LEHRSTUHL THEORETISCHE ELEKTROTECHNIK

Prof. Dr.-Ing. M. Leone

Efficient 2-D Integral Equation Approach for the Analysis of Power Bus Structures With Arbitrary Shape

M. Stumpf, M. Leone

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Introduction

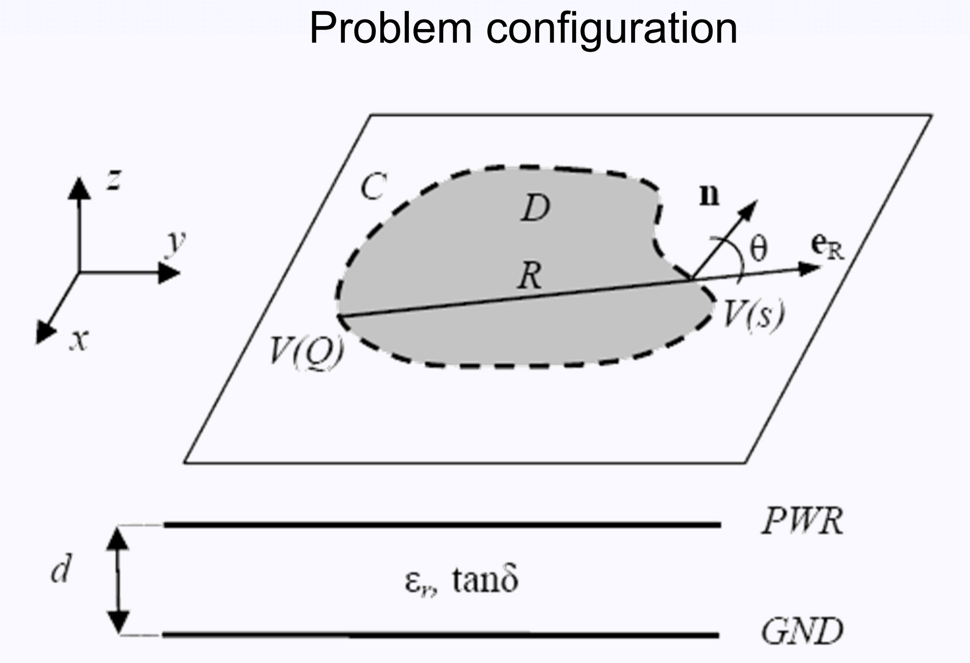
- Design objective for power-bus structures in multilayer printed-circuit board (PCB):
  Sufficient charge storage for fast switching integrated circuits (ICs)
  ⇒ reduction of the switching noise
  ⇒ ensuring power- and signal integrity
  ⇒ minimizing radiated emissions
- Required efficient numerical analysis to determine:
  - voltage distribution between power/ground planes
  - voltage/current relations between the ports
  - electromagnetic emission

2D Contour Integral Formulation

- Weber's solution for cylindrical waves in terms of the boundary voltage $V(Q)$:

$$V(Q) = \frac{1}{2\mathrm{j}}\oint_C \left[k\,\mathrm{H}_1^{(2)}(kR)V(s)\cos\theta - \mathrm{j}\omega\mu_0 d\,\mathrm{H}_0^{(2)}(kR) i_{Sn}(s) \right] \mathrm{d}s$$

Problem configuration

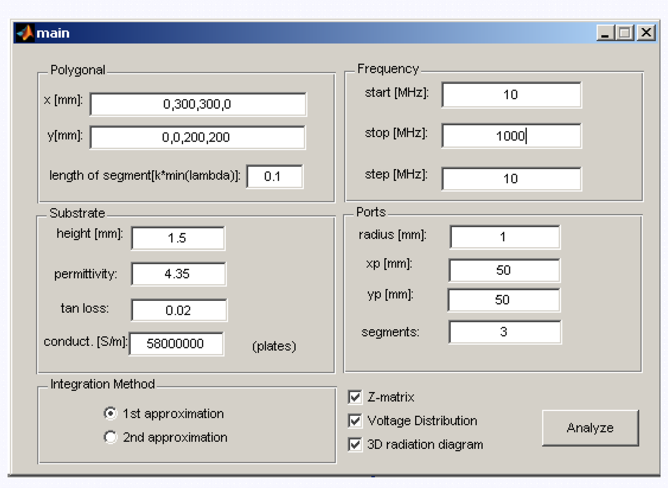


Advantages in comparison with conventional 3D modeling:

