GND Modelling of MTCA.4 Crates

Dr. Heinz Hartmut Ibowski
Rudi Ganss

3rd MTCA Workshop for Industry and Research
Hamburg, 8-11 December 2014

b1 Engineering Solutions: Markets and Solutions

Automotive

Industrial

Medical

Embedded Electronics and Software

Human-Machine-Interfaces

M2M/Internet-of-Things & High-Speed-Connectivity

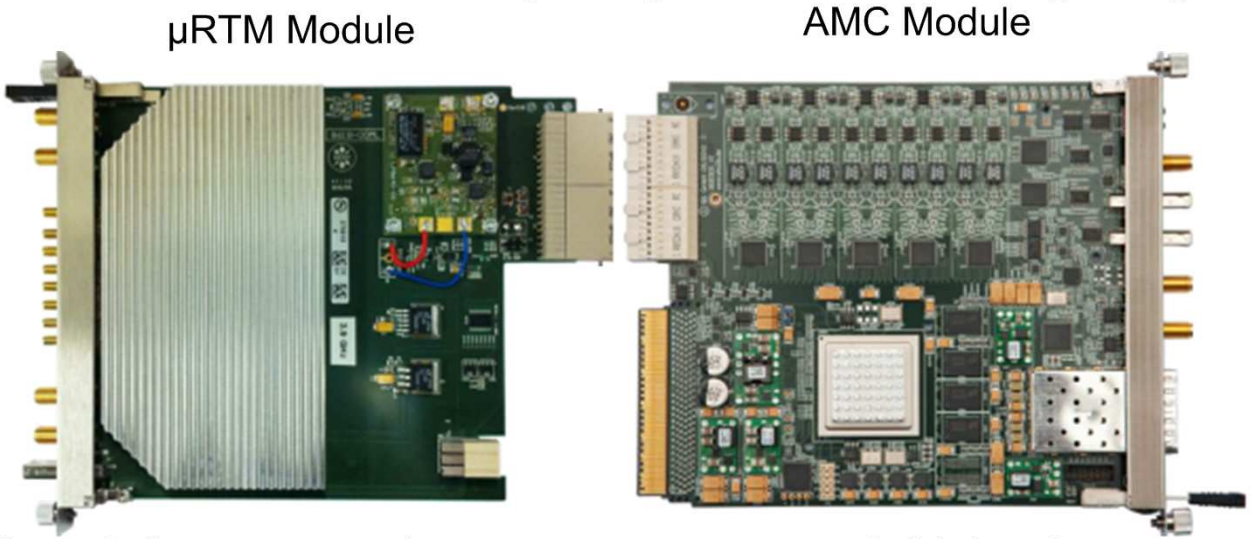
Functional Safety

Concepts & Innovations → **Design, Development, Test & Documentation** → **Lifecycle Services**

Introduction

MTCA.4 →

- Enhanced rear I/O and precision timing possibilities
- Sensitive analogue signals and aggressive digital signals
- Open MTCA architecture
- Unpredictable additional noise impacting the sensitive analogue signals



- Radiation of electromagnetic energy → higher frequency range only
- Conductive EMC (galvanic, capacitive or inductive) → DC to all frequencies

→ Conductive Coupling via GND-System

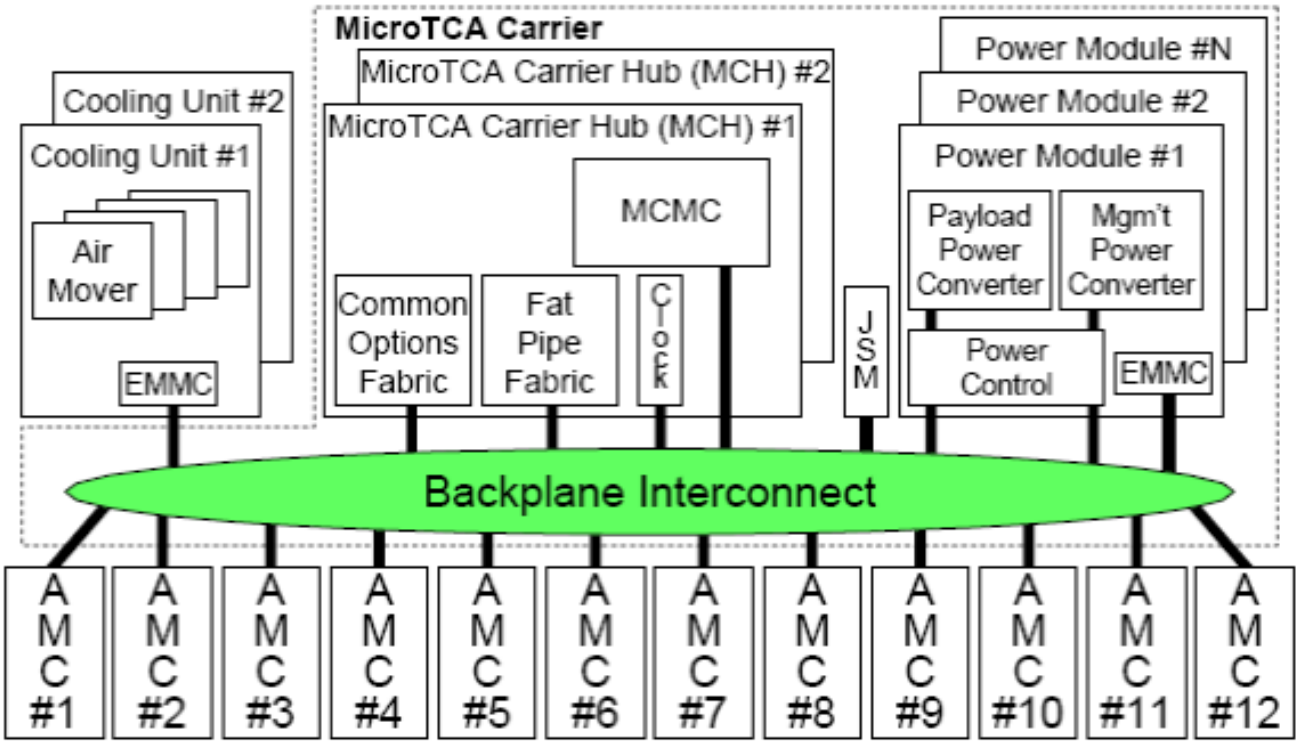
image credit: PICMG MTCA.4, Draft RC1.1, 18-Jul-11

