Implementation of macromodel over several cells under the TLM

Abstract— **I describe the inclusion of parametric behavioral macromodels over several cells within the Transmission-Line Modelling (TLM) method. Only one direction is considered.**

I. Introduction

The second step of the TLM/macromodel hybridisation consists in considering the input and output port macromodels with supply ports. Physically, the input (output) and supply ports are located at different places. Although the wavelength of the treated signals up to now is far more superior to the space separating the various ports, it could be useful to think about an implementation over several cells. The work is presented for a z-oriented macromodel.

II. Recall: Implementation on one cell

The initial equations are [1]:

$$V_z = T_e \left(2\sum_{j=8}^{11} V_j^i - i_{fz} + z^{-1} S_{ez} \right) \quad (1)$$

where V^i denotes the incident voltages on the cell (Fig.1), $z^{-1}S_{ez}$ the previous event (3), i_{fz} the free electric current, T_e (2) and Γ_e (4) respectively the node transmission and reflection coefficients.

$$T_{e0} = \left(4 + g_{e0} + 4\chi_{e0}\right)^{-1} \quad (2)$$

$$S_{ez} = 2\sum_{j=8}^{11} V_j^i - i_{fz} + \Gamma_e V_z - g_e(z) V_z + 4\chi_e(z) V_z \quad (3)$$

$$\Gamma_e = -\left(4 + g_{e1} + 4\chi_{e1}\right) \quad (4)$$

g_{e0}, g_{e1}, $g_e(z)$ and χ_{e0}, χ_{e1}, $\chi_e(z)$ result of the partial fraction expansion of the conductance and susceptibility ((23), (24) in [1]).

We include the macromodel at the node center of one single cell through the conductance. Moreover, the device must be seen as a black-box within the TLM mesh, i.e that no information is available on the element past events. This leads to the simplification of (1)-(4) in (6)-(9), by using the normalized conductance to the impedance of free-space η_0 (5) and taking i_{fz} null.

$$g_{e0} = \eta_0 I_{macro} / V_{macro} \quad (5)$$

$$V_z = T_{e0} \left(2\sum_{j=8}^{11} V_j^i + z^{-1} S_{ez} - \eta_0 I_{macro} \right) \quad (6)$$

$$T_{e0} = \left(4 + 4\chi_{e0}\right)^{-1} \quad (7)$$

$$S_{ez} = 2\sum_{j=8}^{11} V_j^i + \Gamma_{e0} V_z - \eta_0 I_{macro} \quad (8)$$

$$\Gamma_{e0} \quad = \quad -4 \tag{9}$$

The component (- η_0 I_{macro}) in (6) and (8) indicates a macromodel of receiver type. For a driver one, the component is modified by (+ η_0 I_{macro}). Equations (7) and (9) correspond to the coefficients of a free-space node.

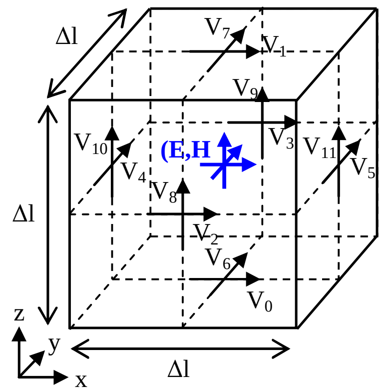


Figure 1. 3D symmetrical condensed node

Knowing the incident voltages on the cell (V^i), the past events (3) and the macromodel current-voltage relations, we look for the couple (V_{macro}, I_{macro}) satisfying (10) with the secant method.

$$2\sum_{j=8}^{11} V_j^i \ + \ z^{-1} S_{ez} \ - \left(V_z / T_{e0} \ + \ \eta_0 \, I_{macro} \right) \ < \ \text{precision} \tag{10}$$

III. Implementation over several cells

We proceed now to the implementation of a distributed macromodel over several cells in one direction.

