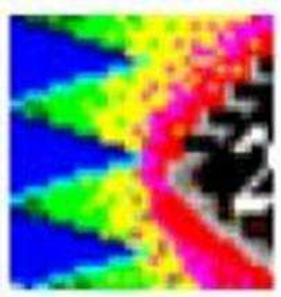
# Learning EMC of ICs with IC-EMC



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EMC EUROPE 2017
ESEO - ANGERS (FRANCE)
04 - 08 Sept.
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# Outline

1. History of IC-EMC
2. Book Basis of EMC of ICs
3. Overview of IC-EMC
4. What can we learn with IC-EMC ?

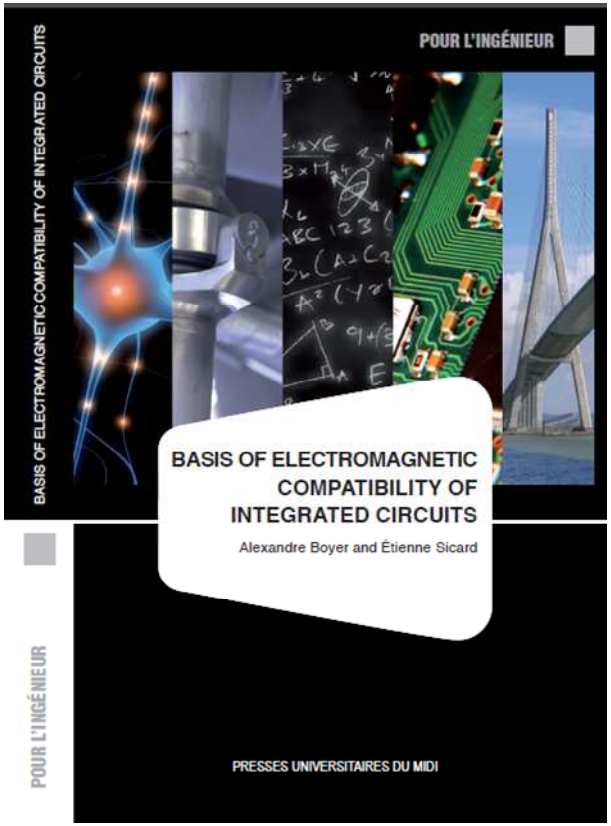
# History of IC-EMC

- ✓First development in 2004 by E. Sicard
- ✓Initial purpose: automatic post-processing of electrical simulation results, demonstration of research results through case studies
- ✓First trainings in 2007 (basic concepts illustration, simple practical work)
- ✓2012: 5-days training for PhD, engineers, teachers, sponsored by Eurodots program
- ✓2016-2019: ERASMUS+ project MECA (Microelectronics Cloud Alliance)
- ✓2017: IC-EMC v2.9 release and publication of the book “Basis of Electromagnetic Compatibility of Integrated Circuits”

*Training in APEMC2010*

# Book Basis of EMC of ICs

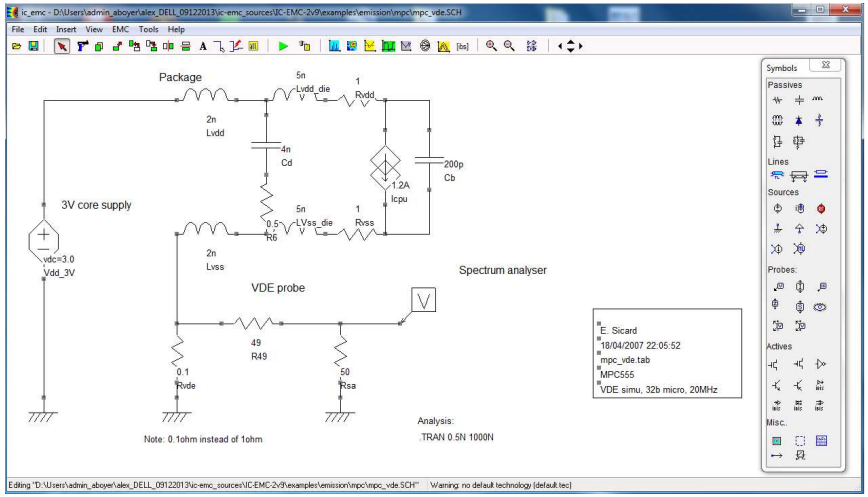
- ✓Published by Presses Universitaires du Midi
- ✓Learning how to model ICs and their surrounding environment (PCB) to simulate emission, immunity and signal integrity issues
- ✓Free companion tool IC-EMC to illustrate theoretical concepts as well as practical case studies
- ✓More than 40 exercises and practical works
- ✓Addressed concepts:
  - basics for EMC
  - overview of EMC issues
  - modeling of passive devices and interconnects
  - IC technology trends
  - EMC meas. for ICs
  - I/O modeling
  - IC models for emission and susceptibility