Concept

- Modelling of the GND system by means of equivalent circuits.
  A qualitative analysis has to be performed looking at signal/coupling paths and the power supply system identifying the critical current loops.
- Definition of sensitivity classes giving limits on emission and immunity for all coupling paths.
  - Evaluate the model parameters, e.g. the impedances of the equivalent circuits
  - Quantify the susceptibility of components (signals, power supply, ..)
  - Calculate the effectiveness of shielding/filtering/distance on noise attenuation
  - Define the allowed noise levels
- In order to quantify the parameters it may be necessary to use:
  - Measurements, e.g. currents, common mode voltages, near fields
    It may be necessary to design a test board for measuring certain parameters
  - Simulation, e.g. current densities on board/in system, near field interference
- Developing methods for compliance checking

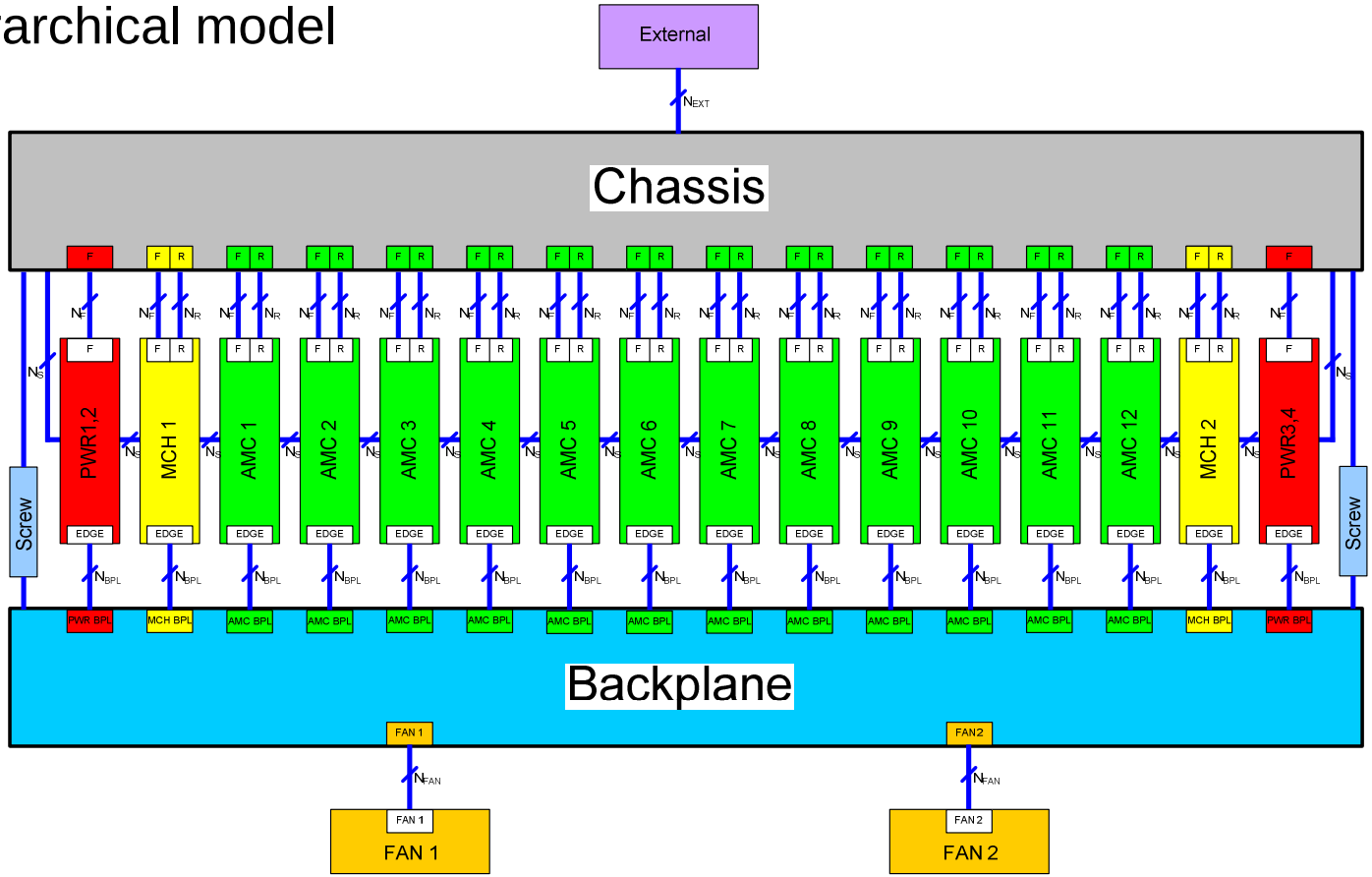
General EMC model for MTCA.4 Crates

- Maximum configuration of the components of a MTCA.4 crate as defined in MTCA Base Specification (PICMG, Rev 1.0, 6-Jul-06)



