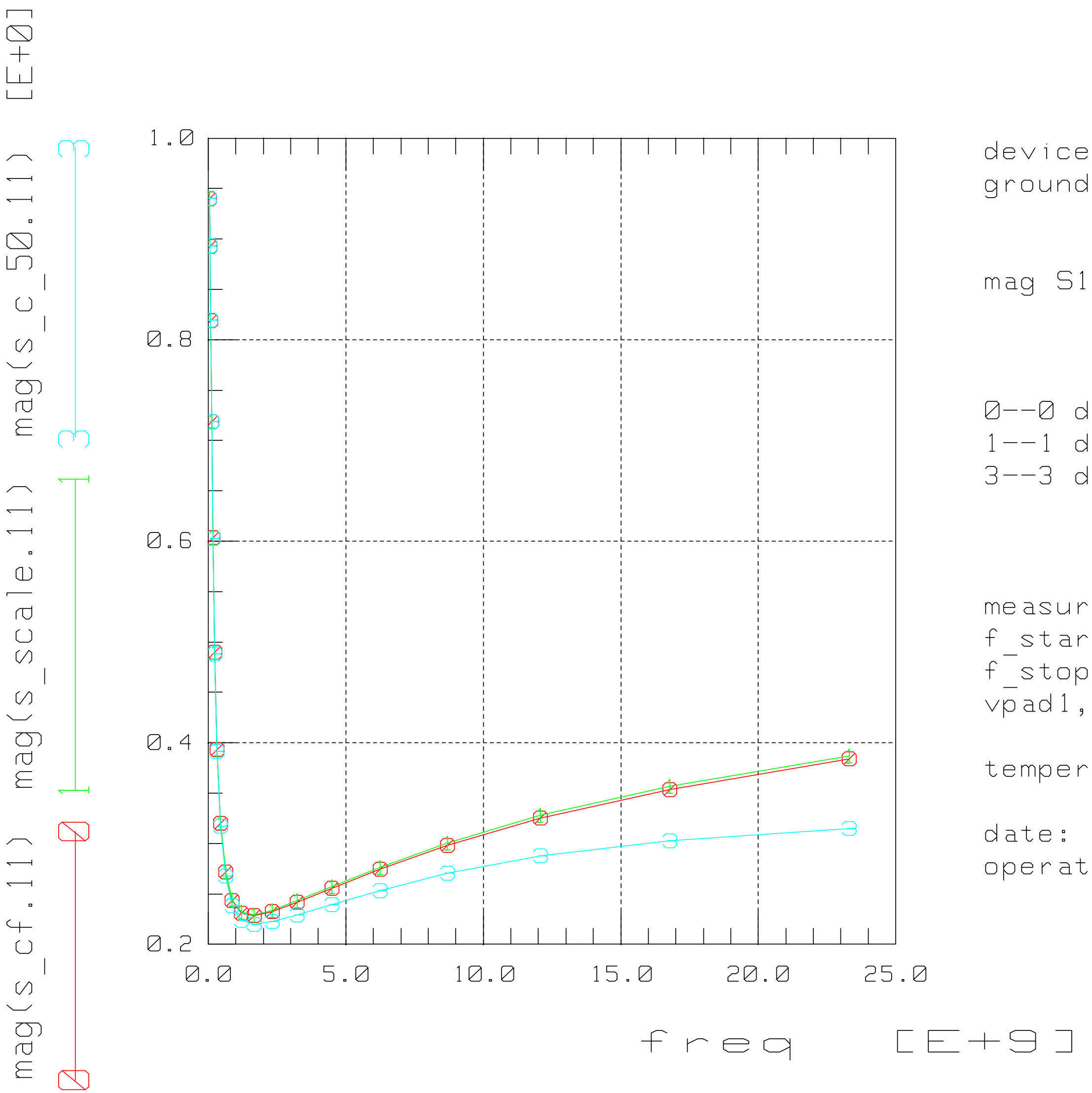

device: nitride capacitor 110 x 110um2
groundshield gap: 140 x 140 um2

mag S11 versus freq[Hz]