Fig.2 shows a macromodel over *m* cells (*m* = 3) in z-direction. The voltage V_{zk} at the center of each node is given by (11), *k* varying from 1 to *m*.

$$V_{zk} / T_{e0} \ + \ g_{e0k} \ V_{zk} \quad = \quad 2\sum_{j=8}^{11} V_{jk}^i \ + \ z^{-1} S_{ezk} \tag{11}$$

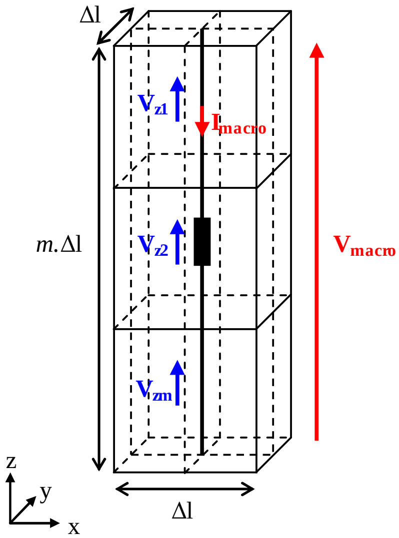
Every conductance g_{e0k} must be equal and proportional to the device one g_{e0} (5). The macromodel voltage over *m* cells is thus defined by (12), rewritten as (13) to find the solution (V_{macro}, I_{macro}).

$$V_{macro} / T_{e0} \ + \ m \, g_{e0} \ V_{macro} \quad = \quad \sum_{k=1}^{m} \left(2\sum_{j=8}^{11} V_{jk}^i \ + \ z^{-1} S_{ezk} \right) \tag{12}$$

with

$$\begin{cases} V_{macro} \ = \ \sum_{k=1}^{m} V_{zk} \\ g_{e01} \ = \ g_{e02} \ = \ \ldots \ = \ m \, g_{e0} \end{cases}$$

$$\boxed{V_{macro} / T_{e0} \ + \ m \, \eta_0 \, I_{macro} \quad = \quad \sum_{k=1}^{m} \left(2\sum_{j=8}^{11} V_{jk}^i \ + \ z^{-1} S_{ezk} \right)} \tag{13}$$



$$V_{z1} / T_{e0} + g_{e01} V_{z1} = 2 \sum_{j=8}^{11} V_{j1}^{i} + z^{-1} S_{ez1}$$

$$V_{z2} / T_{e0} + g_{e02} V_{z2} = 2 \sum_{j=8}^{11} V_{j2}^{i} + z^{-1} S_{ez2}$$

$$V_{zm} / T_{e0} + g_{e0m} V_{zm} = 2 \sum_{j=8}^{11} V_{jm}^{i} + z^{-1} S_{ezm}$$

Figure 2: Macromodel distributed over several cells

Once (V_{macro}, I_{macro}) known, the scatter process needs the V_{zk} calculation on each cell. This is made with (14). Nevertheless, the ratio introduced by the conductance entails some problem for (I_{macro} & V_{macro}) or V_{macro} null(s).

$$V_z / T_{e0} + m V_z \left(I_{macro} / V_{macro} \right) = 2 \sum_{j=8}^{11} V_j^i + z^{-1} S_{ez} \qquad (14)$$

To suppress this drawback and because the current must be the same on each cell, we reintroduce the macromodel current through the free electric current component. By this way, we find back the relations (6) and (8) to evaluate the voltage at the node center and the past event.

IV. Simulations

Fig. 3 shows the modeled structure in the TLM code. The dimensions are specified with the discretisation step *dl* = 1mm. The strip is zero-thickness and perfectly conducting, the substrate is assumed lossless. The configuration is surrounded by absorbing boundary conditions in the lateral and top directions, and a perfect electric conductor one at the substrate back.

