Electromagnetic Design of flexIble SensOrs

Report 5 - DeEmbedding using ADS, HFSS, InventSim

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1.0	22.08.2017		created

1. Double-Delay

Double-Delay idea:

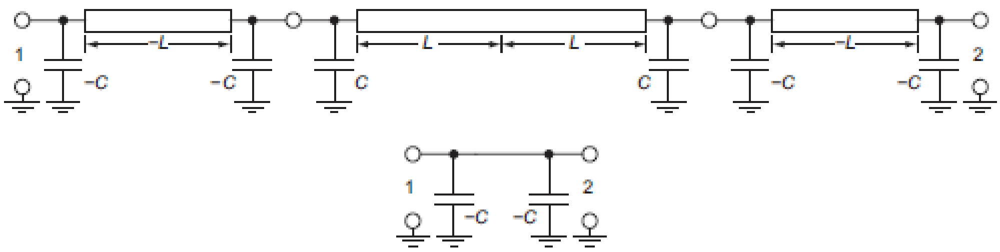

Figure 1: Obtaining port discontinuity.

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}^{-1}_{\text{DoublePort}} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}^{-1}_{L\ \text{Length}} \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{2L\ \text{Length}} \begin{bmatrix} A & B \\ C & D \end{bmatrix}^{-1}_{L\ \text{Length}}$$

Figure 2: Port discontinuity corresponding to Fig.1.

The net result of these matrix manipulations is a double negative port discontinuity, (see Figure 4.2 (Fig.1)*, bottom). "Negative" means the port discontinuity shunt admittance is of opposite sign. The ABCD matrix for the negative discontinuity is the inverse of the positive port discontinuity matrix. In order to de-embed our DUT, we need a single negative port discontinuity. Mathematically, this corresponds to taking a matrix square root of the double negative port discontinuity. In general, the matrix square root is nonunique; there are many possible solutions.* [2]

Consider a matrix that has four squareroots, **ABCD**. All four of these roots can be obtained from the eigenvalues and eigenvectors of **ABCD**. If [**V**,**D**] = eig(**ABCD**), then the squareroots have the general form **Y**=**V*****S**/**V**, where **D**=**S*****S** and **S** has four choices of sign to produce four different values of **Y**: ++, +-, -+, – [4]. To assume:

$$\begin{aligned} (\mathbf{V},\mathbf{D}) &= \mathrm{eig}(\mathbf{ABCD}^{-1}_{DoublePort}) \\ \mathbf{D} &= \mathbf{S}\cdot\mathbf{S} \\ \mathbf{S} &= \mathbf{S}\cdot\mathrm{diag}(\pm 1,\pm 1) \\ \mathbf{ABCD}^{-1}_{Port} &= \mathbf{V}\cdot\mathbf{S}/\mathbf{V} \end{aligned} \tag{1}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{DebedDUT}} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}^{-1}_{\text{Port1}} \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{DUT}} \begin{bmatrix} A & B \\ C & D \end{bmatrix}^{-1}_{\text{Port2}}$$

Figure 3: DeEmbedded structure using roots of **ABCD** matrix.

One case is presented with root ++ (root – have the same phase and magnitude plots, but different signs at ABCD port matrix diagonal, roots +-, -+ give wrong results). Following sections present line definition and results mostly grouped 1by2 with different programs. Following plots correspond to:

- (1,1) Magnitude plot for s_{11} and s_{12} parameters for DeEmbedded (DE) and not DeEmbedded (not DE) cases (2*L Line).

