Electromagnetic Design of
flexIble SensOrs

# Report 3.
# Software Calibration Results on the basis of various Structures and Methods

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# Contents

# 1 Introduction

In the last period of work, the focus was on the comparison of lump port calibration results on the example of various structures. The previously implemented de-embedding Double Delay and SOC methods were applied. A series of tests have been carried out, checking the parameters and the method of performing individual calibration techniques (see appendix). The obtained results in InventSim were compared with result other simulators, Momentum, HFSS, ADS (as reference).

Through interface COM implemented in InventSim it is possible in automatic way obtaining the electromagnetic field distribution. This facilitates the very procedure of SOC calibration. Also problem with normalization of power source in InventSim port relative to HFSS was solved. In the IventSim it is always 1W in the power of the incident wave, while in HFSS, it is the 1V voltage wave (0.02 W, for 50Ω matching).

All of symulations carried out using direct solver (without fast frequency sweept) and adaptive meshing. In the following report, various microstrip structures are considered.

- various microstrip waveguides (substrate isola, FR4)
- example branch coupler, using the symmetry of the structure

# 2 Microstrip Line - substrate ISOLA I-TERAMT

- thickness of the substrate : $0.762mm$
- permeability : 3.45
- strip width : $1.72mm$ ($Z_c = 50\Omega$)
- line length :
  - $0.5L = 18.2025mm$
  - $1L = 36.405mm$
  - $2L = 72.81mm$

## 2.1 Calibration results

The simulation results are presented below, in the form characteristics of reflection coefficients S11[dB] and phase. All of case in circuit simulation with ADS served as a reference.

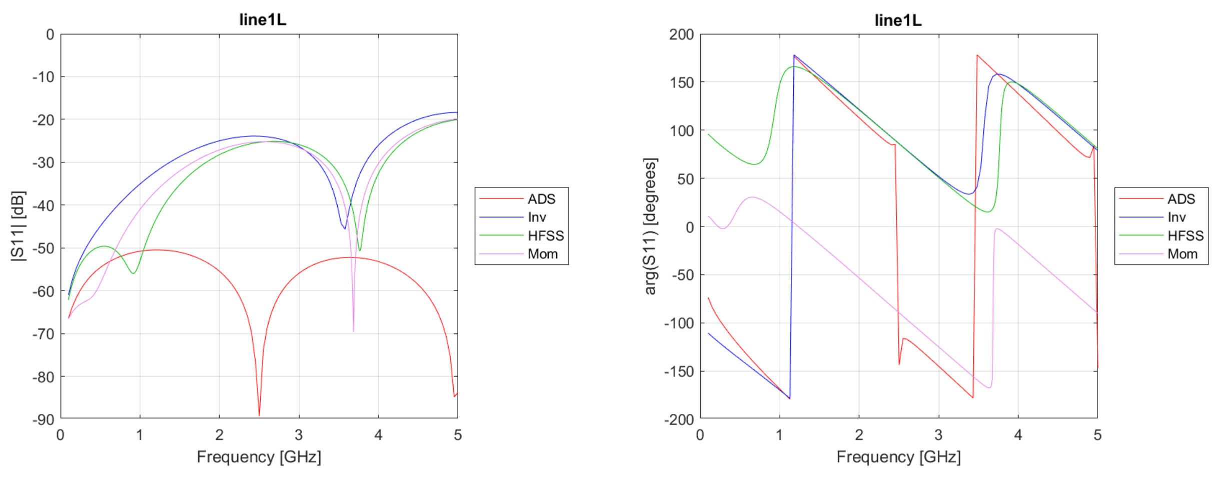



Figure 1: Comparison of results from several simulators without using calibration: ADS (circuit), Momentum, InventSim (lump port), HFSS (lump port).

