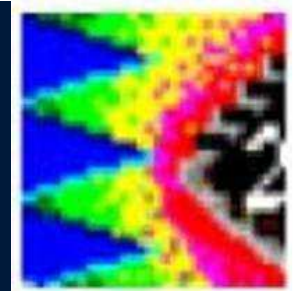


Learning EMC of ICs with IC-EMC



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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 ?**

- ✓ 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

INSA NATIONAL INSTITUTE OF APPLIED SCIENCES TOULOUSE
Department of Laboratory & Electrical Engineering

Ministry of National Education, Higher Education and Research
On funded by the Erasmus+ Programme of the European Union

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 IRE, ICEM and ICIM
- **EMC guidelines** for improved emission and immunity to interference.

Practical sessions
Afternoons are dedicated to **practical sessions** including an access to the EMC laboratory of INSA Toulouse, 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.

Lecturers

Estienne SICARD
Professor at INSA
IEEE EMC Society Distinguished Lecturer
<http://www.erasmus-sicard.fr>
Estienne.usird@insa-toulouse.fr

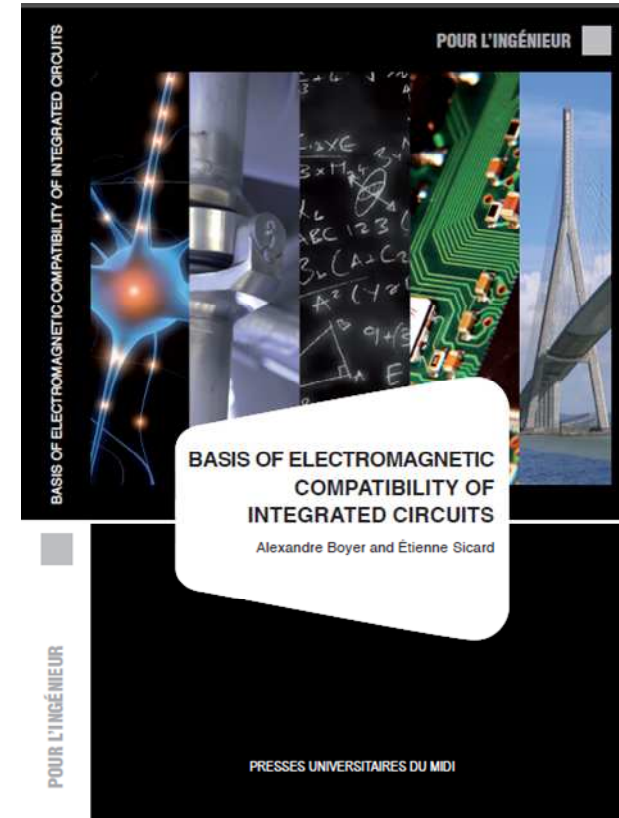
Alexandre BOYER
Senior lecturer
LAAS/CNRS
<http://www.erasmus-boyer.fr>
alexandre.boyer@insa-toulouse.fr

More information: www.ic-emc.org = Trainings
Registration fee: **free** for Erasmus+ Knowledge Alliance MECA Partners (6 attendees max.)
Contact for registration: ic@insa-toulouse.fr

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31 077 Toulouse Cedex 4 FRANCE
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Université de Toulouse

- ✓ 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



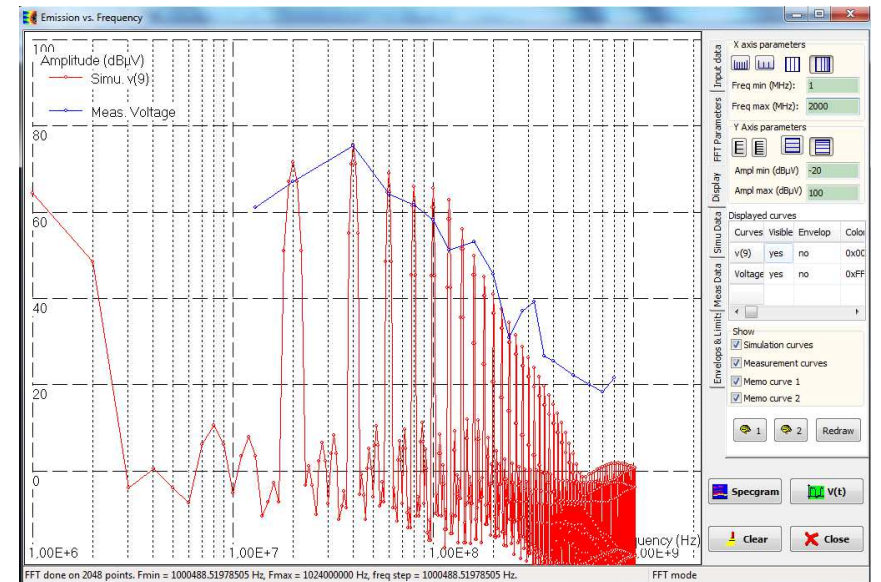
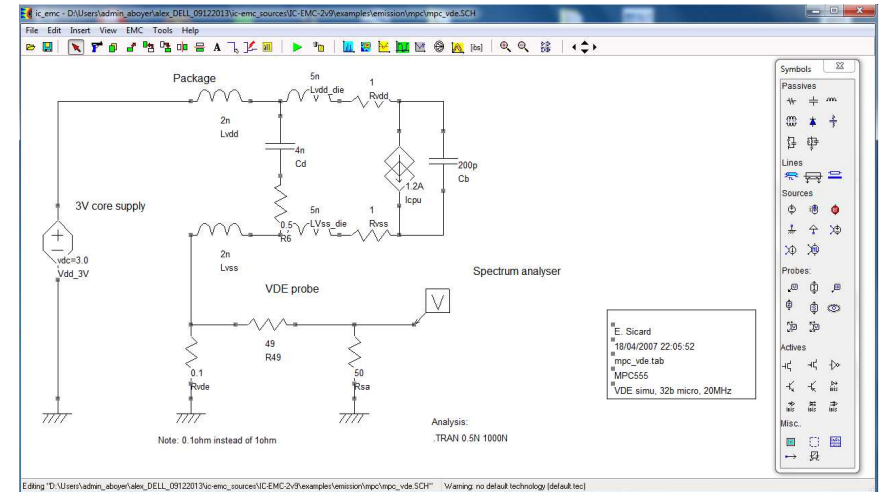
pum.univ-tlse2.fr/~Basis-of-electromagnetic~.html