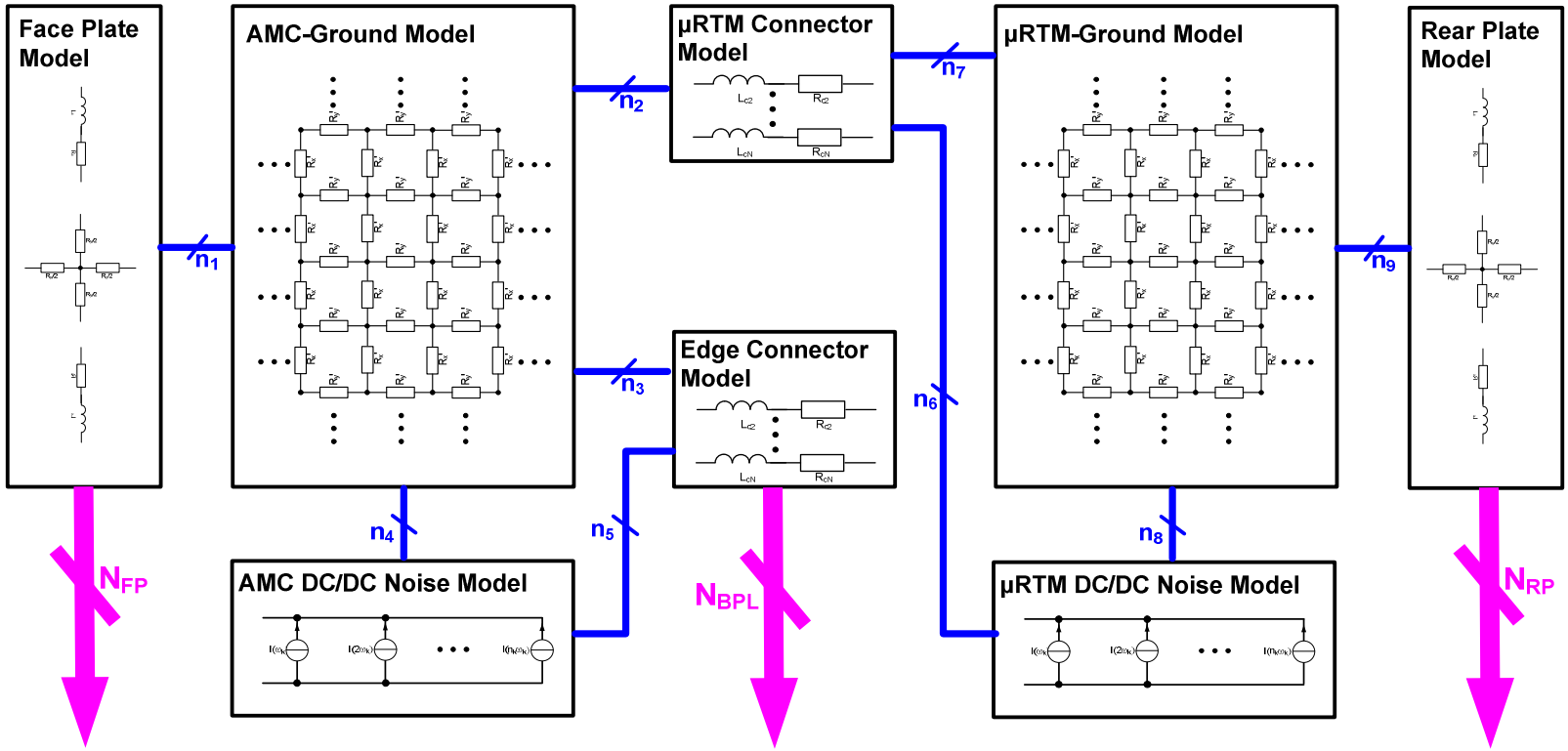
Schematic top level simulation sheet

- GND model, conductive coupling only
- DC-, AC- and time domain analysis → SPICE
- Hierarchical model