0--0 deembeeded with open gap 140x140um2
1--1 deembeeded with scaled open
3--3 deembeeded with open gap 50x50um2

measurement conditions:
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vpad1, vpad2 =0 V

temperature = 27 ´C

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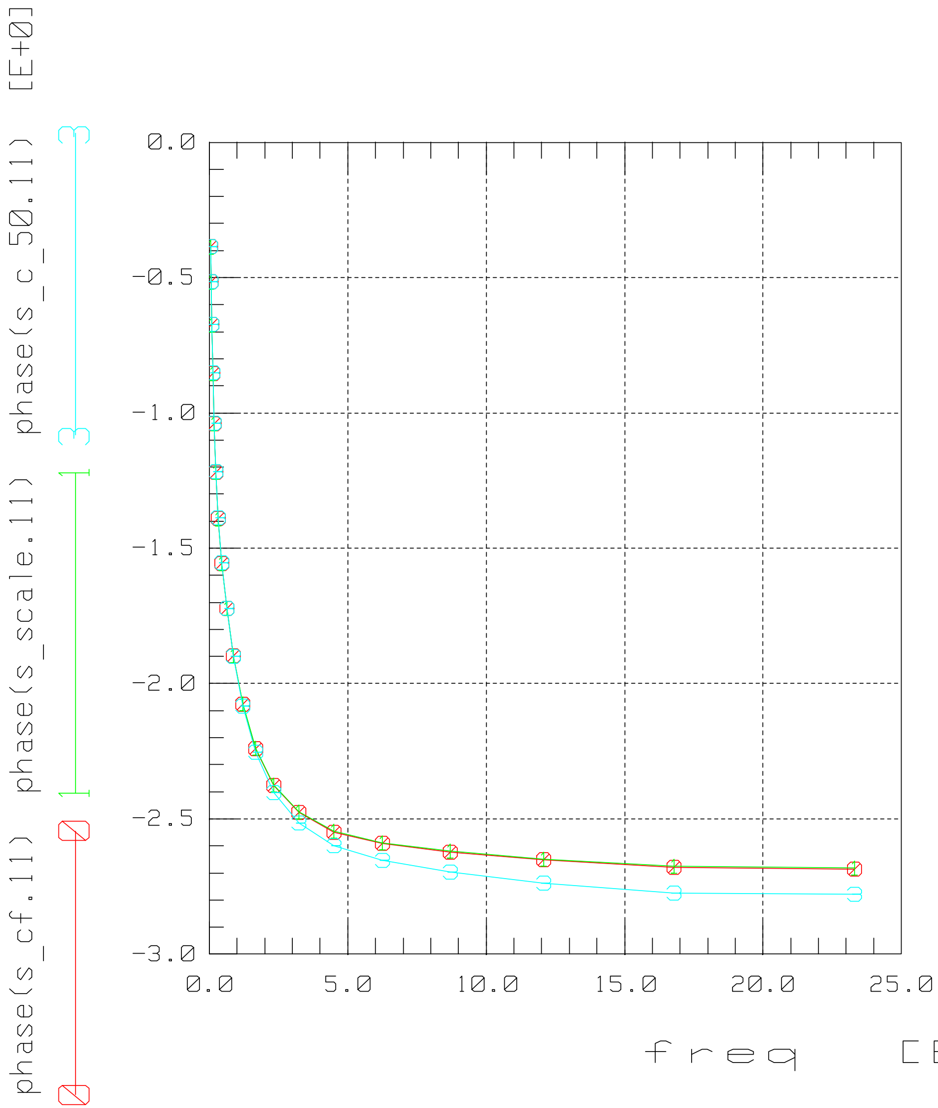
Results



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groundshield gap: 140 x 140 um2