✓ Free simulation software dedicated to the EMC of ICs issues:

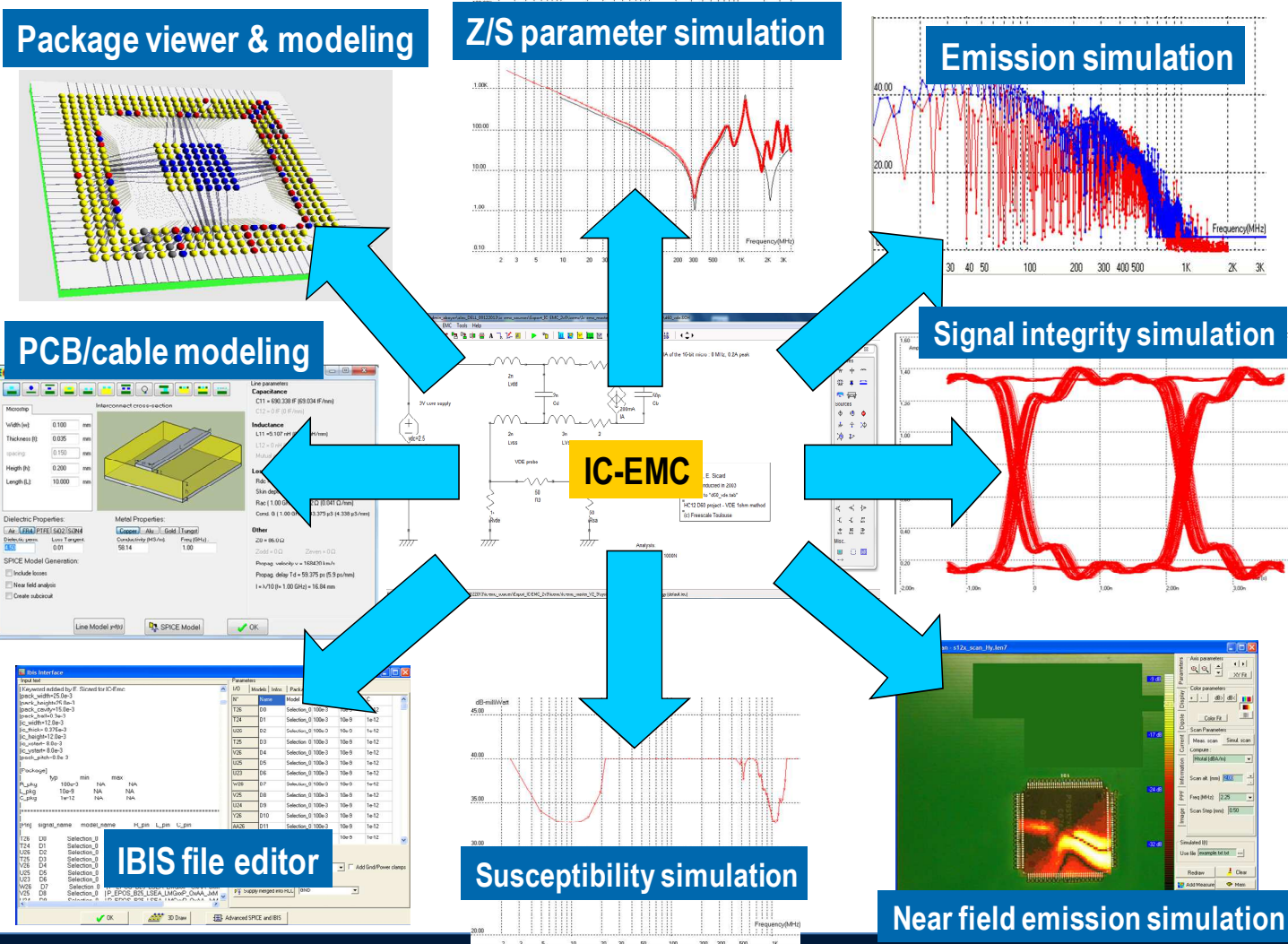
✓ help the user to develop EMC models rapidly for an efficient evaluation of EMC performances

✓ illustrate EMC issues related to ICs for educational purpose of basic notions and modelling techniques related to EMC