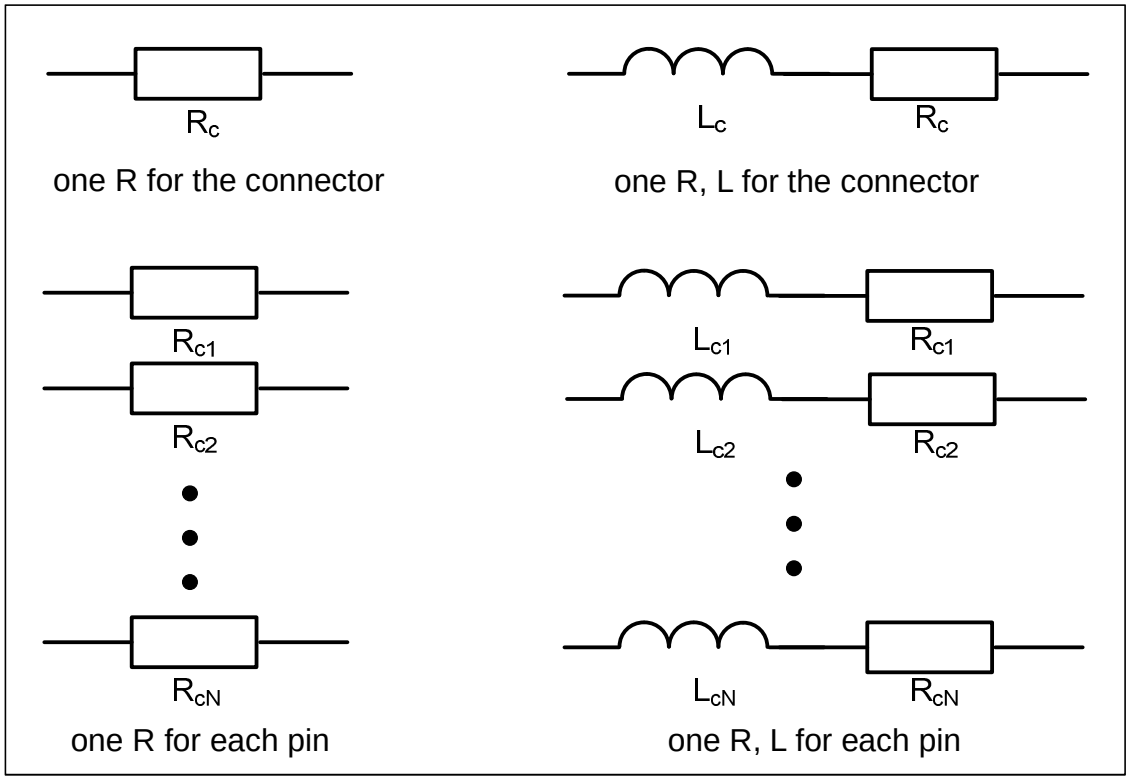
Second Level Block Diagrams

- Second level simulation model for AMC/MCH modules with RTM



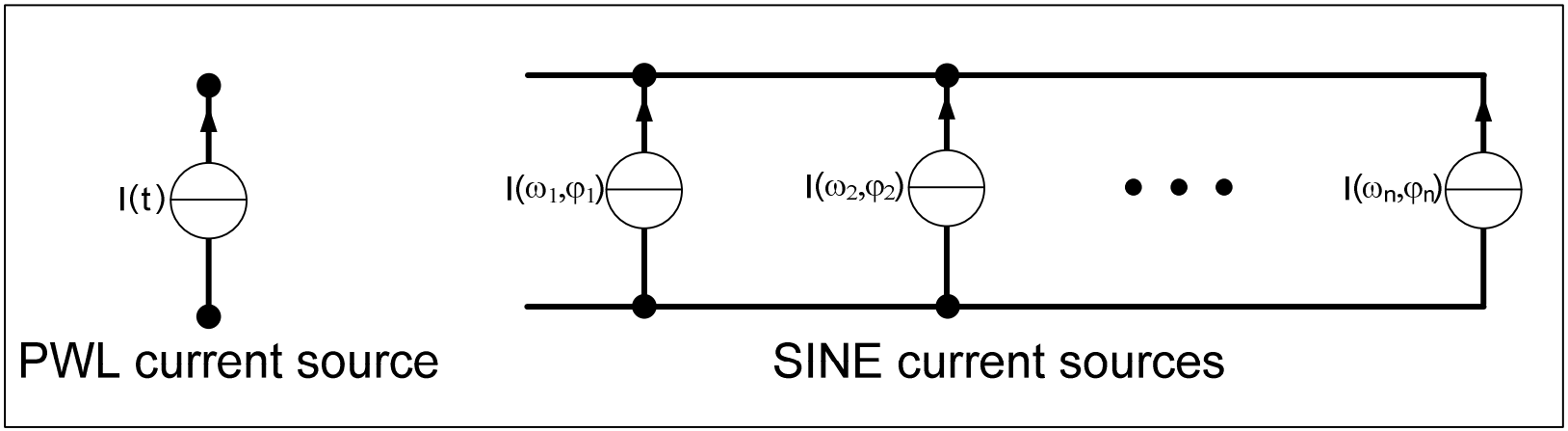
Model Topology of Connectors

- General model topology of connectors for the DC (and low AC frequency) analysis