- (1,2) Magnitude plot for s_{11} parameter for DeEmbedded 2*L Line and cascade L+L Line (Both DeEmbedded). **Optionally**, series with green circles means DeEmbedded reference case (2*L) obtained with software (ADS and HFSS).
- (1,3) Phase plot for s_{11} parameter for DeEmbedded (DE) and not DeEmbedded (not DE) cases (2*L Line).
- (1,4) Phase plot for s_{11} parameter for DeEmbedded 2*L Line and cascade L+L Line (Both DeEmbedded). **Optionally**, series with green circles means DeEmbedded reference case (2*L) obtained with software (ADS and HFSS).
- (2,1:2) Real and Imaginary part of A component of **ABCD** matrices (freq sweep).
- (2,3:4) Real and Imaginary part of B component of **ABCD** matrices (freq sweep).
- (3,1:2) Real and Imaginary part of C component of **ABCD** matrices (freq sweep).
- (3,3:4) Real and Imaginary part of D component of **ABCD** matrices (freq sweep).

2. ADS

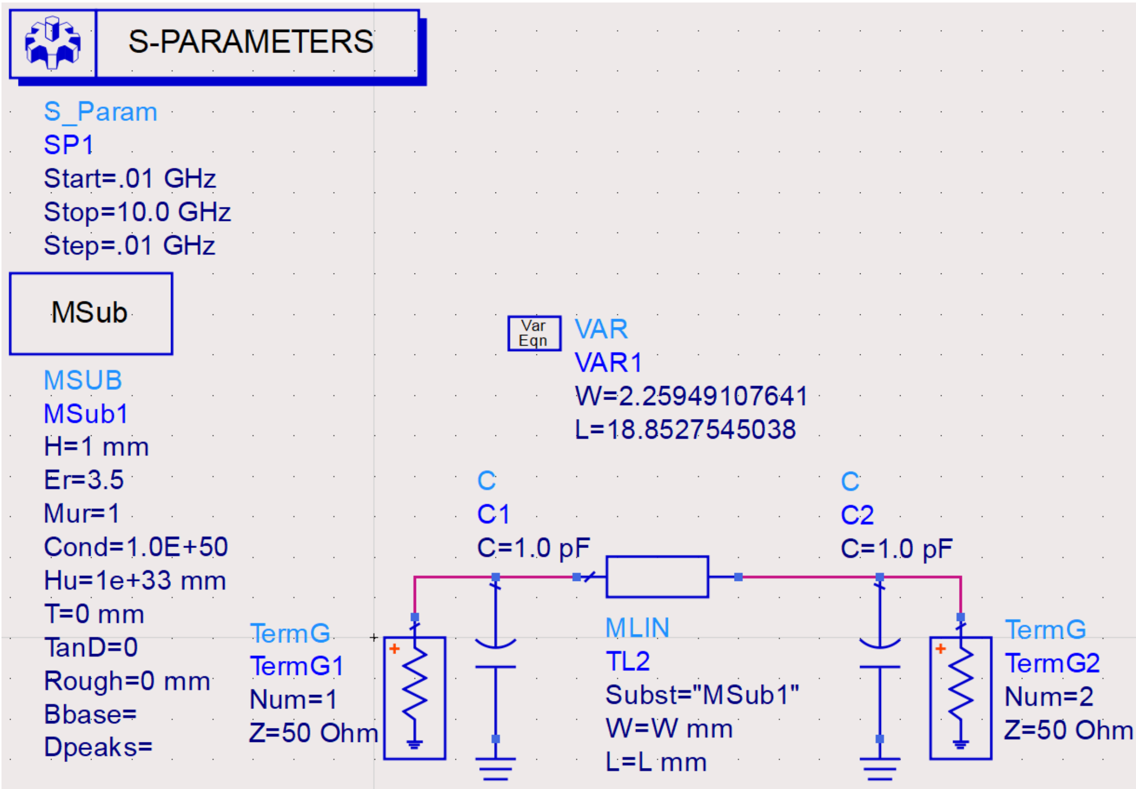

Figure 4: ADS definition of line with shunt capacitor.

The line have been declared using circuit diagram Fig.4. With this case (even root ++) we obtain ideal shape of ABCD matrix as shown at Fig.5. A and D components are very close to +1, B is very close to 0, and C is pure imaginary, linear rising part ($j\omega C$). For 1 port we obtain half of 2 port C components. Full agreement is obtained with reference and cascade case.

With odd root (+- or -+) we obtain total unagreement and we're rejecting this case.

