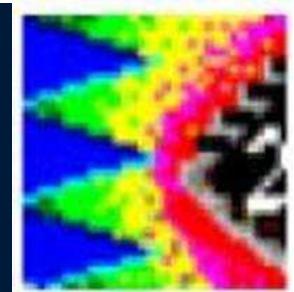


Learning EMC of ICs with IC-EMC



A. Boyer^{1,2}, E. Sicard²

¹CNRS, LAAS, 7 avenue du colonel Roche, 31400 Toulouse, France

²INSA de Toulouse, 135 avenue de Rangueil, 31077 Toulouse, France



www.ic-emc.org

- 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”

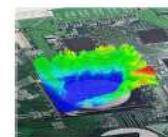


Training in APEMC2010



A One-Week Training in Electromagnetic Compatibility of Integrated Circuits

Sept 18-22, 2017



A unique practical course to take part to a global integrated circuit emission and susceptibility reduction strategy

Audience
EMC engineers, IC users, IC designers, PhD students in electronics, researchers in electronics



Description of the Course
A quality-labeled five-day course focused on electromagnetic compatibility of integrated circuits is proposed by INSA Toulouse, France:

- Basic concepts: trends, influence on IC technology on EMC, specific units, impedance, margins, etc.
- Parasitic emission, with focus on IEC 61967 measurement methods
- Susceptibility, with focus on IEC 62132 measurement methods
- Modeling for predicting EMC (IEC 62433), based on standards such as IBSI, ICEM and ICIM
- EMC guidelines for improved emission and immunity to interference.



Practical sessions
Afternoons are dedicated to practical sessions including an access to a laboratory for hands-on experiments of IC emission and immunity characterization. Illustrations of all concepts are made using IC-EMC www.ic-emc.org freeware including unique features and tools for efficient EMC simulations of integrated circuits.



Etienne SICARD
Professeur at INSA
Toulouse, Society Distinguished
Lecturer
<http://www.etienne-sicard.fr>
Etienne.sicard@insa-toulouse.fr



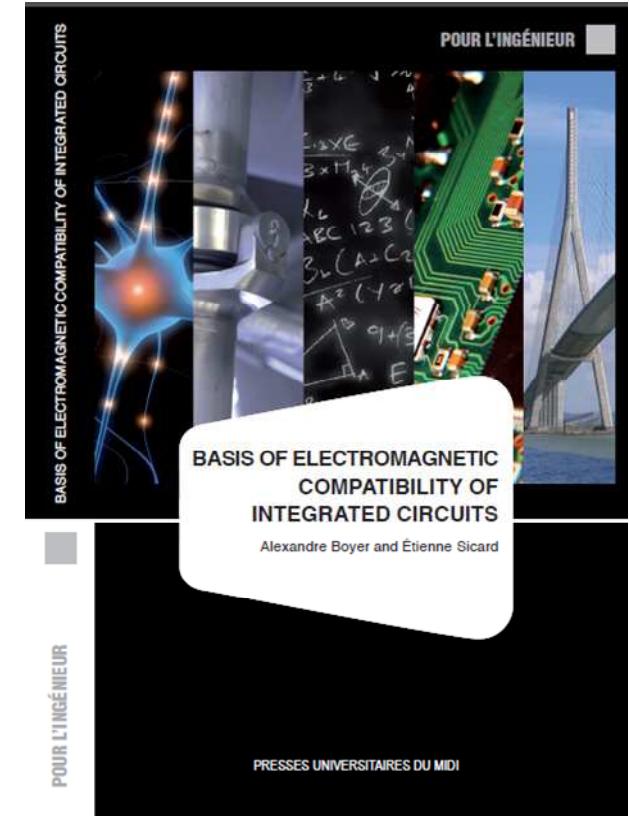
Alexandre BOYER
Senior lecturer
LAAS-CNRS
alexandre.boyer@ensat.toulouse.fr

More information: www.ic-emc.org - Trainings
Registration fee: free for Erasmus+ Knowledge Alliance MECA Partners (8 attendees max.)
Contact for registration: ic@insa-toulouse.fr

INSA TOULOUSE
105 avenue de Narbonne
31 077 Toulouse Cedex 4 FRANCE
Tel +33 5 34 66 95 12 - Fax +33 320 61 00 99
www.insa-toulouse.fr



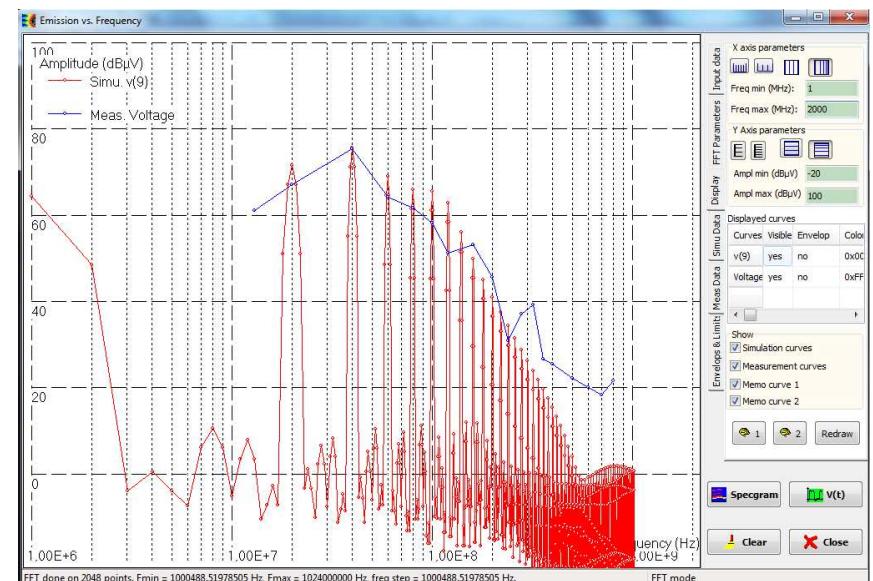
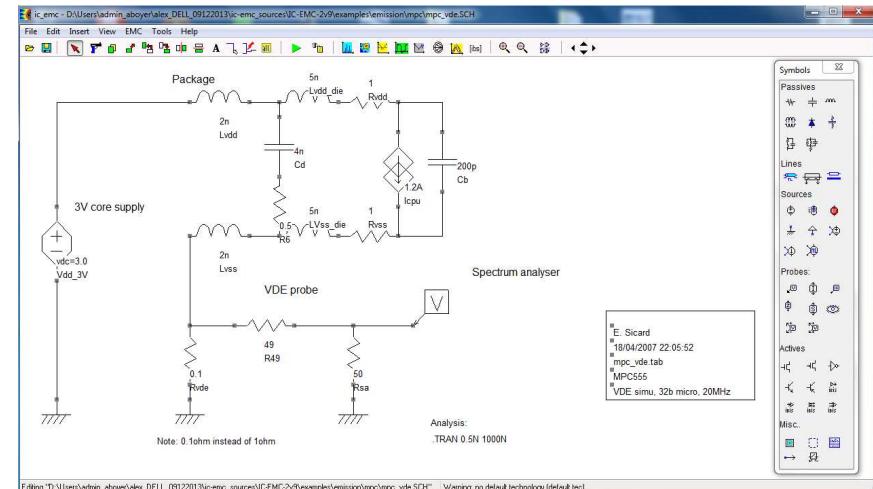
- ✓ Published by Presses Universitaires du Midi
- ✓ Learning how to model ICs and their surrounding environment (PCB) to simulate emission, immunity and signal integrity issues
- ✓ Free companion tool IC-EMC to illustrate theoretical concepts as well as practical case studies
- ✓ More than 40 exercises 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