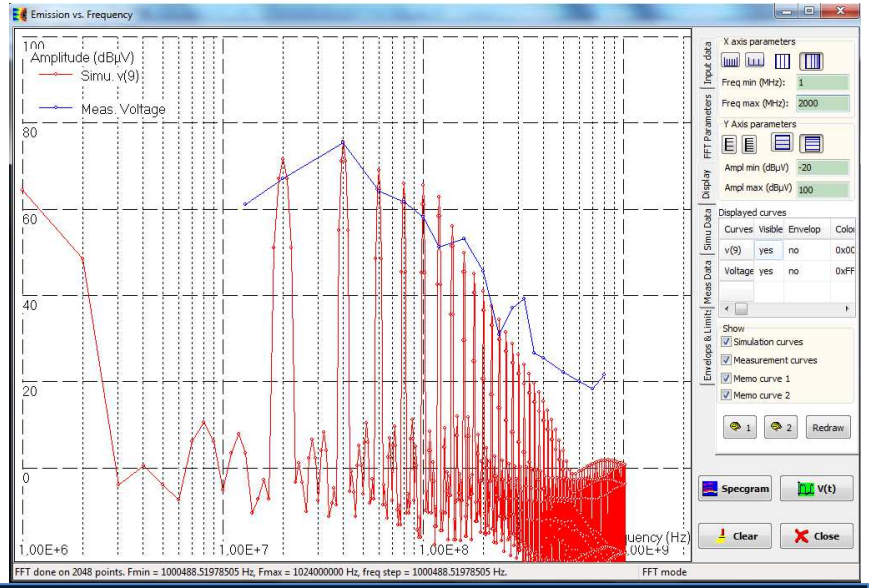



*pum.univ-tlse2.fr/~Basis-of-electromagnetic~.html*

# Overview of IC-EMC

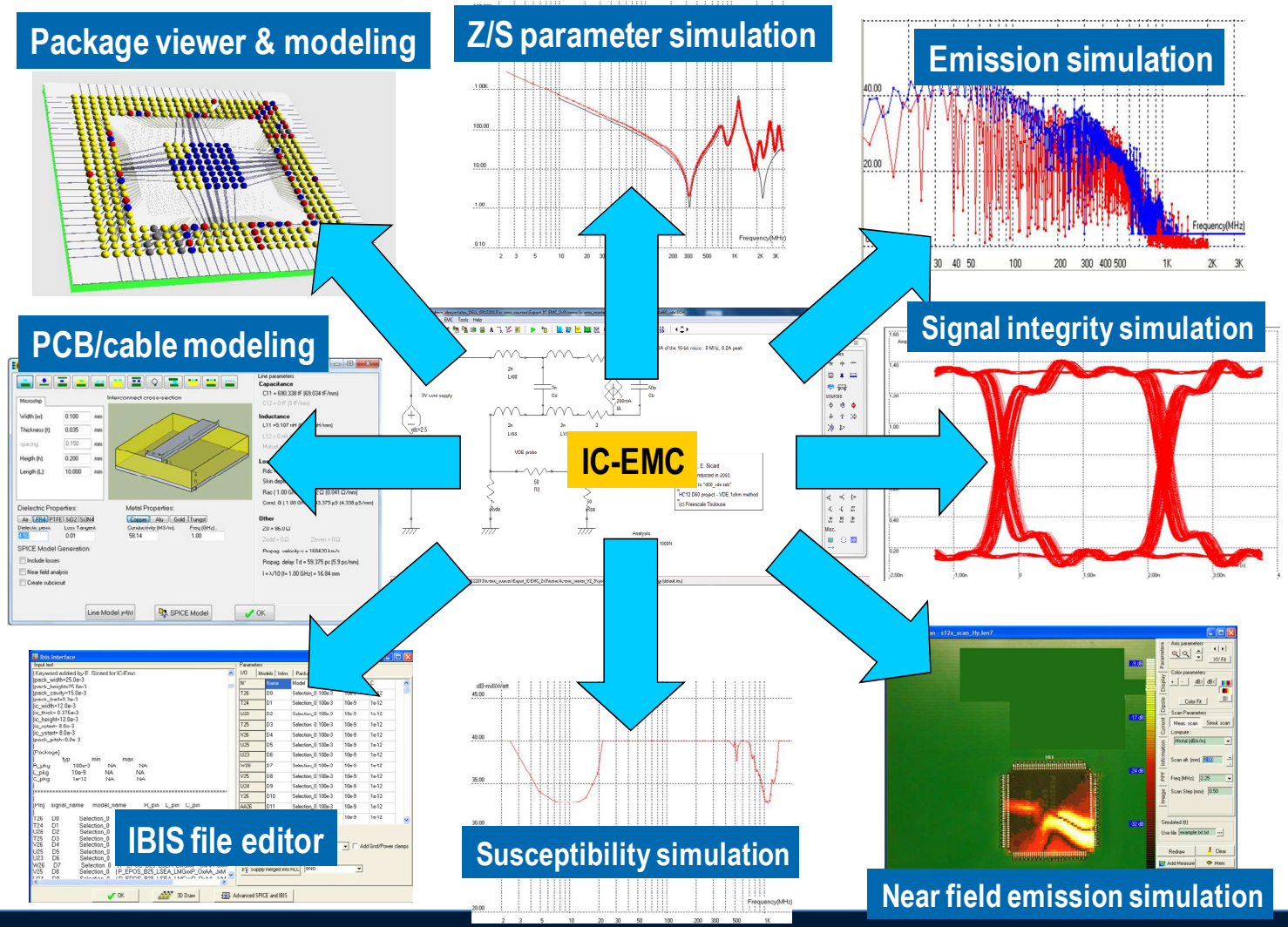
- ✓Free simulation software dedicated to the EMC of ICs issues:
  - ✓help the user to develop EMC models rapidly for an efficient evaluation of EMC performances
  - ✓illustrate EMC issues related to ICs for educational purpose of basic notions and modelling techniques related to EMC
- ✓Executable files, application notes, exercises solutions available at [www.ic-emc.org](http://www.ic-emc.org)