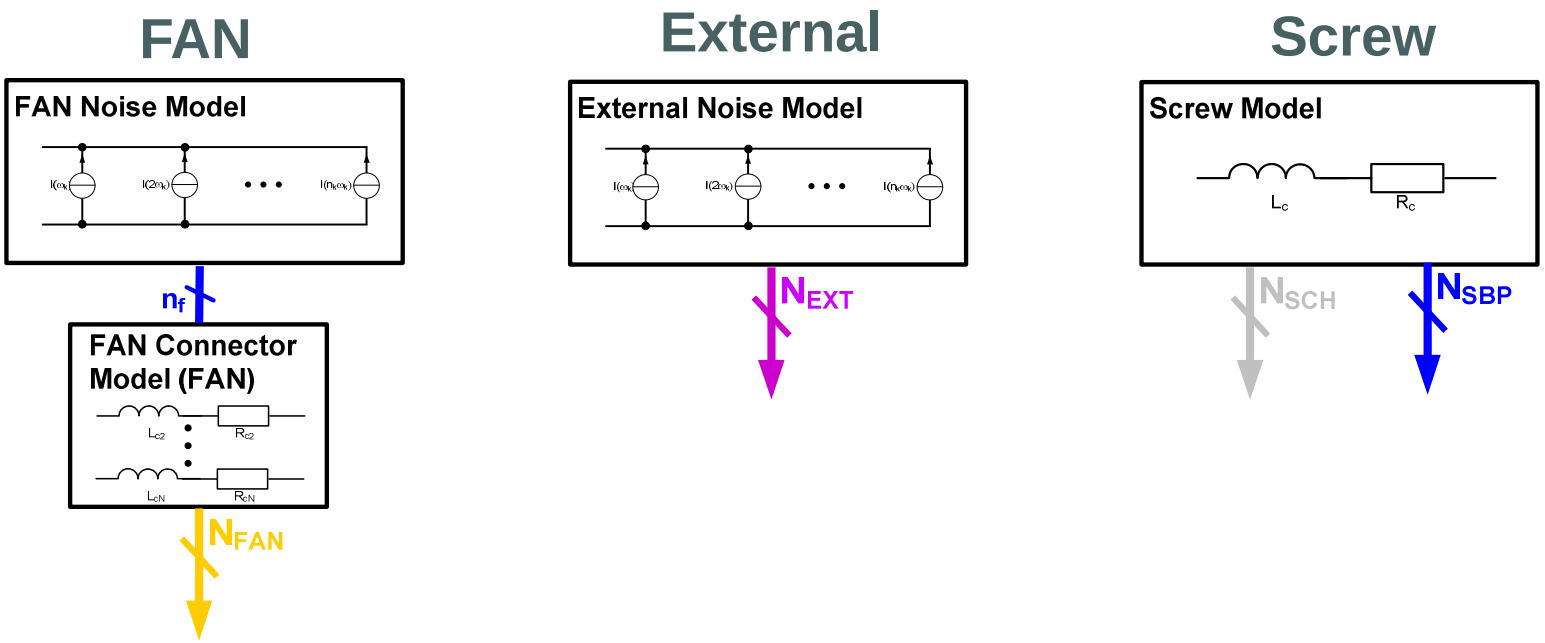
Model Topology of DC/DC Converter Noise

- Time domain model topologies of DC/DC noise for the DC (and low AC frequency) analysis.



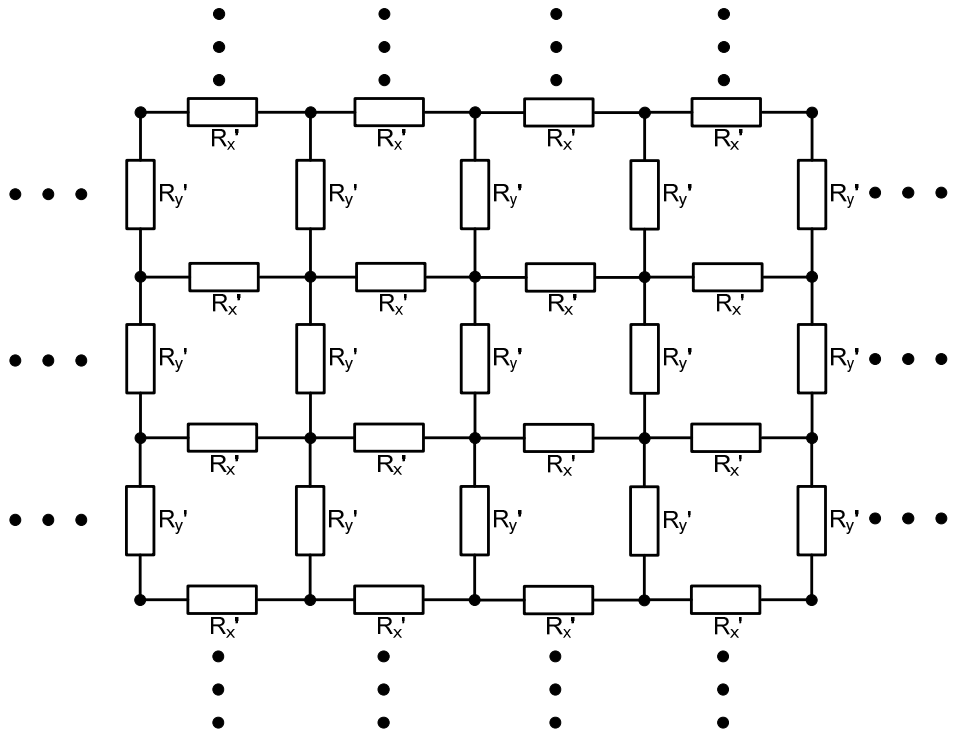
Model Topologies

- Time domain model topologies for the DC (and low AC frequency) analysisof cooling units, external noise and screws



Model Topology of GND Planes

- General model topology for the DC (and low AC frequency) analysis of GND planes



$$R_x' = \frac{\Delta x}{t\,\Delta y\,\kappa} \qquad R_y' = \frac{\Delta y}{t\,\Delta x\,\kappa}$$