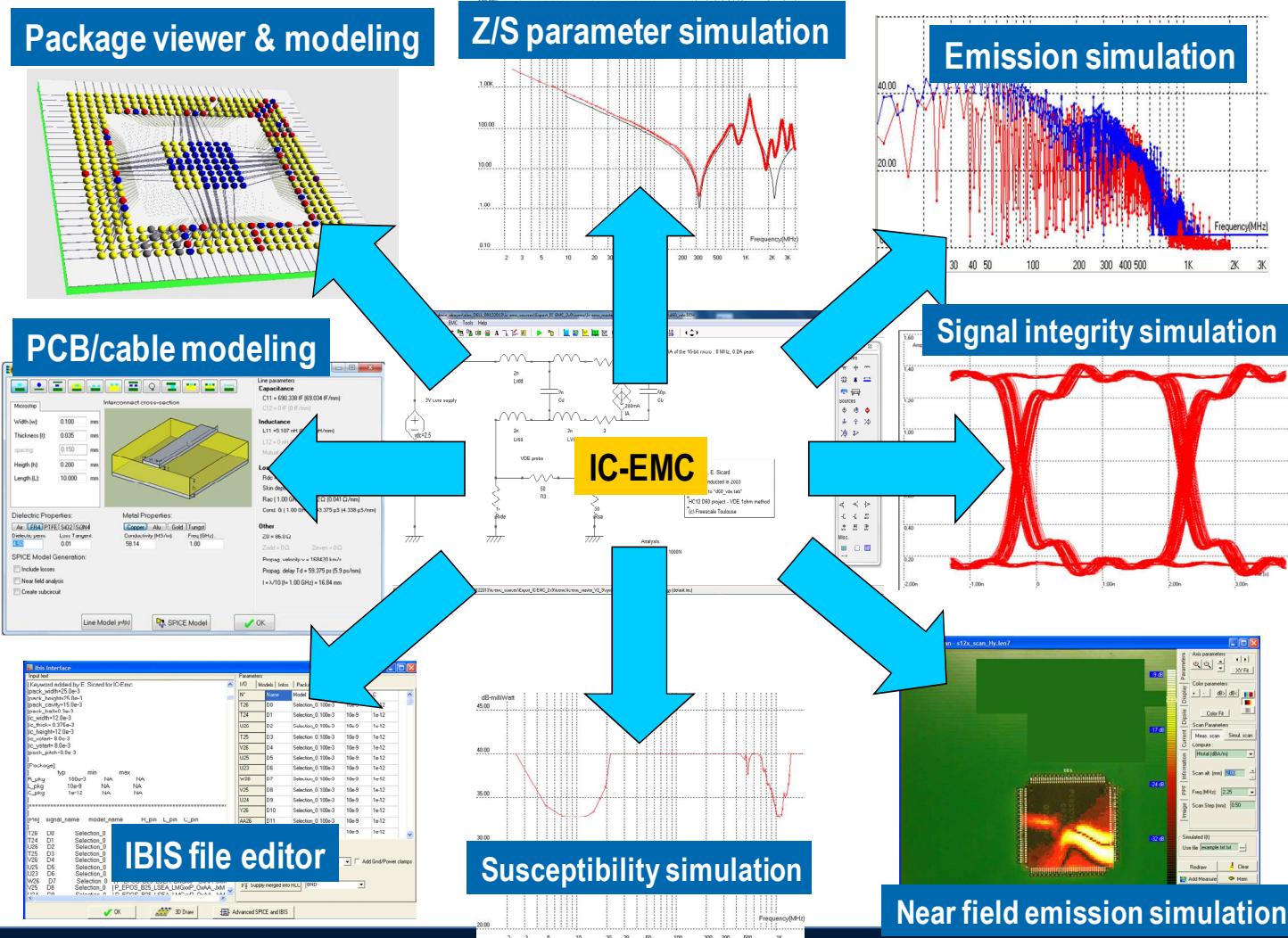
Overview of IC-EMC

- ✓ 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



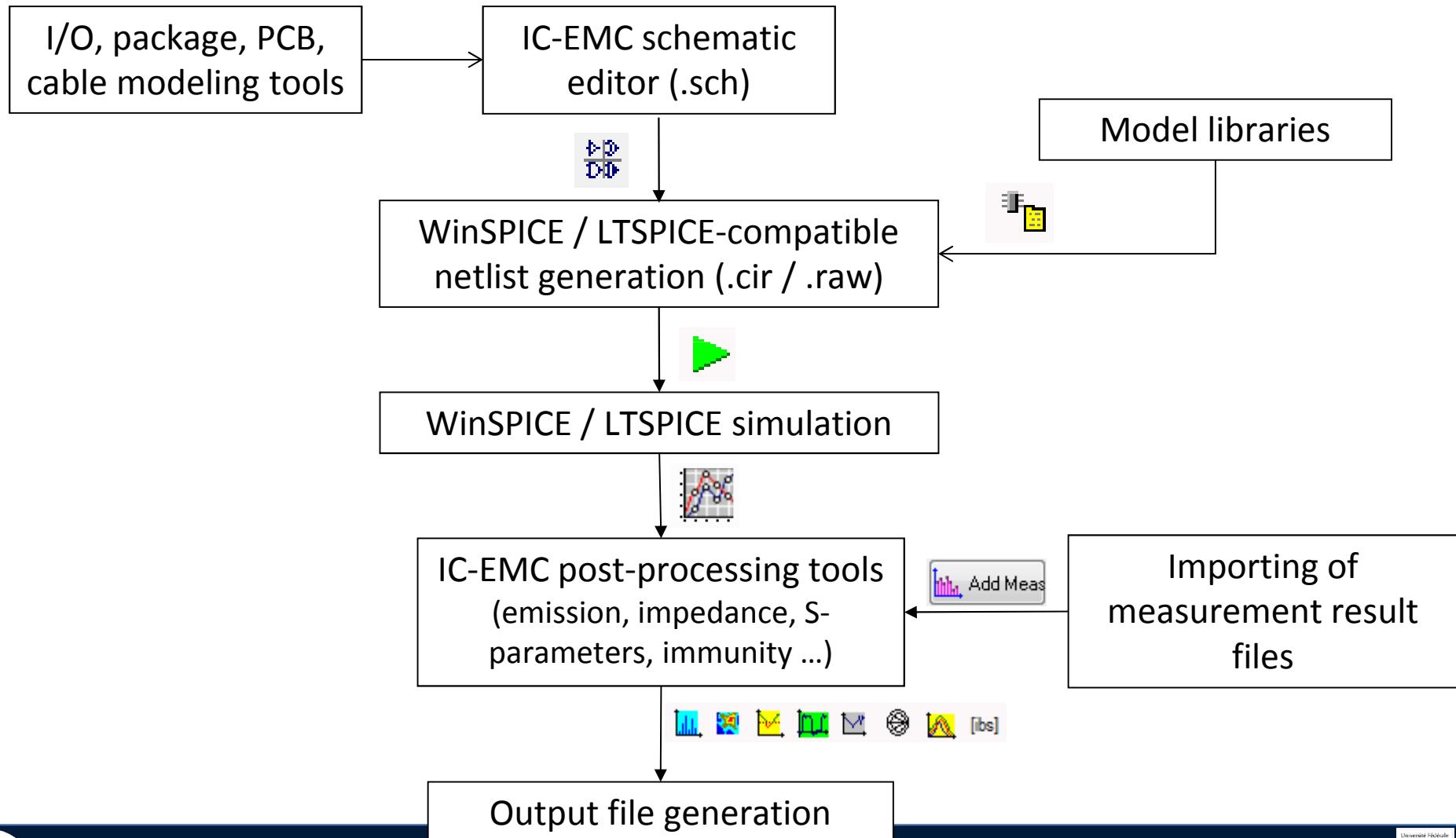
Main functionalities

Overview of IC-EMC



Overview of IC-EMC

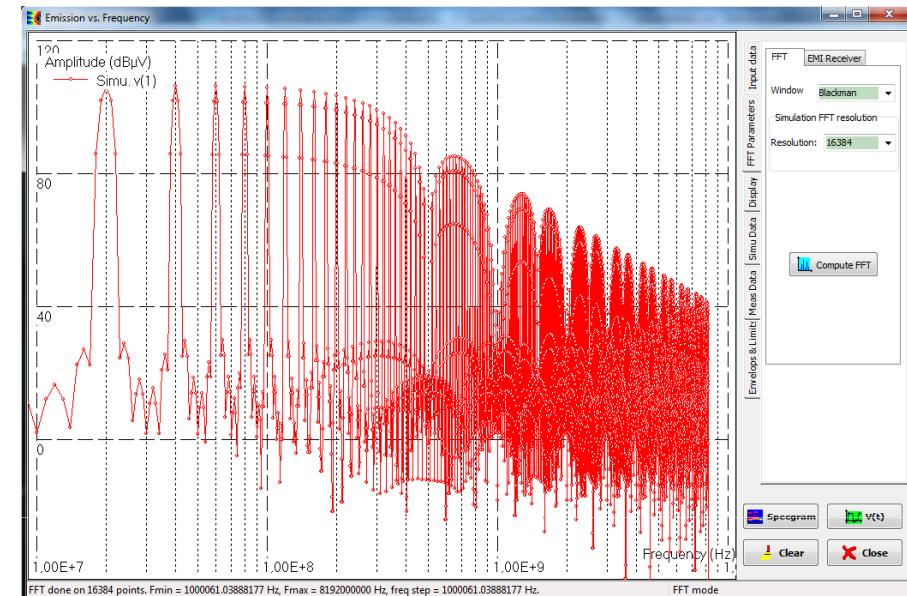
✓ Simulation flow based on SPICE simulation results:



FFT and EMI receiver