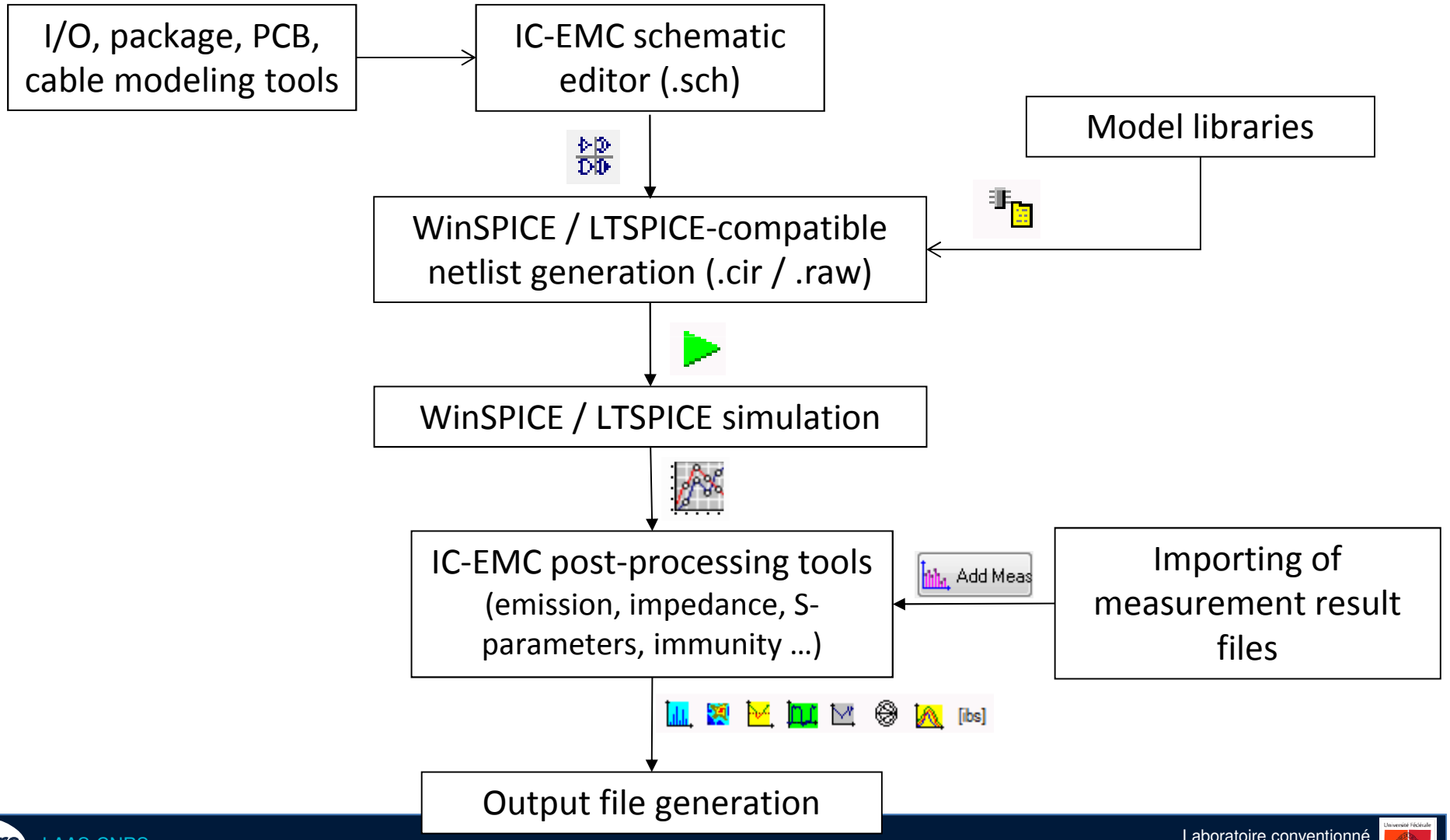
# Overview of IC-EMC

## Main functionalities



# Overview of IC-EMC

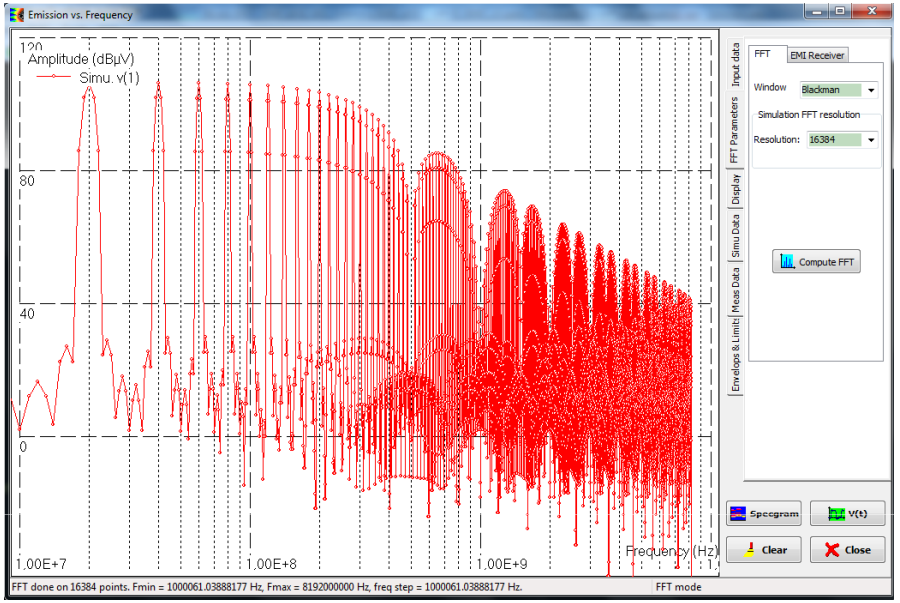
✓Simulation flow based on SPICE simulation results:



# What can we learn with IC-EMC?

## FFT and EMI receiver

- ✓Computation of signal frequency content based on FFT (typical algorithm for emission simulation)
- ✓Number of points and windowing can be changed
- ✓Short-term FFT for time-frequency analysis
- ✓Simulation of an EMI receiver (RBW from 10 kHz to 10 MHz, peak and average detector)

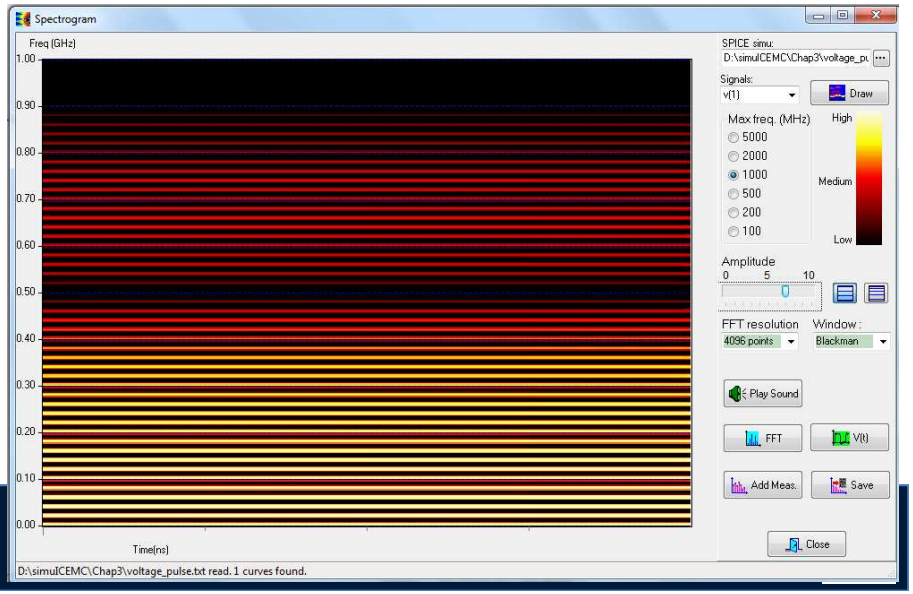



Learning outcomes:

→Learn how to configure FFT for emission simulation

→Analyze the frequency content of signals, relation with timing characteristic

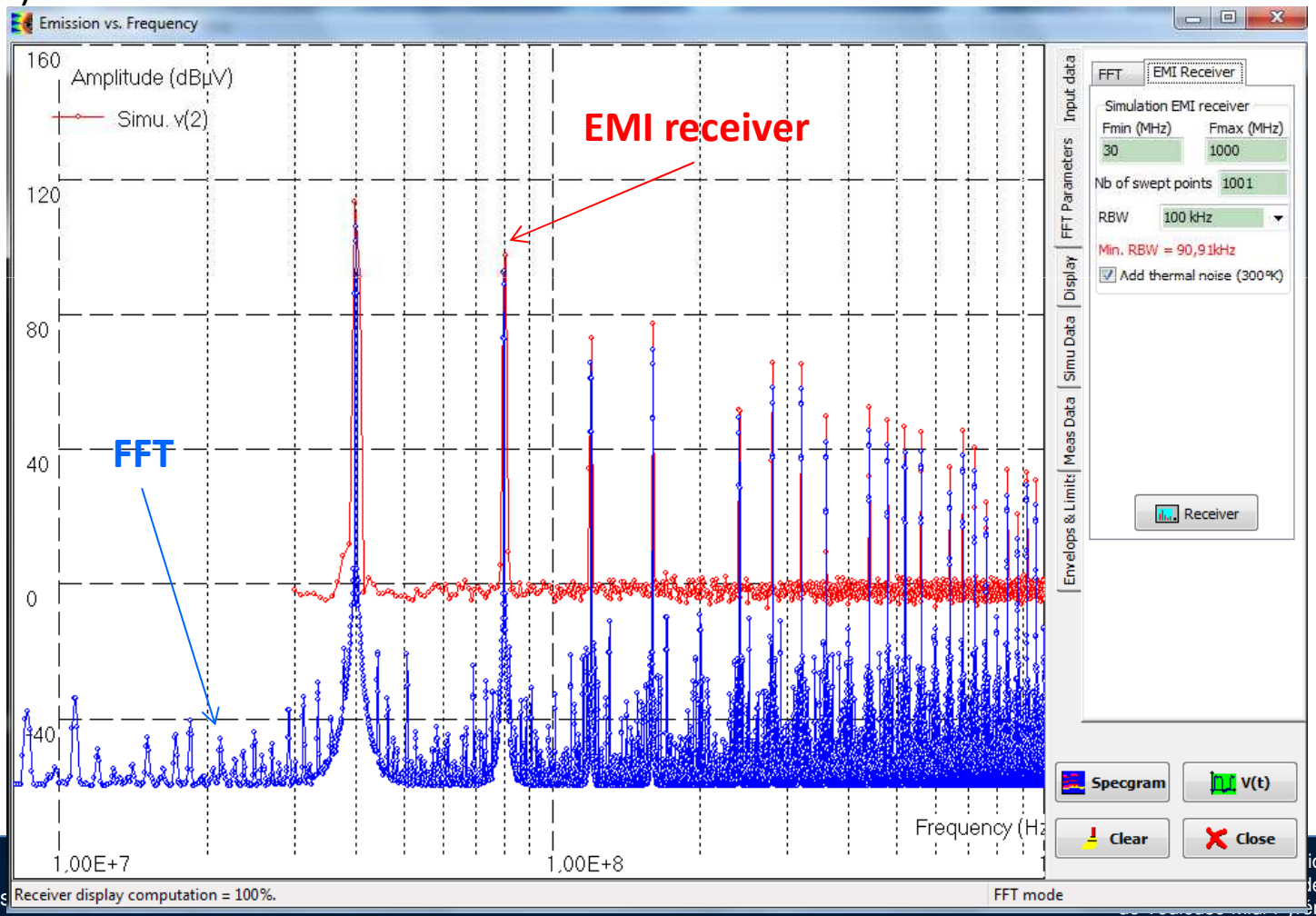
→Understand the impact of RBW, sweep time, detector of an EMI receiver