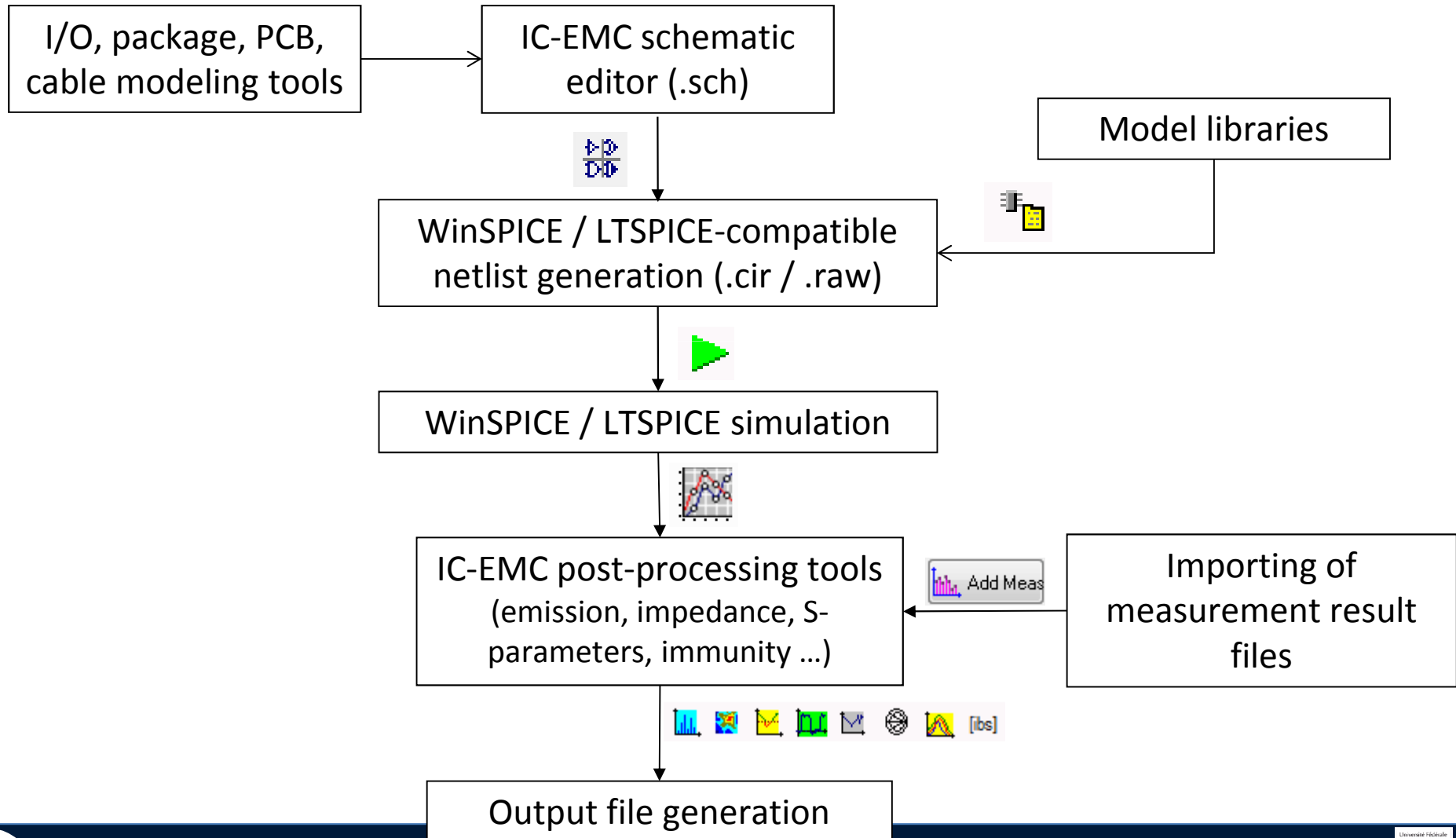
✓ Executable files, application notes, exercises solutions available at www.ic-emc.org



Main functionalities



✓ Simulation flow based on SPICE simulation results:

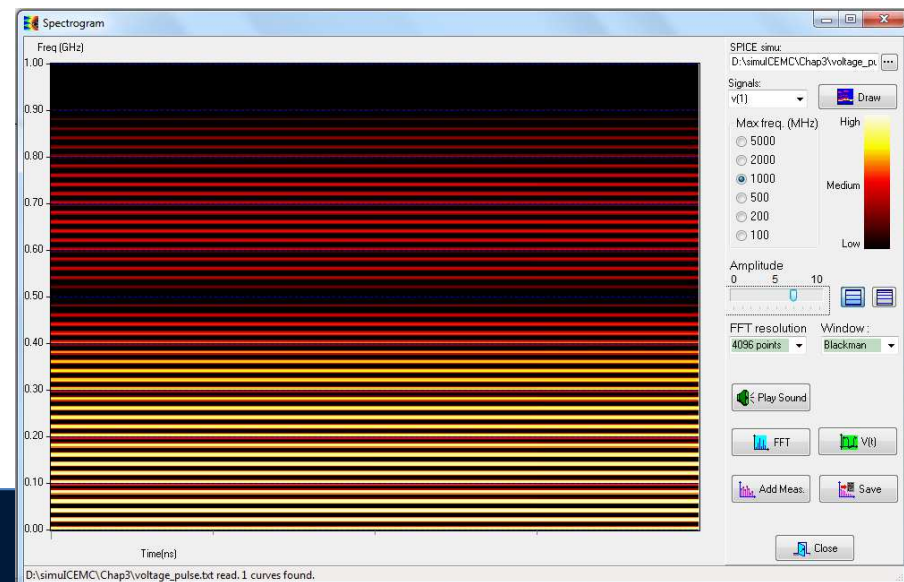
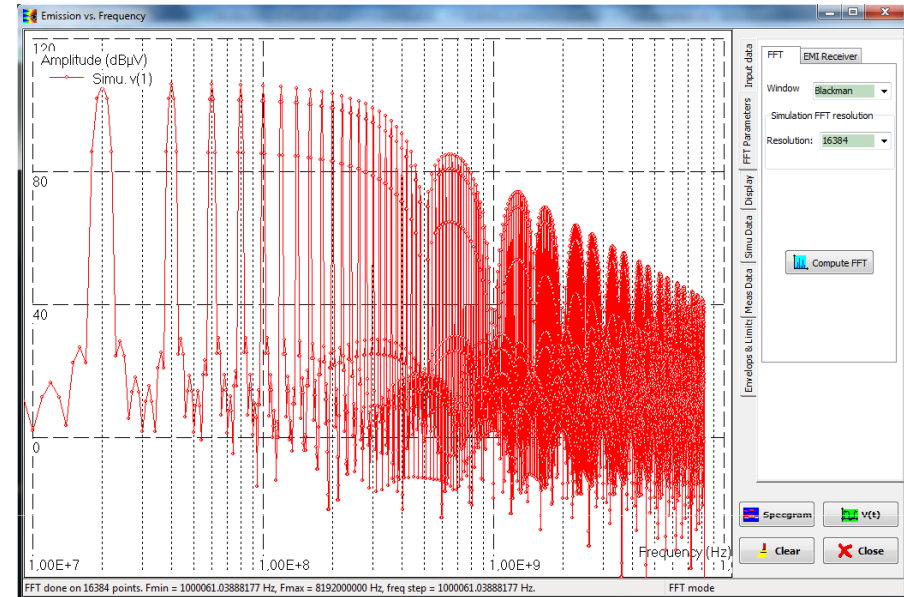