Full agreement is obtained with **shunt capacitor or series inductance**, but for **shunt inductance and series capacitor** unagreement occurs below 0.1 GHz.

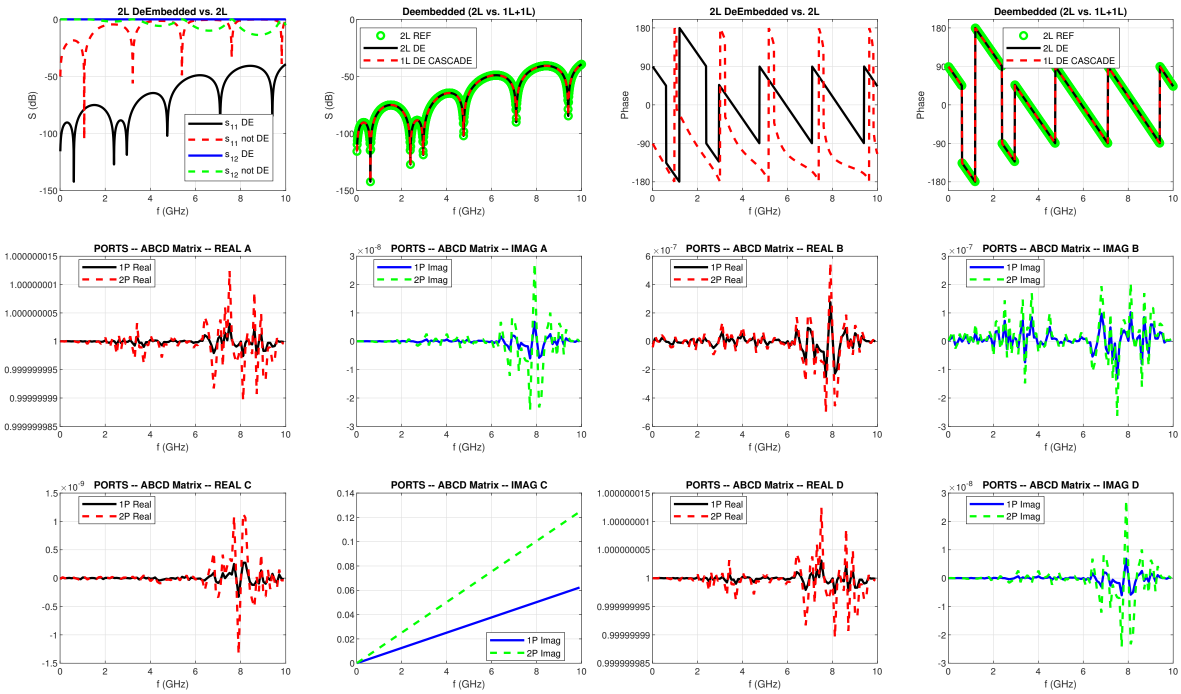

Figure 5: ADS - root ++.

3. HFSS

The structure screenshots are not available at the moment of creating report. Structure preparation is similar like in InventSim.

