Cable Assembly Modeling and Simulation

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Components

- Connectors
  - Usually represented as LC networks
    - Translates easily to SPICE simulators
    - May be laborious to extract
    - Number of segments depends on edge rates
- Cables
  - Models vary by simulation tool
  - Realistic simulation needs frequency dependent characteristics
  - May be difficult to get into SPICE simulators
- Transitions
  - Similar to connector models

Connectors

- Extraction techniques
  - Field solvers
    - Use geometry and material properties
    - 2D - cross sectional representation
    - 3D - full 3D structures
  - TDR data extraction (Z-profile)
    - Easier for single lines(unbalanced)
    - Multiple lines more difficult, but needed for
      - Differential signal paths
      - Crosstalk simulations
      - See e.g. TDA Systems (tdasystems.com)

Cables

- Need RLGC as functions of frequency
- Field solvers a possibility
  - But cables are often made to performance, not geometry
- Time and/or Frequency domain data yield per-unit-length parameters
- Good grasp of MTL theory needed for differential or multi-conductor cables

Cable LRCG (per unit length) Parameters from Data

- TDR/TDT
  - Characterizes impedance, Time delay, etc.
  - Perhaps easiest path to L and C
- Vector Network Analyzer
  - Characterizes attenuation, other parameters as well
  - Perhaps easiest path to R and G

RLCG Example

A shielded differential pair

* Lo - Inductance matrix (H/meter)
2.40147e-7 3.93137e-8
3.93137e-8 2.40147e-7

* Co - Capacitance matrix (F/meter)
7.012e-11 -1.0213e-11
-1.0213e-11 7.012e-11

* Go - DC Conductance matrix
0.00000 0.00000
0.00000 0.00000

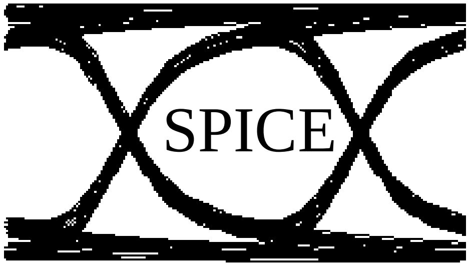
* Ro - DC Resistance matrix (ohm/meter)
0.32115 0.183
0.183 0.32115

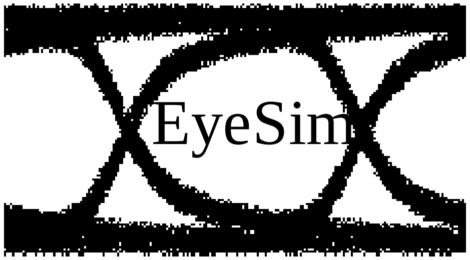
* Rs AC - Resistance matrix
1.05009e-3 7.9815e-4
7.9815e-4 1.05009e-3

* Gd AC - Conductance matrix
1.17765e-12 -9.66858e-13
-9.66858e-13 1.17765e-12

Cables and Simulators

- HSPICE
  - w-element models (need RLGC matrices)
  - Non-standard cables are a problem
    - Use Pole/zero or other forms
- PSPICE and others
  - "Laplace" forms
- HP's MDS and others
  - S-parameter file input
- Pole/zero representation may be available in some simulators
  - Pole/zero fitting is a challenge
- IBIS ???
- EyeSim





Differential Interconnects

- MTL theory provides separation of even and odd modes
- Each mode should be analyzed separately
  - Impedance
  - Time delay
  - Attenuation
- Model
  - Separates modes
  - Represents transfer function
  - Recombines modes
  - Represents impedance, time delay and attenuation

Model Validation

- Connectors and Transitions (use realistic edges)
  - Impedance profile in TDR simulation
  - Crosstalk
- Cables (use realistic edges)
  - Impedance and time delay for differential and common mode signals
  - Attenuation in AC sweep and CW loss
  - Edge degradation for transmitted step
  - Crosstalk where applicable
  - Eye pattern effects with realistic patterns and edges
- Assemblies (use realistic edges and bit patterns)
  - Combine all of the above into a full link simulation

Simulation Suggestions

- Use representative patterns
- Use realistic edges (PWL)
- Get the impedances correct for sources and loads
- Get impedances, time delays, & attenuation correct for all longer transmission line segments of the link (board traces & cables)

Summary - Link Modeling and Simulation

- Connector and Transition models
  - Theory is simpler
  - Relatively higher effort to extract
  - Relatively generic in format
- Cable models
  - Theory is more challenging
  - Relatively lower effort to extract base parameters
  - Format is simulator specific
- Simulation
  - Impedance, time delays and attenuation are all important