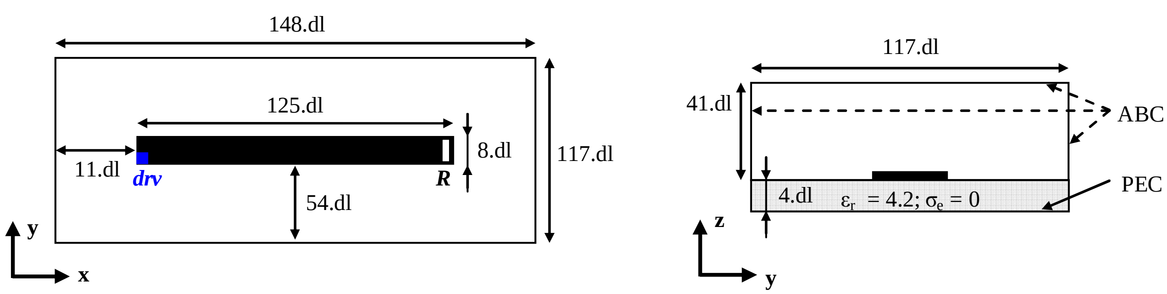
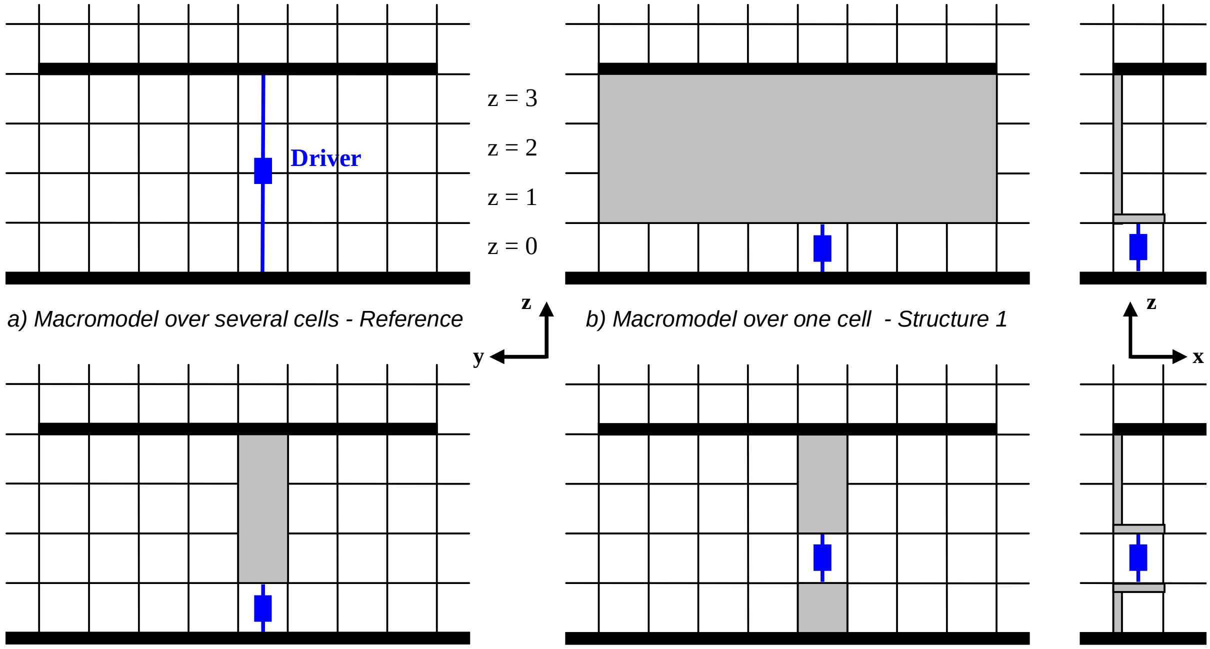


Figure 3: Dimensions of the test microstrip structure

The strip is fed by the driver of a DDR (left side), located as specified in Fig. 4a). Fig. 4 b)-d) represent the comparison structures with a driver implemented on one cell with different metal connections to the strip and place. The load consists of a 50Ω resistance.



a) Macromodel over several cells - Reference

b) Macromodel over one cell - Structure 1

c) Macromodel over one cell - Structure 2

d) Macromodel over one cell - Structure 3

Figure 4: Driver implementation over 4 cells (a)
and one single cell with different metal plates connections and locations

Fig. 5 presents the driver voltage results of Fig. 4a) got directly with (13) and by summing the voltages on each cells (6). Fig. 6-7 show the driver voltage of Fig. 4a) as well as ones of Fig. 4b)-d) and the difference between them (difference = (ref. – structure X) / ref. * 100). A good correlation is observed. For an implantation on one cell, the connection Fig. 4b) should be avoid

V. Conclusion

The distribution of a macromodel over several cells, in one direction, has been introduced. The comparison with an implementation on one single cell has shown good results.