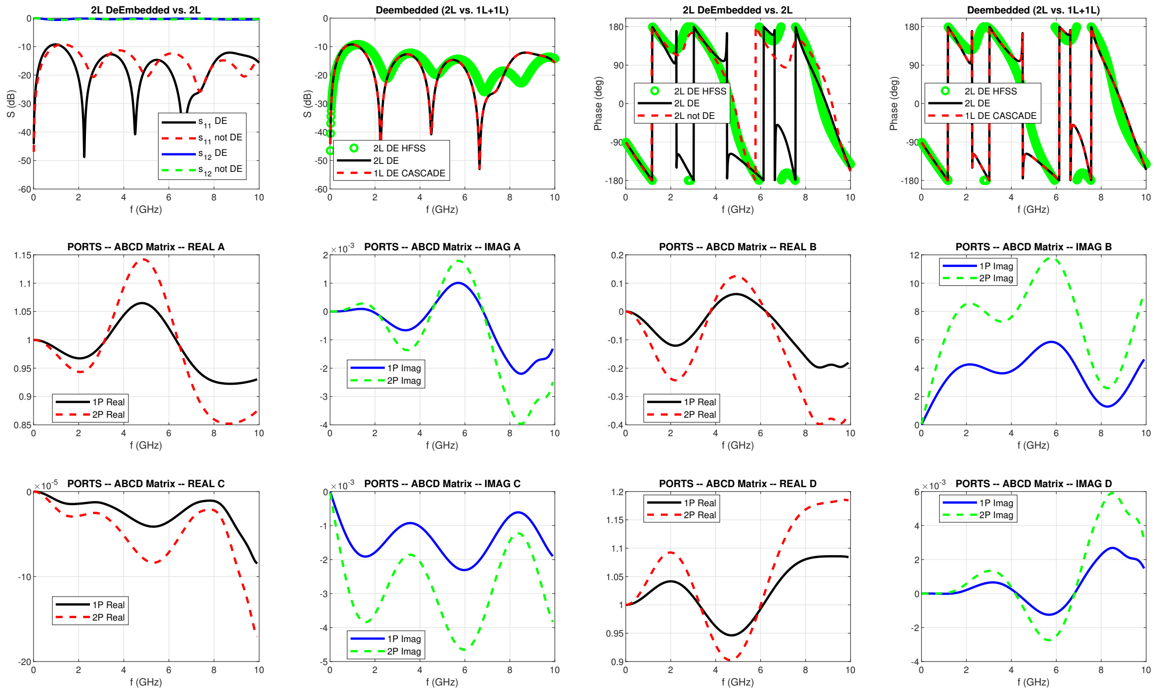

Figure 6: HFSS - root ++.

4. InventSim

Two types of structures in InventSim have been analyzed and in both cases similar results have been obtained.

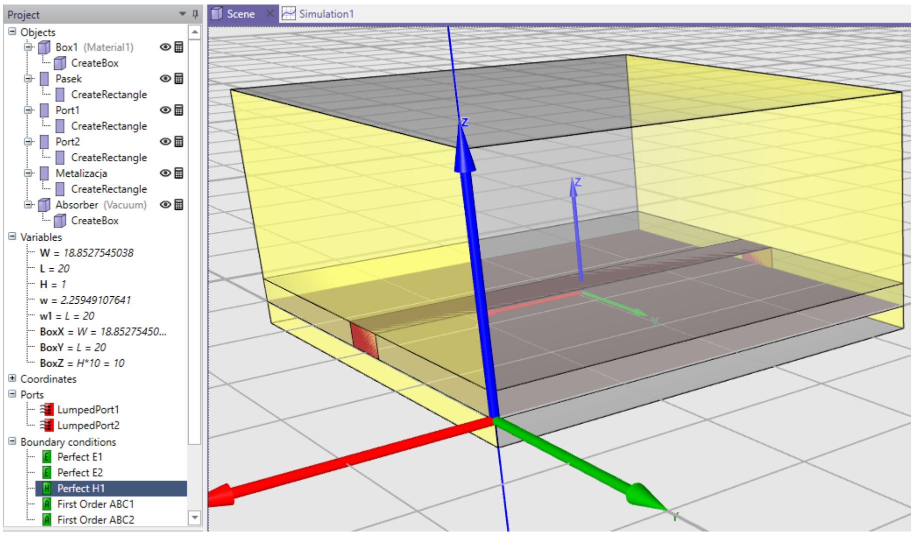

Figure 7: InventSim definition option 1.