Δx , Δy : geometrical discretisation in the x- and y-direction

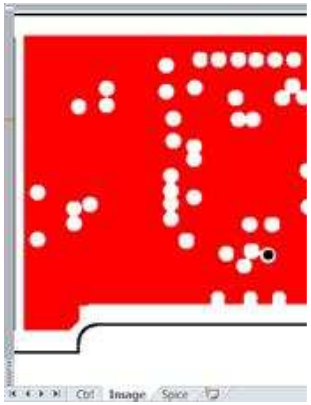
t : thickness of the plane metallisation

κ : conductivity

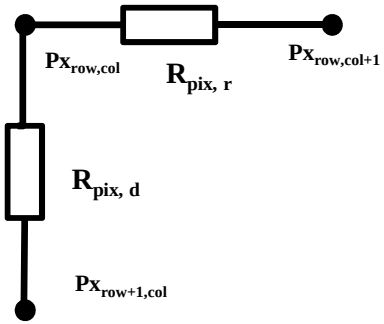
Simplified Model Topology of GND Planes

- Model Topology of GND Planes needed for chassis, backplane and AMC/RTM modules
- Simulation effort (CPU, memory as well as hours of work) strongly depends on complexity and accuracy of the simulation models
- Relation of increasing effort with increasing accuracy
- High accuracy model not always needed
- Black box model sufficient if behaviour at outer ports is sufficient

The High Accuracy Model of GND Planes



$$R_{pix,0} = \frac{1}{t\,k}$$

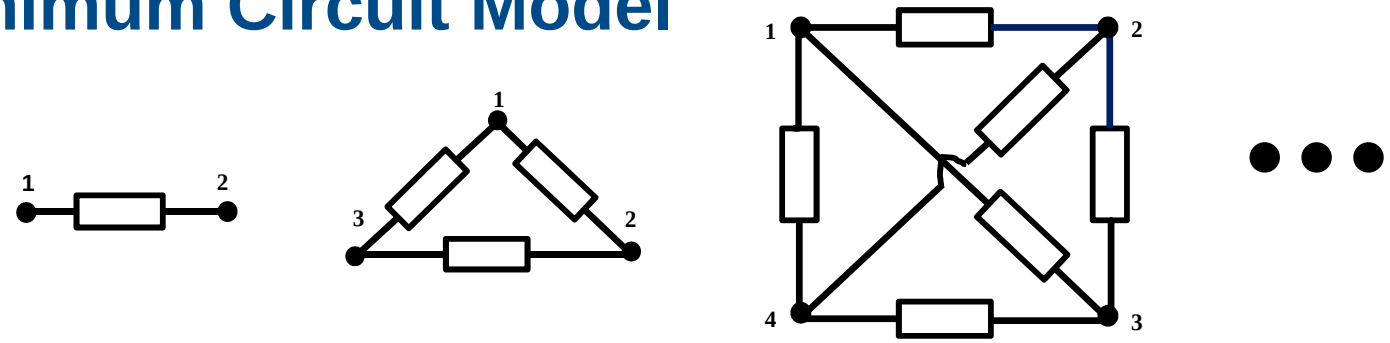


	1	2	3	4	5
944615	Rr_R405C1962	R405C1962	R405C1963	{RPIX}	
944616	Rr_R405C1963	R405C1963	R405C1964	{RPIX}	
944617	Rr_R405C1964	R405C1964	R405C1965	{RPIX}	
944618	Rr_R405C1965	R405C1965	R405C1966	{RPIX}	
944619	Rr_R405C1966	R405C1966	R405C1967	{RPIX}	
944620	Rr_R405C1967	R405C1967	R405C1968	{RPIX}	
944621	Rr_R405C1968	R405C1968	R405C1969	{RPIX}	
944622	Rr_R405C1969	R405C1969	R405C1970	{RPIX}	
944623	Rr_R405C1970	R405C1970	R405C1971	{RPIX}	
944624	Rr_R405C1971	R405C1971	R405C1972	{RPIX}	
944625	Rr_R405C1972	R405C1972	R405C1973	{RPIX}	
944626	Rr_R405C1973	R405C1973	R405C1974	{RPIX}	
944627	Rr_R405C1974	R405C1974	R405C1975	{RPIX}	
944628	Rr_R405C1975	R405C1975	R405C1976	{RPIX}	

\+ Model generation from layout data
\+ Implementation in Excel starting from a bitmap of the plane
\+ Accuracy depending only on the resolution of input data
\+ Detailed analysis of the GND plane possible

\- Large circuit files
\- For small design parts only

The Minimum Circuit Model



- Complexity dependant on number of outer ports ($n_R = N \cdot (N-1)/2$ branches)
- Extraction using numerical methods (implemented in Excel Sheet)

measured

i \ j	2	3	4	5	6	7	8
1	0.404797	0.476091	0.512579	0.467672			
2		0.375269	0.587029	0.560503			
3			0.759832	0.741301			
4				0.494941			
5							
6							
7							
8							
9							

$$\underline{G}^{(i+1)} = \underline{G}^{(i)} - \left[\underline{\underline{J}}\left(\underline{G}^{(i)}\right)\right]^{-1} \cdot \underline{g}\left(\underline{G}^{(i)}\right)$$

ModelParam

R_ij \ j	2	3					
	)78358	1.350236	1.523951	2.47931	0.677164	4.151137	3.774276
		0.584912	2.343853	8.777285	5.251531	1.816296	2.062471
			3712184	7.24E+08	6.31E+08	2.055622	4.085959
				1.034474	83980047	5.843641	1.634127
					0.890041	3.129852	1.326545
						1.81668	1.191275
							0.367362

