# Comparing DC/DC conducted EMI Simulation with Measurement Results (Part2)

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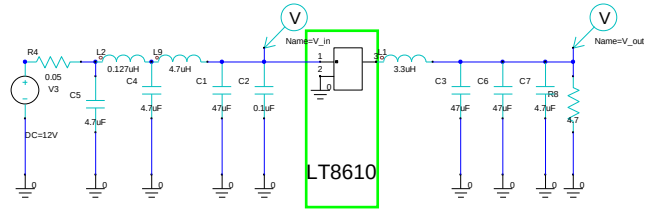
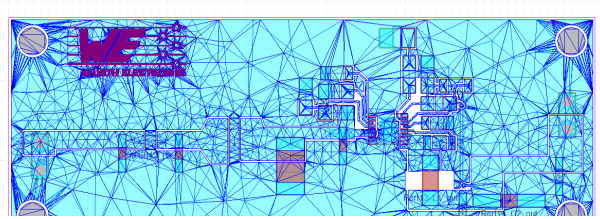
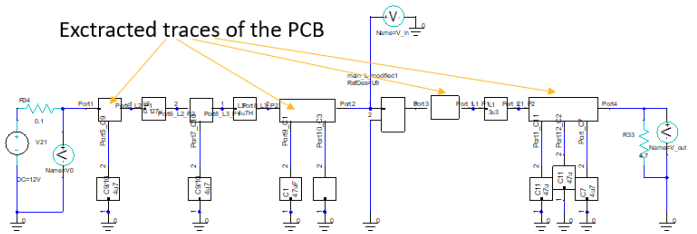
11th Power Analysis & Design Symposium

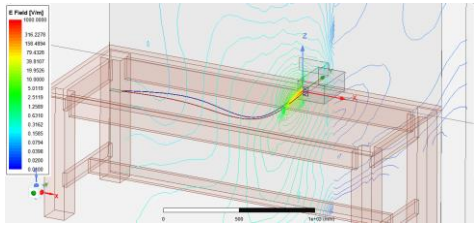
# Agenda

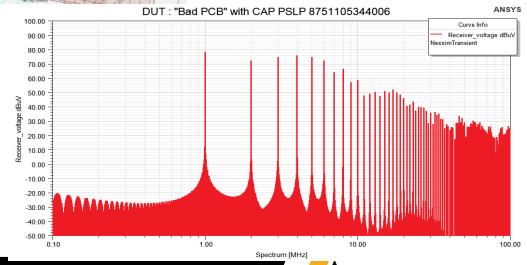
- Overview design flow and methodology
- Description of PCB variations and circuit
  - -initial ( “bad”)  layout
  - -improved ( “good”) layout
- Accuracy enhancement by modeling the LISN network and measurement setup on table to be included in the circuit m
- Discussion of results
- Outlook and conclusions
- Optional : demo of setup



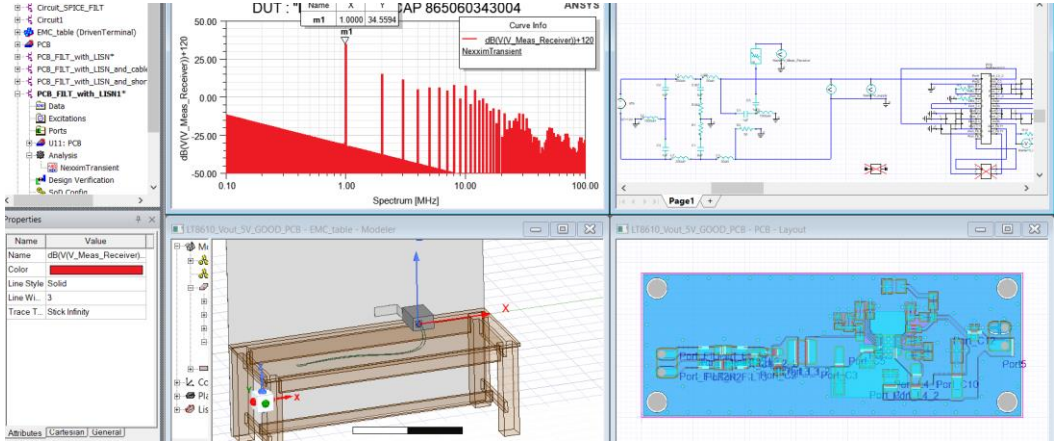


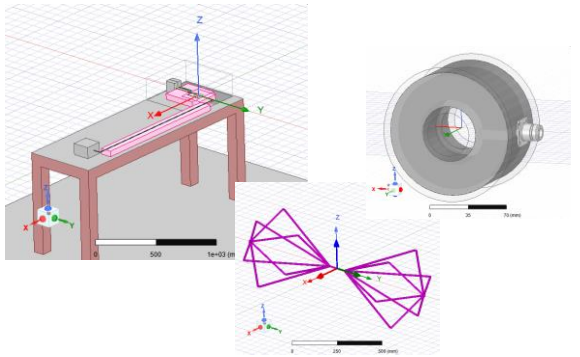


# Overview of ANSYS Electronics Desktop (AEDT) as simulation environment

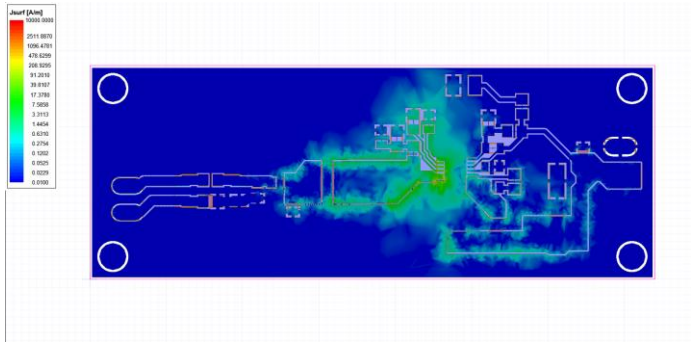
The Ansys Electronics Desktop is a comprehensive simulation environment which enables bidirectional coupled multi-physics simulations addressing the needs of electronic engineers with simulations like



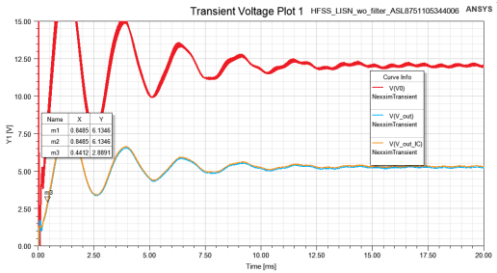
EMC relevant library



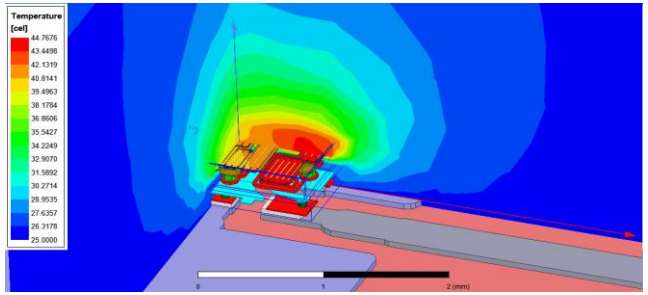
Electromagnetic extraction of 3D Geometries using FEM (HFSS ™) and PCBs using hybrid solver(Siwave ™)



Circuit simulation ( transient, harmonic balance, linear, …)



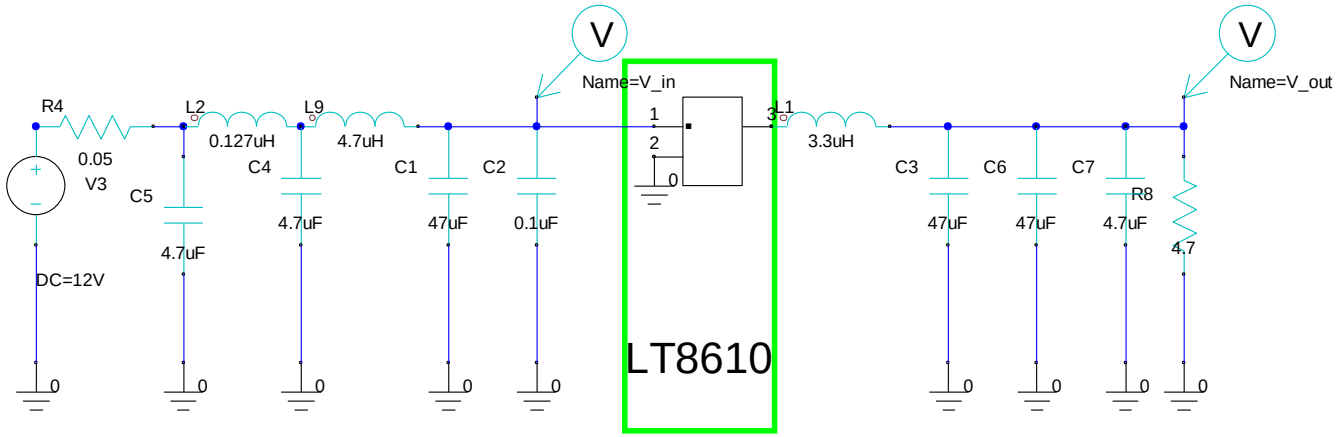

Thermal simulation using heat conduction, radiation and convection using ( ICEPAK ™)



# Model description: circuit of a switched power supply

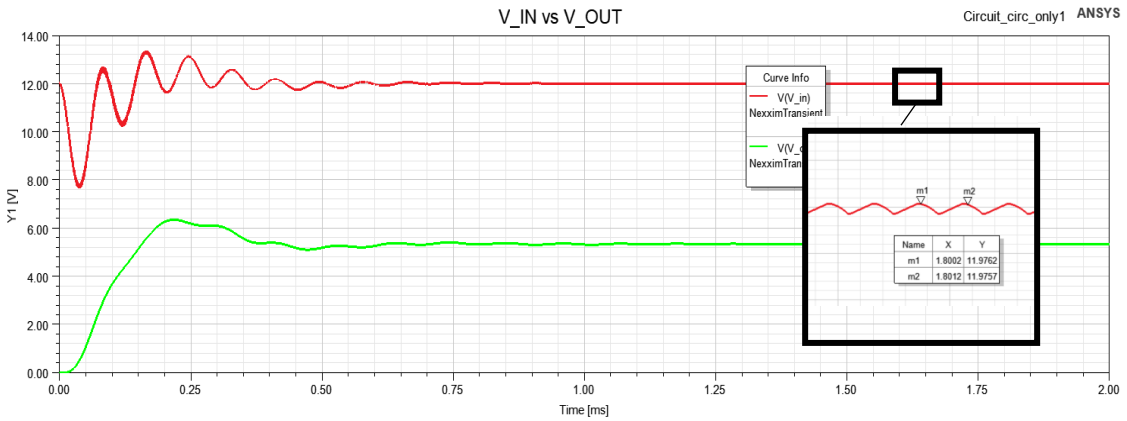
Schematic of power supply circuit with SPICE model of voltage regulator (derived from LT8610) with 1MHz internal switching frequency

Transient circuit simulation without frequency dependent parasitic effects (coupling, attenuation) of the PCB