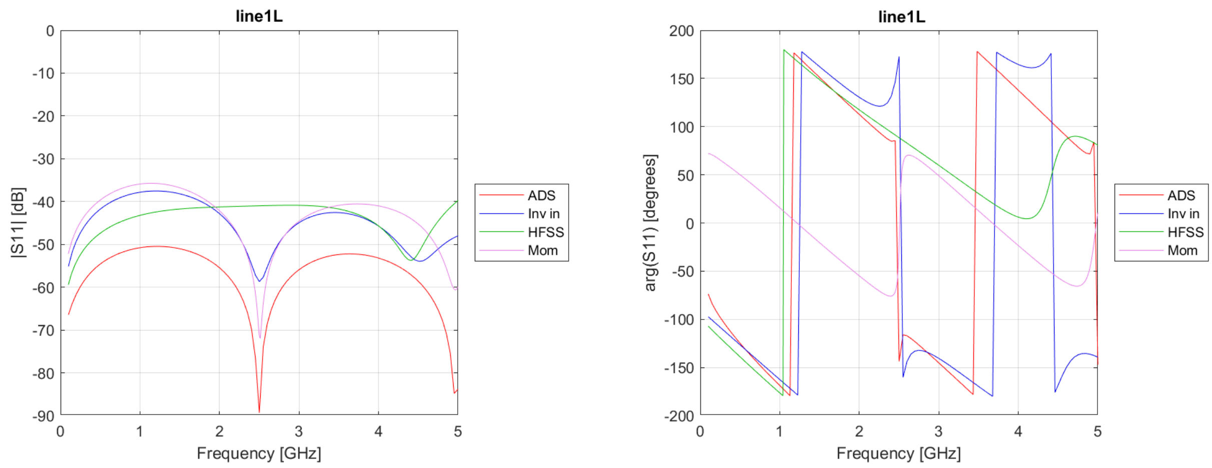
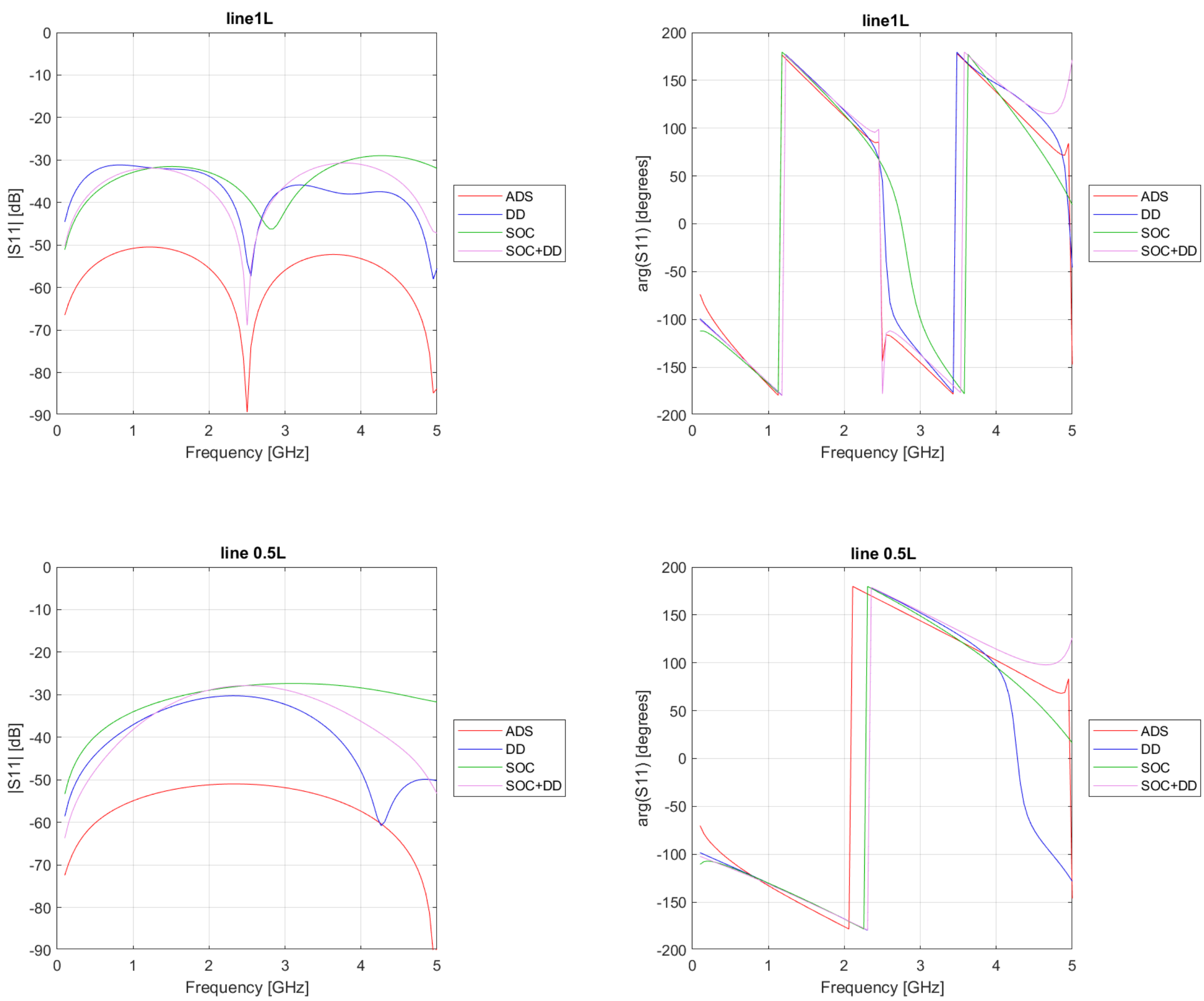
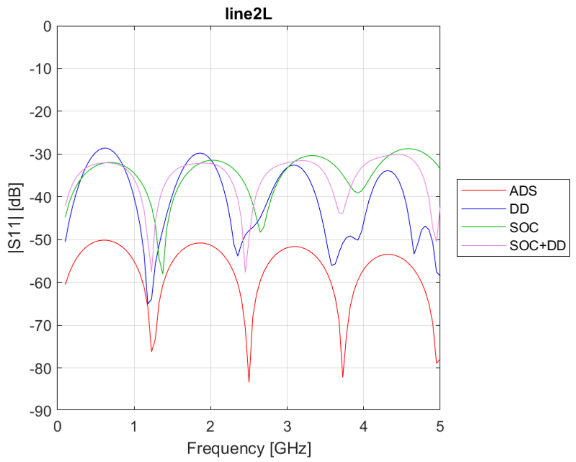
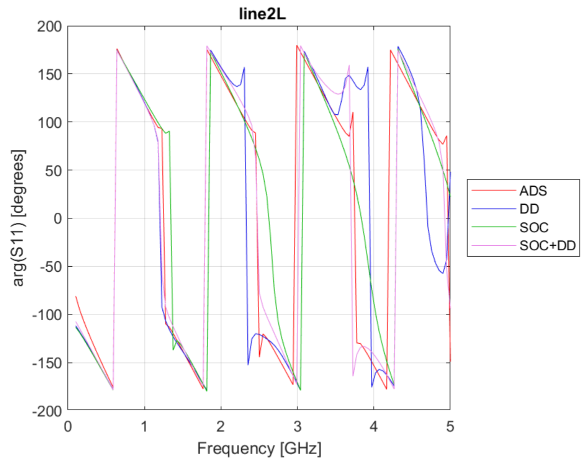



Figure 2: Comparison of results from several simulators with built-in calibration, Momentum TML, HFSS (lump port) and InventSim (lump port on the side wall internal line (extended substrate) without calibration).