# What can we learn with IC-EMC?

## FFT and EMI receiver

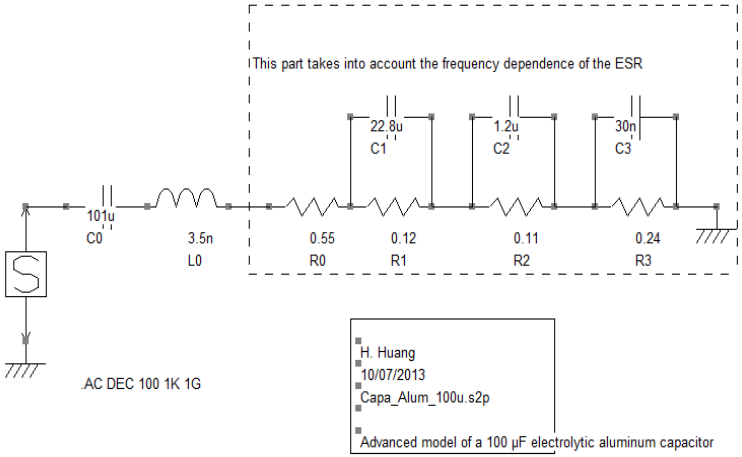
✓Example: FFT (65536 points) vs. EMI receiver mode (30 – 1000 MHz, RBW = 100 kHz, peak detector)



# What can we learn with IC-EMC?

## Modeling impedance of components

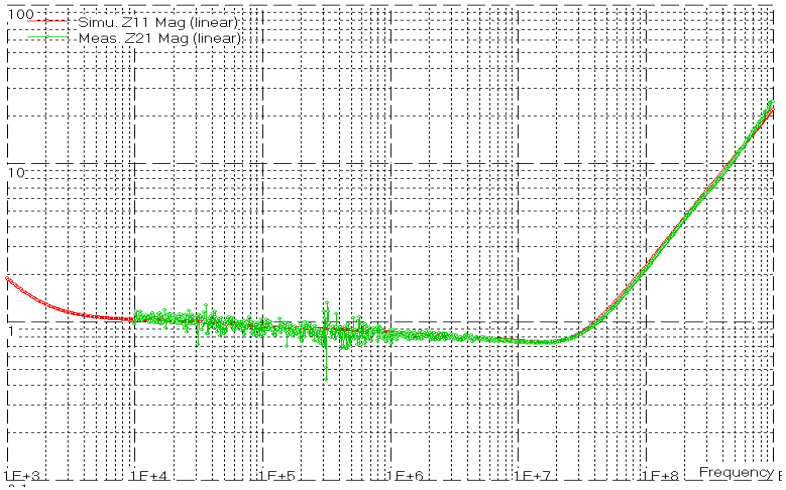
✓S and Z parameter computation, up to four port
✓Modeling of passive devices, interconnects, IC PDN, measurement equipments…
✓Touchstone import / export
✓Mixed-mode representation (ideal for common-mode and differential-mode representation)




Model of 100 µF electrolytic capacitor

Learning outcomes:

→ Clarify the role of filtering components (ferrite, choke, capacitor…)
→Show non-ideal frequency behavior of passive devices
→Learn to build equivalent electrical model of linear passive devices
→Clarify the role of stray components on EMC performances (e.g. filtering, decoupling, IC package)

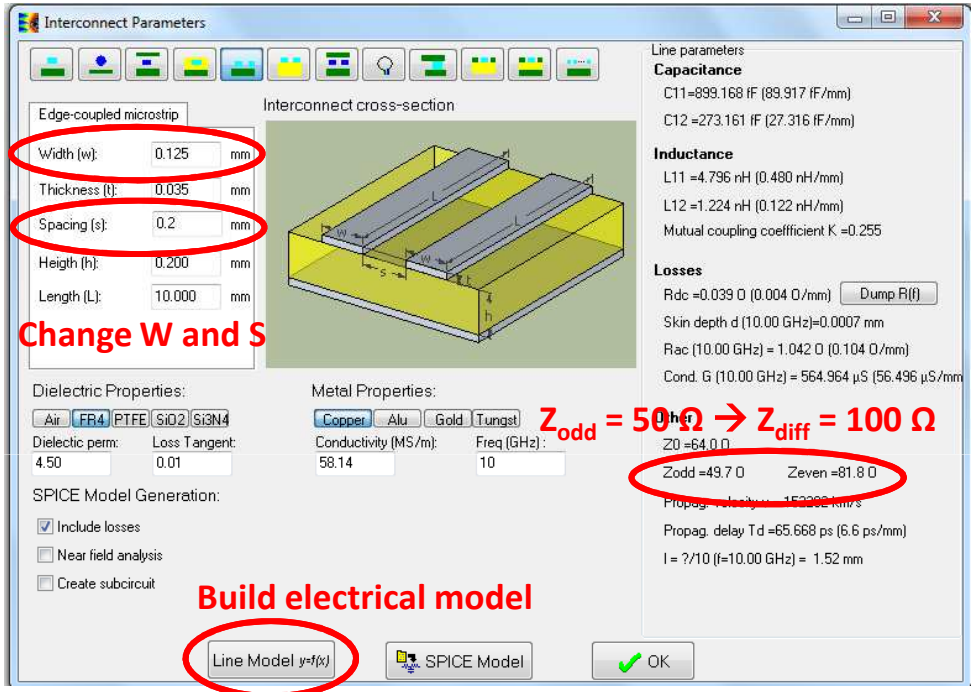



Comparison between meas. and simu.