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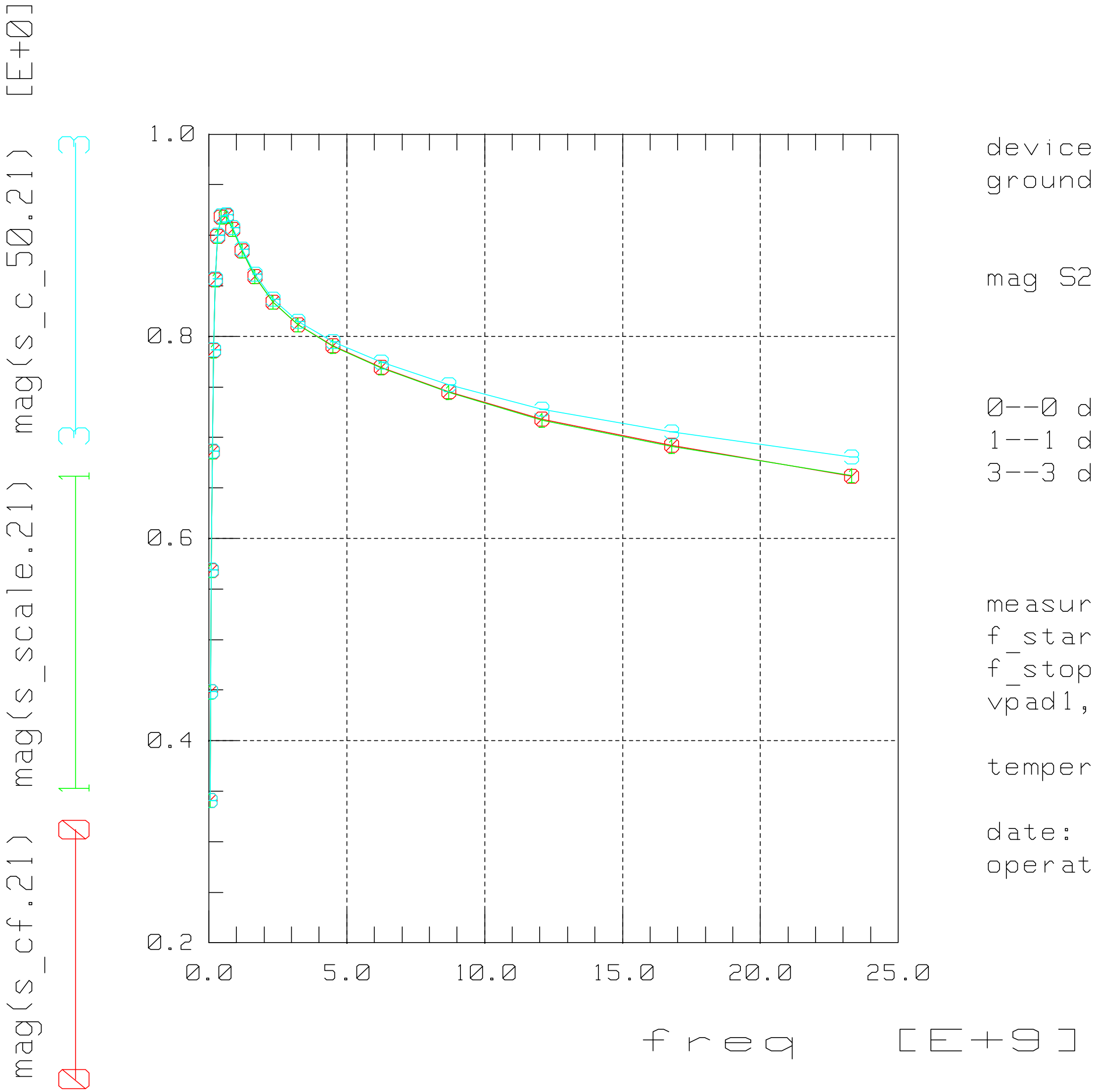