FFT and EMI receiver

- ✓ 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)

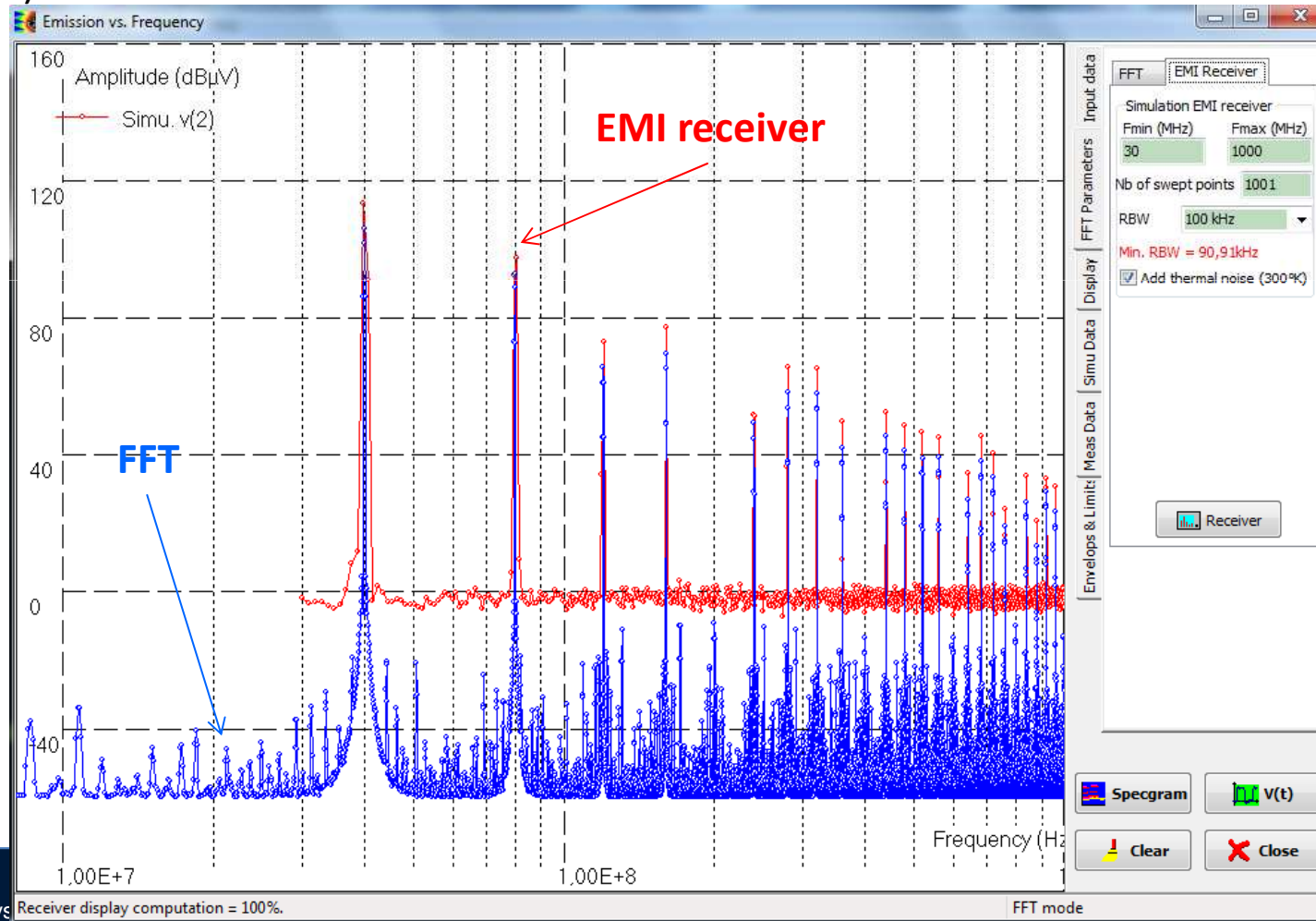
Learning outcomes:

- 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



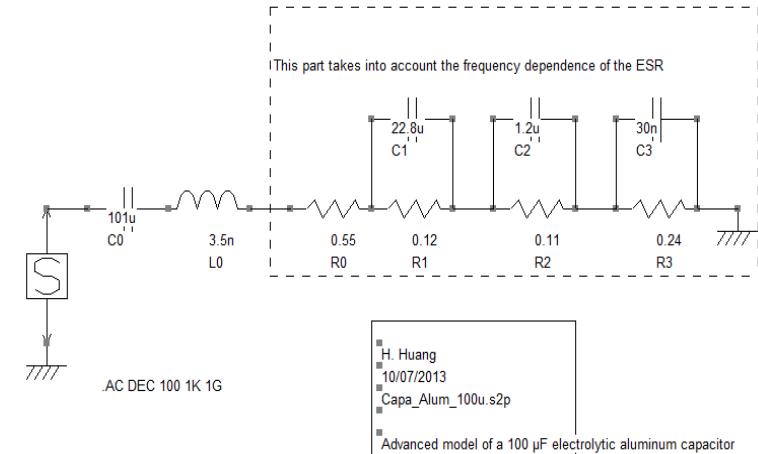
FFT and EMI receiver

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



Modeling impedance of components

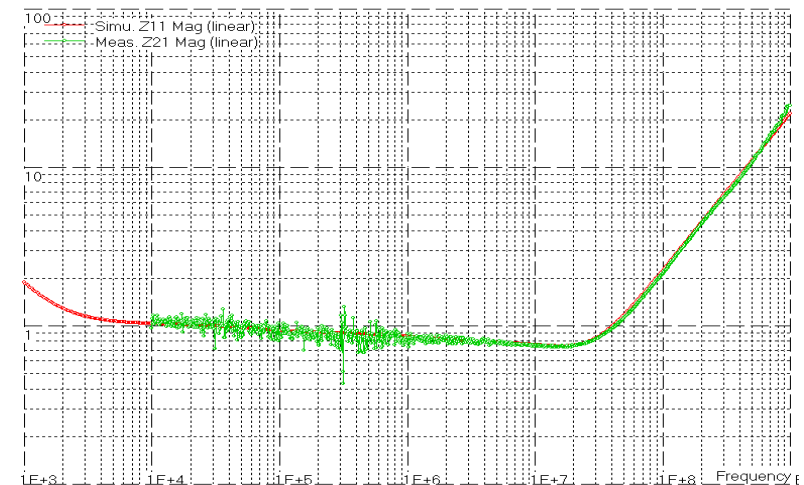
- ✓ S and Z parameter computation, up to four port
- ✓ Modeling of passive devices, interconnects, IC PDN, measurement equipments...
- ✓ Touchstone import / export
- ✓ Mixed-mode representation (ideal for common-mode and differential-mode representation)



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)



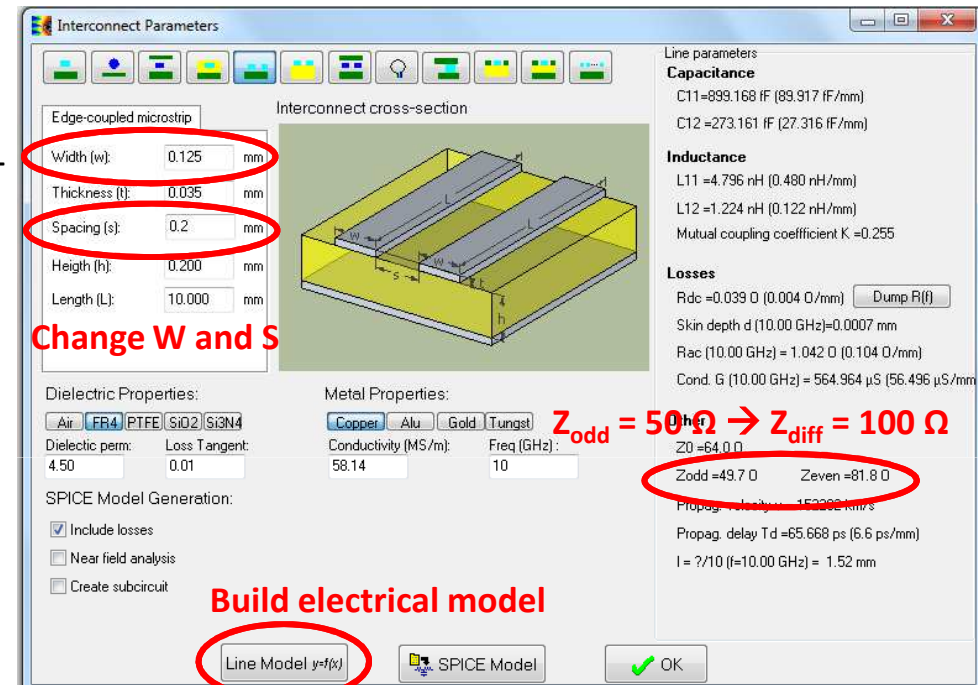
Comparison between meas. and simu.