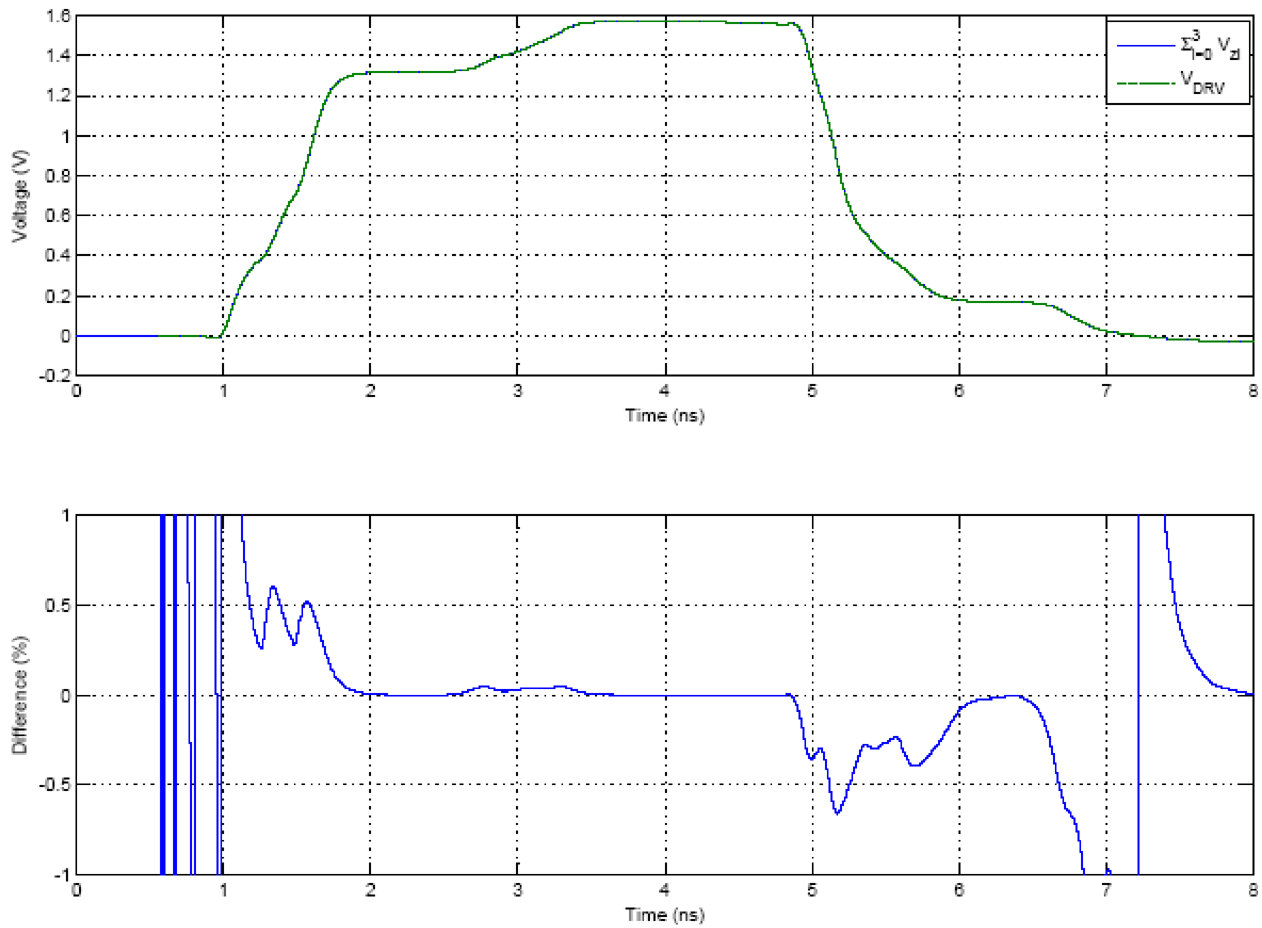


Figure 5: Driver voltage of the macromodel implementation over the substrate height (Fig.4 a)). Comparison of the voltages got directly by solving (13) and by sum of each single cell (6)