device: nitride capacitor 110 x 110um2
groundshield gap: 140 x 140 um2

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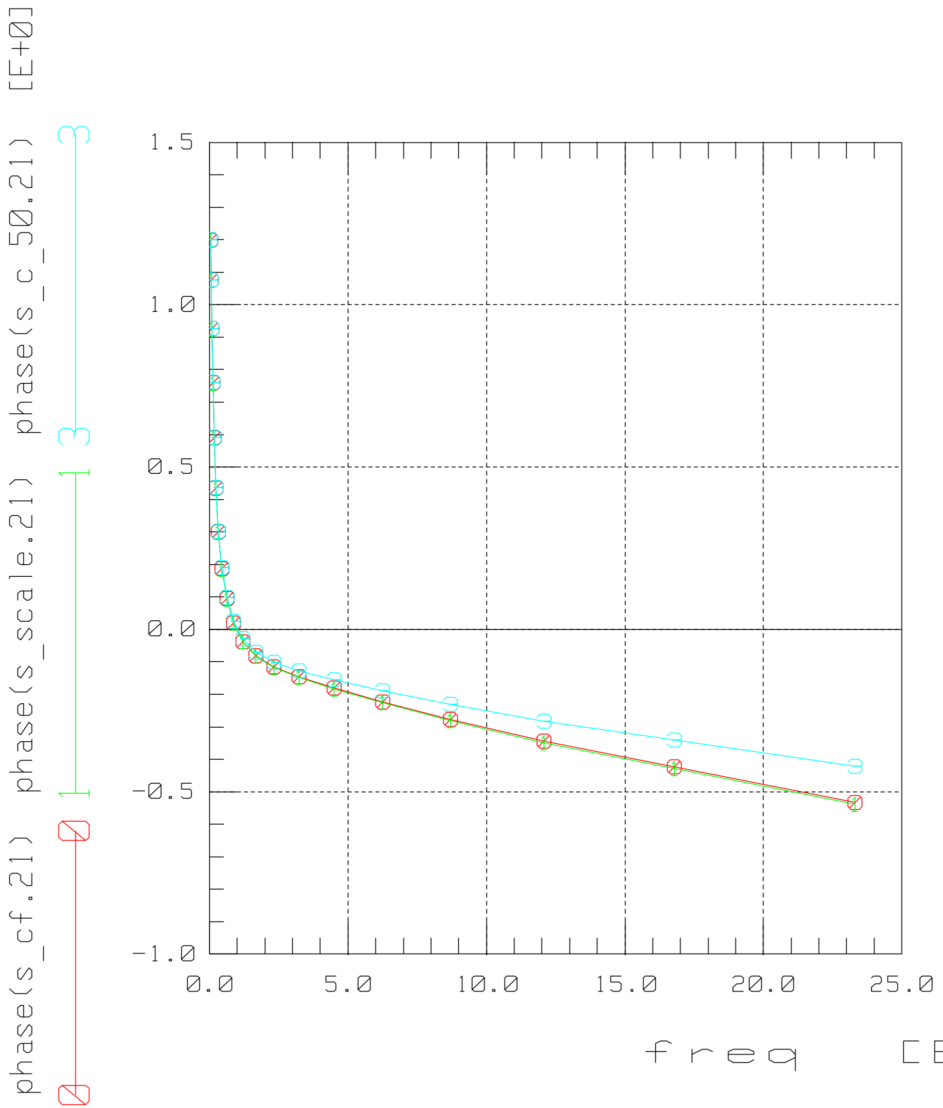

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groundshield gap: 140 x 140 um2

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Conclusions

- Comparison of standard and groundshielded open structure was shown.
- Scalability of open structure was demonstrated.
- Economical impact was discussed.
- Characterization of full-blown testchip inc. structures for 3-way de-embedding and SOLT calibration is underway.

Literature

References

[1] P.J. van Wijnen *et.al., BCTM*, 1987

[2] M.C.A.M. Koolen *et.al., BCTM*, 1991

[3] E.P. Vandamme *et.al., IEEE Trans. Electron Devices*, Apr 2001

[4] T.E. Kolding, *IEEE Trans. Electron Devices*, Apr 2000

[5] J.T. Colvin, *et.al., BCTM*, 1999

[6] T.E. Kolding *et.al., ICMTS*, 2000

and finally . . .

Thank you!