Application note

Power line models for dummies

Version: 1.0.0
Last update: 2019-02-21
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Opal-RT Technologies

Contents

Document revision history

v 1.0	First version	Feb 20, 2019

1. Executive summary

This document objective is to explain the various line models that exists in ARTEMiS: pi-line, Bergeron line with losses (Constant parameter line in EMTP-RV), Modal-Frequency-Dependent line (Marti-type) and Wideband line model (Phase-domain frequency-dependent line or Universal Line models).

The ARTEMiS toolbox has been upgraded in 2019 with a new Wideband line model (v2.0) that is simpler to use and this application note will explain this also. The wideband line/cable fitter that comes included with ARTEMiS will also be explained and compared with EMTP-RV.

2. Line models

Many line models exists in SPS, ARTEMiS-SSN, EMTP-RV and Hypersim. They are:

1- pi-line

2- Bergeron line with losses (Constant parameter or CP-line in EMTP-RV)

3- Modal-Frequency-Dependent line (Marti-type)

4- Wideband line model (Phase-domain frequency-dependent line or Universal Line models).

TABLE 1: Line model and their main characteristics

Line type	Accuracy	Computational load	Preferred applications	notes
π line	medium	Low- medium	General 50-60 Hz simulation, transients	Cannot be used to split a system into several part by virtue of traveling wave delays SPS pi-line model cannot model unbalanced lines
Bergeron with losses (Constant Parameters CP line)	good	low	Transient simulation	Traveling-wave method
Frequency Dependant (Marti-type)	Very good	Medium	High-accuracy transients simulation (overhead lines, balanced and lightly unbalanced)	Not available in SPS
Frequency dependant (Phase-domain / WideBand type)	Excellent	High	High-accuracy transients simulation especially cable and unbalanced lines	Not available in SPS

2.1 Bergeron and pi-line

Pi-line models is an RLC approximation of the line that is exact only at the specified frequency, typically the power frequency. A line can be modeled by several pi-section in series, which help to emulate some traveling wave effects.

Bergeron line with losses or Constant parameter line (also named Distributed Parameter Line or DPL) model uses the traveling wave method to model transmission line. The model is characterized by an ideal transfer function of traveling wave to which resistive losses are added.

Model advantages: can mimic the traveling wave effects, for example during faults. Can be used as a decoupling element in parallel simulations on multi-core simulator such as eMEGAsim and Hypersim.

Model disadvantages: Surge impedance and traveling wave function are only valid at one frequency. Typically, high-frequency damping is neglected in this model.

2.1.1 Unbalanced pi-lines

The native SPS pi-line model cannot model unbalanced pi lines, a useful model in distribution grids. ARTEMiS now provides such a model, available in ARTEMiS/Tools/Custom Models.

2.2 Frequency-Dependant Modal Line model (Marti-type)

This model, also called simply FD-line, improves the frequency response of DPL by correctly fitting the surge impedance and traveling wave functions in the model domain. This model is fully accurate in balanced line systems and very good with lightly unbalanced systems. It is however inaccurate in the case of unbalanced lines and cables. The reason for this is that the FD-line model used a constant modal transformation matrix, evaluated at a fixed frequency, an inaccurate assumption for cables and unbalanced lines.

Cable are always unbalanced, the capacitance to ground from inner wire and outer wire cannot be equal. FD-line should not be used to simulate cables.

2.3 Wideband line/cable model

The line/cable wideband model, also called the Universal Line Model or ULM, is a fully accurate line and cable model in which all surge impedance and traveling wave functions are modeled into the phase domain directly. It is highly recommended for transients studies involving cables.

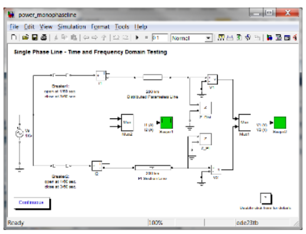
Model advantages: Most accurate model for lines and cables. Can be used as a decoupling element in parallel simulations on multi-core simulator such as eMEGAsim and Hypersim.