# What can we learn with IC-EMC?

## PCB interconnect modeling

✓Microstrip line, edge-coupled stripline, coplanar waveguide, via, rectangular power-ground plane pair …
✓Line parameter extraction
✓Characteristic impedance extraction
✓Automatic generation of electrical model (including freq-dependent losses)



$Z_{odd}$ = 50 Ω → $Z_{diff}$ = 100 Ω

Matching and modeling a differential line

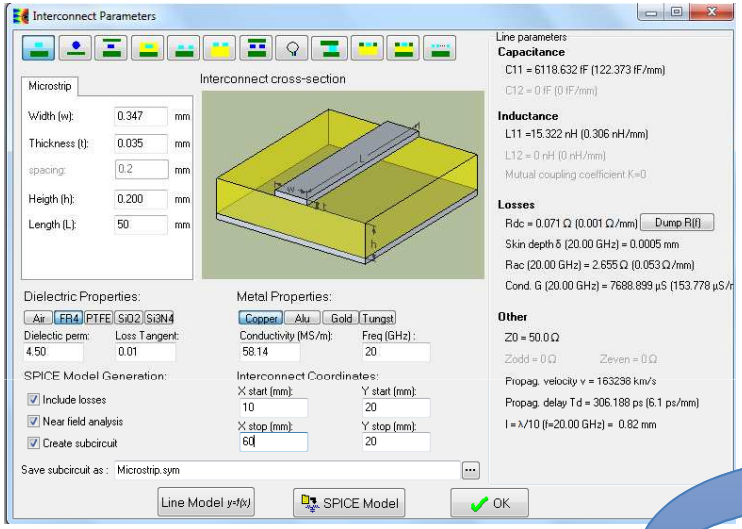
Learning outcomes:

→Select dimensions for impedance matching
→Analyze physical behavior (eg. line or plane resonance, increase of losses at high freq.)
→Canonical line model for SI simulation
→Estimation of radiation of PCB lines

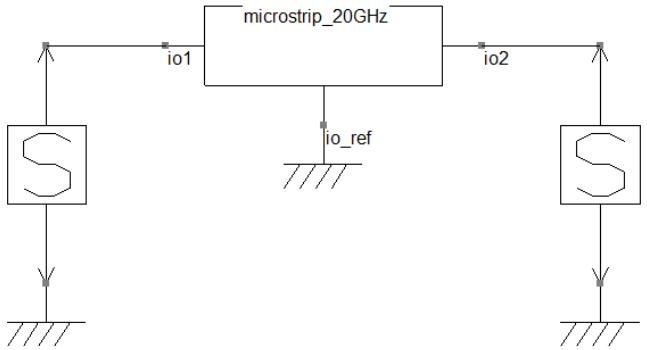
# What can we learn with IC-EMC?

## PCB interconnect modeling

✓50 Ω microstrip line model up to 20 GHz



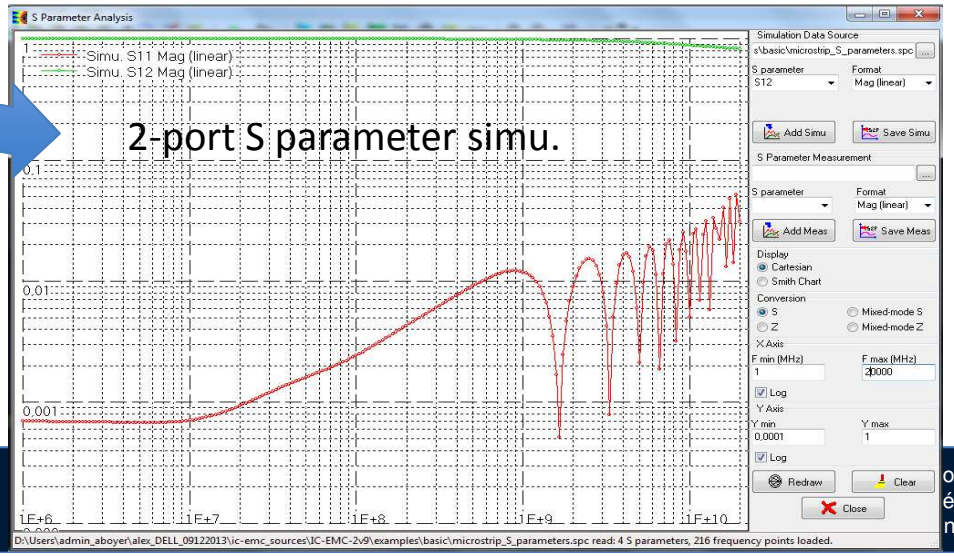

Electrical model




.AC DEC 50 1MEG 20G

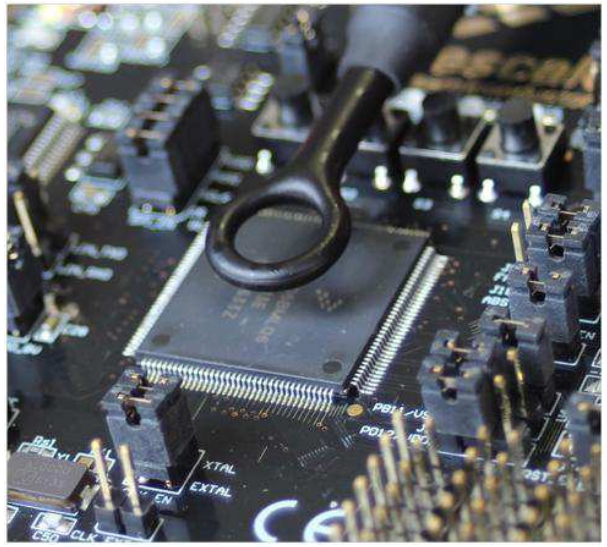
microstrip_20GHz is a SPICE subcircuit ge

It describes a microstrip line with: w=0.347 r



# What can we learn with IC-EMC?

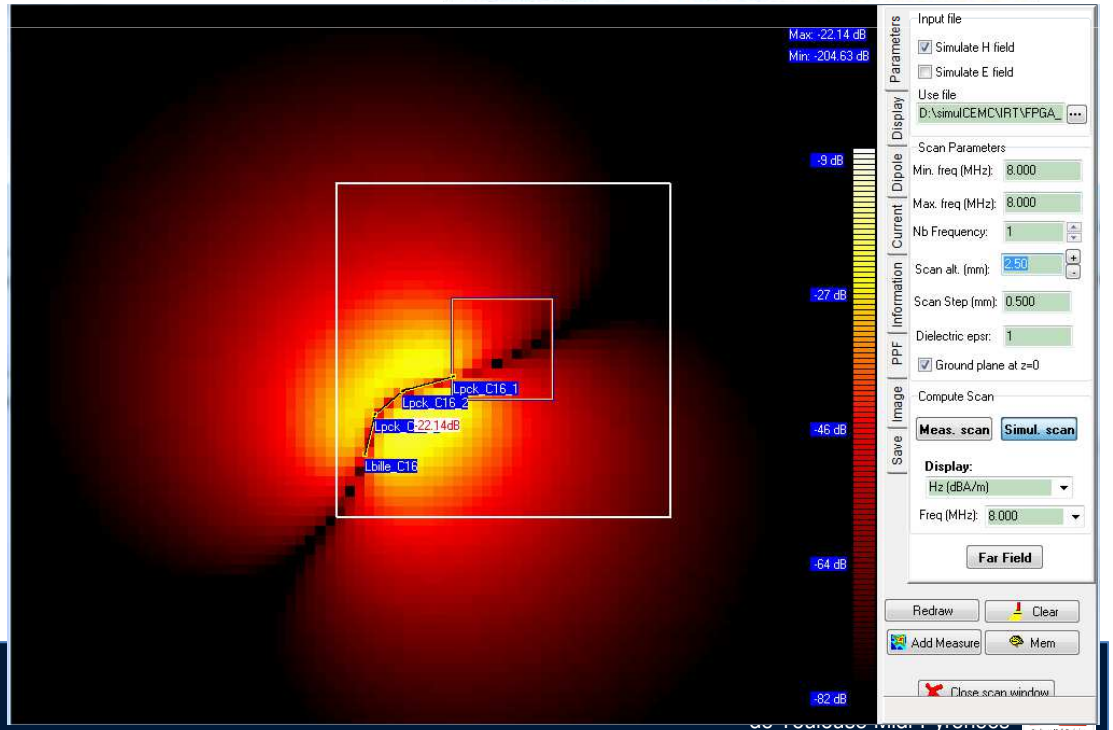
## IC and PCB radiation



✓Rapid simulation of near-field emission from SPICE simulation result
✓Computation of amplitude and phase of E and H fields
✓Computation of far-field emission