\+ Model extraction from measurement and simulation

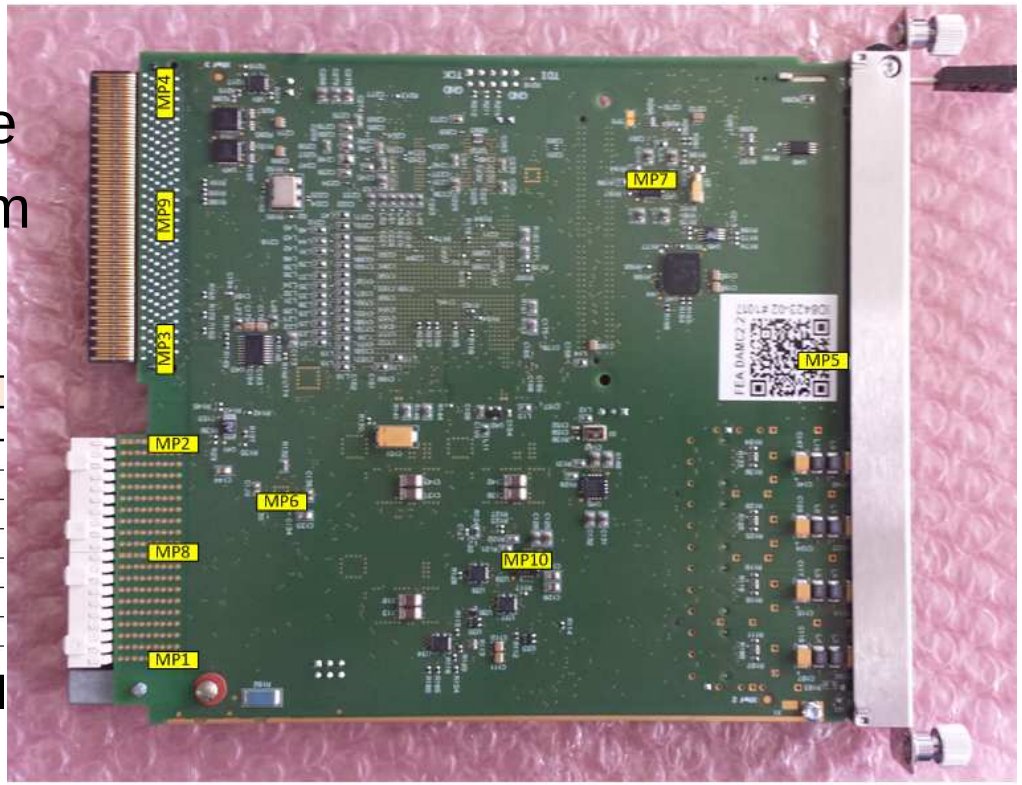
\+ Minimum effort

\- Black box model only

\- Numerical problems with large number of ports

Measuring DC Resistance

- Defining Measuring Points
- Four-terminal sensing
- Using pairs of adjacent vias to compensate via-resistance
- Measurement error <10µOhm



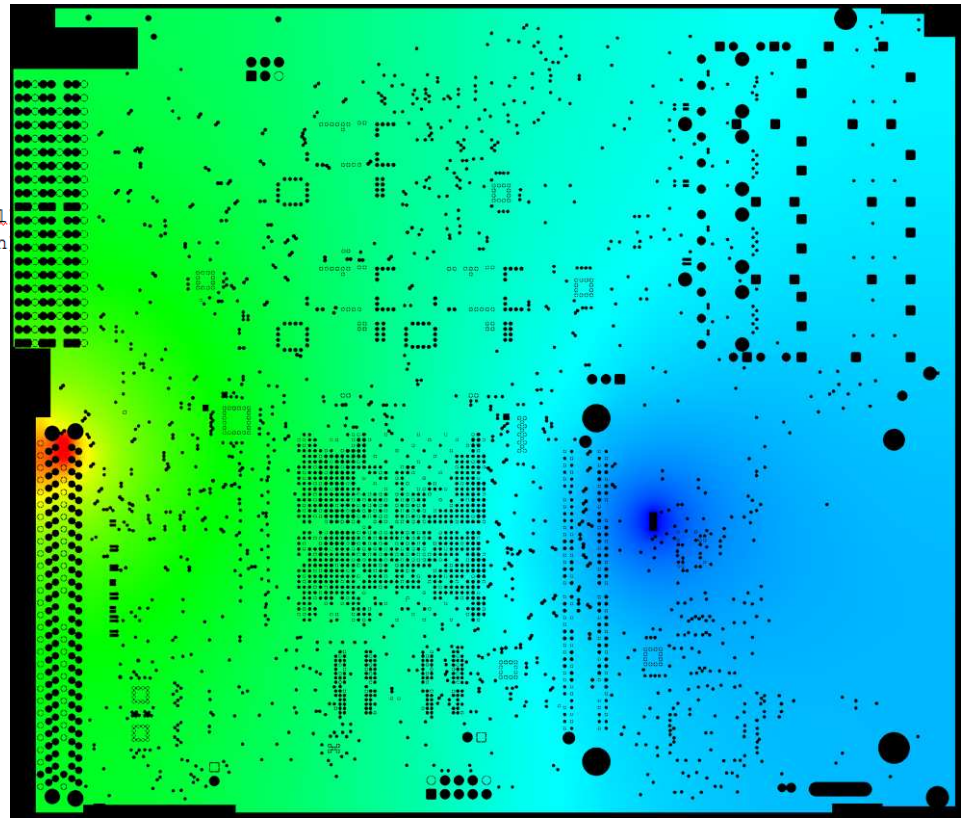
measured

i \ j	2	3	4	5	6	7	8
1	0.404797	0.476091	0.512579	0.467672	0.358212	0.445740	0.412607
2		0.375269	0.587029	0.560503	0.499891	0.449190	0.439881
3			0.759832	0.741301	0.686295	0.534697	0.528391
4				0.494941	0.61658	0.568762	0.498247
5					0.415345	0.482272	0.417805
6						0.431265	0.384799
7							0.249277
8							
9							