Lump port calibration has been performed. DUT were three microstrip line with lengths 0.5L, 1L, 2L. Three calibration methods were used DoubleDelay, SOC oraz and the combination of both methods (first DoubleDelay and next SOC). The based on tests a length (see appendix) of the calibration section i.e. "errox box", on SOC method selected on 1.4mm.






As you can see all calibration methods, caused line matching below -30dB in the whole band from 0 to 5 GHz. The most effective is combination of both methods (convergence of the shape of the match and phase characteristics).

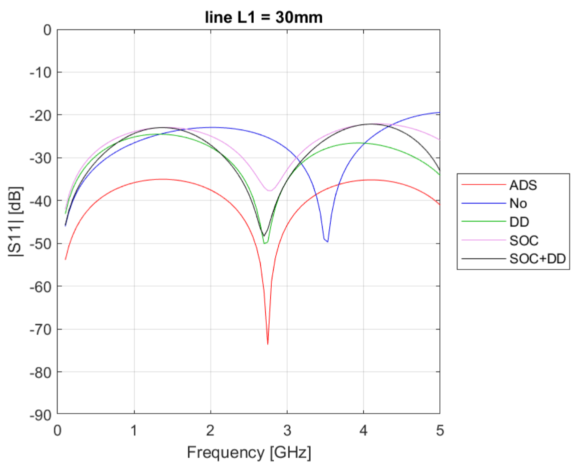
# 3 Microstrip Line - FR4

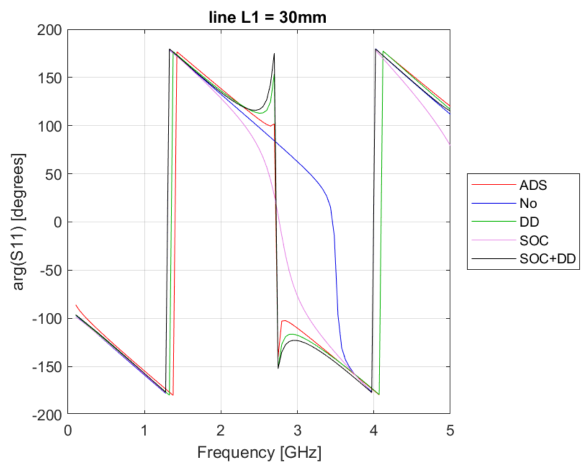
- thickness of the substrate : $0.51mm$
- permeability : 4.4
- strip width : $0.983mm$ ($Z_c = 50\Omega$)
- line length :
  - $L1 = 30mm$
  - $L2 = 40mm$

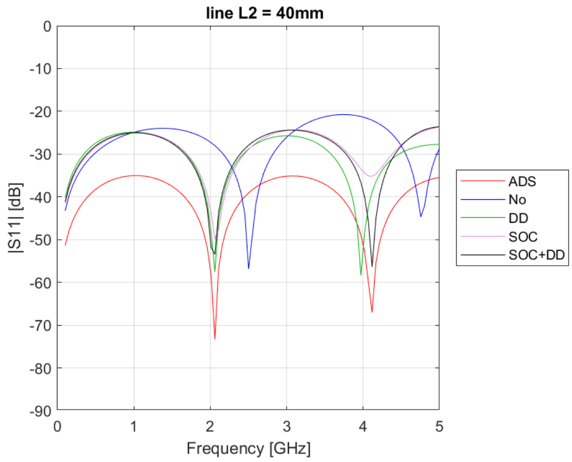
## 3.1 Calibration results

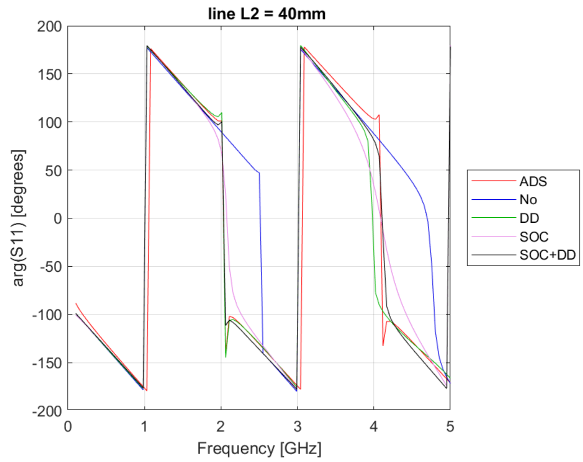
Similarly, the simulation results are presented below, in the characteristics of reflection coefficients S11 [dB] and phase. In all cases, the results from circuits simulation with ADS served as a reference.

- No - without calibration
- DD - Dobule Delay
- SOC - Short Open with add error box in the shape of line about length 1.4mm
- SOC+DD - First Short Open (error box 1.4 mm) and next Dobule Delay






As you can see, as in the previous example, all methods improved the match of the line and phase convergence. The effectiveness of combining both methods is also confirmed.