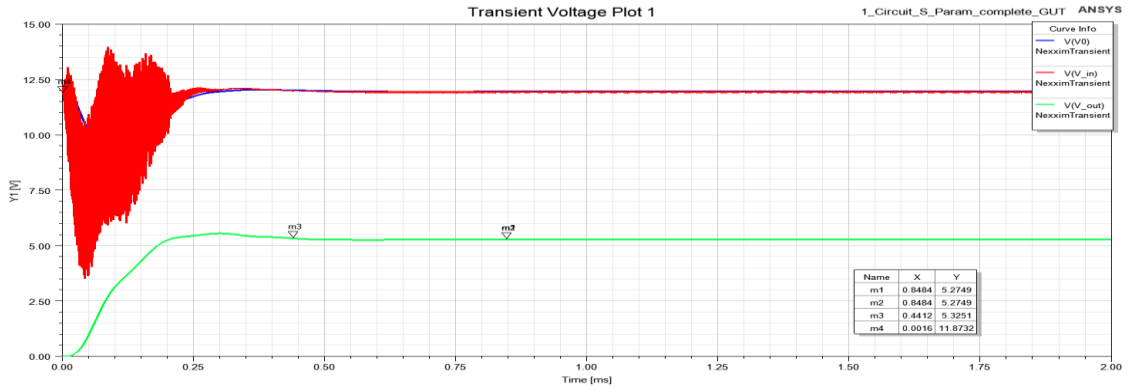



Circuit setup with ideal components, effects of traces are missing

Circuit with Ideal discrete omponents



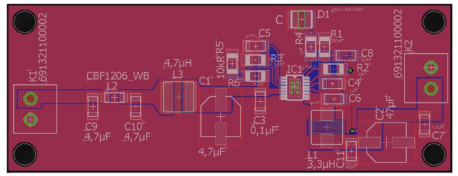

Circuit with SPICE models of discrete components -



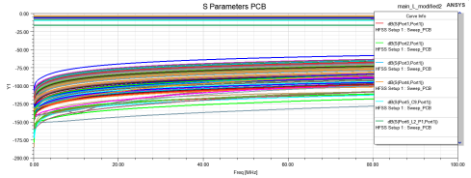

This approach does not include any parasitic effects due to PCB layout or external connections

# Design Flow EMC System Analysis

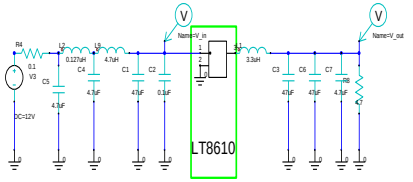
Import PCB and Component Definitions from 3rd Party Layout



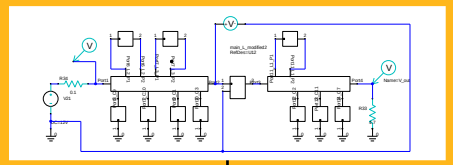
Full-wave Extraction using FEM or planar solver



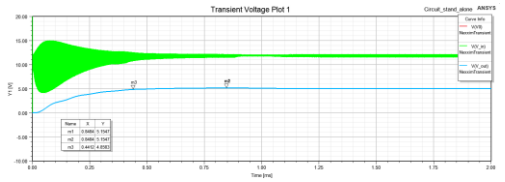
Schematic generation in circuit simulator




Embedding extracted EM model in circut simulator

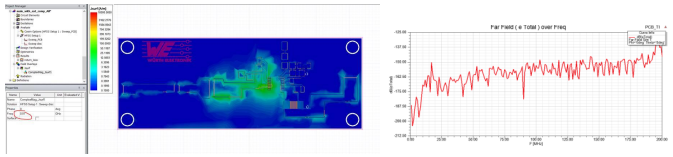


Transient analysis circuit with embedded EM model (optional with model of measurement setup)

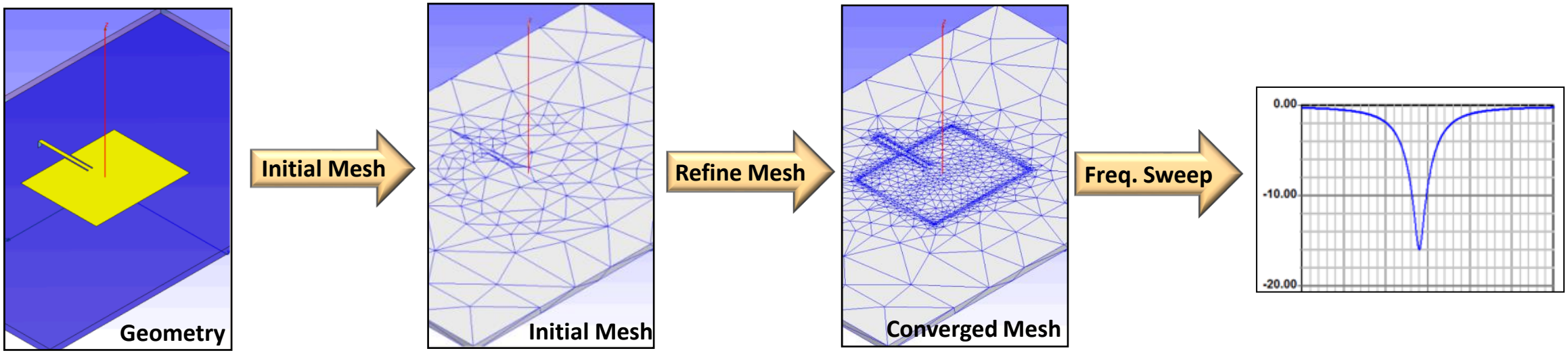


FFT

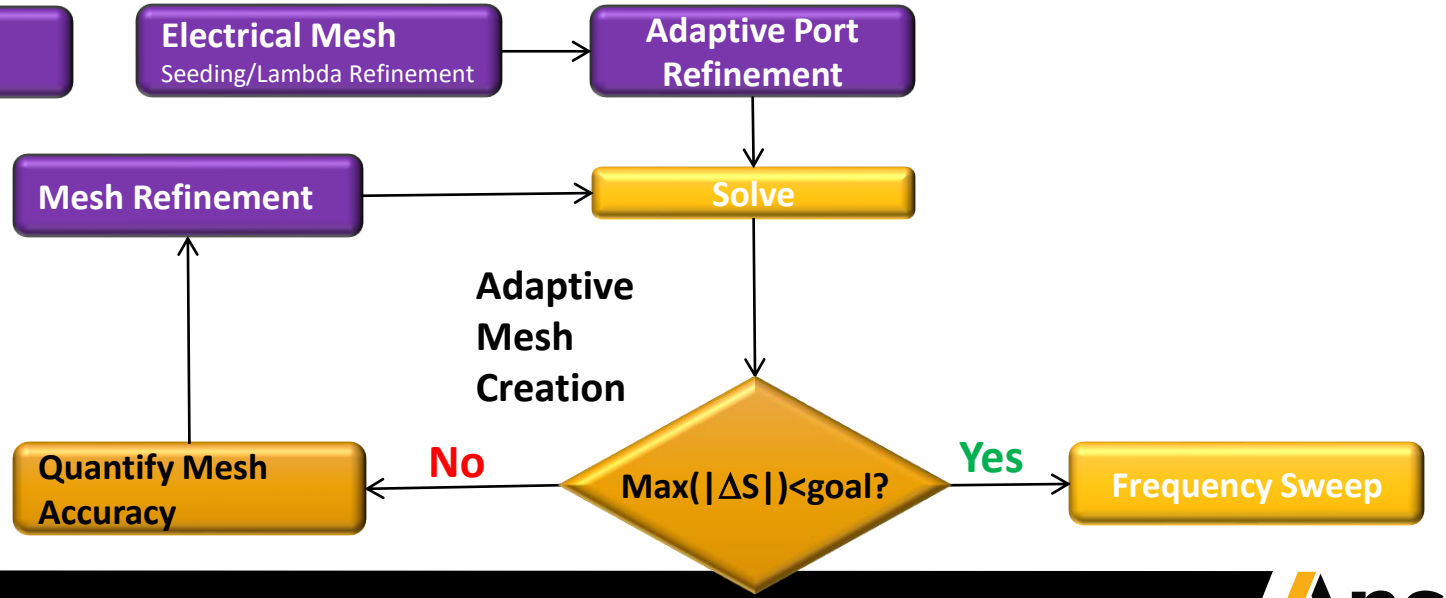
Visuzalization of current distribution Near- and Far-field calculation



# Adaptive Mesh Refinement in HFSS –FEM solver (antenna example)




Autoadaptive mesh refinement is a well established method [2] which allows scalable accuracy that does not depend on individual user knowledge.



# Model description: PCB

Original layout / geometry

- Imported layout from ALTIUM using edb or ODB++ file exchange format

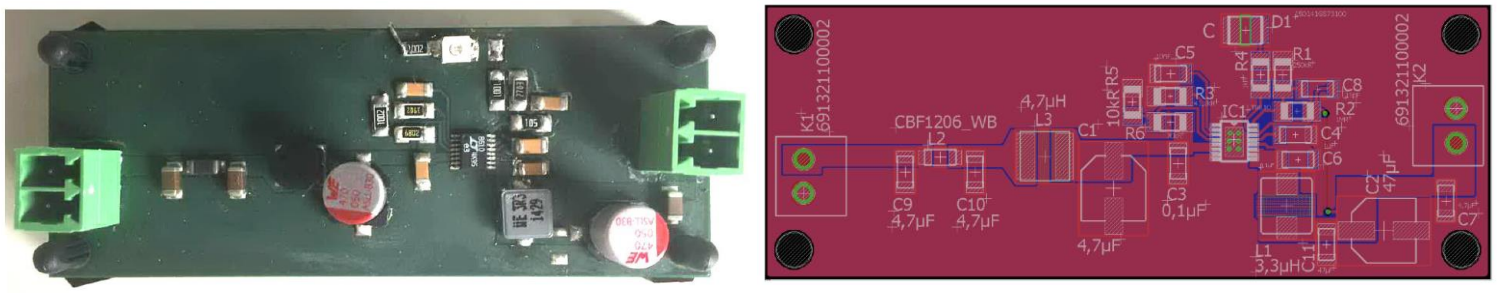
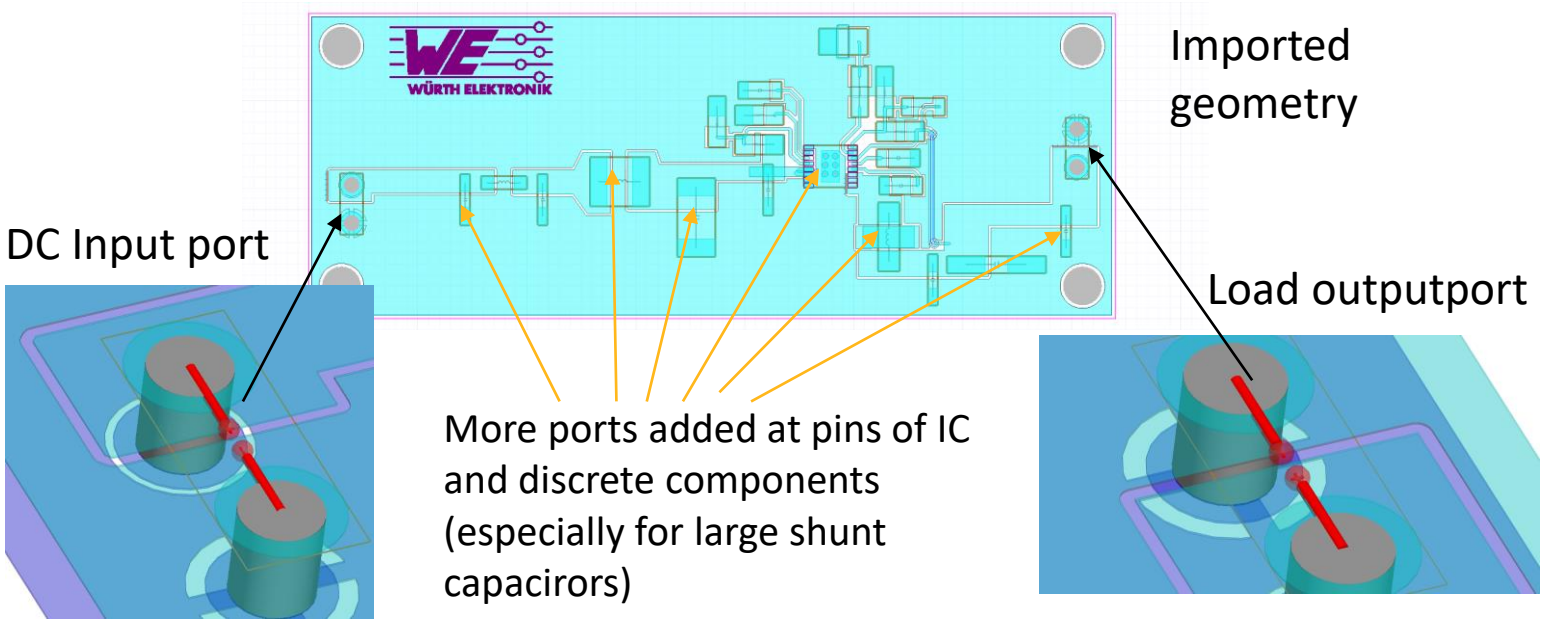