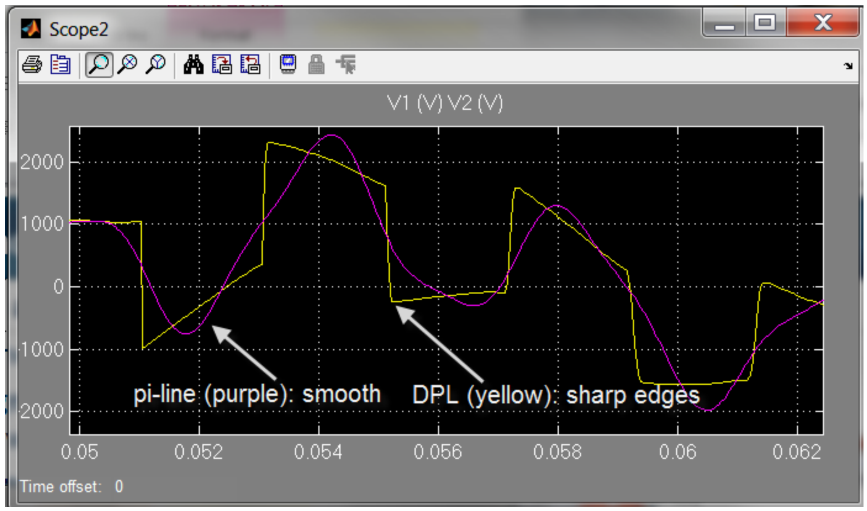
Model disadvantages: The model is slower than all other model due to its complexity. Surge impedance and traveling wave function must be approximated by rational functions with 'fitter'. This fitting process can be tricky sometimes and fitters are continuously been improved for this reasons.

3. Some comparisons

3.1 Pi-line vs. Bergeron line

The SPS demo >>power_monophaseline can be used ot view the differences between Pi-lline and CP-line. On the figure below, one can observe the traveling wave edges caused by the fault in the CP-line (Bergeron line). The pi-line also mimics this effect but with much less accuracy.

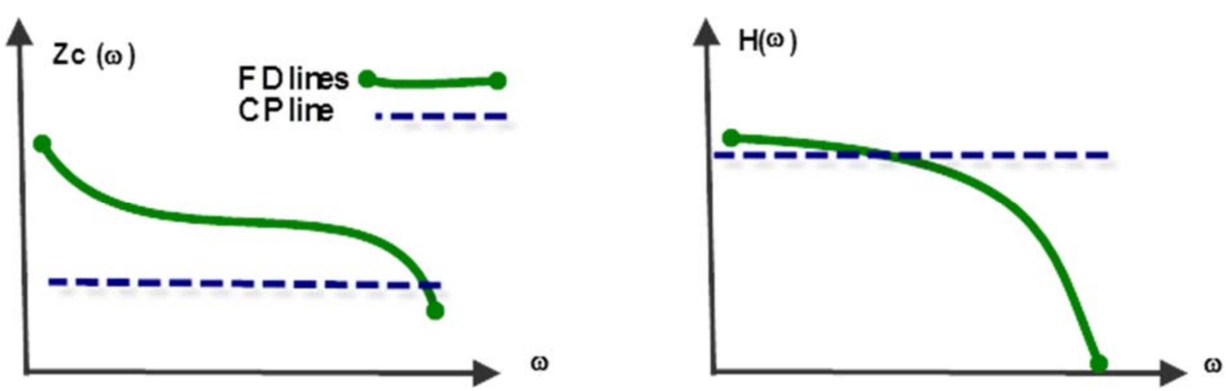




3.2 Frequency-dependence effects

- FD-line model (modal and phase type) Include wire skin effect and ground return frequency dependence.
- Typically Bergeron-line model will not damp enough high-frequency components
- FD-line (Marti): functions computed in the modal domain.
- ULM (WideBand): functions computed in the phase domain directly.

The following figure shows the differences between FD and non-FD line models in terms of their surge impedance Zc and their traveling wave function H.