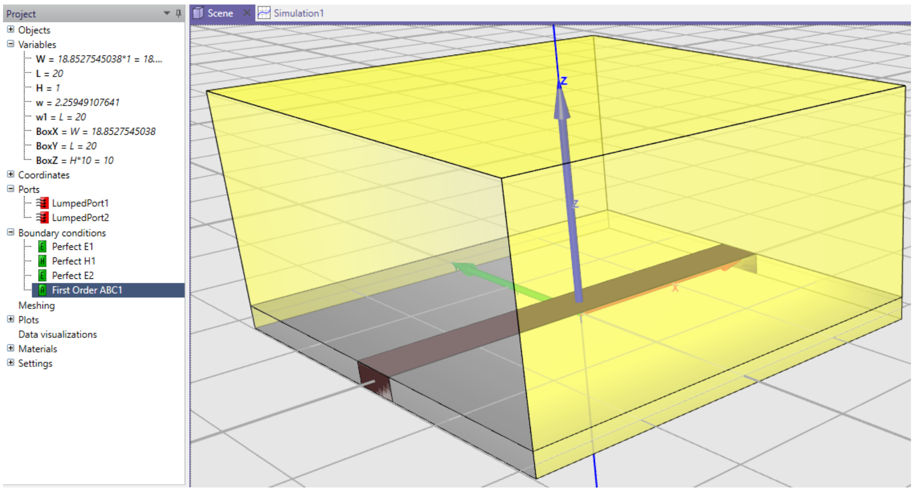

Figure 8: InventSim definition option 2.

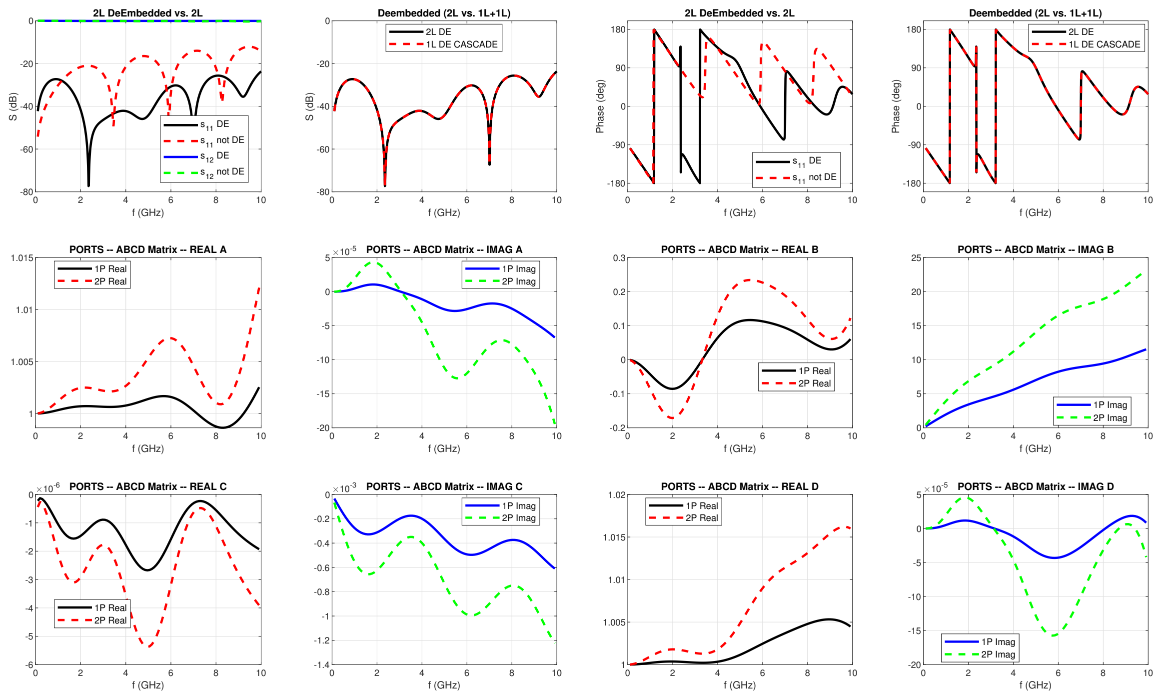

Figure 9: InventSim - root ++ Option 1.