Image source : Wuerth Elektronik

Imported geometry in HFSS Layout Interface

- Electromagnetic model extraction using FEM
- Definition of “Ports” needed for S-Parameter calculation of coupled PCB traces
- FEM simulation extracts data comparable to a VNWA measurement at the port position

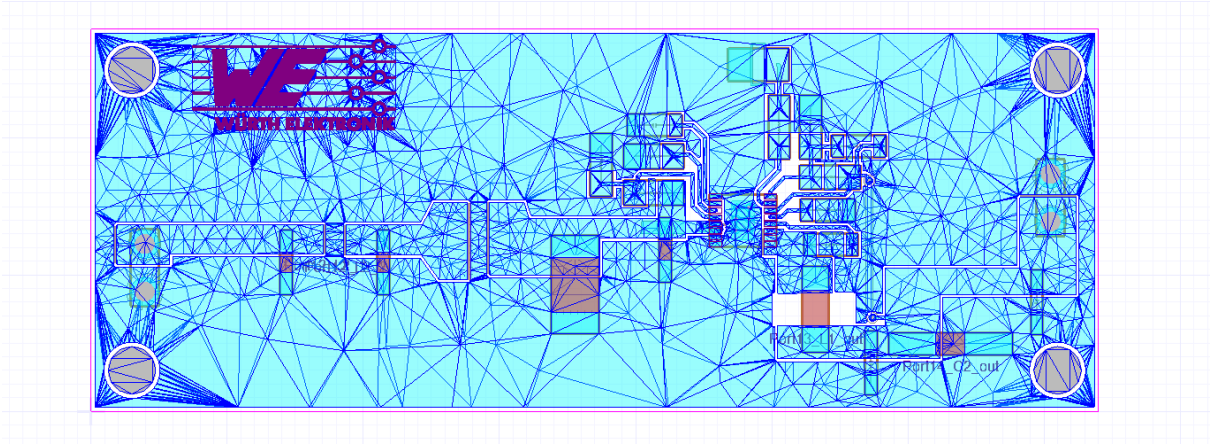


# Model description: FEM simulation

FEM Mesh on PCB

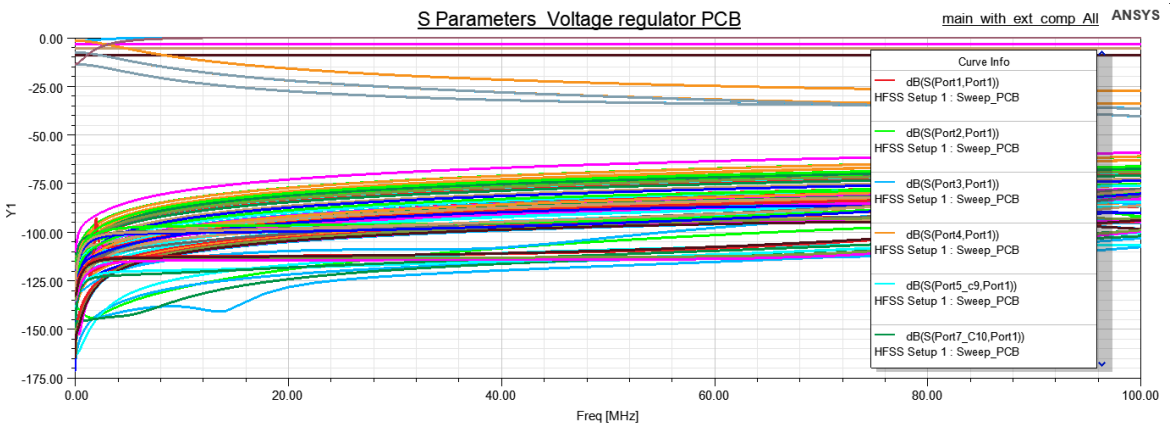
- Mesh has been auto-adaptive refined to accomplish S-parameter accuracy of better than 0.5%

| Pass N... | Solved El... | Max Mag. Delta S |
|---|---|---|
| 1 | 69009 | 1 |
| 2 | 87469 | 0.053935 |
| 3 | 99641 | 0.0041296 |



S-parameter between all included traces:

Includes all coupling and losses up from DC to 100MHz

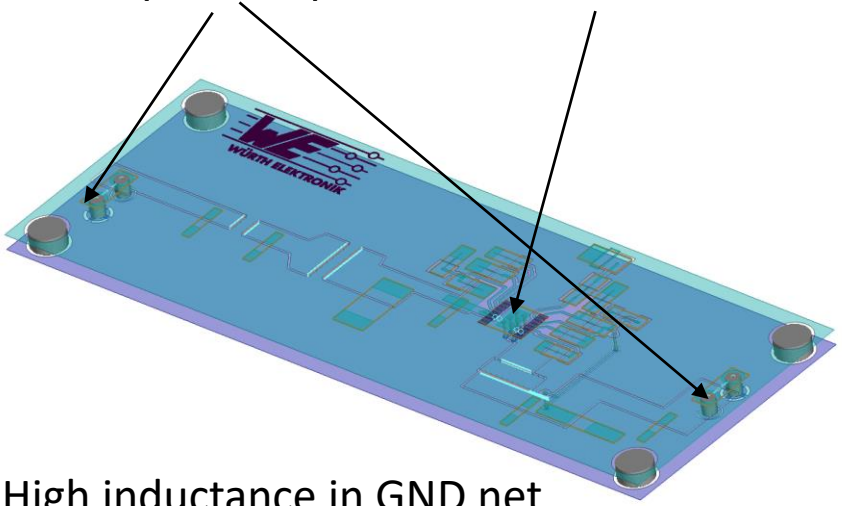


# Comparison of two concept - PCBs

**“Bad layout”** ( provided by Wuerth Elektronik)

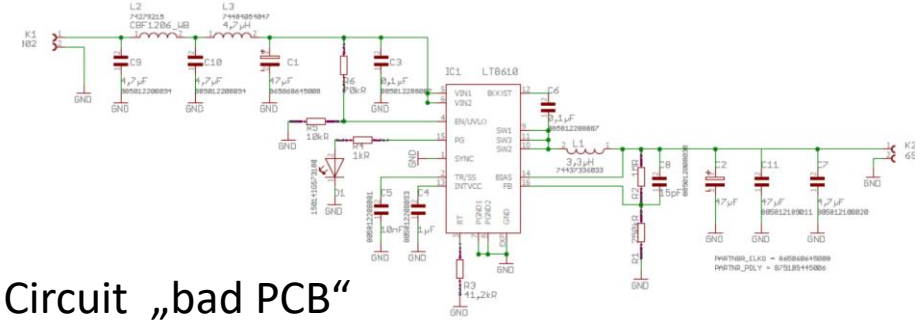
Just a few vias for connecting upper an lower GND

near input/output  near VRM-IC



-> High inductance in GND net

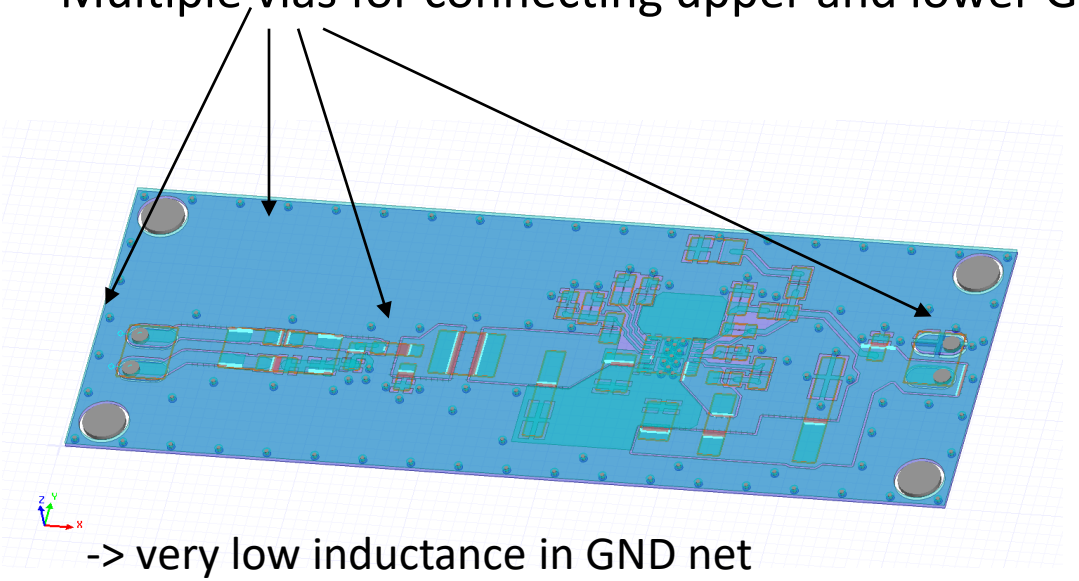
-> resonances possible



Circuit  „bad PCB“

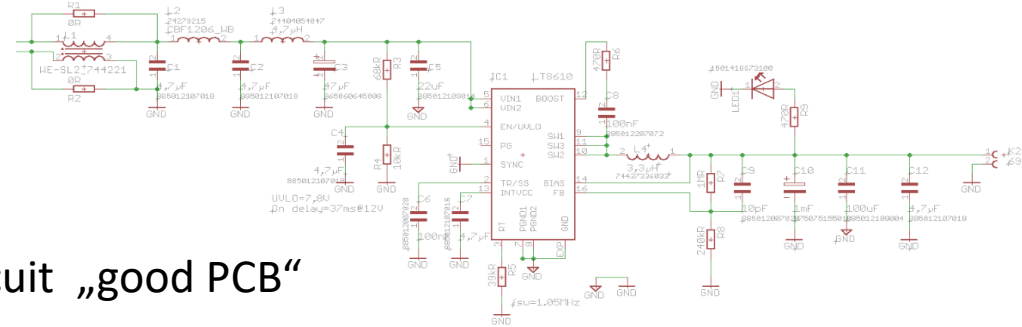
**“Good layout”** ( provided by Wuerth Elektronik)