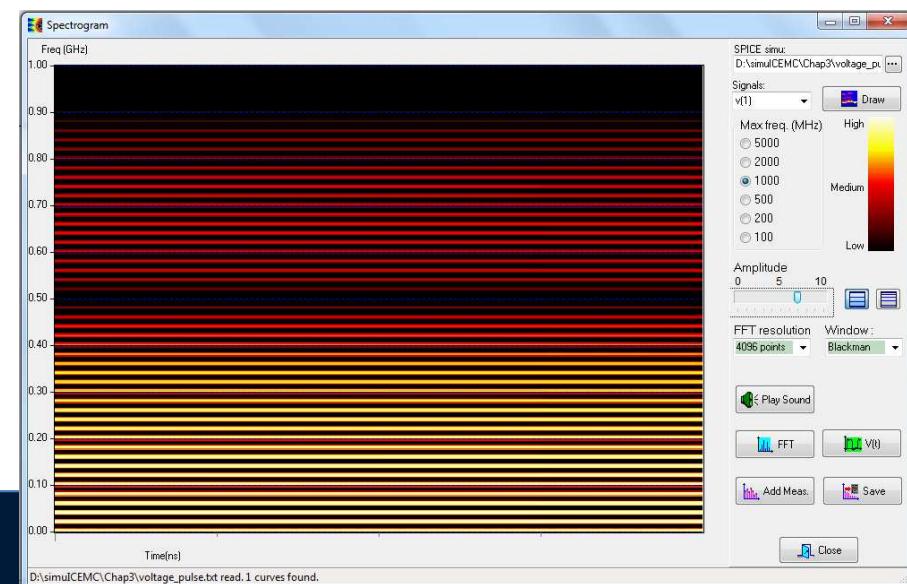
- ✓ Computation of signal frequency content based on FFT (typical algorithm for emission simulation)
- ✓ Number of points and windowing can be changed
- ✓ Short-term FFT for time-frequency analysis
- ✓ Simulation of an EMI receiver (RBW from 10 kHz to 10 MHz, peak and average detector)

What can we learn with IC-EMC?