<u>Learning outcomes:</u>

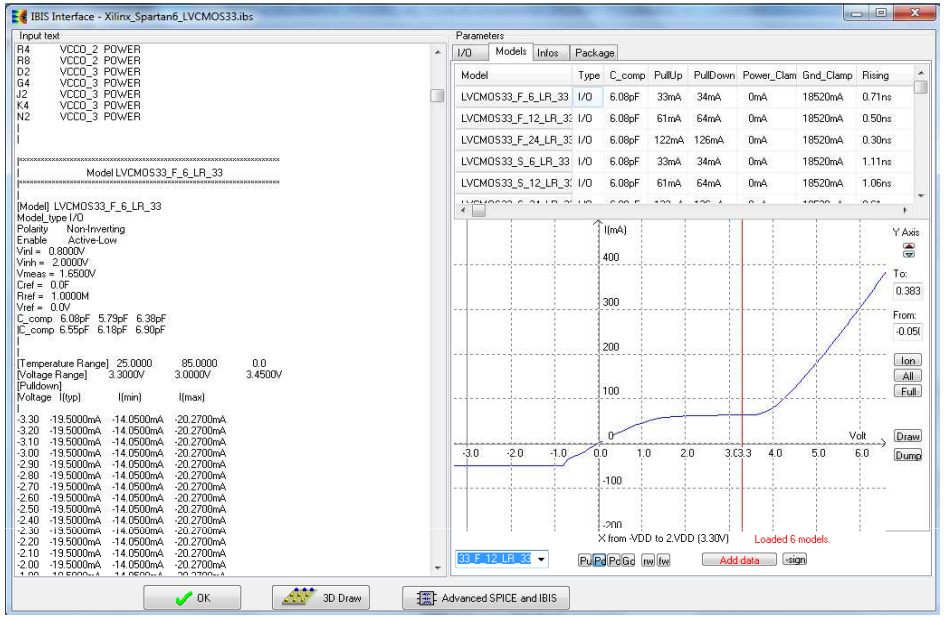
→Radiation of PCB or package interconnects
→Electric vs. magnetic field source
→Rapid decrease of near-field emission with distance
→Illustrate simple techniques to reduce radiation



# What can we learn with IC-EMC?

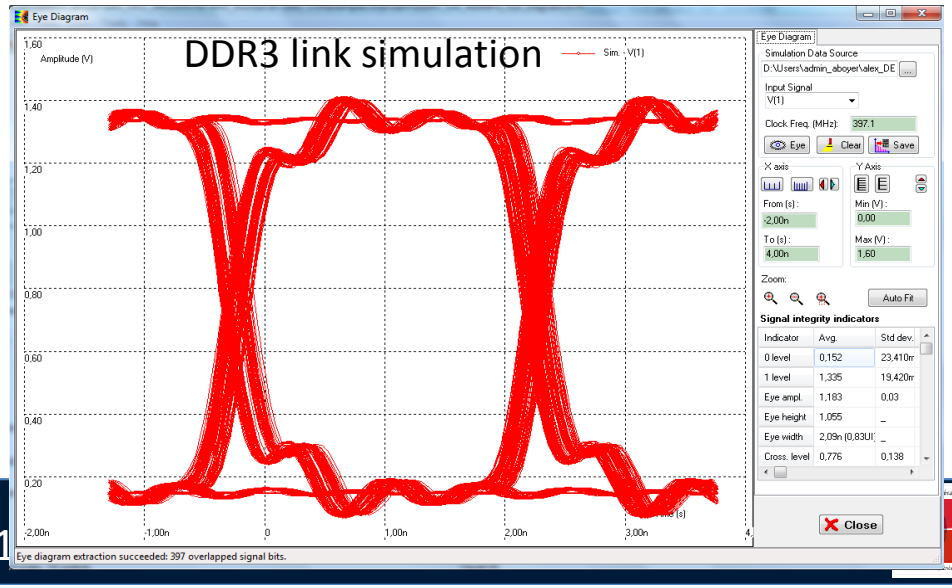
## IBIS interface and signal integrity simulation

- ✓IBIS file editor
- ✓Plot I/O characteristics (I/V, V(t))
- ✓Extract I/O model
- ✓Transient signal characteristics
- ✓Eye diagram simulation




Learning outcomes:

→Analyze the structure and content of IBIS file
→Build equivalent electrical model of input/output buffer
→Visualize signal integrity issues
→Understand eye diagram
→Influence of line matching, buffer characteristics on signal integrity