Multiple vias for connecting upper and lower GND



-> very low inductance in GND net

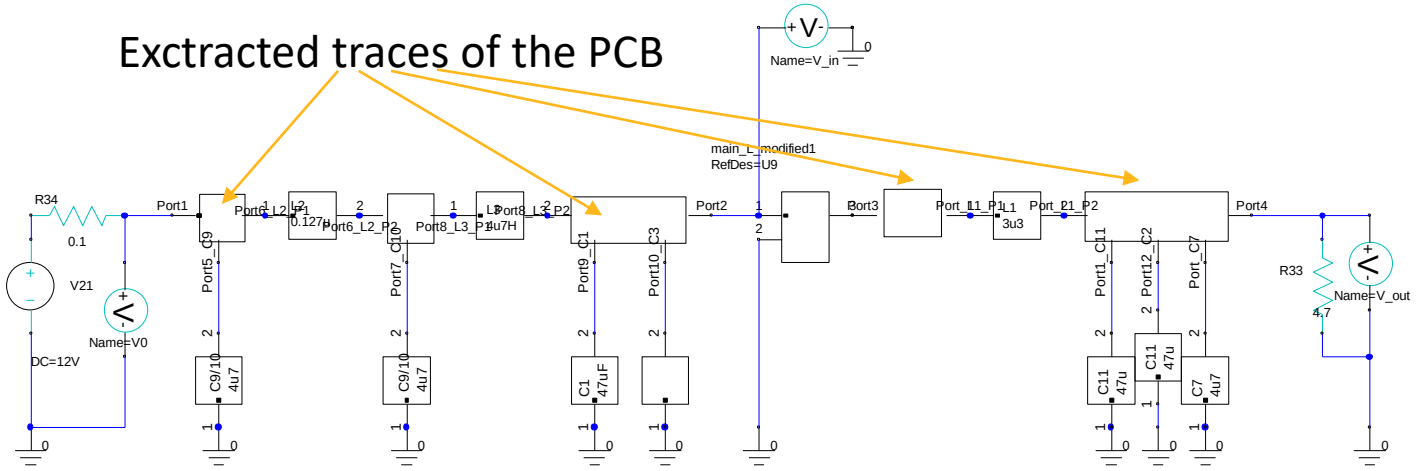
-> strongly reduced coupling, no resonances in the frequency range of usage



Circuit  „good PCB“

# Model description: Extracted EM Model inside circuit

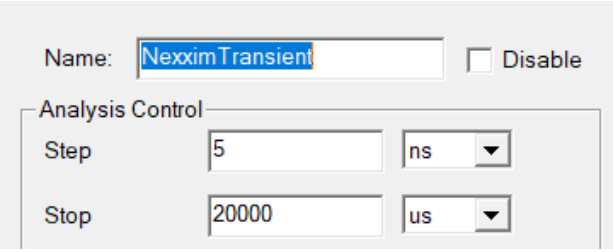
EM model of PCB embedded in circuit and SPICE models for discrete components




SPICE models have been placed at positions of ports in the EM setup as due to the extreme low-pass behavior o f the L/C arrangement no energy would propagate at MHz frequencies

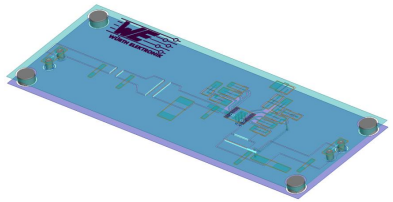
Transient simulation setup

( 5ns step, 20ms duration)

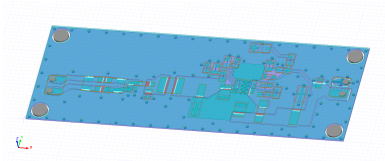


# Comparison of two concept – PCBs (transient simulation data)

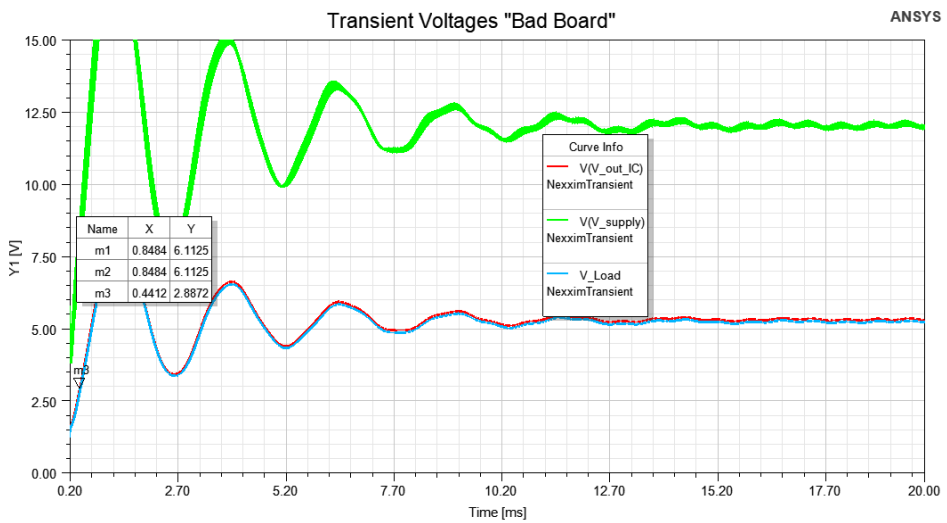
**“Bad layout”**



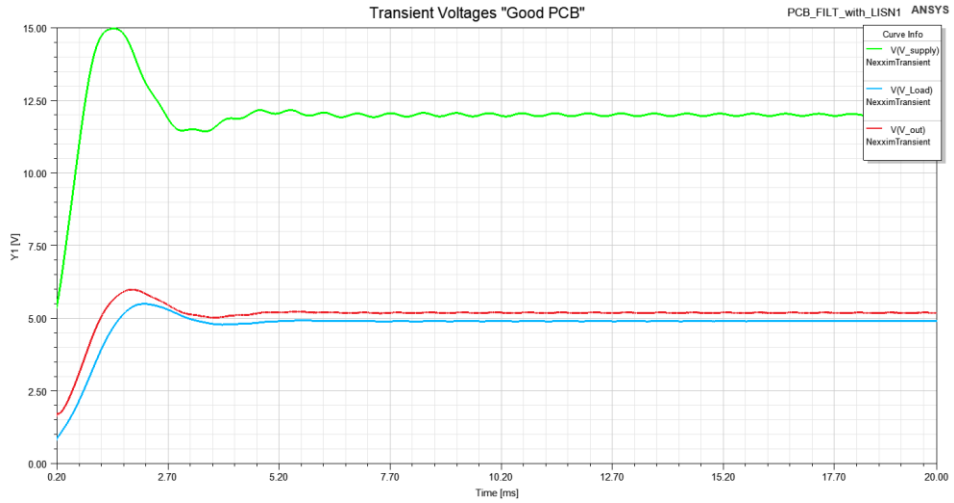
**“Good layout”**



V_supply : voltage at DC supply input of PCB
V_out_IC : voltage at output pin of VRM – IC
V_Load : voltage at 4.7 Ohm load




Strong voltage ripple at input pin

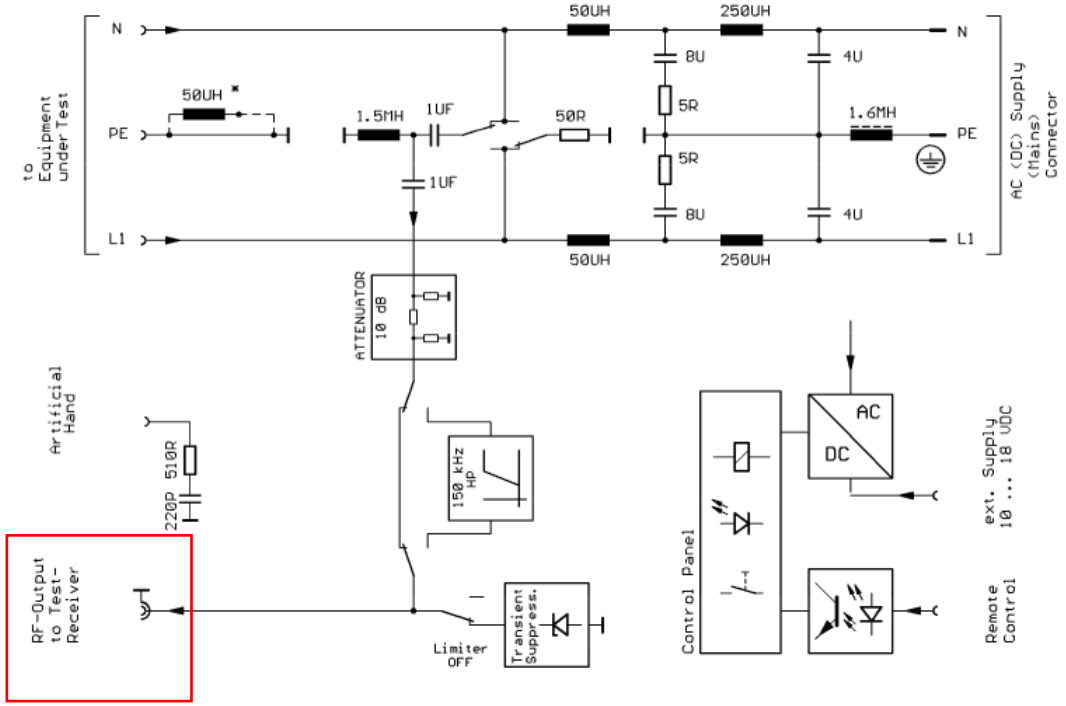



Moderate voltage ripple at input pin

-> This kind of analysis could not be accomplished without the electromagnetic model of the PCB

# Accuracy enhancement: Model of LISN ENV216 from Rohde & Schwarz

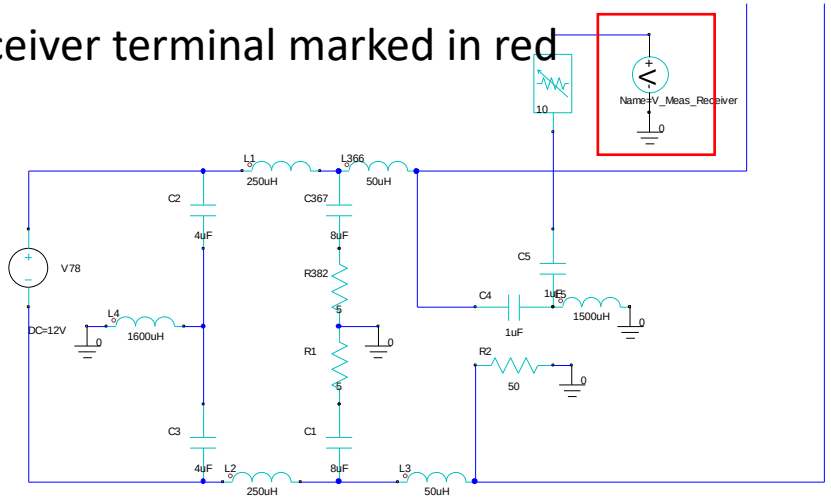
Block diagram taken from Rohde & Schwarz manual of LISN ENV216 [3]