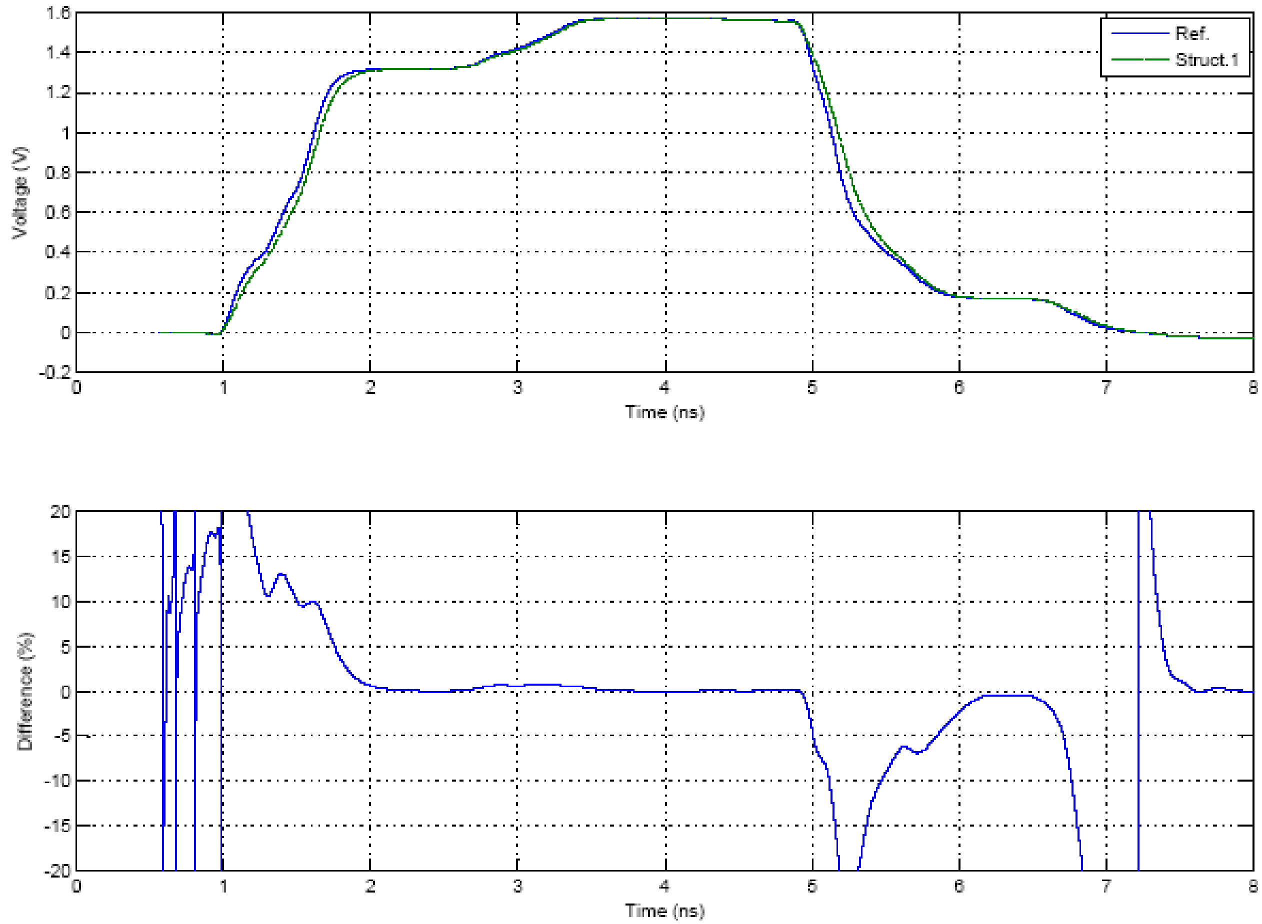


Figure 6: Driver voltage comparison of the configurations Fig.4 a) and b)