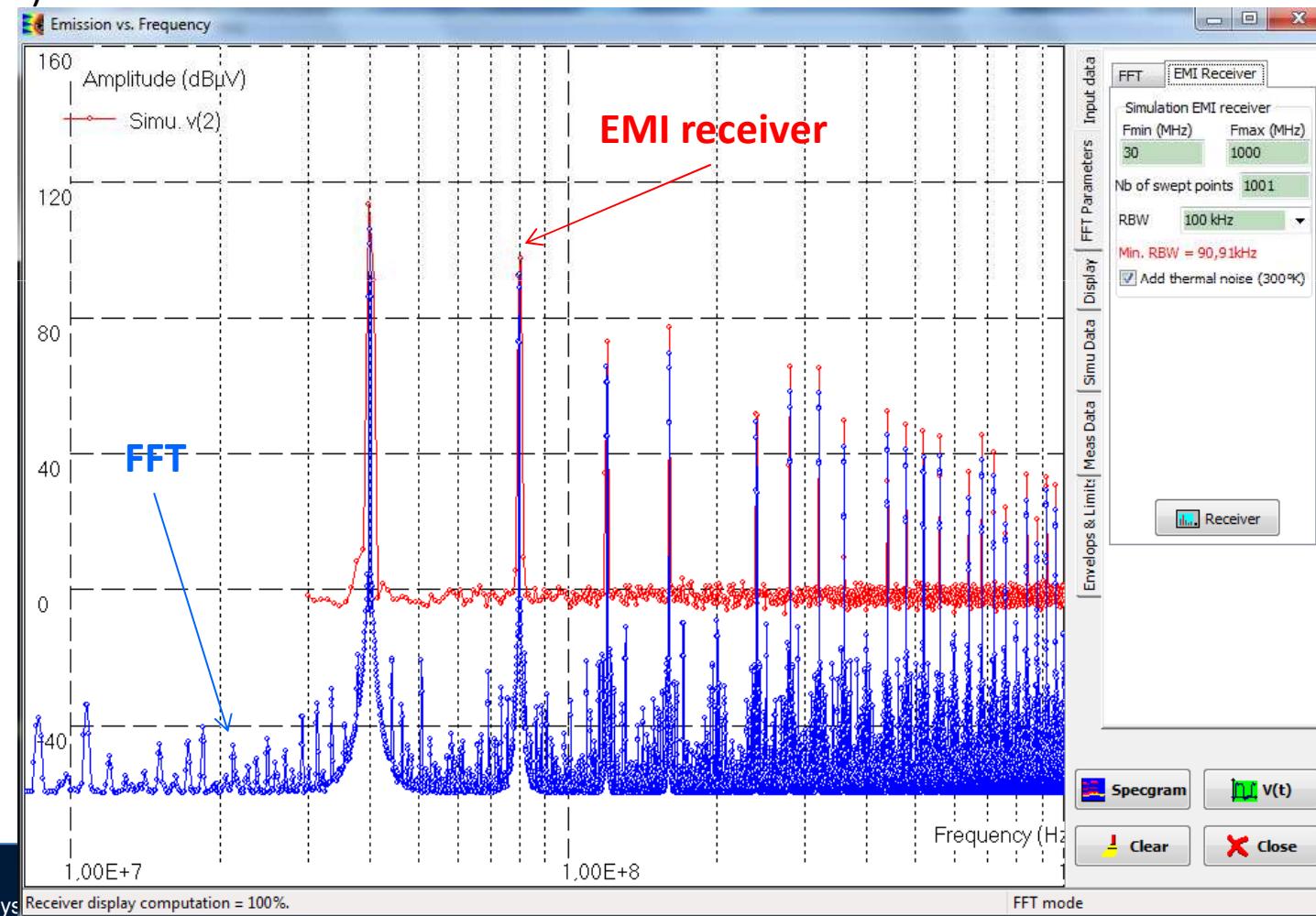
Learning outcomes:

- 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



FFT and EMI receiver

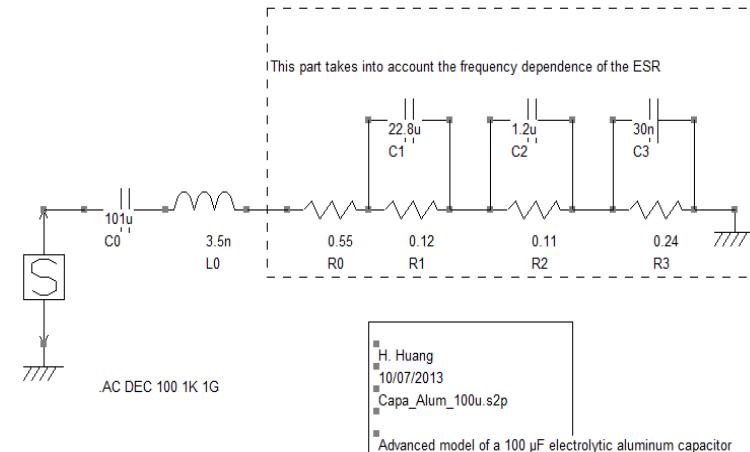
- ✓ Example: FFT (65536 points) vs. EMI receiver mode (30 – 1000 MHz, RBW = 100 kHz, peak detector)



What can we learn with IC-EMC?

Modeling impedance of components

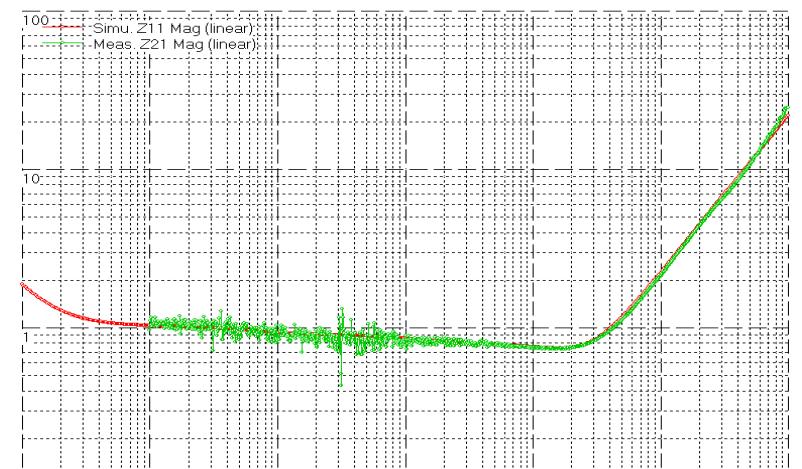
- ✓ S and Z parameter computation, up to four port
- ✓ Modeling of passive devices, interconnects, IC PDN, measurement equipments...
- ✓ Touchstone import / export
- ✓ Mixed-mode representation (ideal for common-mode and differential-mode representation)



Model of 100 μ F 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)

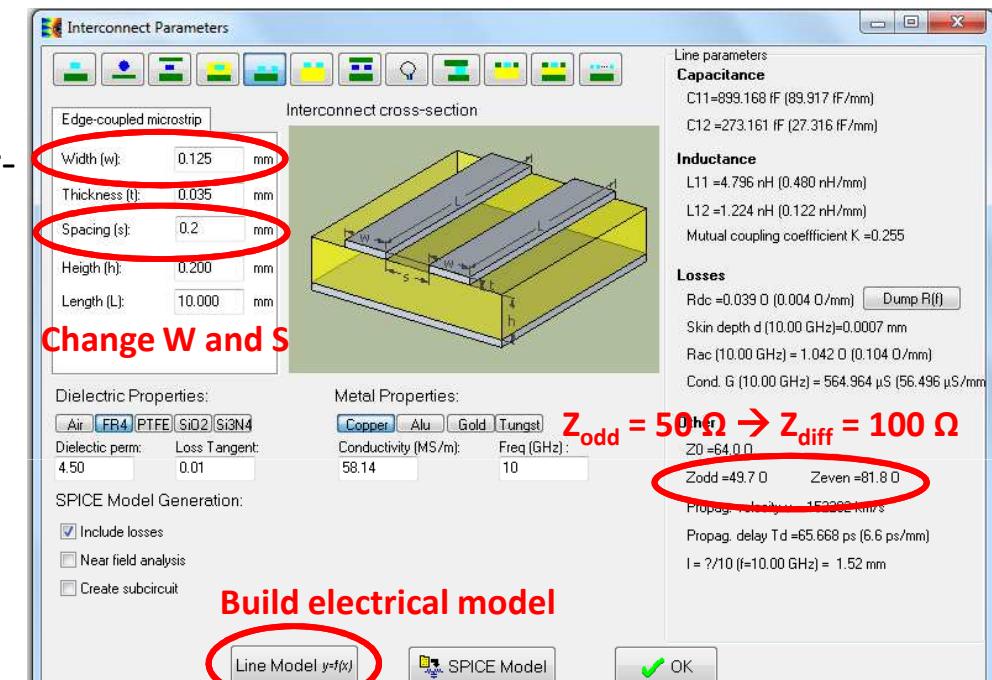


Comparison between meas. and simu.