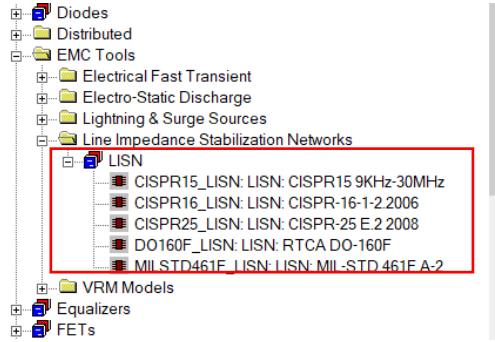

Model of measurement setup within the circuit simulation

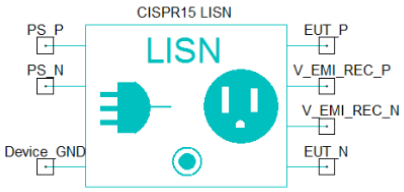
EUT

Receiver terminal marked in red



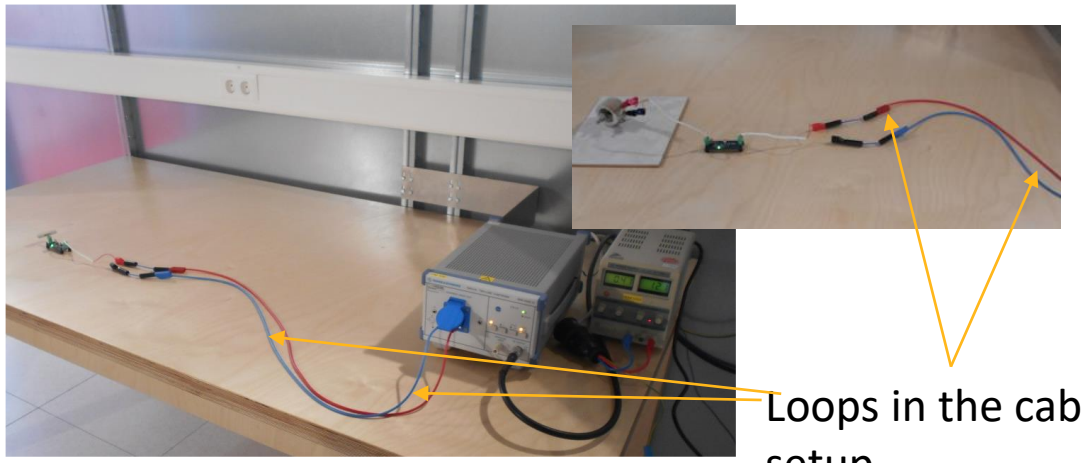

Also Library of LISN setups available



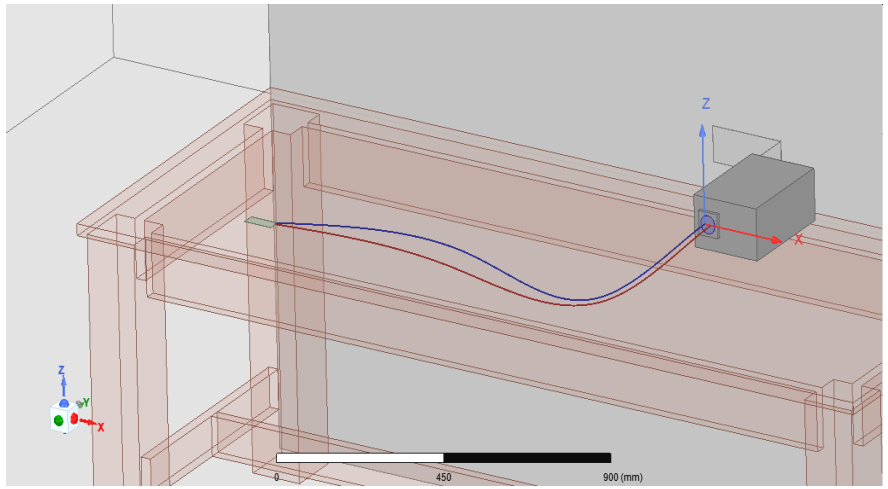
# Accuracy enhancement: Model of the EMC measurement cable

## Measurement setup in the EMC lab



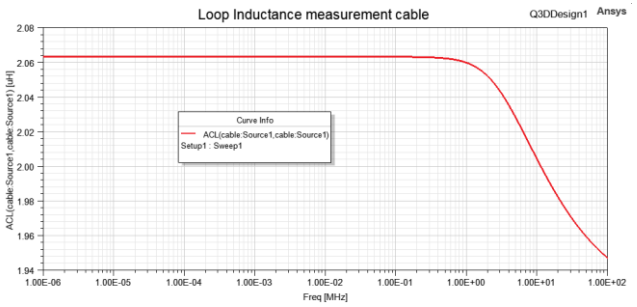
Loops in the cable setup

## Model of measurement setup in HFSS



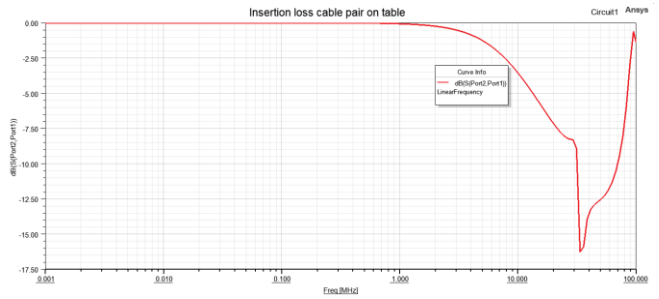

The measurement cable setup (1500mm assumed in the model) adds some inductance and losses which are taken into account by an EM Model created from an FEM - simulation

## Calculated loop inductance of approx 2 uH




This will act as a low-pass filter and may also add resonances

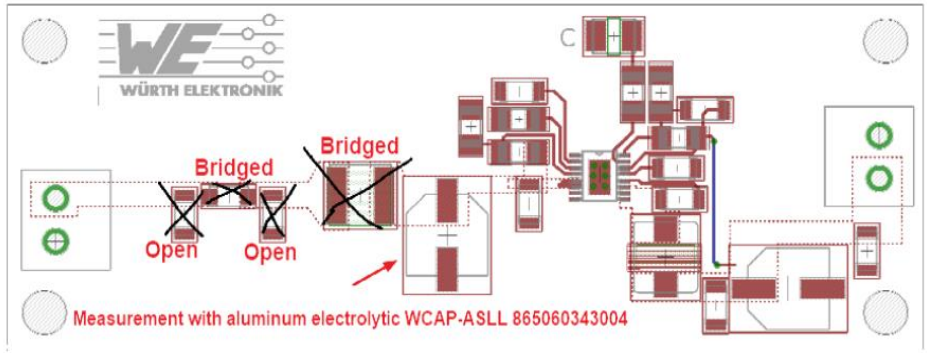
## Corresponding insertion loss of cable setup



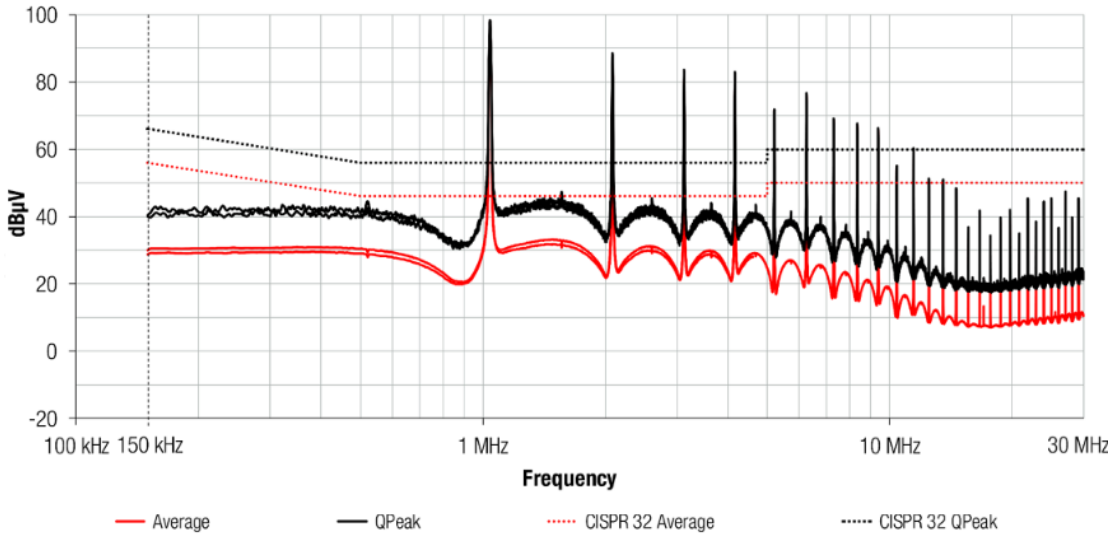

Strong change in losses at higher frequencies can be observed

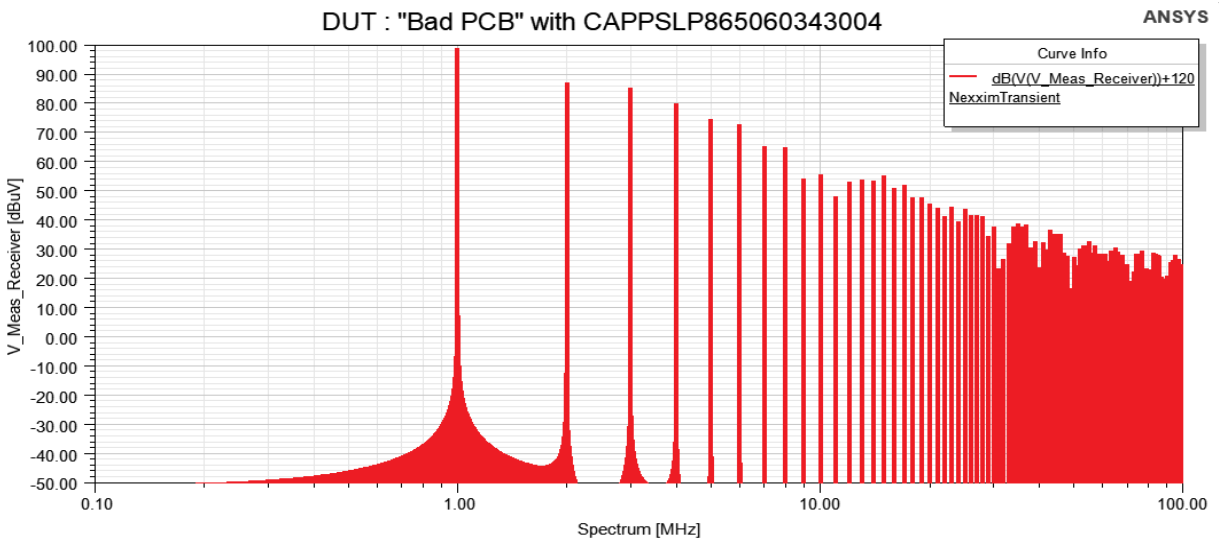
# Comparison with Measurements (Aluminium Electrolytic Capacitors)

The PCB with the “bad” layout has been tested with different types of capacitors which are due to the technology more or less suitable for suppression RF-current contents



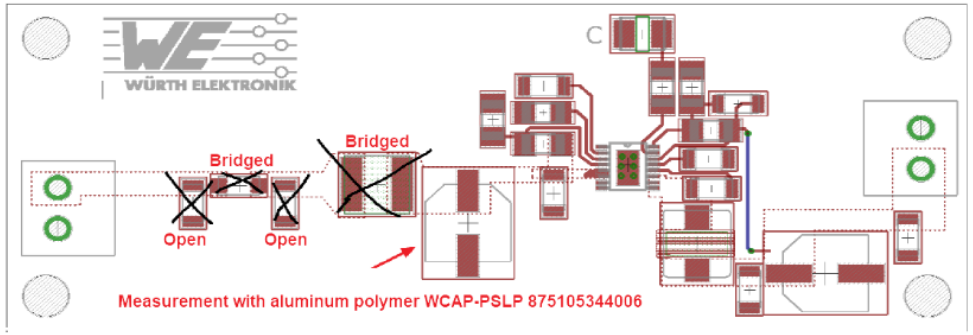

Aluminium Electrolytic Capacitors - SMD
WCAP-ASLL 47uF 16V 20%
Wuerth part 865060343004 [4,5]