# 4 Branch coupler

Single calibration of the microstrip line may not show all phenomena occurring in the port. Also, in practice engineering, simulations of more complex systems are performed than a single line. In order to verify previous results, an example simulation of four-ports was carried out. Analysed branch coupler it is symmetrical so it's possible divide the structure in half and then connect its in network. In theory, if the port is properly calibrated both simulations should give the same result.

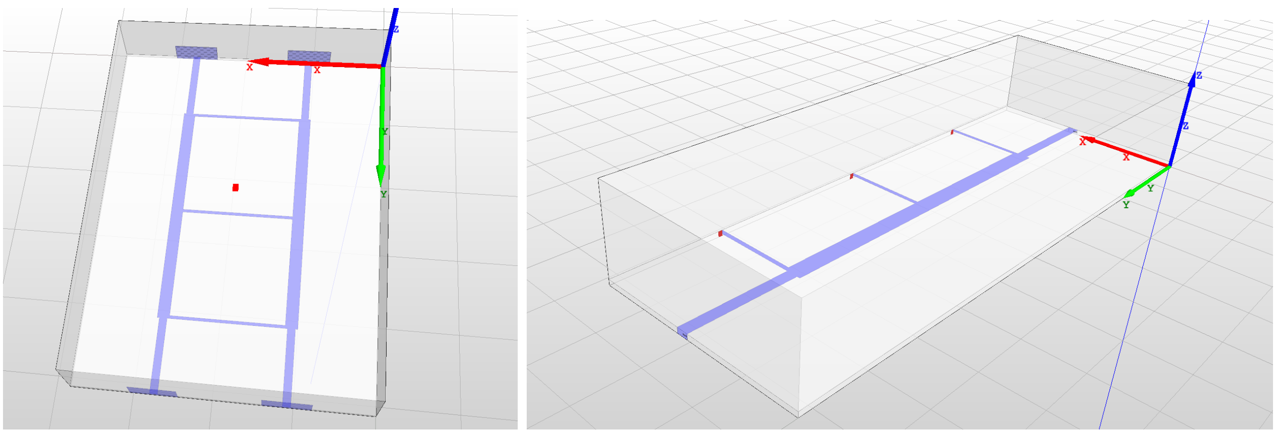


Figure 3: On the left the full structure of the coupler (with wave port), on the right half (with lump port). As a result, the five ports is simulated.

- strip width : $0.4mm$
- strip lenght : $15mm$

## 4.1 Line used to calibration

- width strip : $1.72mm$ ($Z_c = 50\Omega$)
- length line : $0.5 = 36.405mm$

The calibration procedure was performed in the same measure as in the previous cases. The results are presented in an identical way. (see 3.1)

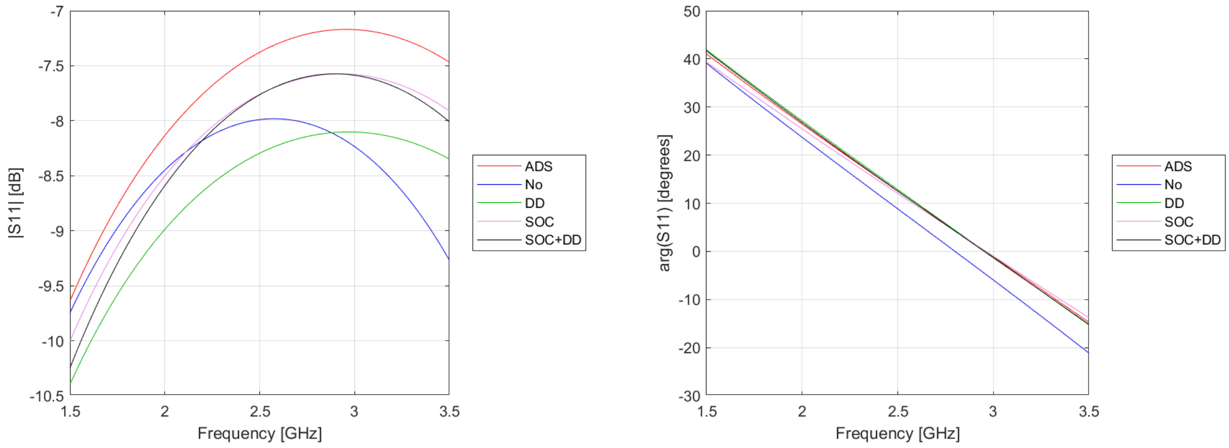
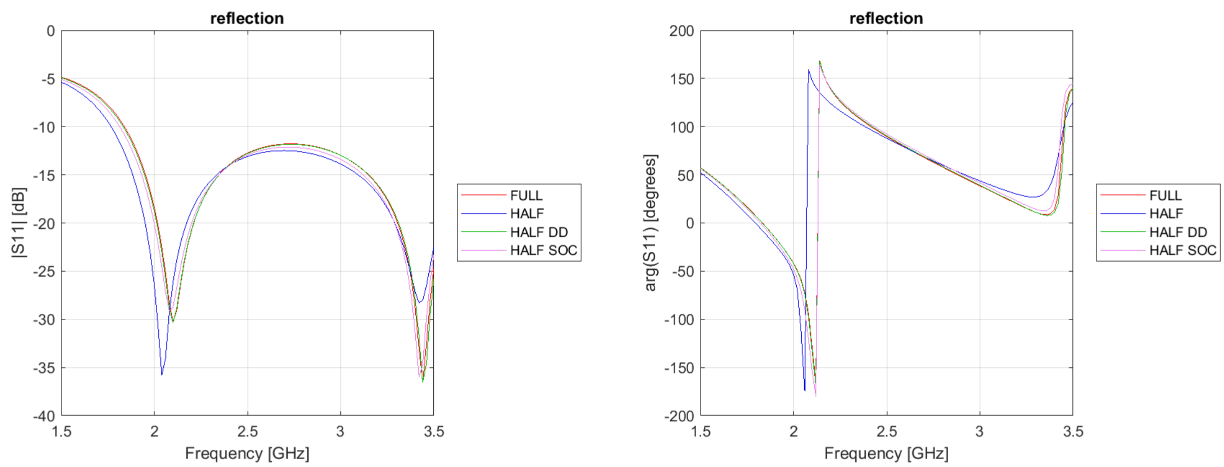