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)

Learning outcomes:

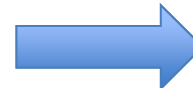
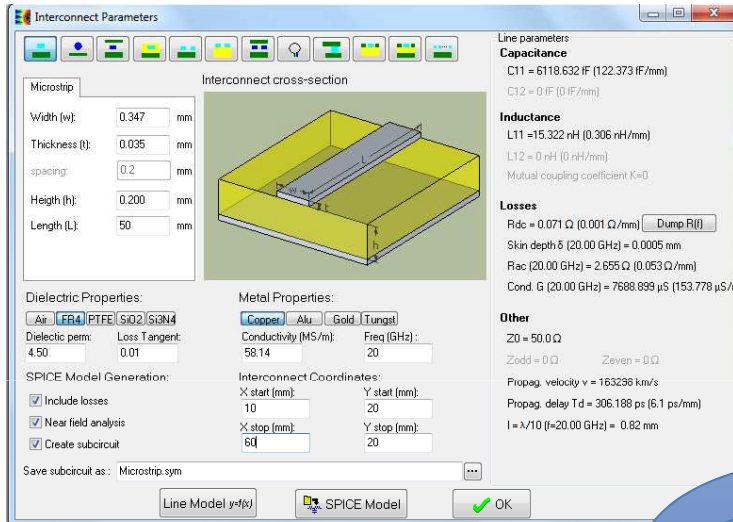
- Select dimensions for impedance matching
- Analyze physical behavior (eg. line or plane resonance, increase of losses at high freq.)
- Canonical line model for SI simulation
- Estimation of radiation of PCB lines



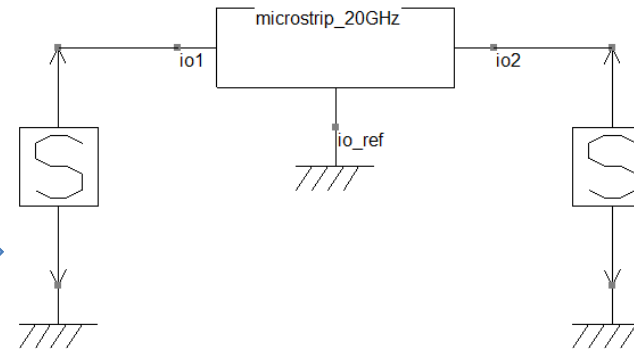
Matching and modeling a differential line

PCB interconnect modeling

✓ 50 Ω microstrip line model up to 20 GHz



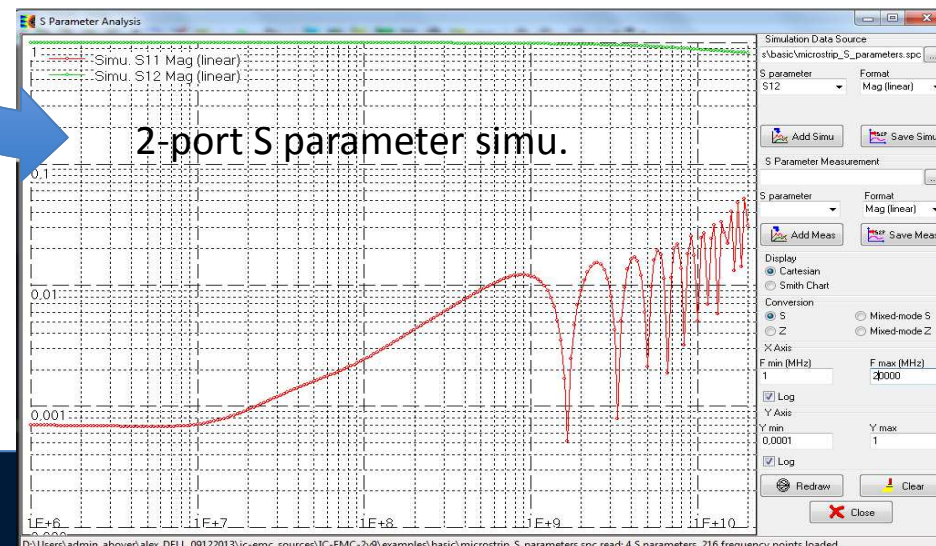
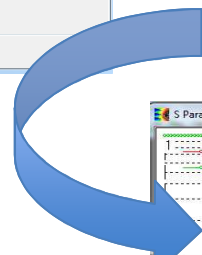
Electrical model



.AC DEC 50 1MEG 20G

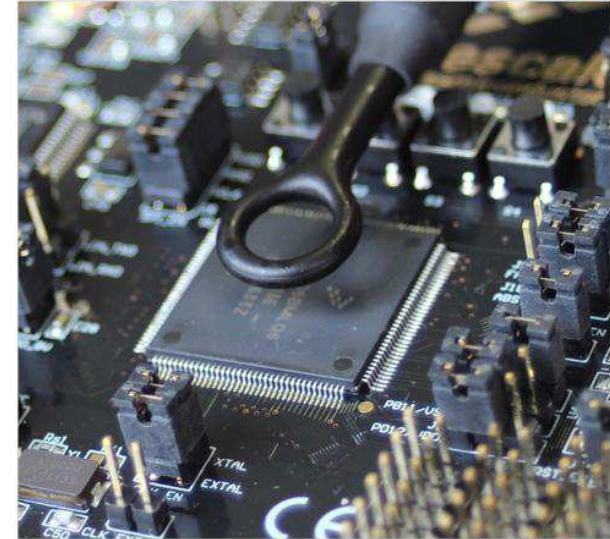
microstrip_20GHz is a SPICE subcircuit ge