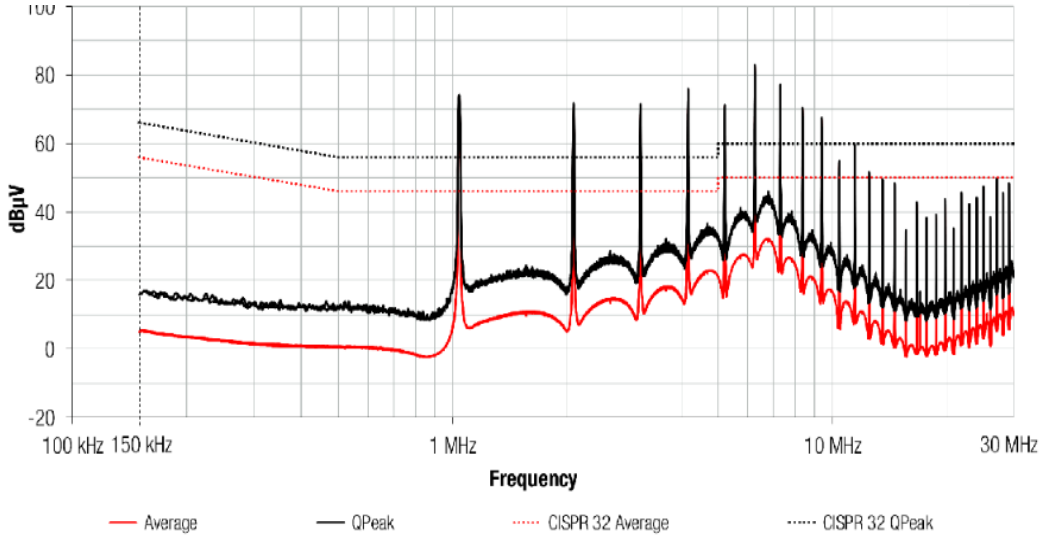



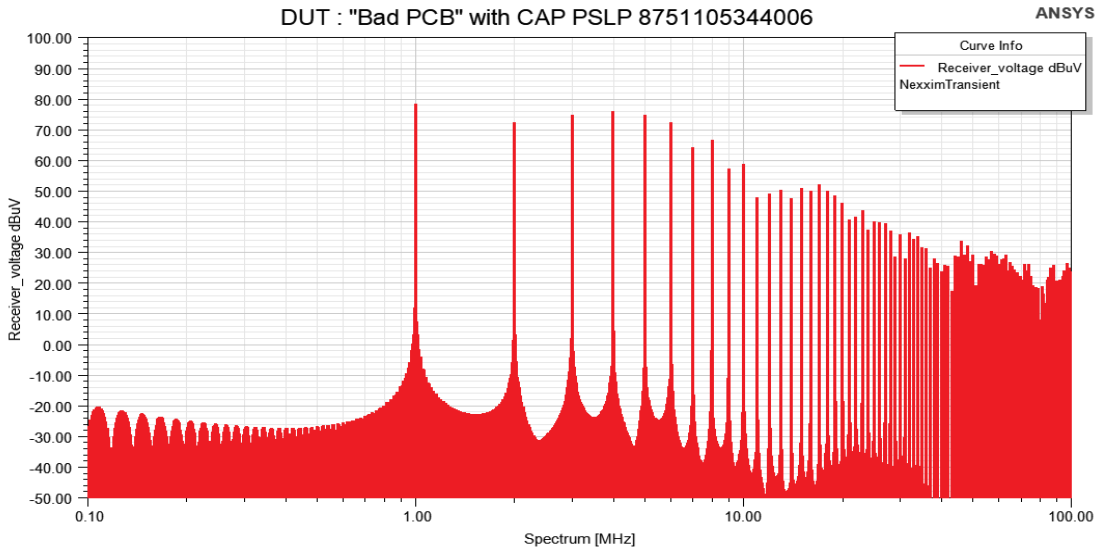
# Comparison with Measurements (Aluminium Polymer Capacitor)

The PCB with the “bad” layout has been tested with different types of capacitors which are due to the technology more or less suitable for suppression RF-current contents



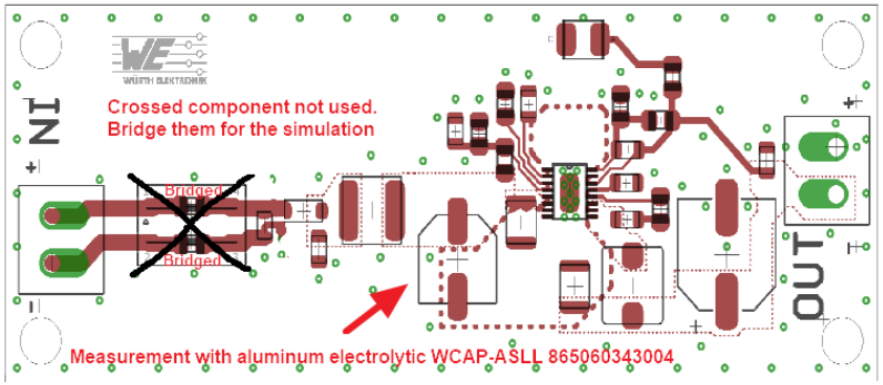

Aluminium Polymer Capacitors WCAP-PSLP
16V 47uF 20%
Wuerth part 875105344006 [4,5]



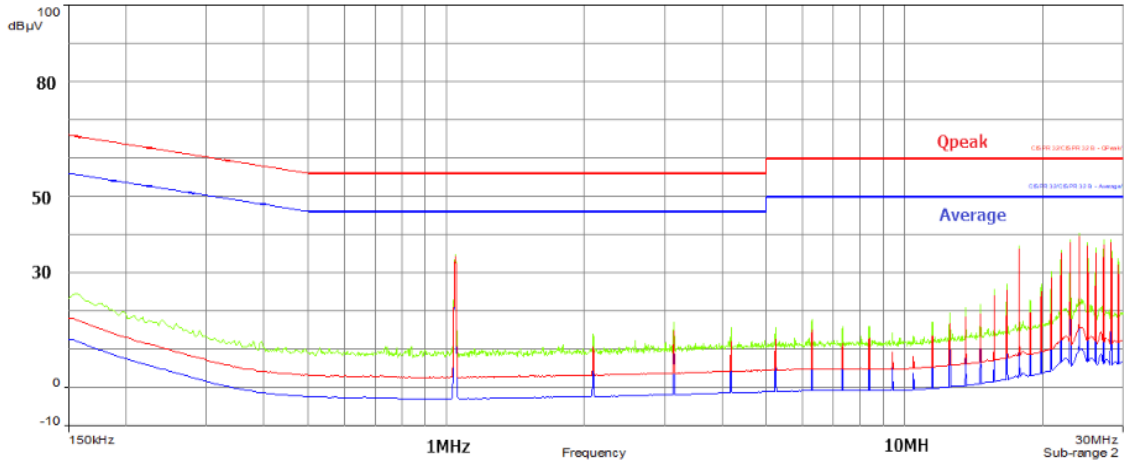



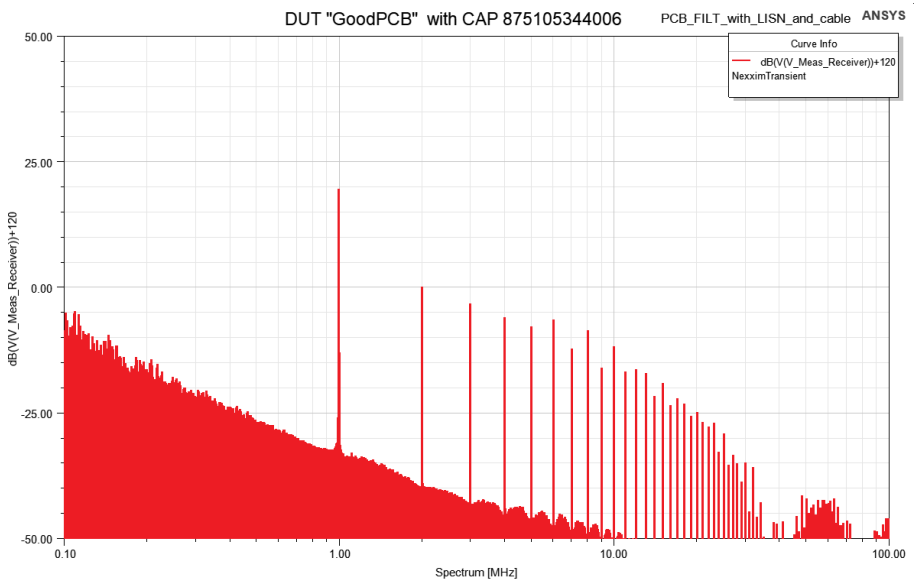
# Comparison with Measurements (Aluminium Organic Polymer Capacitor)

The PCB with the “good” layout has been tested with different types of capacitors which are due to the technology more or less suitable for suppression RF-current contents



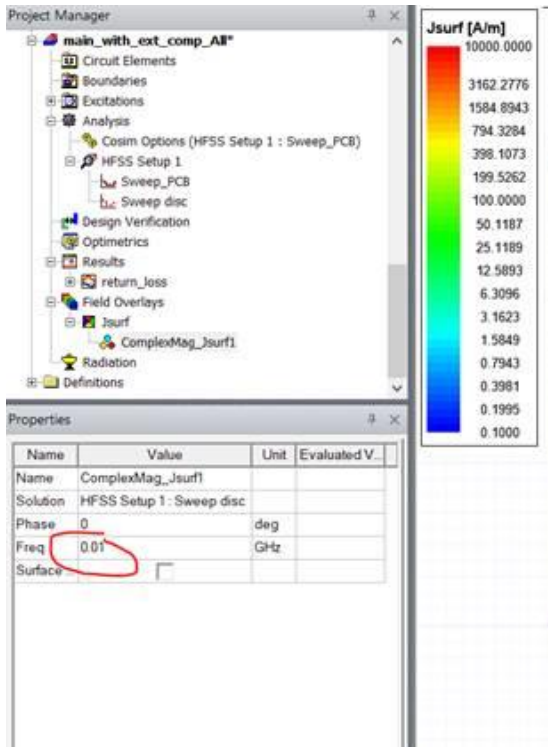

Aluminium Electrolytic Capacitors - SMD
WCAP-ASLL 47uF 16V 20%
Wuerth part 865060343004 [4,5]