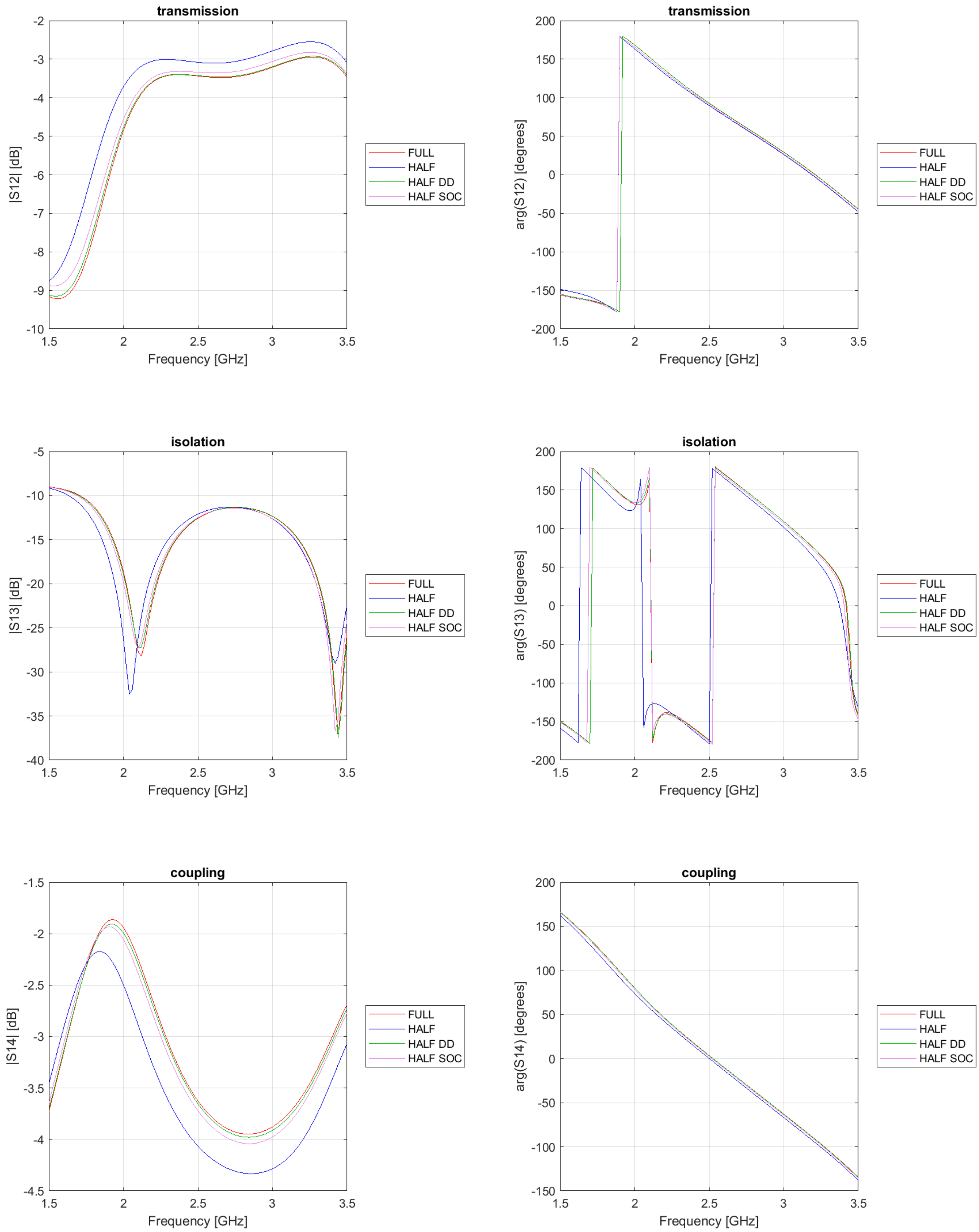

Figure 4: The result of the calibration of the line of a single line forming part of the coupler.

## 4.2 Structure symmetry, connection and de-embedding result

The results of simulation were separated due to its coupler basic parameters (resulting from the scattering matrix), reflection, transmission, isolation, coupling, assuming the reciprocity of the network.