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)



Matching and modeling a differential line

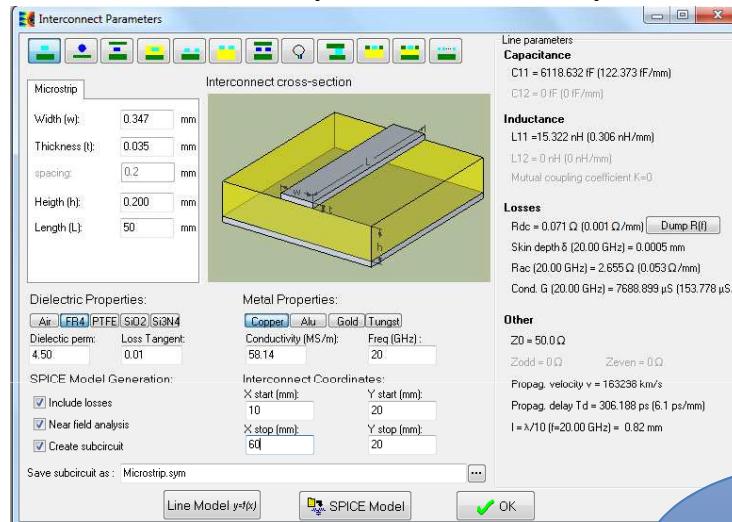
Learning outcomes:

- 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

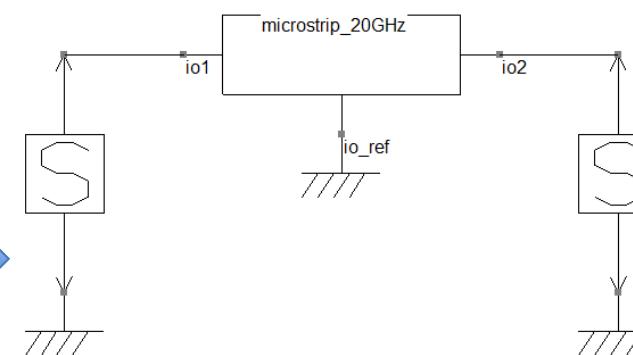
What can we learn with IC-EMC?

PCB interconnect modeling

✓ 50 Ω microstrip line model up to 20 GHz

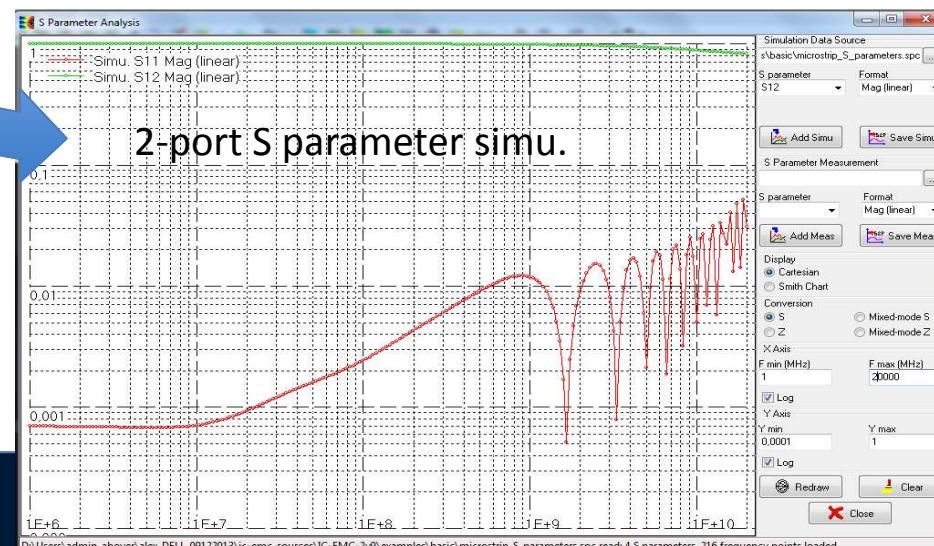


Electrical model



AC DEC 50 1MEG 20G

microstrip_20GHz is a SPICE subcircuit
It describes a microstrip line with: w=0.347



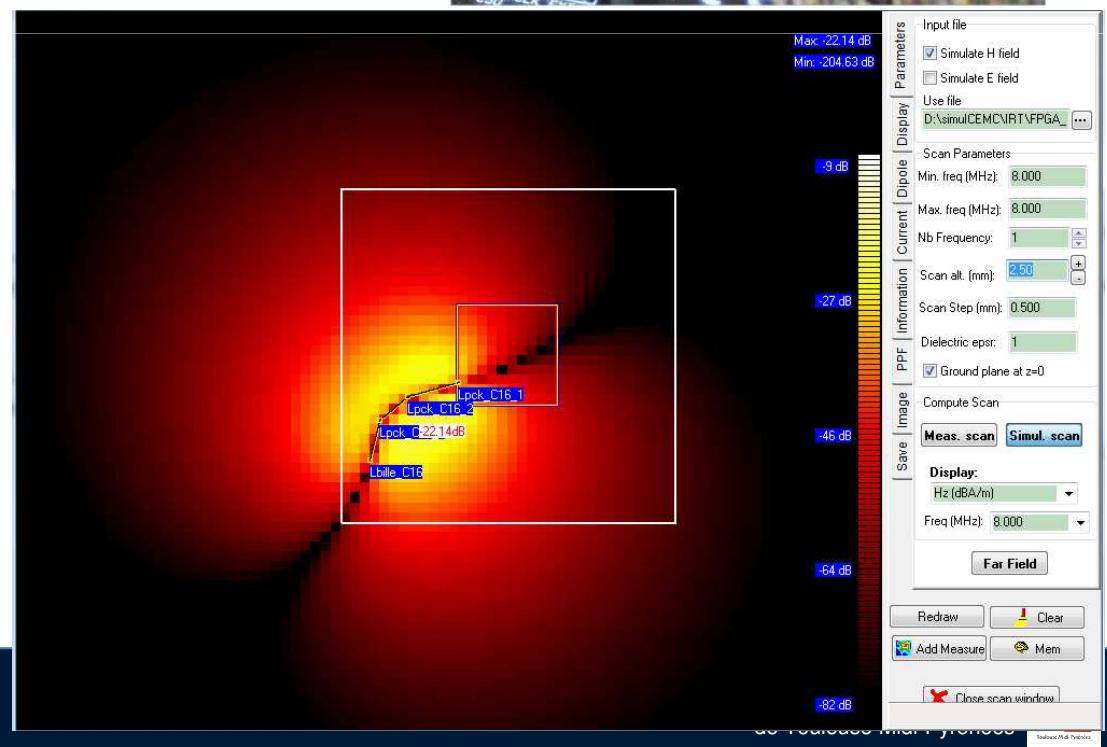
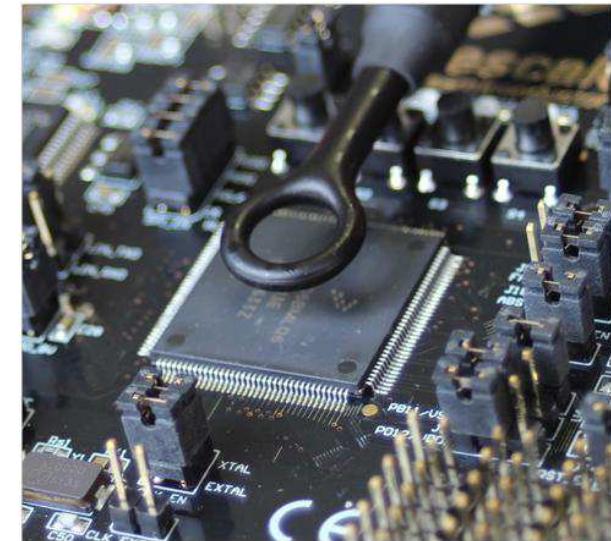
IC and PCB radiation