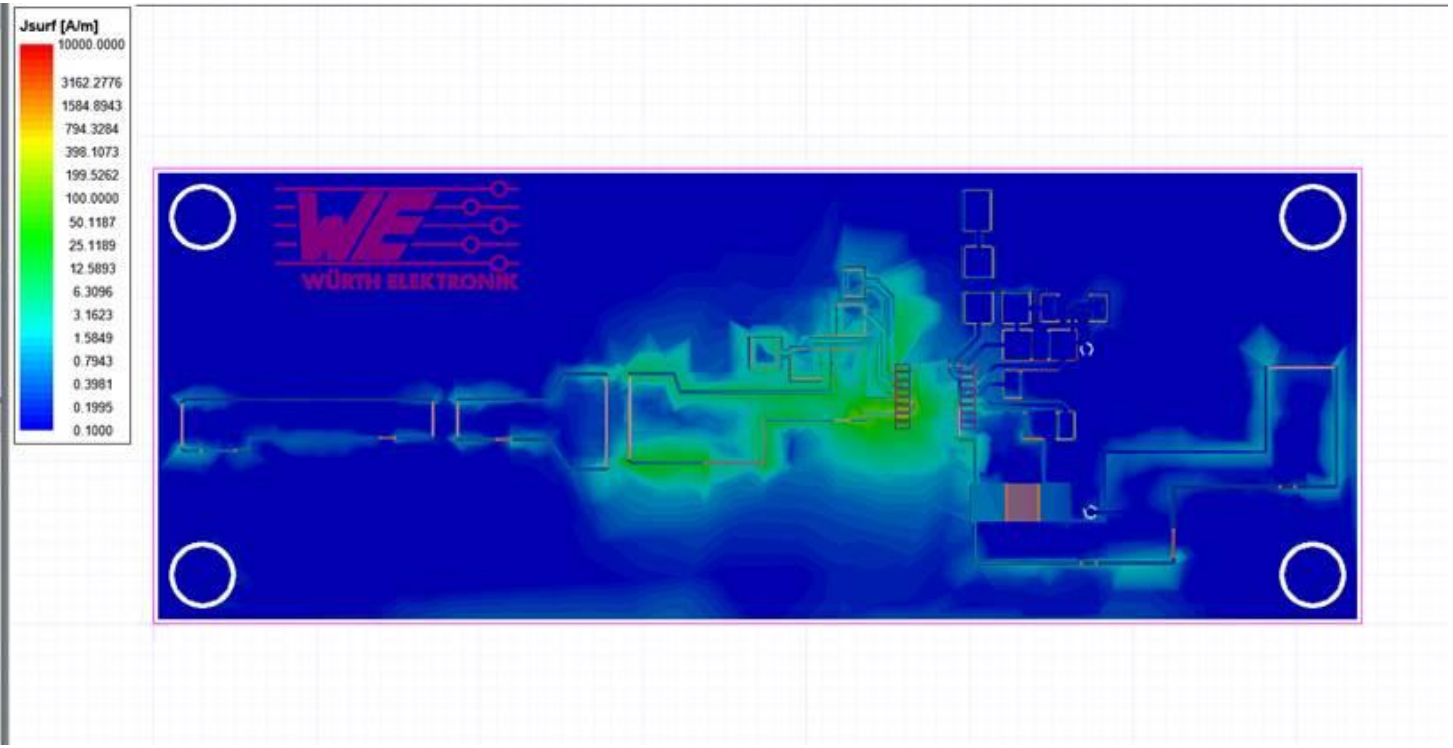


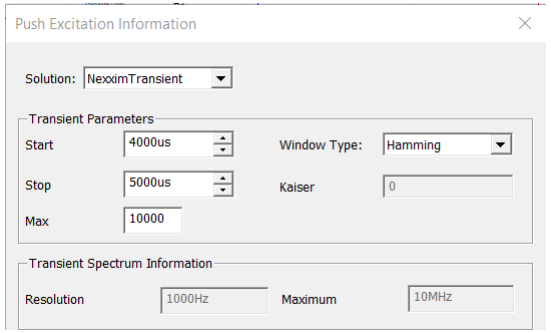

Here some stronger devitions can be seen

# Model description: Extracted EM Model inside circuit (“Bad design”)

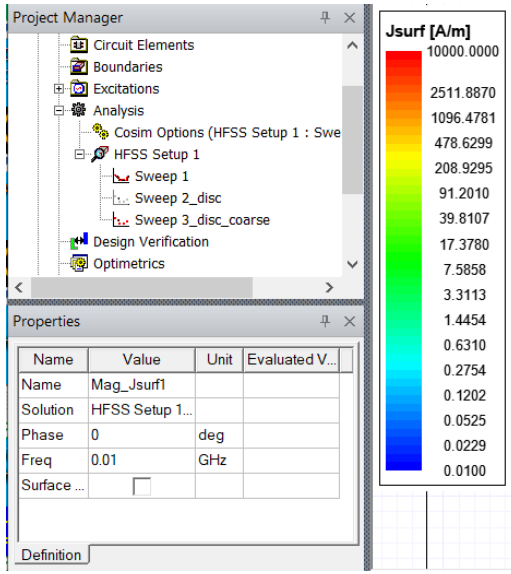



Current density on PCB 10 MHz

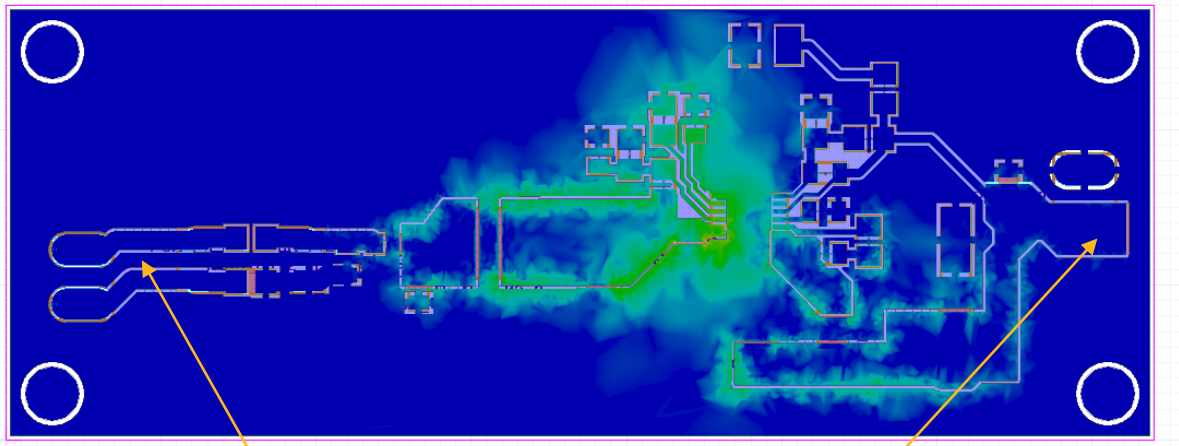


# Model description: Extracted EM Model inside circuit (“Good design”)

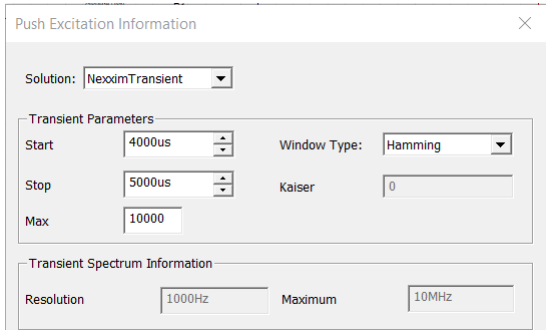








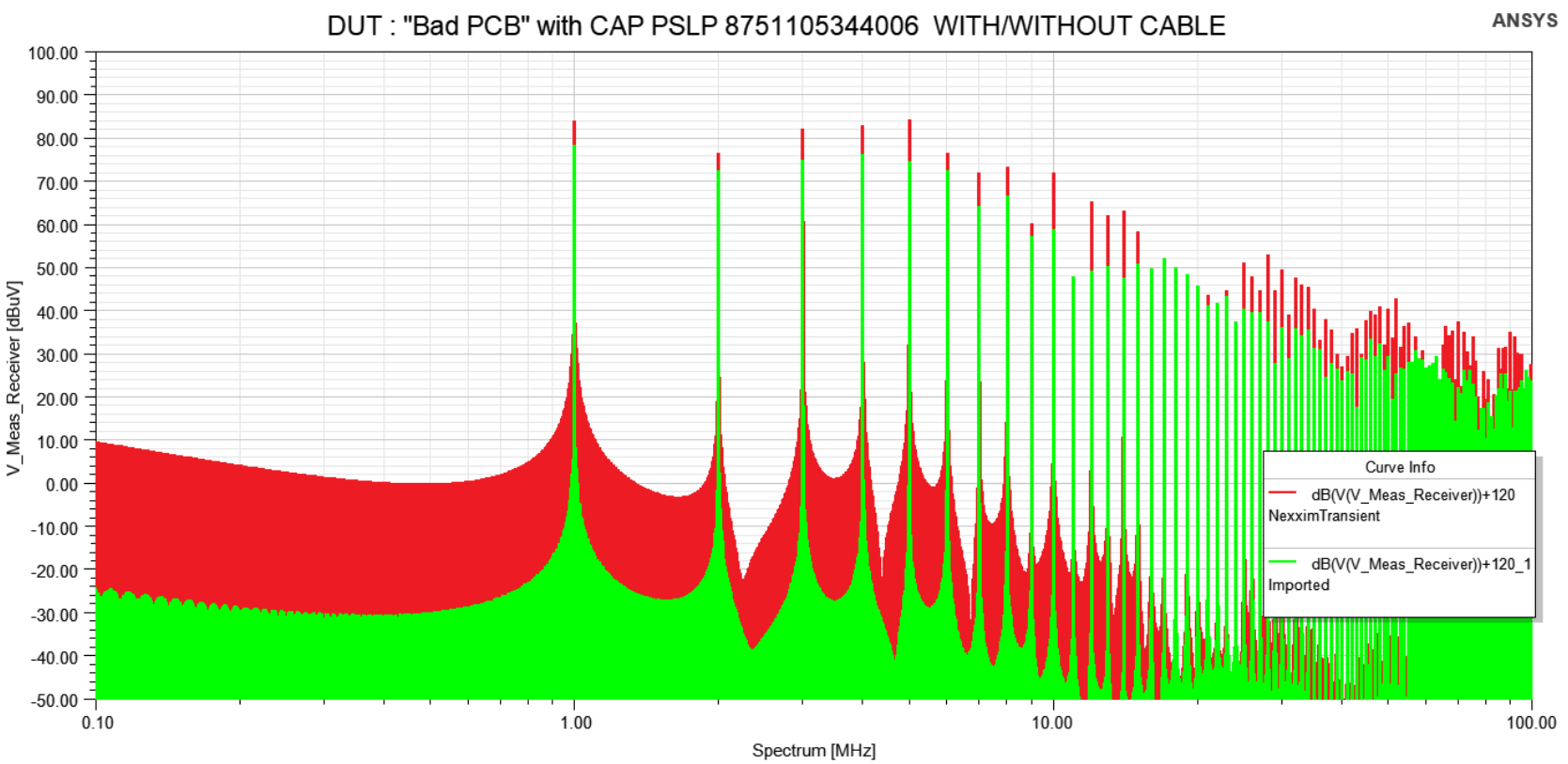
Current density on
PCB 10 MHz

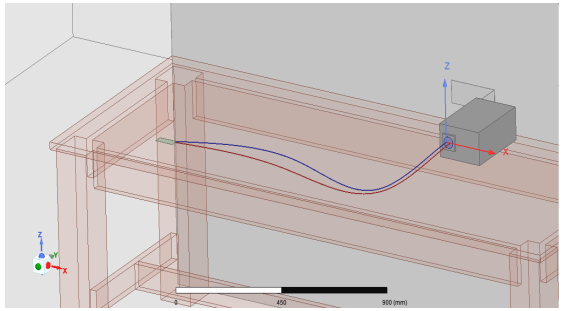



Less current density in outer parts of condutors near input and output

# Comparison of receiver spectrum with / without cable

Comparative simulation results
with masurement cable setup / without measurement cable setup



A variation up to approx 15 dBuV can be seen at higher frequencies due to the cable inductance

-> This should be considered in the arrangement of the cables during measurement

# Outlook: Design improvement by decoupling capacitor optimization

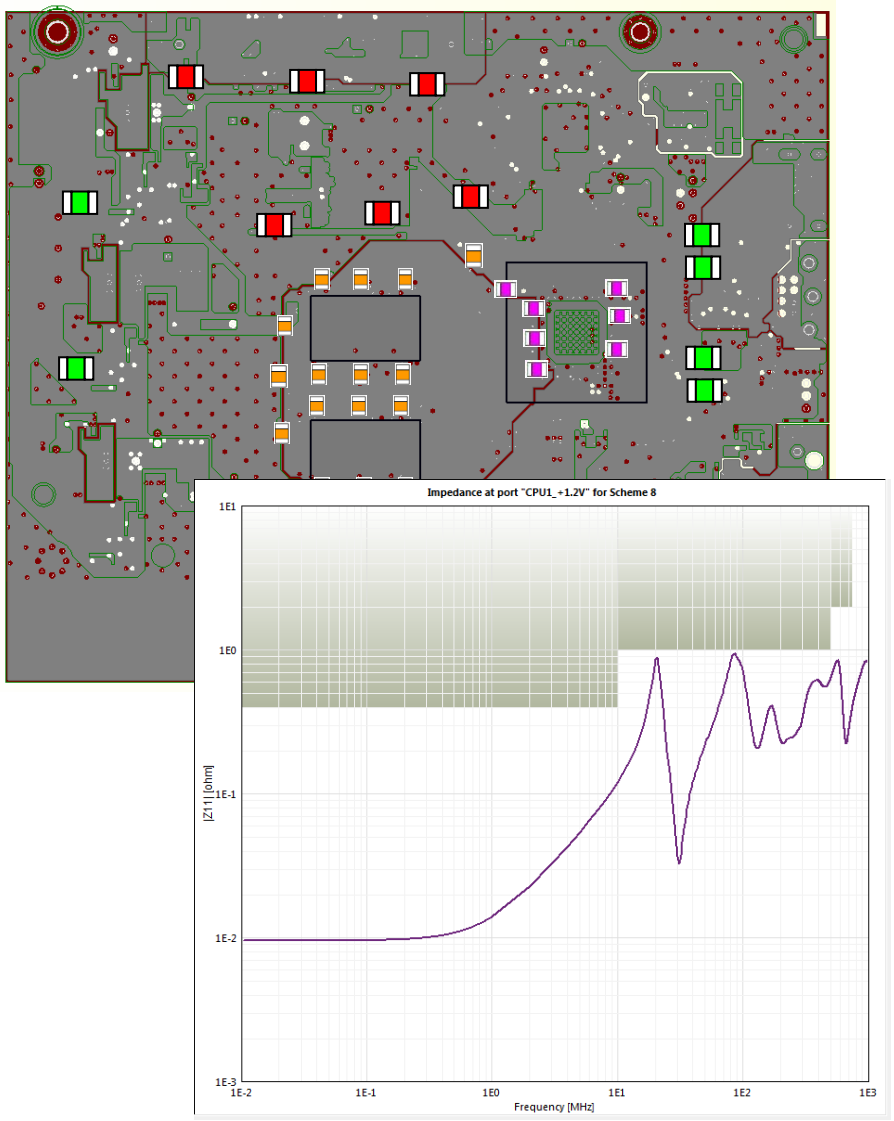
ANSYS SIwave enables optimization of decoupling capacitors to meet a target impedance.