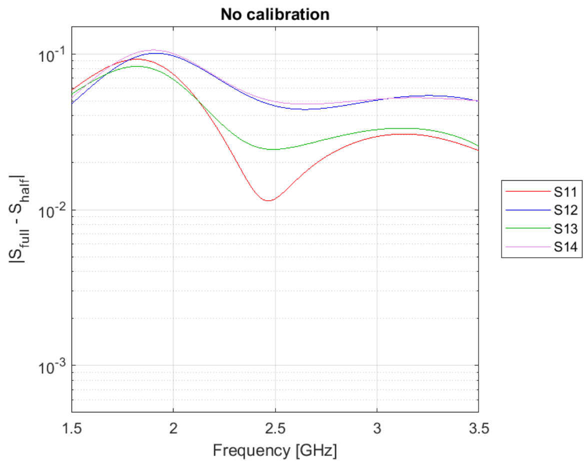
- FULL - simulation with ports the whole structure without "cutting"
- HALF - the combination of two symmetrical five-ports, in effect four-ports come into being
- HALF DD - as above with the use of calibration Double Delay
- HALF SOC - as above with the use of calibration Short Open

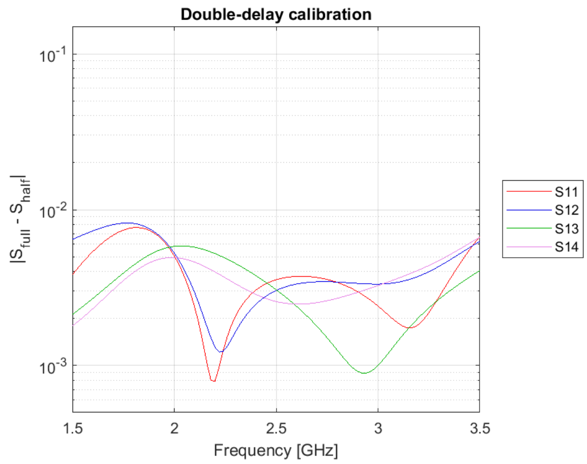


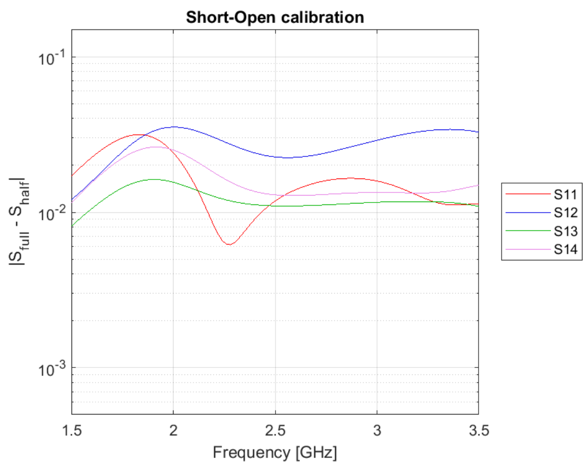


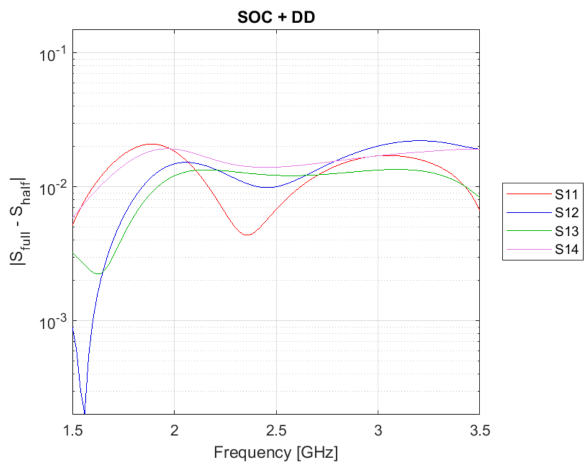

As you can see, after calibration the results coincide to the simulation of the whole structure. A combination of SOC + DD was also made, but the effect was identical to that of the SOC itself. Let's look at the level of convergence, by means of error plots.

## 4.3 Convergence error plots




The Double Delay technique proved to be the best in this case. This is due to the fact that when connecting structure, the port discontinuity doubles. In the double delay method, we get directly the matrix of the double port. This is confirmed by the above error characteristics. After calibration, the error reduces by two orders of magnitude.

## 5 Conclusion

For ganeral case calibration procedure was successful. As you can see the results of the calibration give a positive effect. The Double Dalay method is simpler and gives better SOC results. However, Short Open may be addition increasing the accuracy of the Double Delay calibration.

The coupler simulation shows that it is possible to use the calibration for designing systems using symmetry.

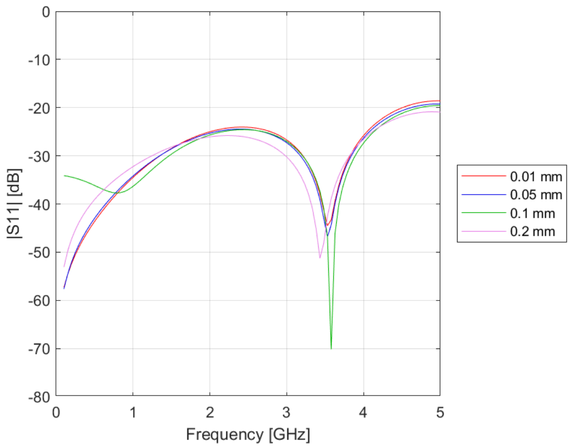
The most important results from the last period were presented. In the next stage of work, few more examples of structures will be analysed (for example line with stub). It is necessary to carefully examine the form of "error fields" used during de-embedding. When designing planars systems, it is planned to use even, odd excitation.