- Reduction of the problem dimension (3D → 2D)
  ⇒ simple input of geometry for arbitrary polygonal shape
  ⇒ small number of unknowns
  ⇒ low CPU and memory demands
- Rapid calculation of frequency-dependent transfer characteristic for multiple ports

Numerical Implementation

User interface of the Matlab® program



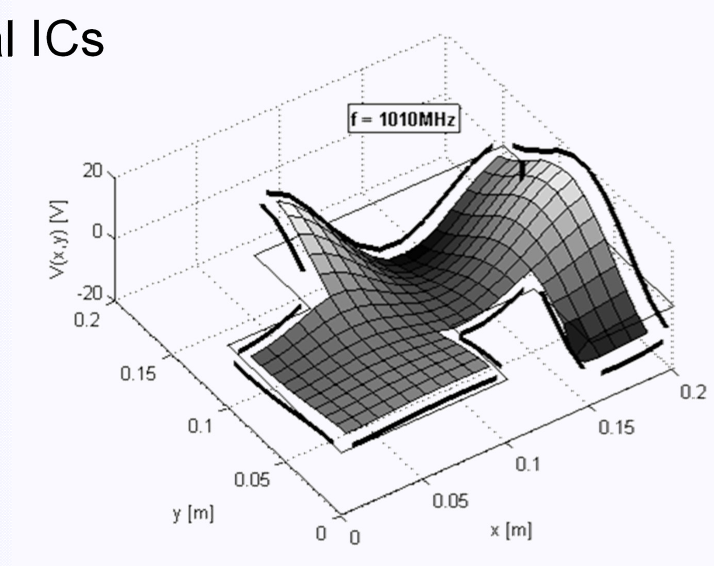
Voltage distribution $V(x,y)$ and far-field radiation characteristic

- Proper choice of the placement of critical ICs
- Calculation of radiated fields, based on the field equivalence principle

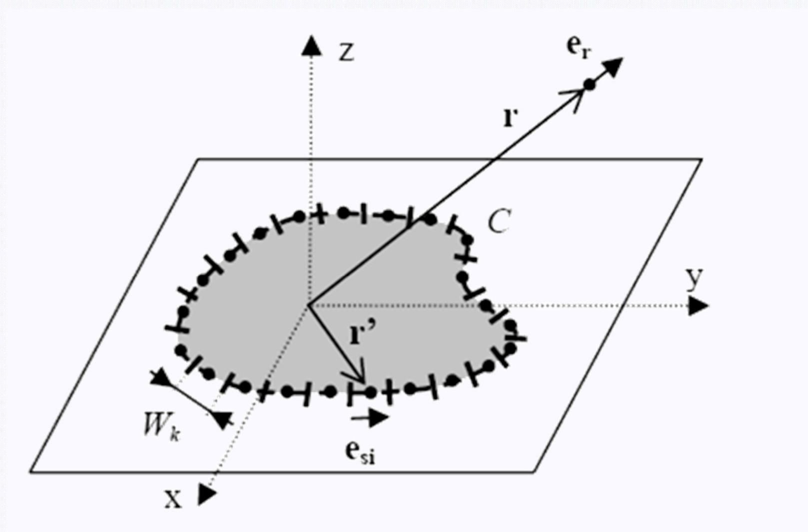
$$\mathbf{E}(\mathbf{r}) = \frac{\mathrm{j}k_0 d}{4\pi}\frac{\mathrm{e}^{-\mathrm{j}k_0 r}}{r}\int_C M_S(\mathbf{r}')\,\mathrm{e}^{\mathrm{j}k_0 \mathbf{r}'\cdot\mathbf{e}_r}\left(\mathbf{e}_r \times \mathbf{e}_s\right)\mathrm{d}s$$

Equivalent magnetic current:

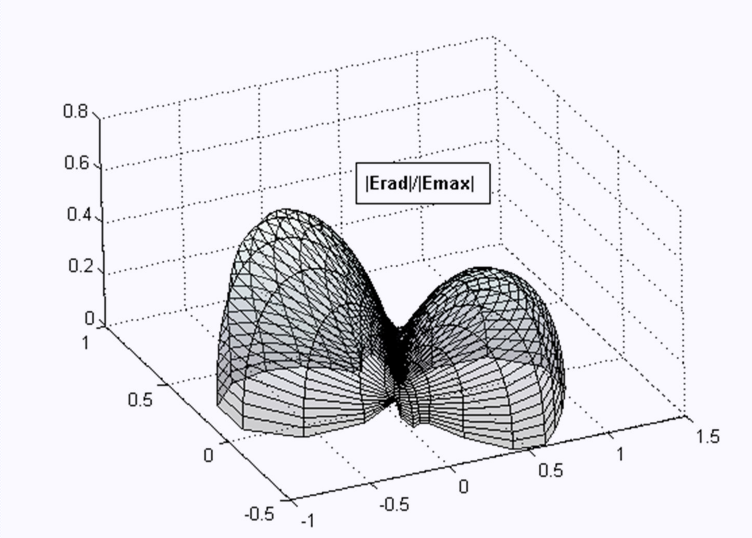
$$\mathbf{M}_S = -\mathbf{n}\times\mathbf{E} = \frac{V(s)}{d}\mathbf{e}_s$$