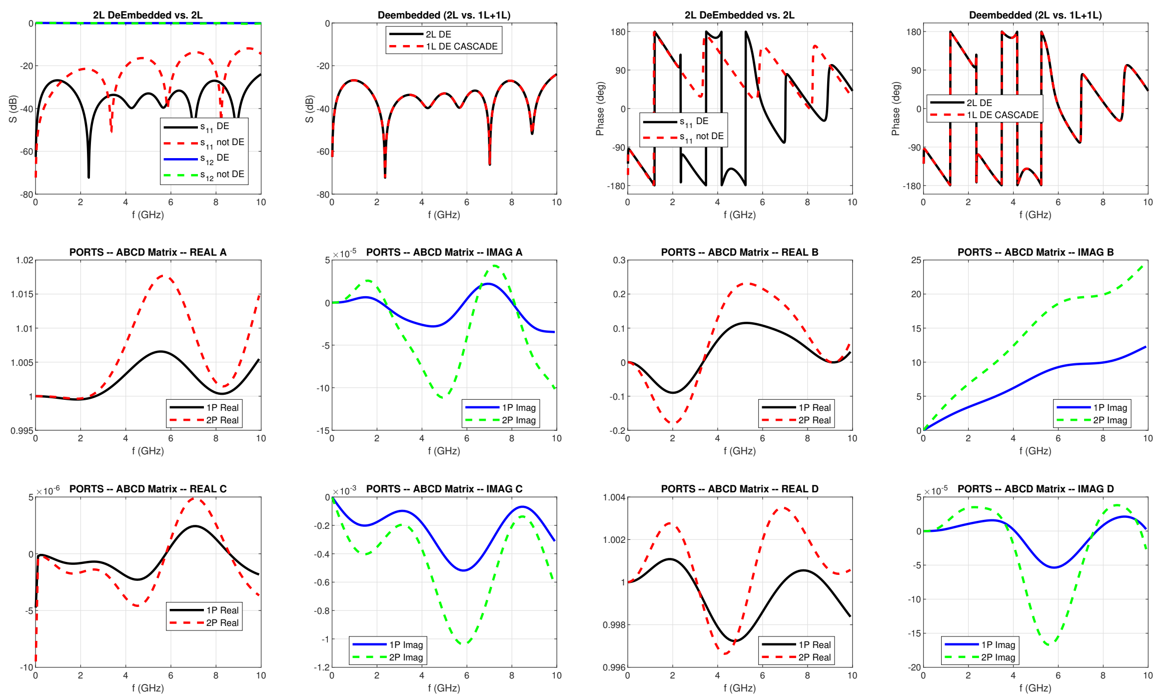

Figure 10: InventSim - root ++ Option 2.

5. Conclusions

Double-delay technique works well as long as discontinuity acts like a single component. Criteria for determining if technique is valid might be:

- shape of ABCD matrix
- full agreement of cascade of deembedded short lines with corresponding length deembedded line (magnitude and phase)

If one of above fails, then program should switch to another deembedding technique.