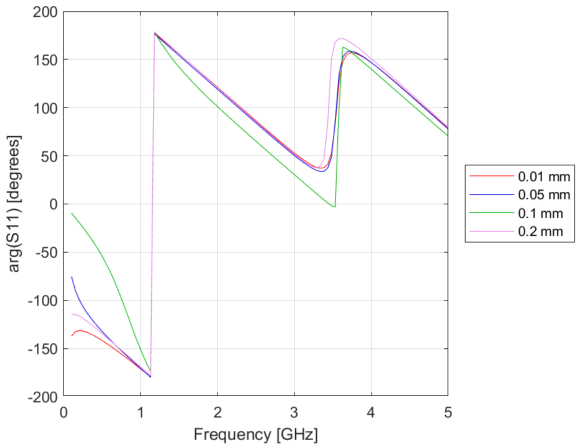
# Appendix : Test SOC - error box

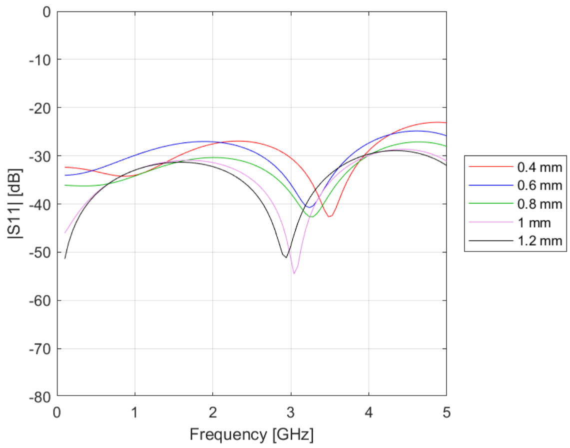
This appendix presents how the length of the attached line section apply to the calibration Short Open method. The above tests, was carried out for the 1L microstrip line, isola (see 2.1).

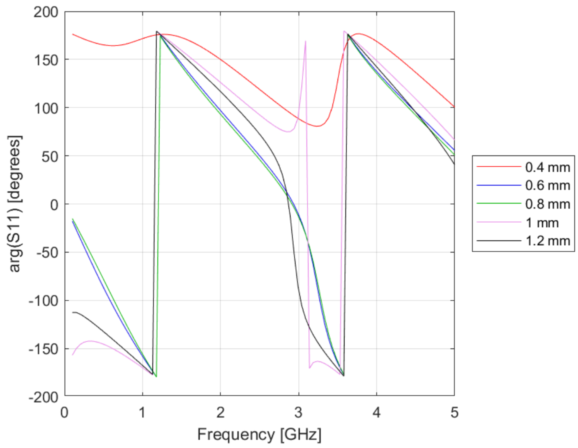
## A.1 Only Short Open

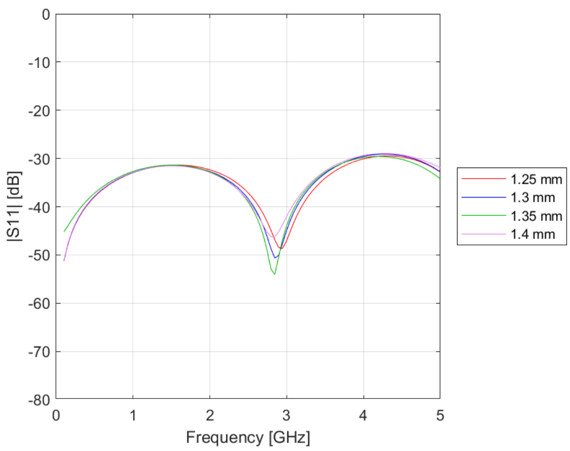
The simulation results are presented below, in the form characteristics of reflection coefficients S11[dB] and phase. Line of a small length is attached to the circuit as an error box.