Simulating DC resistance

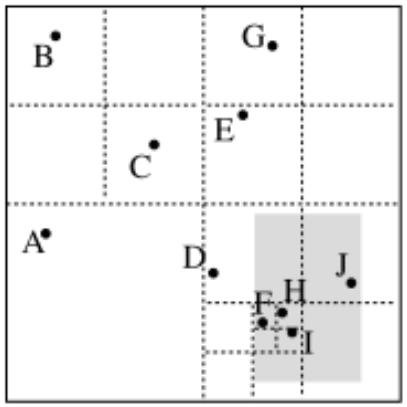
- IDC2D open source (see http://idc2d.sourceforge.net)
- Solves the finite difference representation of Laplace's equation
- One simulation per port pair
- Accuracy depending on resolution of bitmap
- Partially long simulation times

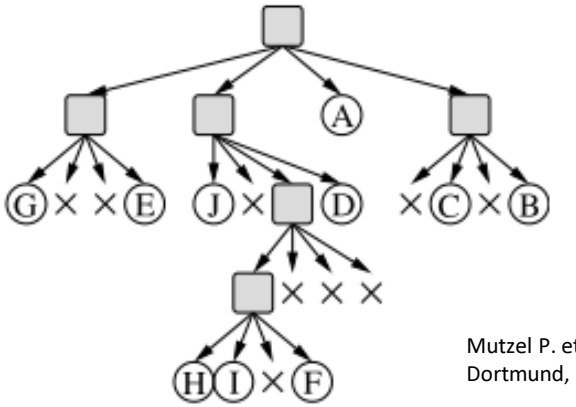
```
55  ------------------------------------
56  Number of threads: 4
57  Simulation parameters:
58    Max. iterations           = 10000
59    Cutoff                    = 1e-008
60    Pixel dimensions          = 56,45 x 56,45 um (2,22244 x 2,22244 mil
61    Image dimensions          = 174,6 x 149,31 mm (6,87401 x 5,87836 in
62    Layer thickness           = 34,0571 um (1,34083 mil)
63    Source voltage            = 0,1 V
64    Initial temperature       = 20 deg C
65    Material 1 conductivity   =    58,0046 MS/m   Copper Foil (Cu)
66    Material 2 conductivity   =    61,3497 MS/m   Silver (Ag)
67    Material 3 conductivity   =    59,0319 MS/m   Copper Pure (Cu)
68    Material 4 conductivity   =    7,93651 MS/m   Tin (Sn)
69    Material 1 conductance    = 1975,47 S/pixel
70    Material 2 conductance    = 2089,39 S/pixel
71    Material 3 conductance    = 2010,45 S/pixel
72    Material 4 conductance    = 270,294 S/pixel
73    Total iteration count     = 8124
74
75    Total supply current      =       75,48174  A
76    Effective DC resistance   =    0,001324824  Ohms
77    Maximal pixel current     =       3,107374  A
78    Minimum pixel current     =  1,690261e-008  A
79    Peak current density      =         1616,3  MA/m^2
80  Finished in 1470,884704 s
81  ------------------------------------
```



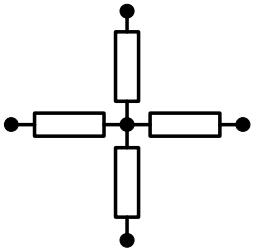
The Quadtree Model

- Adaptive discretisation of 2D planes
- Implemented in C-program starting with a bitmap format





Mutzel P. et al., 2006,, University of Dortmund, SS2006



R-Star

\+ Adjustable accuracy depending on maximum/minimum square sizes

\+ Detailed analysis of the GND plane possible

\+ Model generation from layout data

\- Connectivity of multilayer GND planes

Extension to Low Frequency AC simulations

- Connectors: high accuracy models provided by the manufacturer.
- DC/DC: already AC models
- GND system models: High Accuracy Model and the Quadtree Model
  - include inductances and capacitances in the basic cells
  - model parameters require appropriate field simulations for 2D/3D structures
- Minimum Circuit Model
  - there is no easy way to see for an AC extension
  - new kind of topology?

Conclusion & Outlook

- Description of DC GND modelling and simulation of MTCA.4 crates
- Schematic top level and second level simulation sheets have been presented
- Optimization effort vs. Accuracy for GND plane models
- The presented DC GND model is in principle easy to extend to low frequency AC simulations.

Next:

- Evaluate the EMI behaviour of AMC modules by spectral or time domain measurements of ground noise currents and voltages
- Using an adaptor board with minimal impact of the measurement into the grounding system

Thank you

Heinz Hartmut Ibowski
Senior Hardware Engineer
B1 Engineering Solutions GmbH
heinz.ibowski@b1-es.com

www.b1-es.com