It describes a microstrip line with: w=0.347 mm



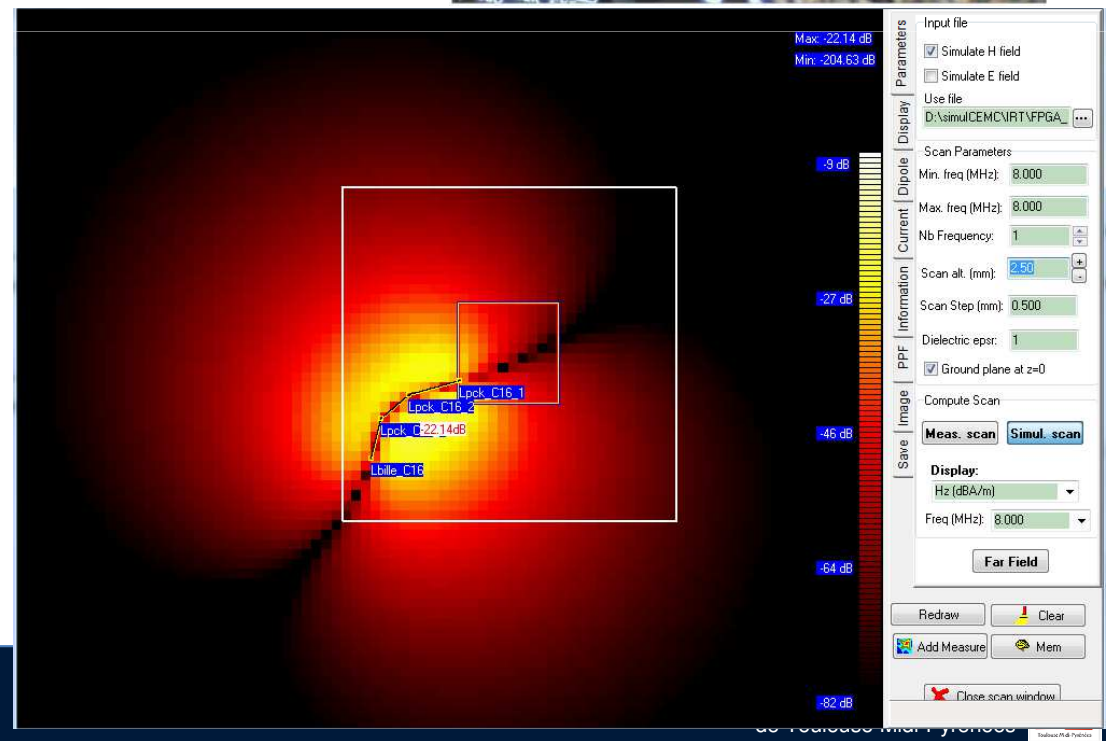
IC and PCB radiation

- ✓ 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

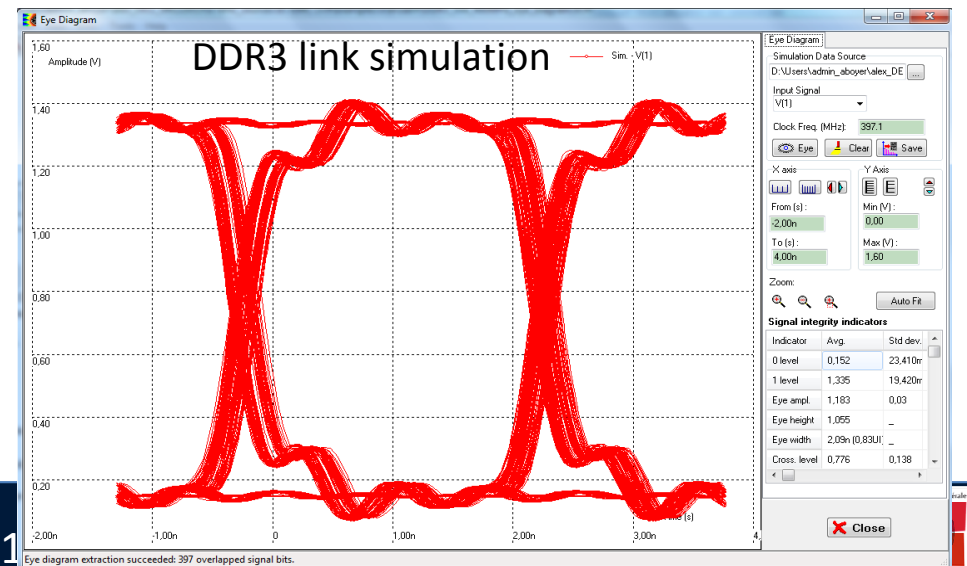
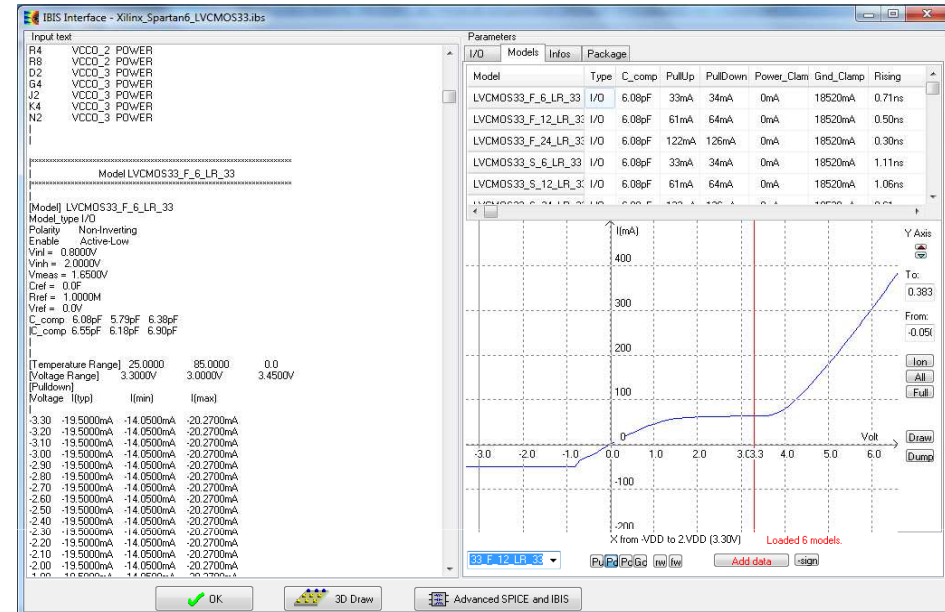