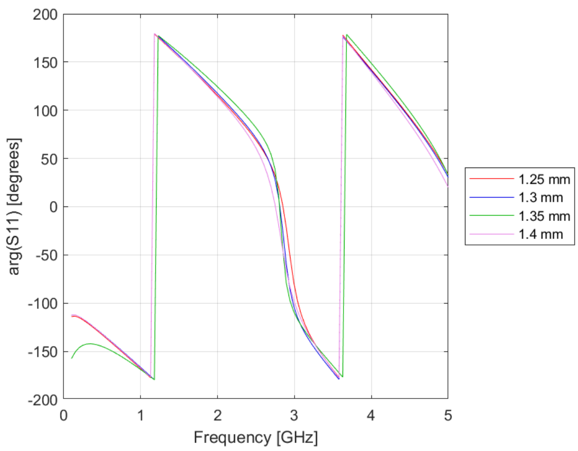


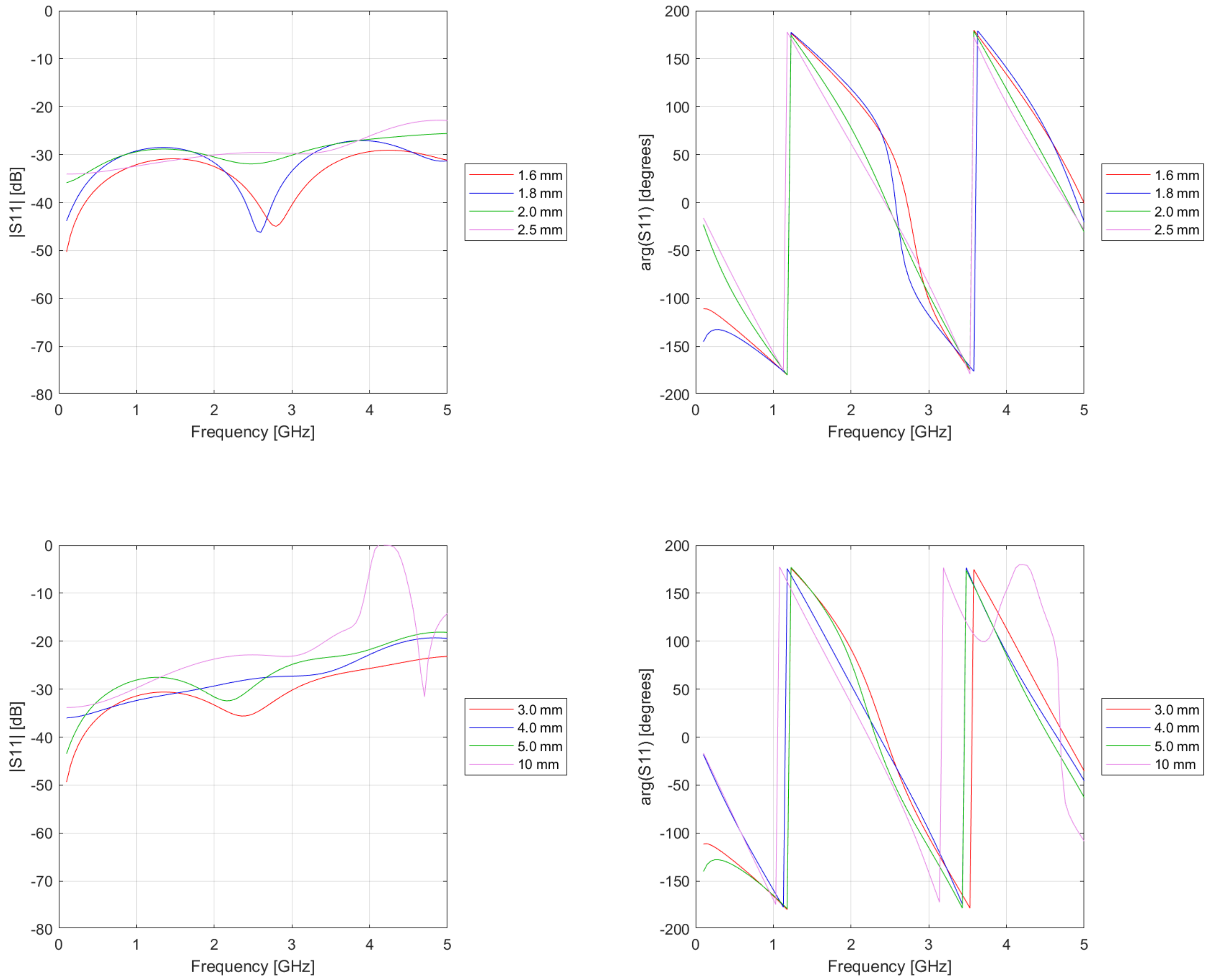



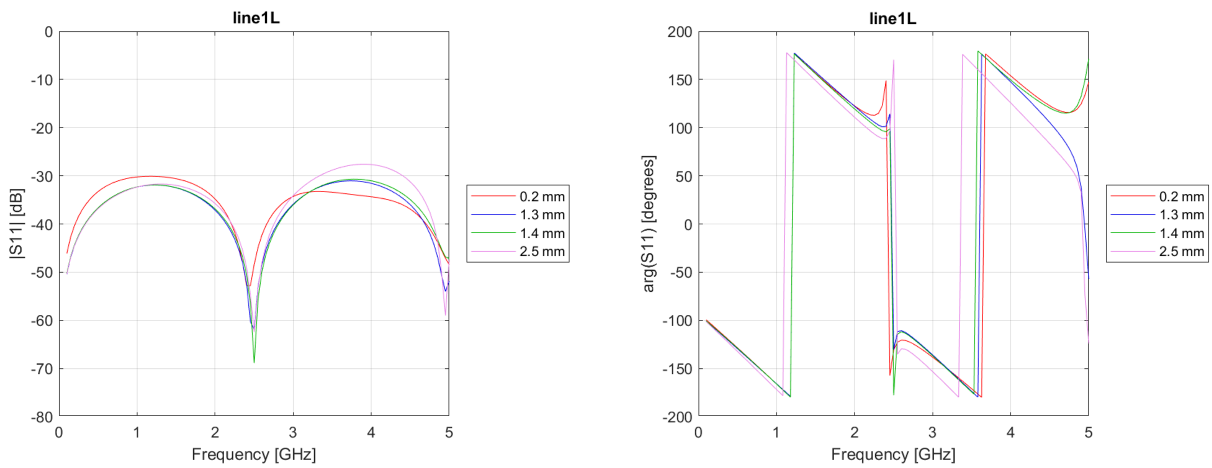






- the best results are obtained for a section from 1.2 mm to 1.8 mm
- for a very small section the results are almost unchanged
- for a very long episode, the results worsen

## A.2 First Short Open, next Double Delay




Based on the above data and the previous results, it was noted that for error box with a length of 1.3 mm phase is better calibrated while reflectance module better for 1.4 mm. It is very possible that this is the effect of resonant phenomena.