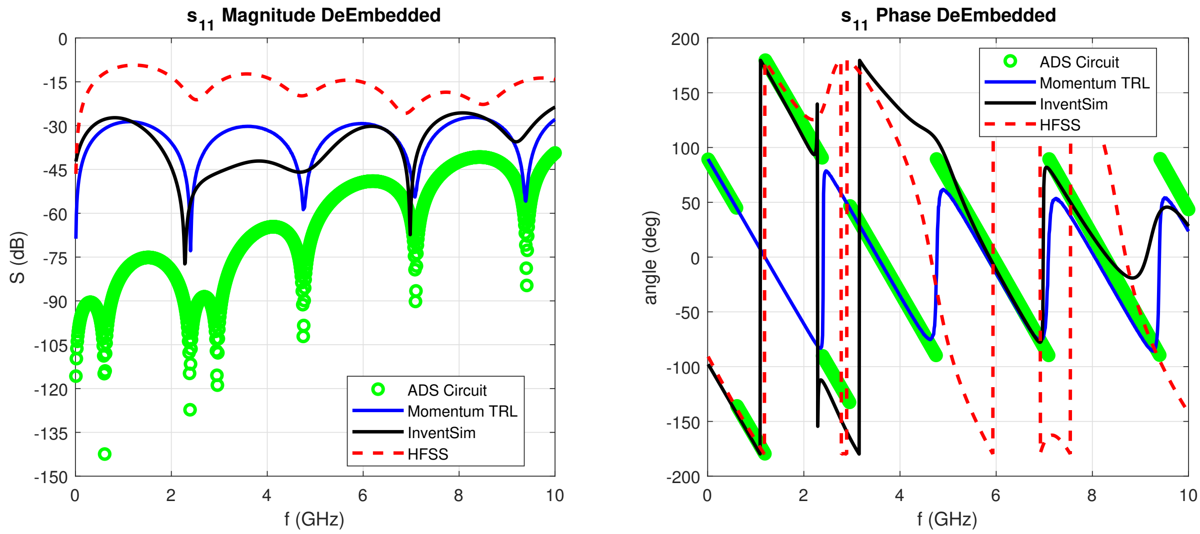

Figure 11: Summary with InventSim option 1.

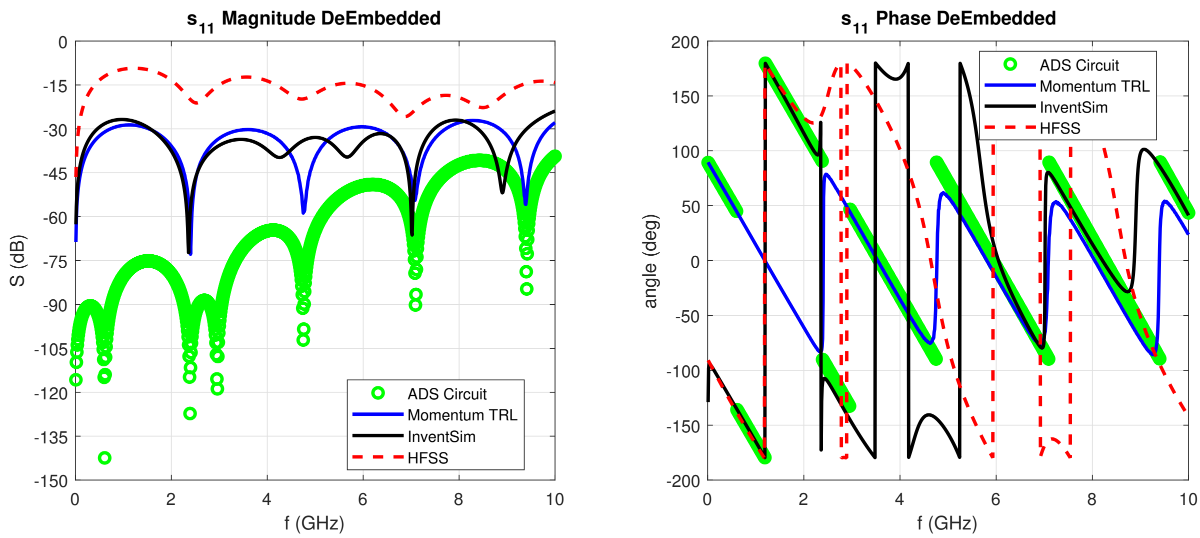

Figure 12: Summary with InventSim option 2.

References

[1] Rautio, James C., and Vladimir I. Okhmatovski. *Unification of double-delay and SOC electromagnetic deembedding.* IEEE transactions on microwave theory and techniques 53.9 (2005): 2892-2898.

[2] Rautio, James C. *High-Frequency and Microwave Electromagnetic Analysis Calibration and De-embedding.* Microwave De-embedding. 2014. 151-188.

[3] Frickey, Dean A. *Conversions between S, Z, Y, H, ABCD, and T parameters which are valid for complex source and load impedances.* IEEE Transactions on microwave theory and techniques 42.2 (1994): 205-211.

[4] https://www.mathworks.com/help/matlab/ref/sqrtm.html