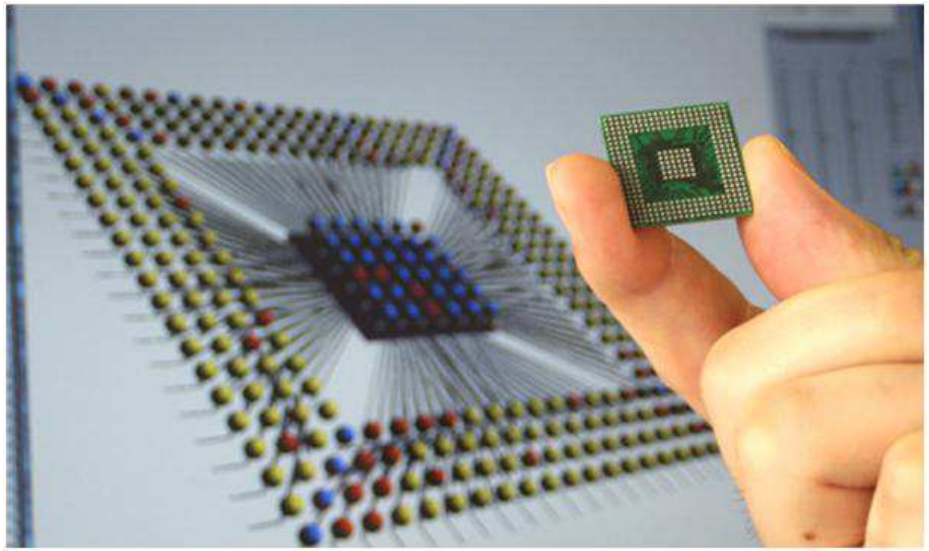


# What can we learn with IC-EMC?

## Package modelling

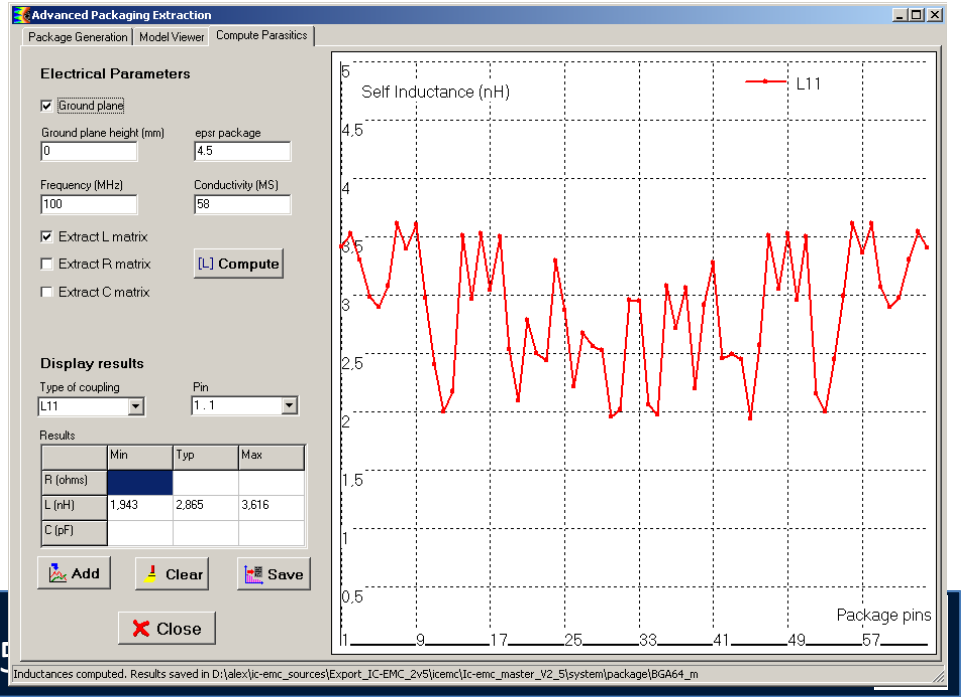
✓Construction of 3D model of IC package from pin-out and package dimensions

✓Extraction of electrical model



<u>Learning outcomes:</u>

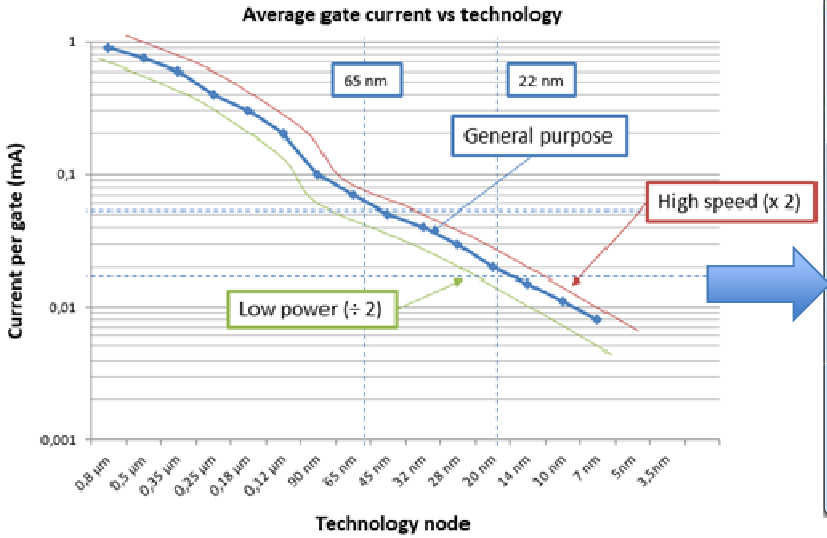
→Observe the placement of Vdd/Vss pairs at package level
→Estimate the order of stray inductance and capacitance of IC package pins
→Analyze the influence of Vdd/Vss pair position and number on PI / CE / RE



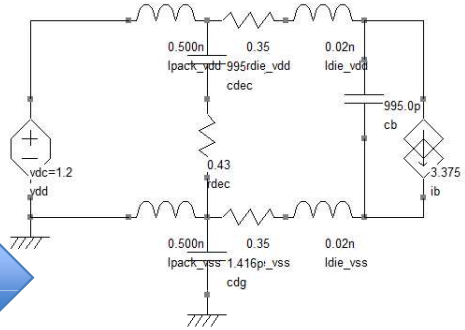
# What can we learn with IC-EMC?

## ICEM Expert

✓Estimation of 1st order model of digital ICs from technological information (ICEM model)








Rapid ICEM construction

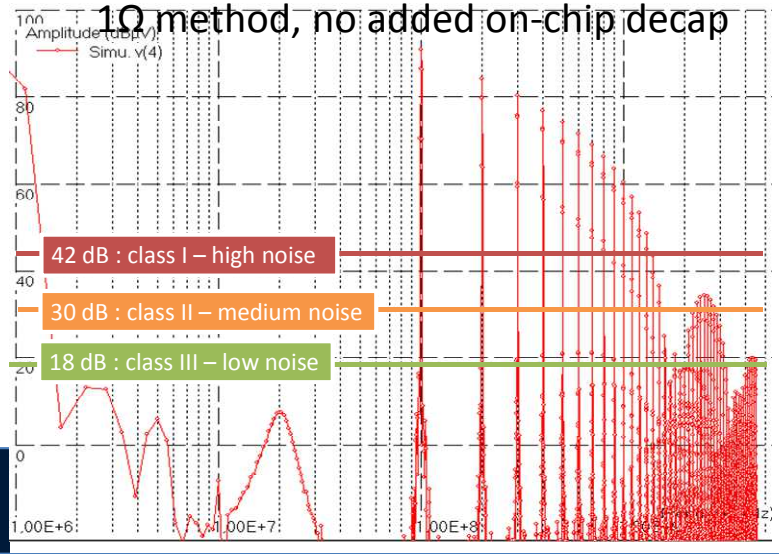
<u>Learning outcomes:</u>

→Rapid simulation of IC conducted/radiated emission

→Analyze the influence of technology on emission issues

→Evaluate the influence of on-chip capa, package inductance, on-chip resistance on emission issues