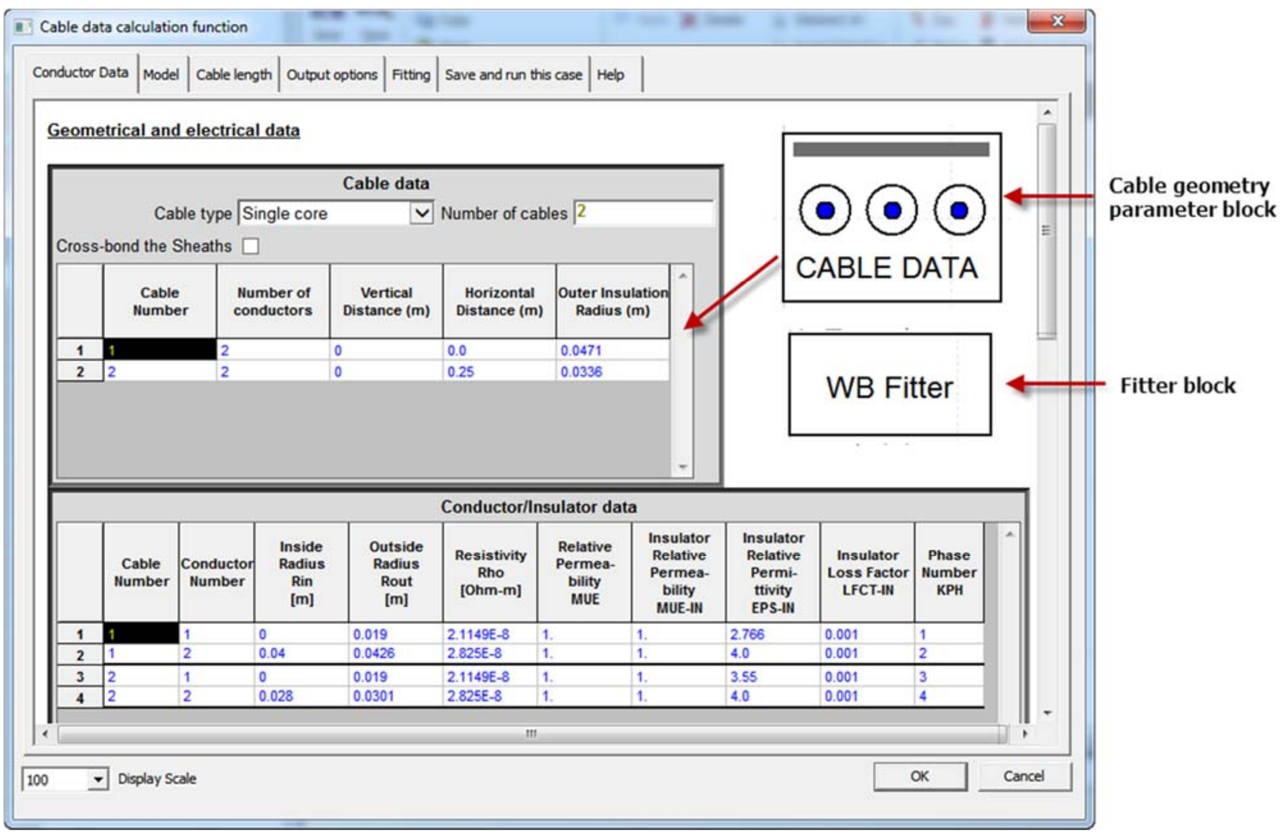
4. Wideband line fitters

To use wideband line models into a simulation, one must first use a fitter tool to build the tabulated values of the line or cable impedance and admittance (RLCG matrices) into Laplace domain rational functions with similar responses. These Laplace domain approximation are then discretized by the circuit solver to compute the line responses in the time domain.

Fitters are functionally similar from one simulation package to another: the user inputs the line or cable geometry and the fitter compute the RLCG matrices for a certain frequency range and then compute the poles and zeros of the Laplace function.