**Inputs:**

- Target impedance versus frequency
- Capacitor locations (fixed)
- Candidate vendor capacitor models
- Optional: price per capacitor

**Outputs:**

- Capacitor schemes that indicate which capacitor model, if any, to populate at each location
- Impedance versus target for each scheme
- Loop inductance from active device(s) to each capacitor location

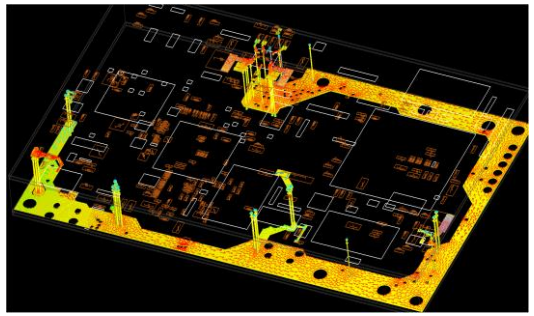


# Summary

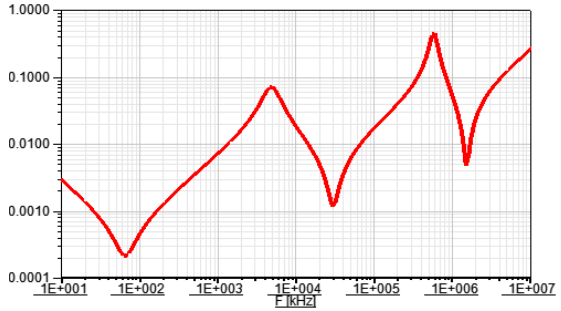
- The accuracy of a SPICE model circuit simulation can be enhanced by including extracted  EM- models from the board geometry based on numerical simulations
- Boards layout data can be used with embedded models of passive circuit elements or using ports for external circuit connection
- Enhanced accuracy of PCBs as noise emitters can be modeled in a simulation environment which contains both a physical model of the measurement setup and a circuit of the LISN-network
- Changes in PCB layout as well as the choice of discrete components can be used for comparison of different layout concepts and usage of most suitable discrete components
- The appropriate choice of capacitors can be addressed by suited (typ. “genetic”, i.e. non gradient) optimization algorithms

# SIWAVE: a dedicated simulation tool for PCBs

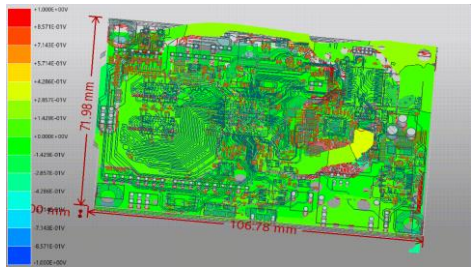
**DC/IR analysis** (optional with thermal)



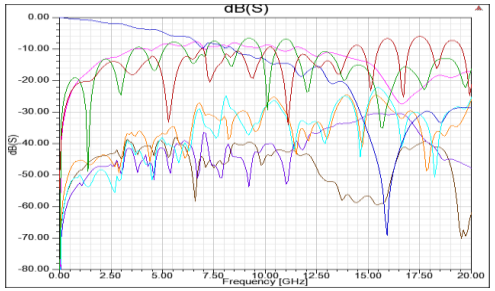
**Power-Delivery Network improvement** (reduction of target impedance in PDN, avoiding resonances, improvement of decoupling capacitors)



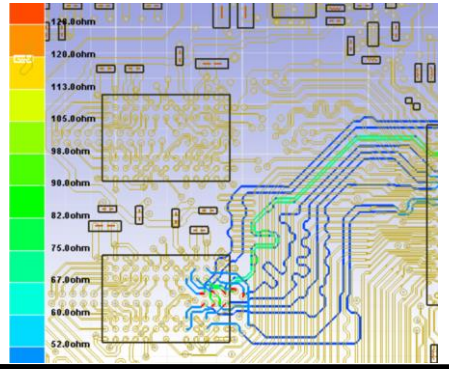

**Resonance analysis extraction** (responsible for peaks in target impedance)



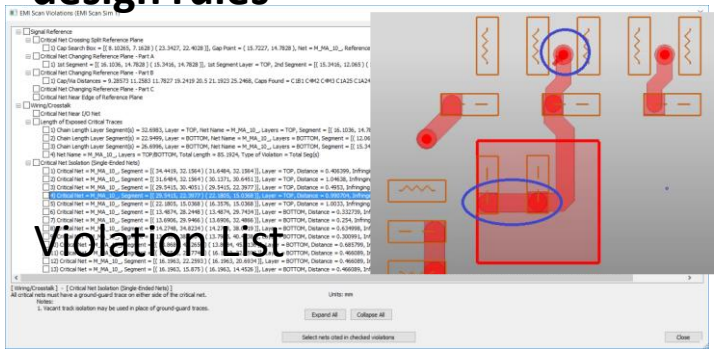

**S-Parameter / SPICE model extraction** ( e.g. for coupling with circuit analysis)



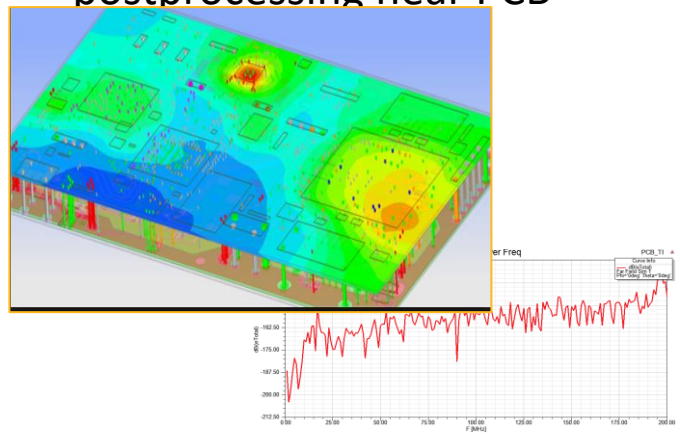

**Quality of transmission lines** with respect to impedance, coupling, susceptibility and more



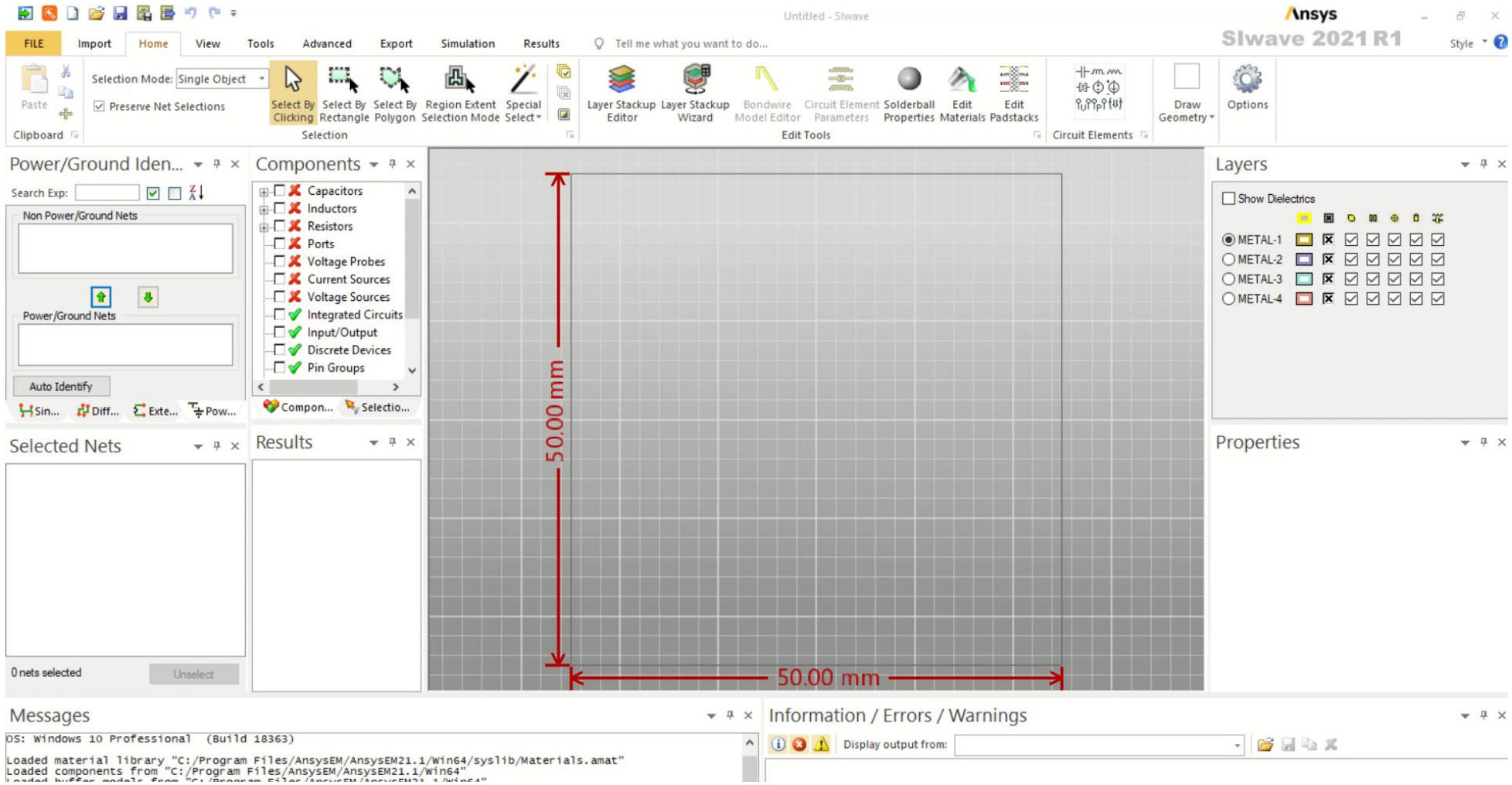

**Automated EMI-Scanner for design rules**




**Near Field / Far Field** postprocessing near PCB



# Import and setup of ports in the PCB model in SIWAVE (recorded animation)



# Appendix :

1) https://www.analog.com/en/products/lt8610.html#

2) Din Kow Sun, Zoltan Cendes, and Jin-Fa Lee: „Adaptive Mesh Refinement, h-Version, for Solving Multiport Microwave Devices in Three Dimensions“, IEEE TRANSACTIONS ON MAGNETICS, VOL. 36, NO. 4, JULY 2000, pp 1596-1599

3) https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/dl_common_library/dl_manuals/gb_1/e/env216_1/ENV216_UserManual_en_04.pdf

4) https://www.we-online.com/catalog/en

5) https://redexpert.we-online.com/redexpert/#/

6) https://www.ansys.com/applications/emi-emc

***Special thanks to Mr. Frank Puhane/Würth Elektronik eiSos GmbH & Co. KG for providing layout data , measurement data and helpful discussions***