1Ω method, no added on-chip decap



# What can we learn with IC-EMC?

## Emission simulation example: Efficient decoupling



✓Use of IC emission model to optimize decoupling at PCB level

✓Requirements on power integrity and conducted emission

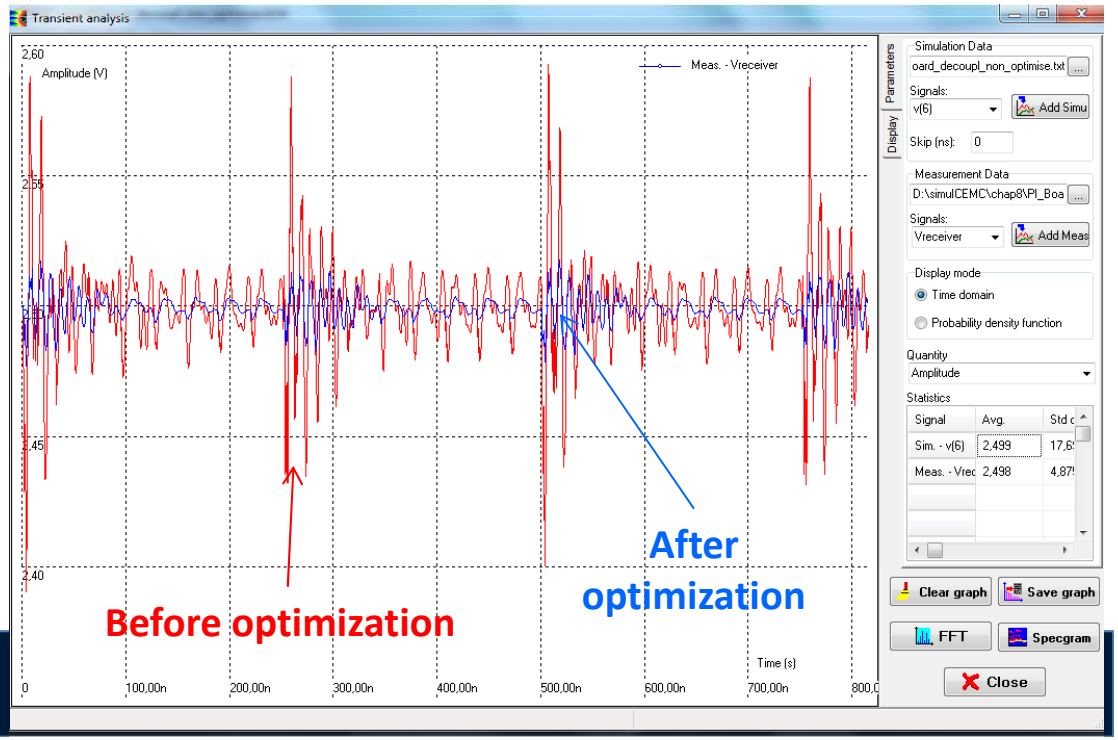
**~ EXERCISE NO. 5 – SILENTCORE DECOUPLING BUDGET**

*The SilentCore microcontroller is dedicated to high-reliability applications requiring very low electromagnetic noise. The circuit is designed in CMOS 65 nm low-power technology. It includes a 32-bit microprocessing unit. An on-chip PLL provides an internal operating clock running at 80 MHz from an external 16 MHz crystal oscillator. The microcontroller includes SRAM and Flash memories, several peripherals and 3 ports of 8 I/O lines.*
*The circuit is mounted in a TQFP64 package. The nominal power supply voltage of this circuit is 2.5 V. It is provided by several power and ground pins:*

- *Vdd1/Vss1 and Vdd2/Vss2 for the CPU*
- *VddIO1/VssIO1 and VddIO2/VssIO2 for I/O buffers*
- *VddPLL/VssPLL for the internal oscillator and PLL*
- *VddA/VssA for analogue blocks*

Learning outcomes:

→Create IC, PCB, ceramic capacitor models
→Manage target impedance
→Observe the actual efficiency of decoupling capacitor (role of ESL, ESR,)
→Strategy to decouple board
→Influence of number and values of decoupling capacitors



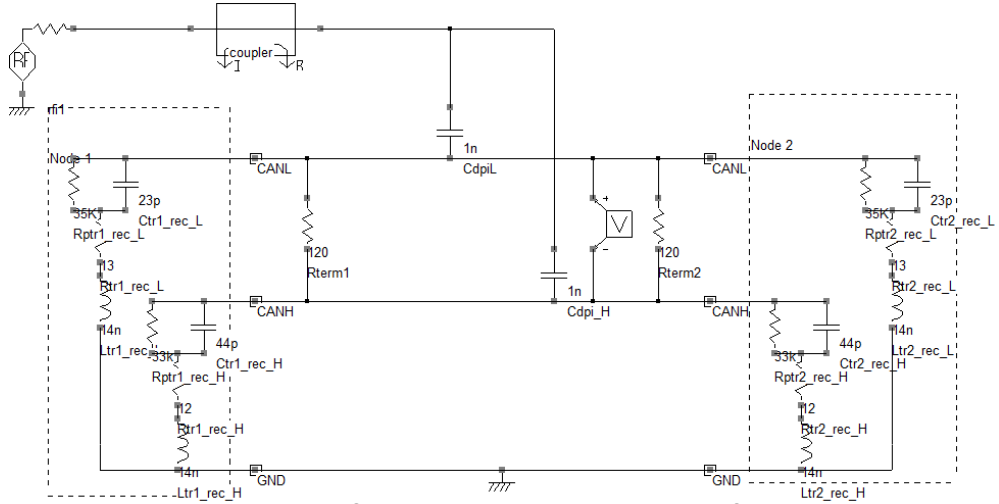
# What can we learn with IC-EMC?

## RF susceptibility simulation: Virtual CAN bus test bench

✓Build simple IC susceptibility model including PDN, non-linear elements, failure detection

✓Simulate susceptibility to harmonic disturbance

✓Examples of practical works: Simulation of DPI/BCI of CAN bus




*Model of DPI on CAN bus interface*

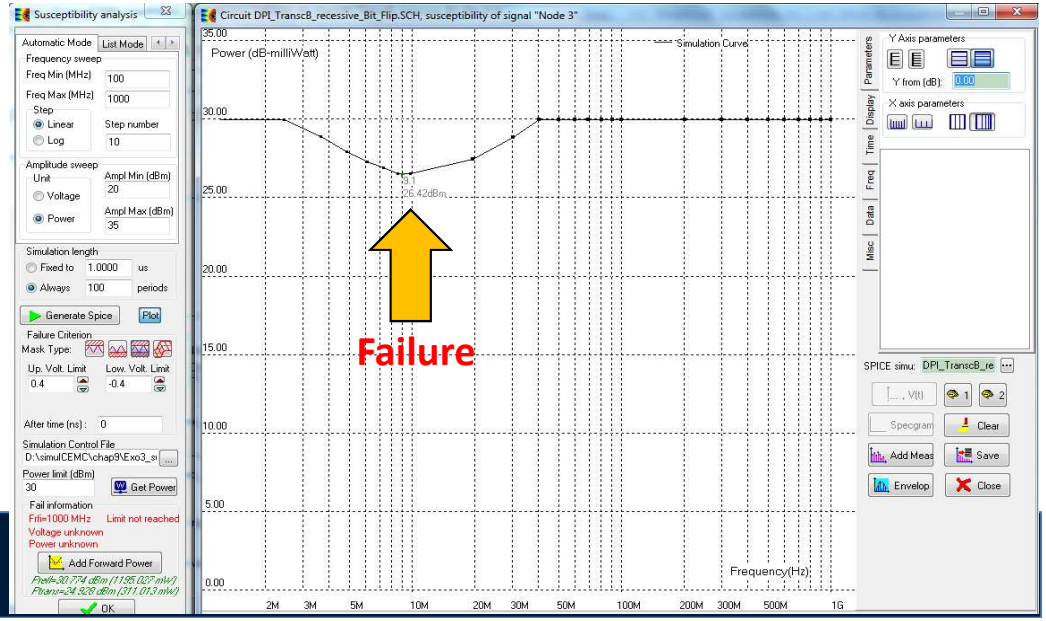
Learning outcomes:

→Model of typical IC immunity set-up

→Model equivalent impedance of CAN interface pins and bus

→Common-mode vs. differential-mode disturbance

→Influence of symmetry



# Acknowledgments


PUM Presses universitaires du Midi

Micro Electronics Cloud Alliance

Co-funded by the Erasmus+ Programme of the European Union


✓We wish to warmly acknowledge all our former PhD students who developed numerous case studies with IC-EMC.

✓Software, user's manual, application notes, correction of exercises and video available on [www.ic-emc.org](http://www.ic-emc.org)

# Thank you for your attention