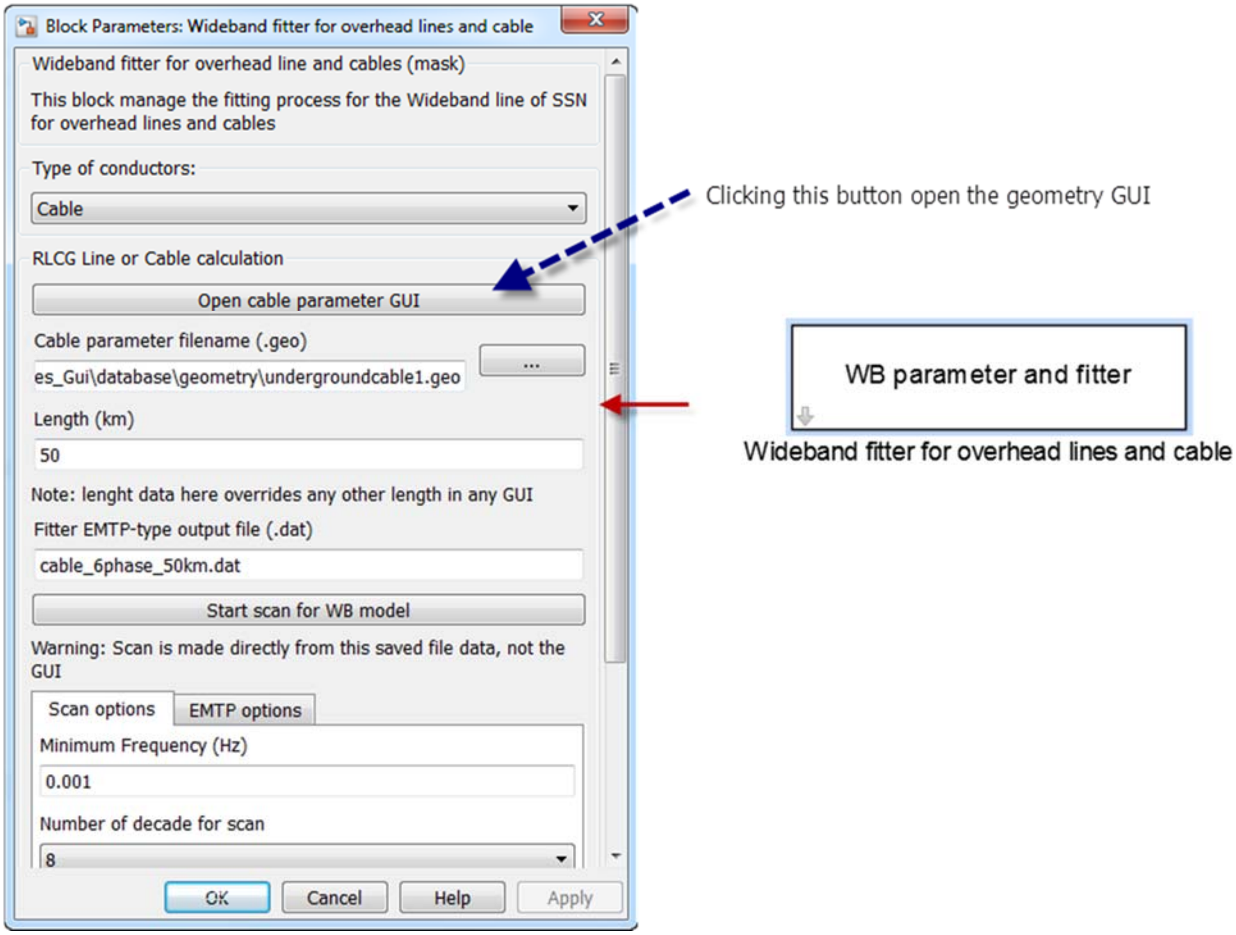
4.1 EMTP-RV wideband fitter

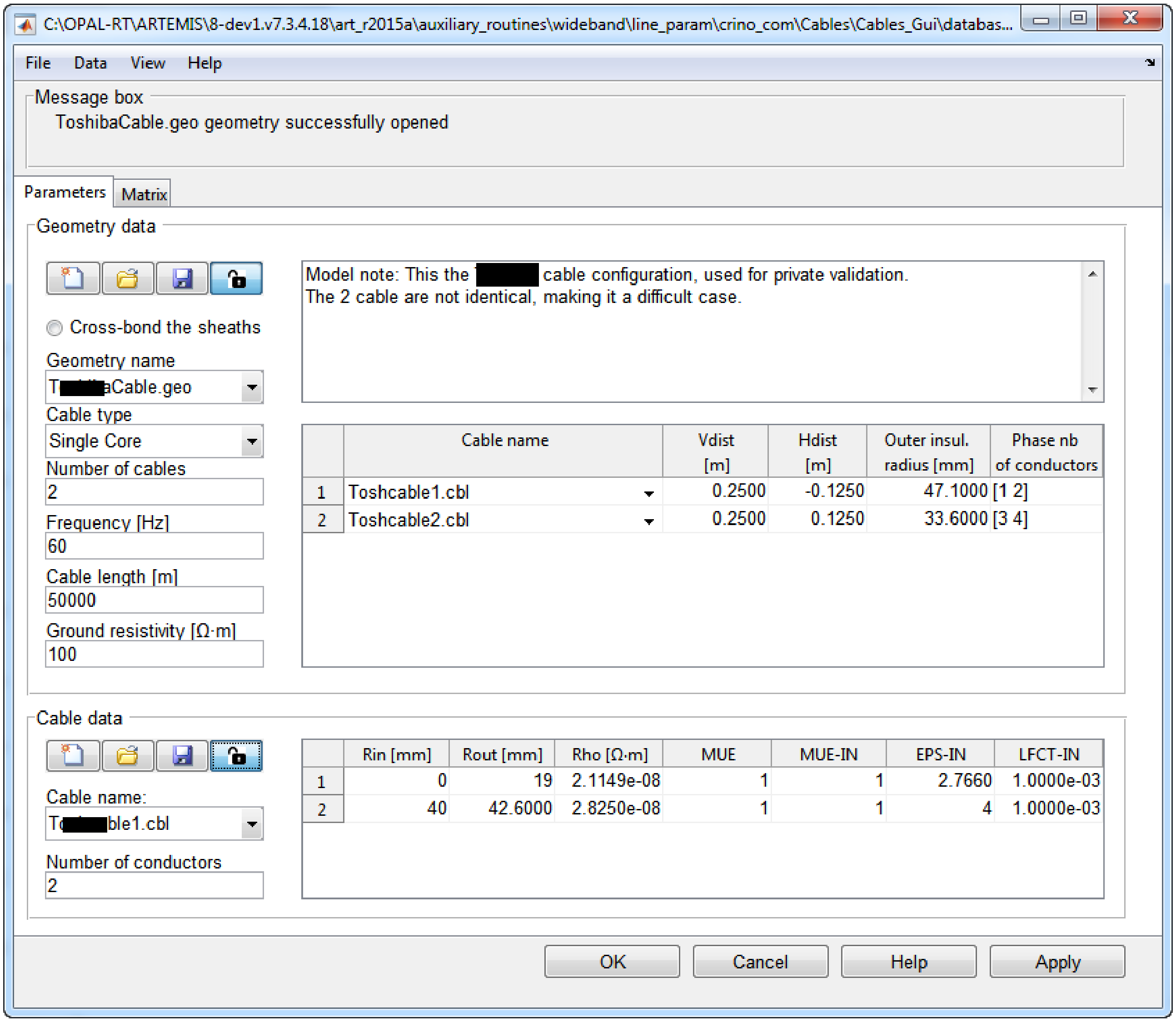
Due to the expertise of its author, the EMTP-RV line/cable fitter is reputed to be the most accurate fitter in all software package in existence.



The 'WB fitter' block produces the poles/zeros .dat file use by the ARTEMiS-SSN Wideband Line model (v2.0).