- ✓ 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

Learning outcomes:

- 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?



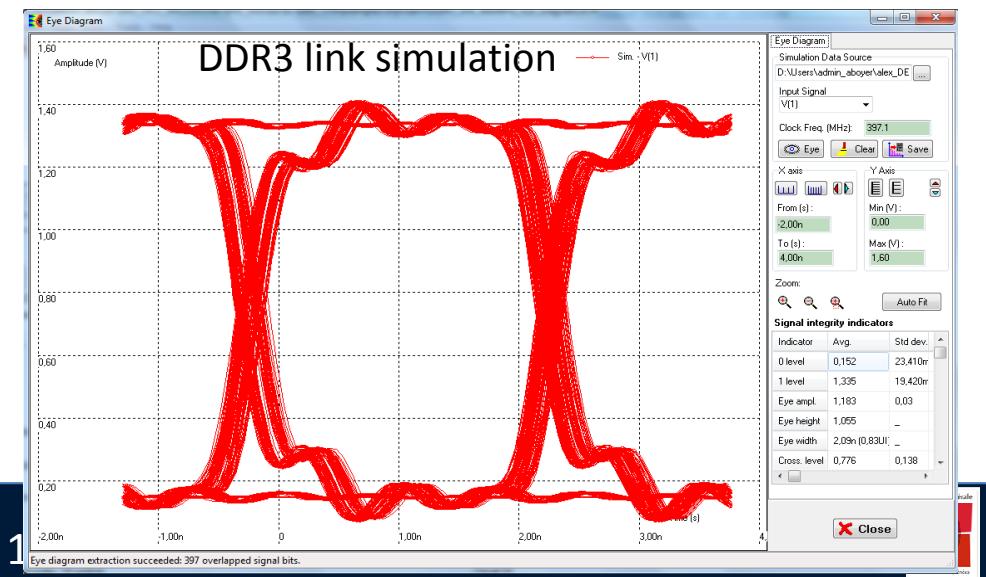
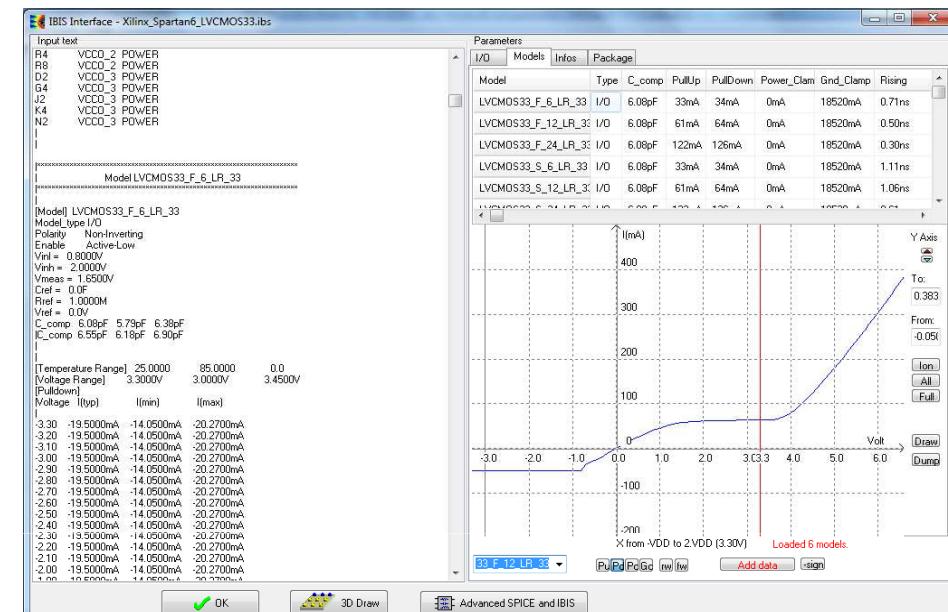
IBIS interface and signal integrity simulation

- ✓ 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

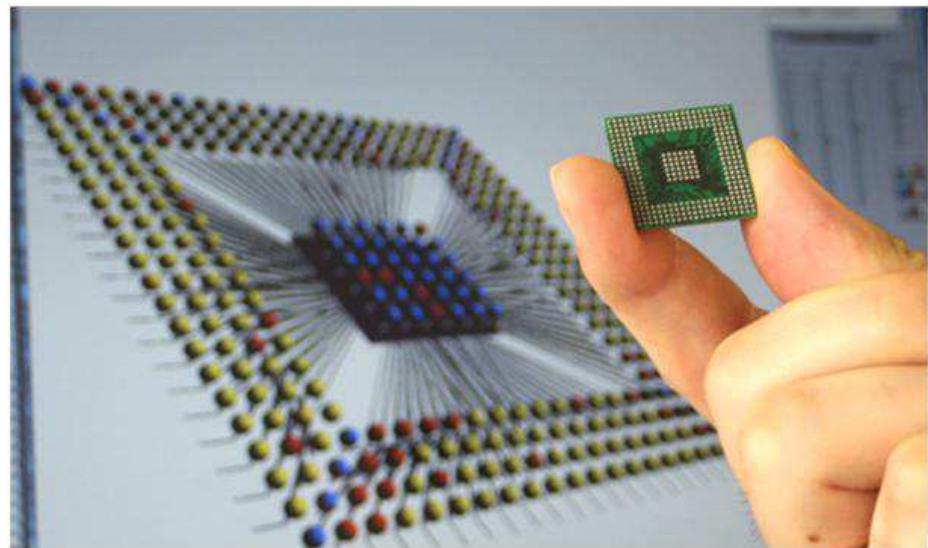
What can we learn with IC-EMC?