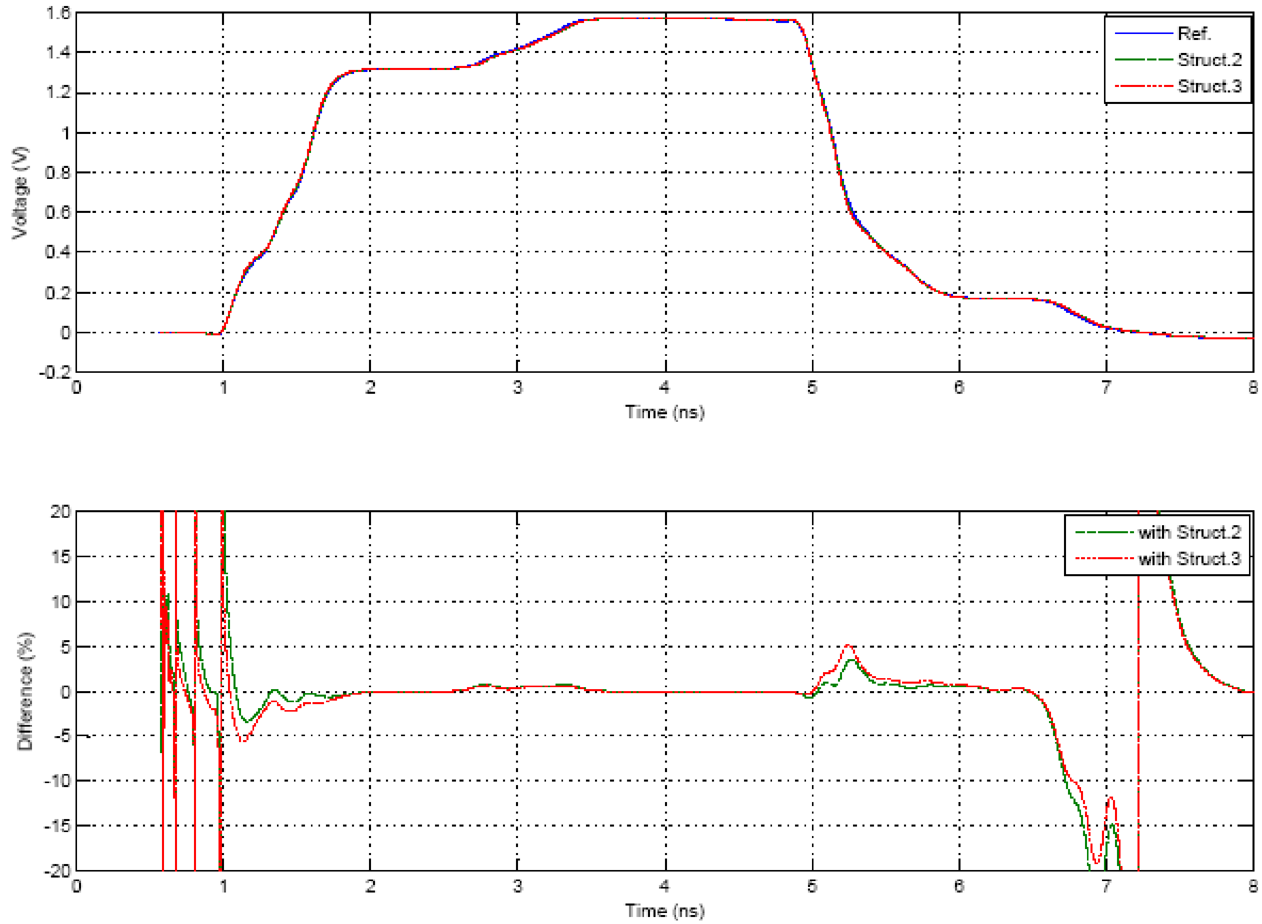


Figure 7: Driver voltage comparison of the configurations Fig.4 a) and c), d)

REFERENCES

[1] J. Paul, C. Christopoulos, D.W.P. Thomas, “Generalized material models in TLM-Part I: materials with frequency-dependent properties”, IEEE trans. on AP, vol. 47, no 10, pp 1528-1534, October 1999.