4.2 eMEGAsim wideband fitter

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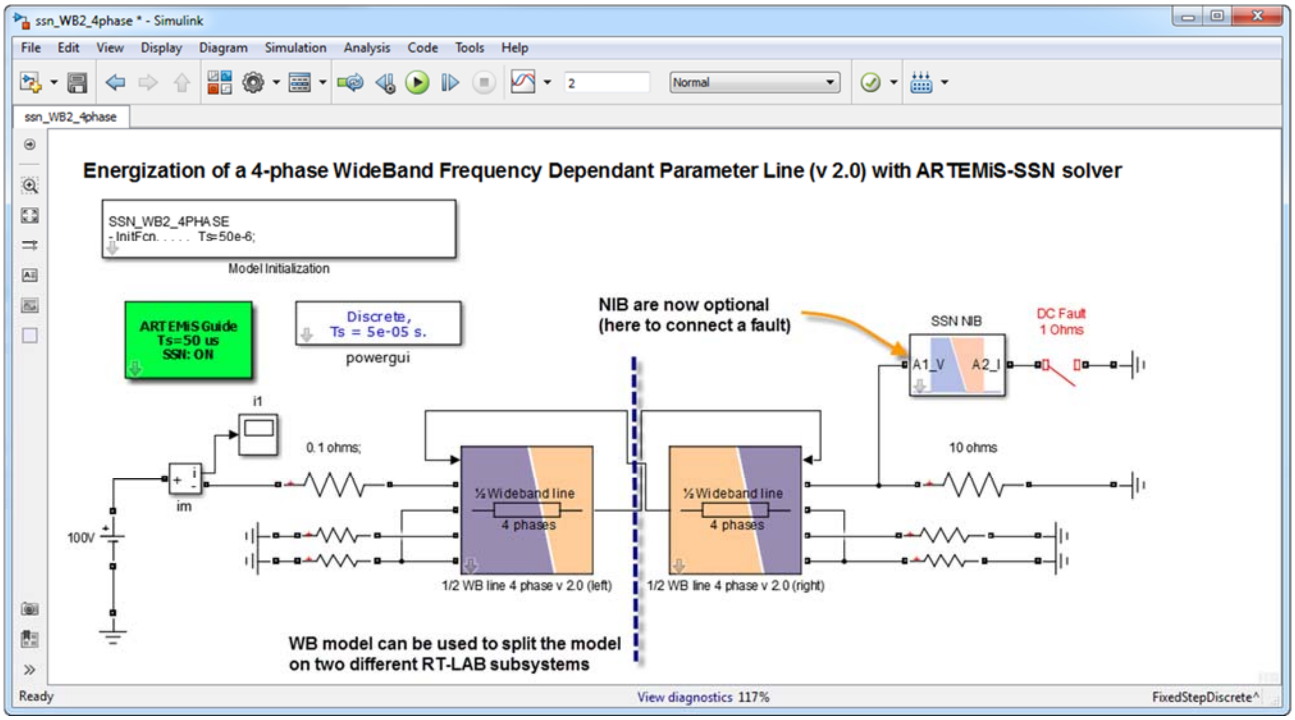
File Data View Help
Message box
ToshibaCable.geo geometry successfully opened
Parameters Matrix
Geometry data
Model note: This the [redacted] cable configuration, used for private validation.
The 2 cable are not identical, making it a difficult case.
Cross-bond the sheaths
Geometry name
T[redacted]aCable.geo
Cable type
Single Core
Number of cables
2
Frequency [Hz]
60
Cable length [m]
50000
Ground resistivity [Ω·m]
100
Cable name | Vdist [m] | Hdist [m] | Outer insul. radius [mm] | Phase nb of conductors
1 Toshcable1.cbl 0.2500 -0.1250 47.1000 [1 2]
2 Toshcable2.cbl 0.2500 0.1250 33.6000 [3 4]
Cable data
Cable name:
T[redacted]ble1.cbl
Number of conductors
2
Rin [mm] | Rout [mm] | Rho [Ω·m] | MUE | MUE-IN | EPS-IN | LFCT-IN
1 0 19 2.1149e-08 1 1 2.7660 1.0000e-03
2 40 42.6000 2.8250e-08 1 1 4 1.0000e-03
OK Cancel Help Apply

5. The new Wideband line model (v2.0) in ARTEMiS

Since early 2019, a new model of the wideband line has been released in ARTEMiS, dubbed v2.0.



New wideband model features:

1- No need to use X-type NIB to connect the Wideband v2.0 model. SSN is still required and NIB can be used to connect loads for example.

2- Simple mask: only the Wideband .dat fitter file is required now to run the model.

3- Explicit model for task separation: the model comes has two half-line that can be placed into 2 different RT-LAB subsystems to take advantage of tasks separation induced by the delays of the wideband model.

6. References

[1] C. Dufour, J. Mahseredjian , J. Bélanger, “A Combined State-Space Nodal Method for the Simulation of Power System Transients”, IEEE Transactions on Power Delivery, Vol. 26, no. 2, April 2011 (ISSN 0885-8977), pp. 928-935

[2] Atef Morched, Bjrn Gustavsen, Manoocher. Tartibi, “A universal model for accurate calculation of electro-magnetic transients on overhead lines and underground cables”, IEEE Trans. on Power Delivery, Vol. 14, No. 3, pp. 1032-1038, July 1999.

Appendix: FD-line (Marti-type) fitter

Note that the FD-line also makes uses of fitters to compute rational functions, in the modal domain this time. More information on the use of the FD-line model and fitter can be found in the document entitled: Obtaining_FDline_model_parameters_from_EMTP_RV.pdf located in

$\ARTEMIS\version\art_r2015a\auxiliary_routines\marti_fd_line\line_param

Important note: since ARTEMiS 7.3.6, a new SSN Marti-type FD-line model is available. Similarly to the new Wideband model v 2.0, this new model simplifies the parameter extraction phase and only requires the EMTP .pun fitting file as input parameter. The new model also do not require to be interfaced with X-type NIB (SSN nodes). The demo named *ssn_Marti2_3ph* is available in the MATLAB path (R2015a+).