Package modelling

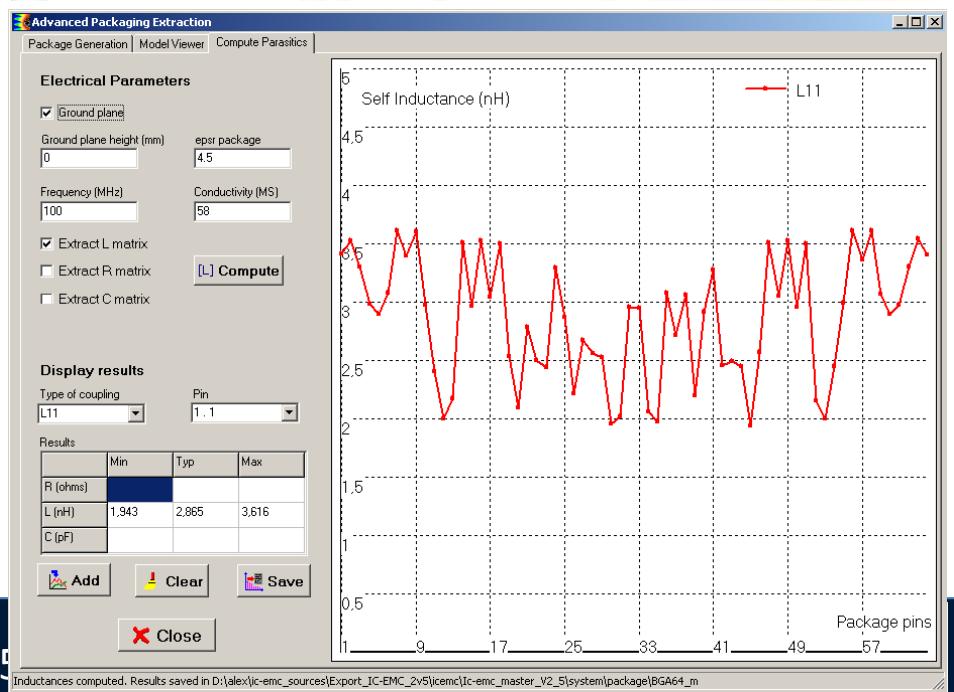
- ✓ Construction of 3D model of IC package from pin-out and package dimensions
- ✓ Extraction of electrical model

What can we learn with IC-EMC?



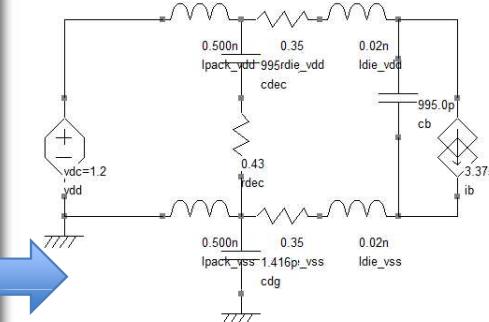
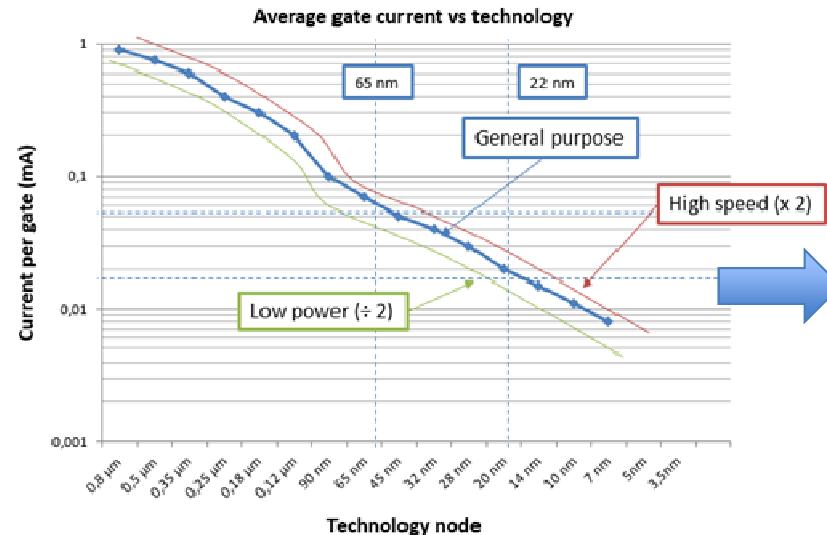
Learning outcomes:

- 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?

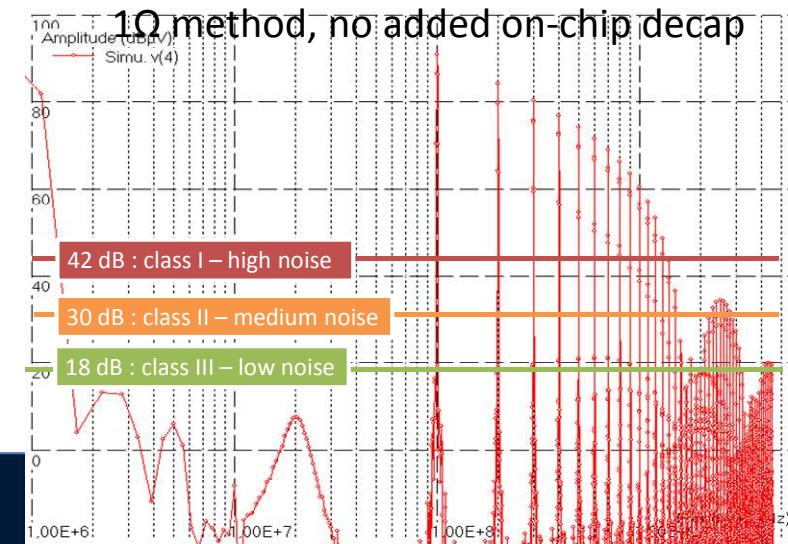
- ✓ Estimation of 1st order model of digital ICs from technological information (ICEM model)



Rapid ICEM construction

Learning outcomes:

- 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



What can we learn with IC-EMC?

Emission simulation example: Efficient decoupling

XI. Modelling IC emission

- ✓ Use of IC emission model to optimize decoupling at PCB level
- ✓ Requirements on power integrity and conducted emission

Learning outcomes:

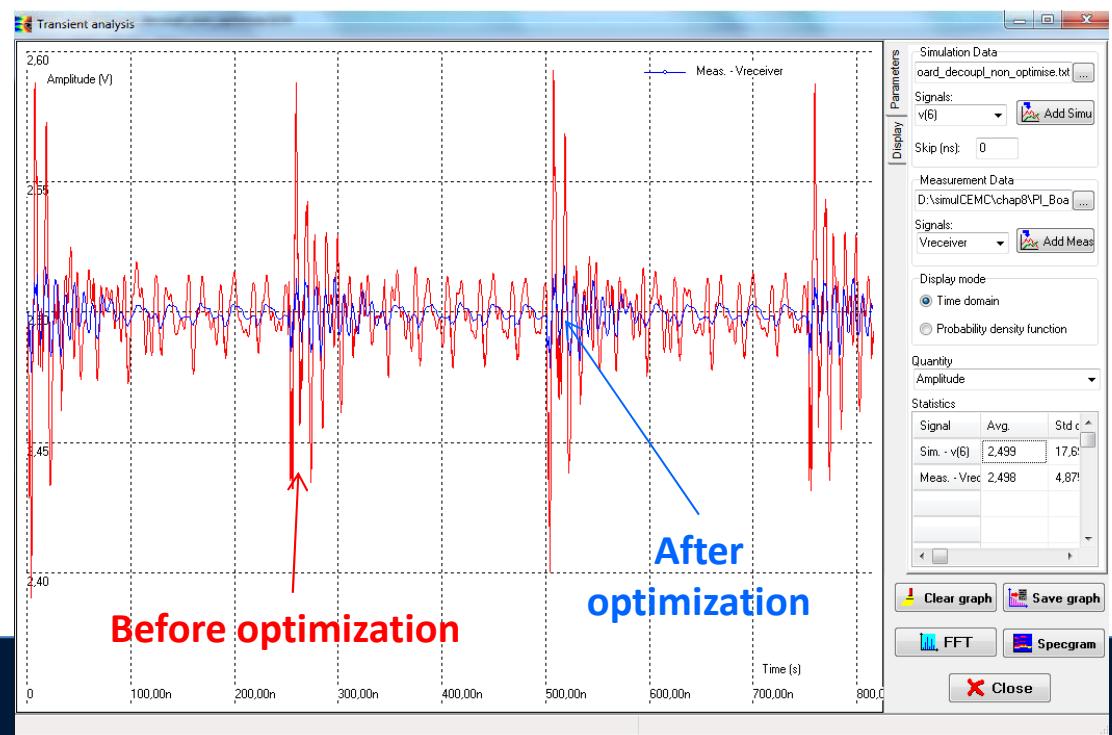
- Create IC, PCB, ceramic capacitor models
- Manage target impedance
- Observe the actual efficiency of decoupling capacitor (role of ESL, ESR,)
- Strategy to decouple board
- Influence of number and values of decoupling capacitors

~ 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:

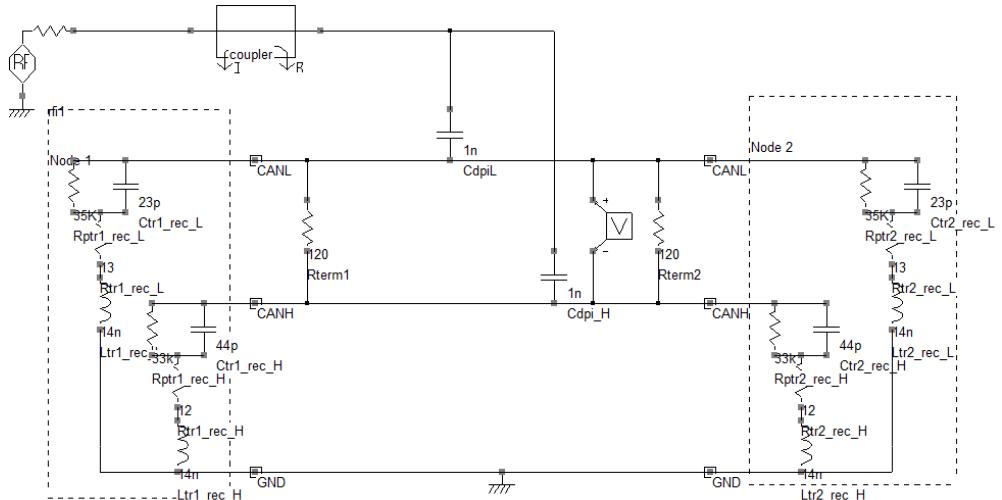
- $Vdd1/Vss1$ and $Vdd2/Vss2$ for the CPU
- $VddI01/VssI01$ and $VddI02/VssI02$ for I/O buffers
- $VddPLL/VssPLL$ for the internal oscillator and PLL
- $VddA/VssA$ for analogue blocks



What can we learn with IC-EMC?

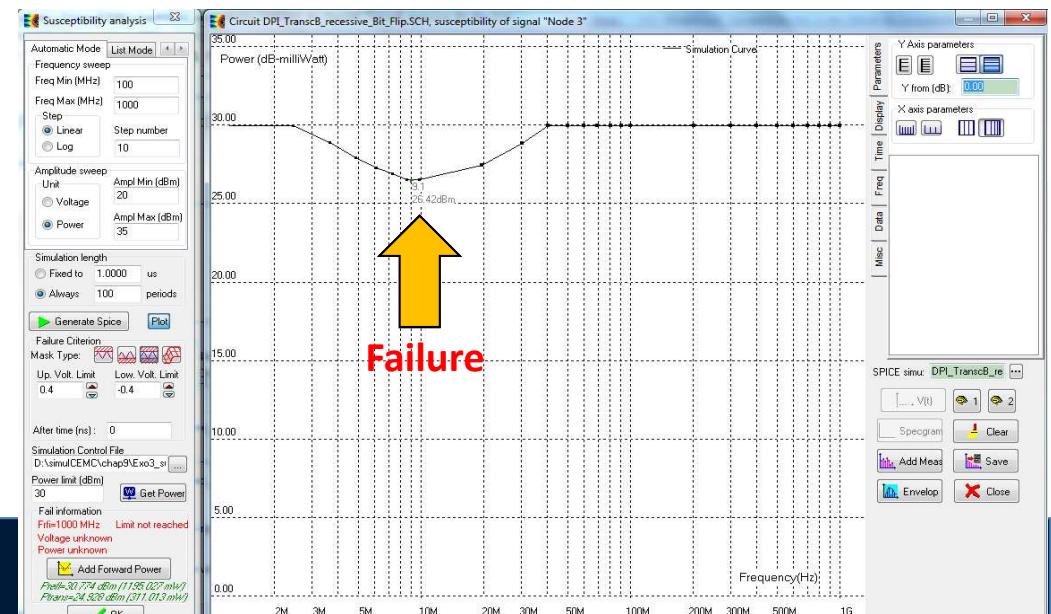
RF susceptibility simulation: Virtual CAN bus test bench

- ✓ 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

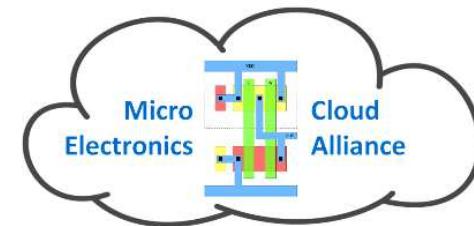


Learning outcomes:

- 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



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



The screenshot shows the IC-EMC website homepage. At the top, there is a navigation bar with icons for back, forward, search, and a link to www.ic-emc.org. Below the navigation bar, there is a large image of a microchip with a red and yellow heatmap overlay. To the right of the image, there are two sections: "Download Software" and "Documentation". The "Download Software" section contains text about the IC-EMC software (Version 2.9 June 2017) for Windows, mentioning WinSpice and LTSpice. It includes download links and "More" buttons. The "Documentation" section links to the User's Manual Version 2.9, which was released on June 2017. At the bottom of the page, there are logos for INSA, LAAS-CNRS, and the University of Toulouse, along with a small image of a book titled "Electronics Circuits Analysis and Design" by H. T. Lin et al., published in 2017.

Thank you for your attention