Frequency dependent line: FD m-phase

1 Theoretical background

This model is more accurate than the Constant Parameters (CP) line model. It is however computationally slower. Unlike the CP-line model the Frequency Dependent (FD) line model takes into account the frequency dependence of R' and L' (series resistance and inductance of the line per unit length).

This model is also based on modal decomposition techniques. The modal transformation $\mathbf{T_i}$ (also denoted by $\mathbf{Q}$) used to relate modal and phase quantities, is assumed to be constant and real. The model represents frequency dependence by approximating with rational functions the characteristic impedance Z_c and the propagation function $A = e^{-\gamma \ell}$ for each mode. The details of the model can be found in [1]. The theoretical background on the distributed parameter line model can be found in the Help section of the "CP m-phase" device.

2 Available versions

There is only a multiphase version of this device. It is not allowed to change phases. Some options in the Drawing tab of this device can result in broken connections that the user might need to repair manually. It is assumed that such options are selected before making final connections to the line. The Drawing tab allows using 3-phase pins when the device has 3 phases.

3 Parameters

The data for this device can be obtained from the "Line Data" device in the lines.clf library. Related details are available in the Help section of the "Line Data" device. An example of usage is given in Line_Data\LTC5A.ecf under the EMTPWorks directory Examples.

The **Number of phases** allows selecting the number of wires for this device. This number must be equal to the one found from the model data files specified below. If the model data files are generated by the "Line Data" device then the number of phases will be set automatically after clicking OK.

The section **Time-domain model data from Line Data** is for naming the model file used in the time-domain computations.

The **Frequency-domain model data from Line Data** allows specifying separate models for the frequency domain computations in steady-state or frequency scan options of EMTP. The first option "Use model in steady-state solution (Exact-PI model)" allows selecting the Exact-PI circuit file for the steady-state-only solution. If not checked, EMTP will use the time-domain model data for calculating the steady-state solution. If the steady-state solution is followed by a time-domain solution, EMTP will automatically revert to the time-model file for performing steady-state initialization.

The second option "Use this model in frequency scan solution (Exact-PI model)" allows requesting the Exact-PI model data file for the frequency scan solution. If not checked, EMTP will use the time-domain model data for finding the line frequency scan model.

The Exact-PI option allows calculating the pi-section model of the line with representation of frequency variation in line parameters. There are no approximations, since the pi-section is available for each frequency of the selected range.

Since this device needs data files to work, it provides an option for managing the locations of the data files: **Save data file names using relative path**. This option allows EMTP to use a relative path for the selected data files. It works only for files located in the same directory as the design or in a directory below the design file. Using relative path simplifies the maintenance of designs with model data files. It also simplifies the task of using this design on other computers.

3.1 Generic rules

The model data file format must the one given in the "Line Data" device. There is no extra testing for wrong data or numerically unstable cases.

It is not allowed to delete any pins or change pin attributes. The drawing of "FD m-phase" is continuously updated according to the selected number of wires and selected options in the "Drawing" tab.

4 Netlist format
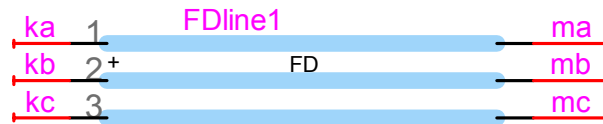
The Netlist format example show below is given for the 3-phase FD-line shown above.

```
_FD;FDline1;6;6;ka,kb,kc,ma,mb,mc,
3,1,0,1,1,
LTC5A_rv.pun,
LTC5Api_rv.pun,
0
0
0
```

Field	Description
_FD	Part name
FDline1	Instance name, any name.
6	Total number of pins
6	Number of pins given in this data section
ka,kb,kc	Signal names connected to k-pins, any names, as many as wires
ma.mb,mc	Signal names connected to m-pins, any names, as many as wires
3	Number of phases
1	Use Exact-PI file for steady state-study: -1 for no, 1 for yes
0	Use Exact-PI file for frequency scan study: 0 for no, 1 for yes
1	Use relative path when 1
1	Units for trapped charge value
LTC5A_rv.pun	Name for the model data file for time-domain study, any name.
LTC5Api_rv.pun	Name for the Exact-PI data file for frequency scan or steady state study, any name.
Trapped charge	Trapped charge as many lines as wires

Comma separated data is saved into the ParamsA attributes. The rest of the data is saved into the ModelData attribute.

5 Steady-state model

The steady-state solution can be calculated from the time-domain data or from the Exact-PI circuits. The time-domain model data file is the one used for initialization.
The user can also request a steady-state only solution and use the Exact-PI model. The needed design steady-state frequencies must be available in the generated Exact-PI model file.

6 Initial conditions

Automatic initial conditions are found from the harmonic steady-state solution. The line is initialized for quickly achieving steady-state conditions in time-domain at simulation startup.

The user can enter manual initial conditions for each wire. This represents trapped charge on the line. If the line is energized in steady-state then the user should not also provide trapped charge data.

7 Frequency Scan model

The frequency scan model is the same as the steady-state model. The ultimate precision is obtained using the Exact-PI model data file. In this case the frequency range chosen in the "Simulation Options" (for the frequency scan range) must be in accordance with the frequency of the Exact-PI data file generated by "Line Data". An error message will stop the program if a frequency range mismatch occurs.

8 Time-domain model

The time-domain representation is explained in [1]. Rules similar to the CP-line model are enforced.

9 References

[1] J. Marti: "Accurate Modeling of Frequency Dependent Transmission Lines in Electromagnetic Transient Simulations", IEEE Trans. On Power Apparatus and Systems, vol PAS-101, pp 147-157, 1982.