Voltage distribution within a power-bus

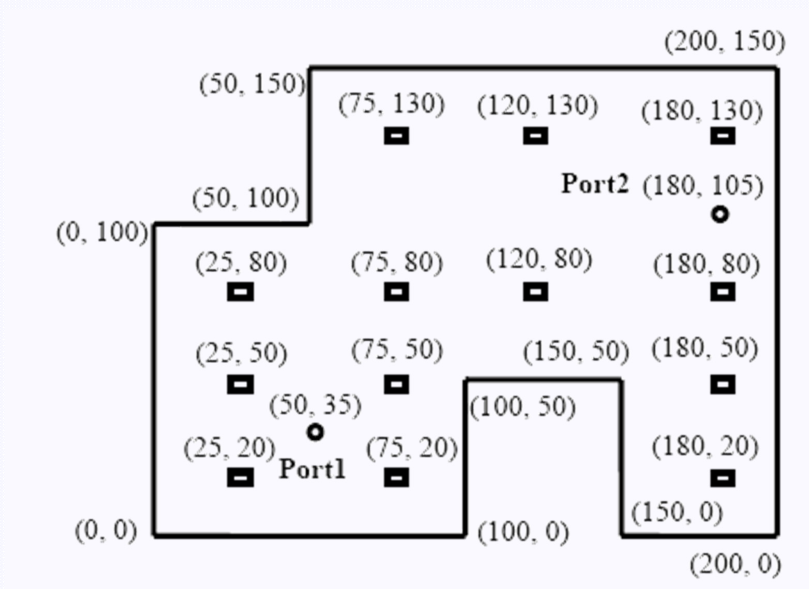


Numerical evaluation of radiated far fields

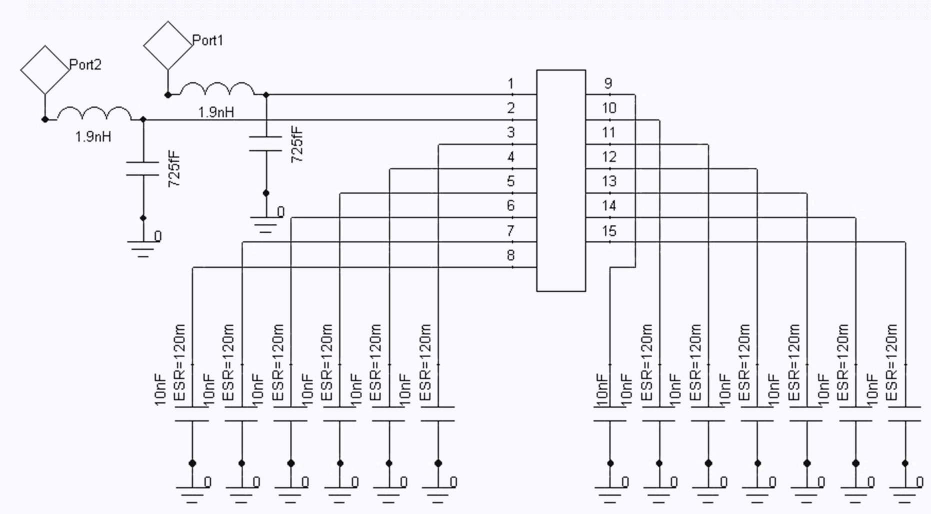


Radiation characteristic @ 1010 MHz.

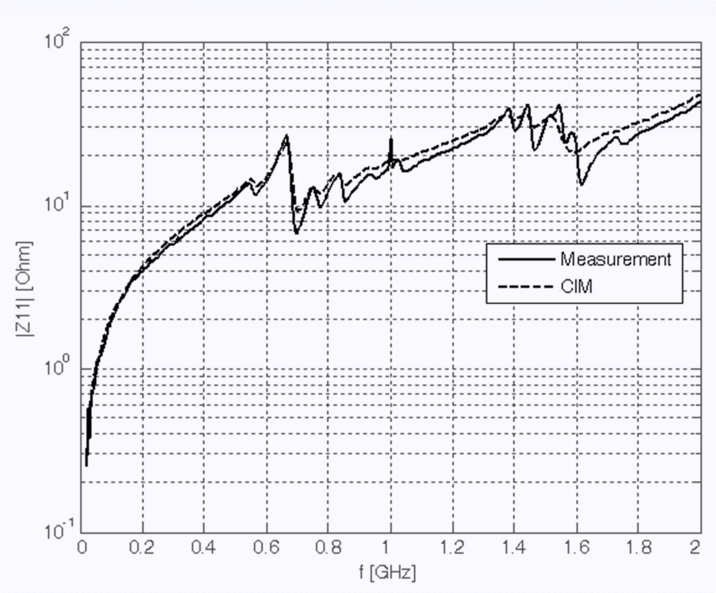
Experimental validation by measurement of populated PCB



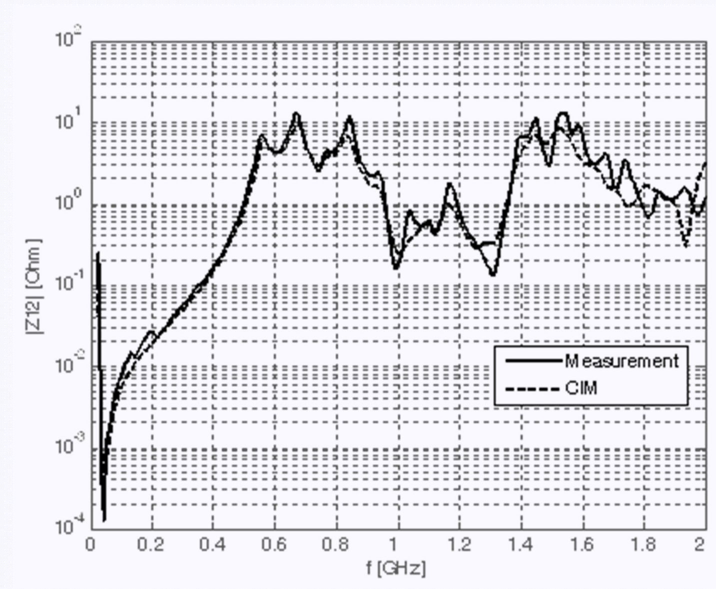
Test board with SMD decoupling capacitors



Circuit-level simulation of populated PCB



Input impedance at one port



Transfer impedance between two ports

Conclusion

- Numerically efficient and versatile EMC-analysis tool for power-bus structures in PCBs has been developed, implemented and experimentally validated. It allows
  - rapid N-port characterisation for circuit-level simulation
  - calculation of radiated fields

IGET Institut für Grundlagen der Elektrotechnik und Elektromagnetische Verträglichkeit

OTTO-VON-GUERICKE-UNIVERSITÄT MAGDEBURG