IBIS interface and signal integrity simulation

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

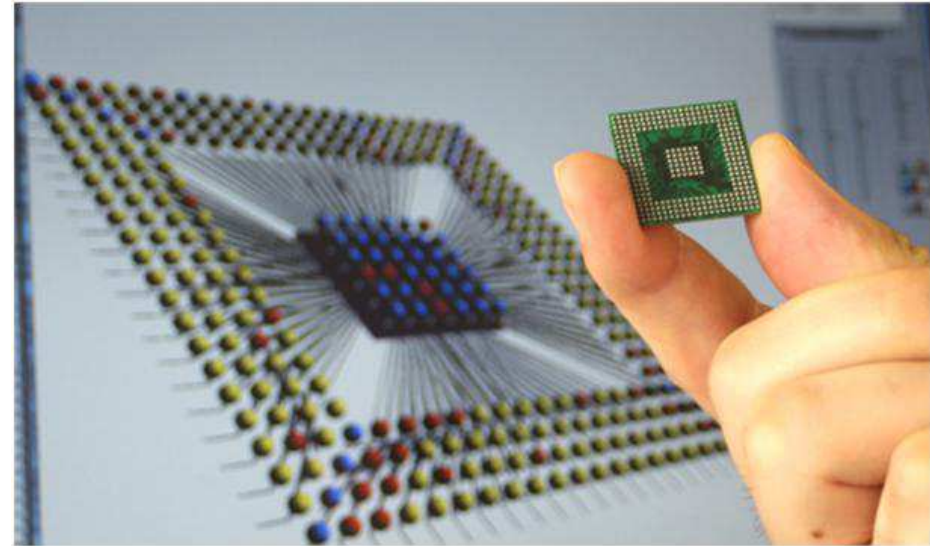
Learning outcomes:

- 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



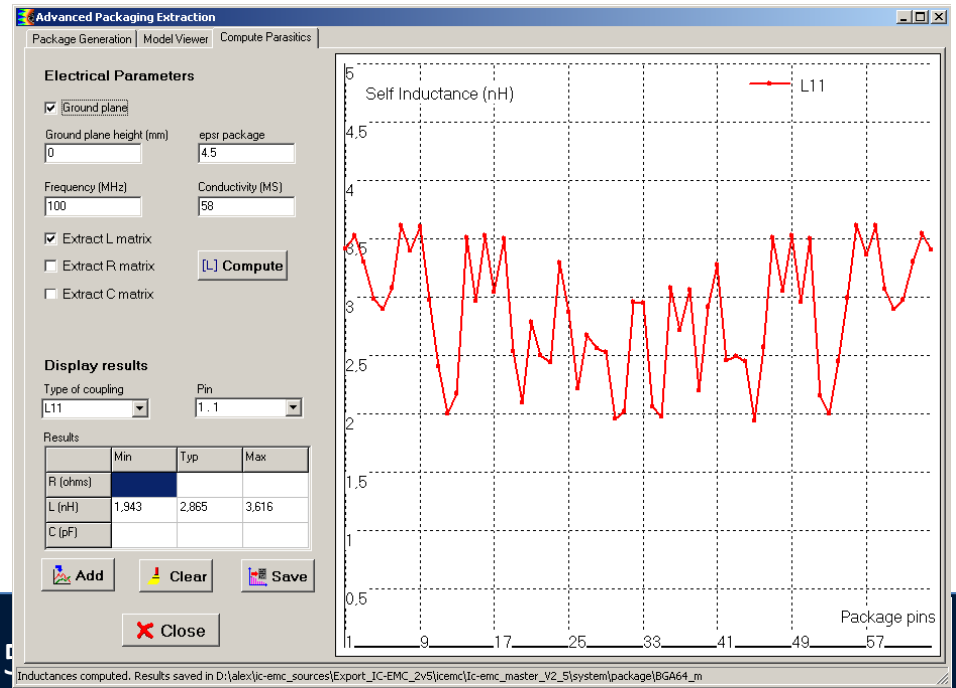
Package modelling

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



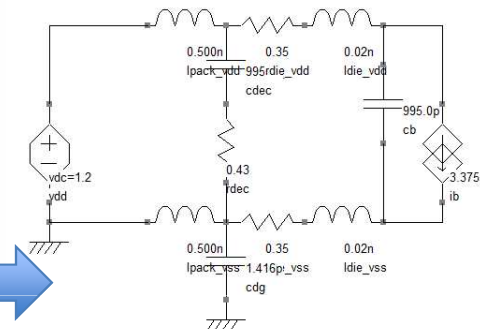
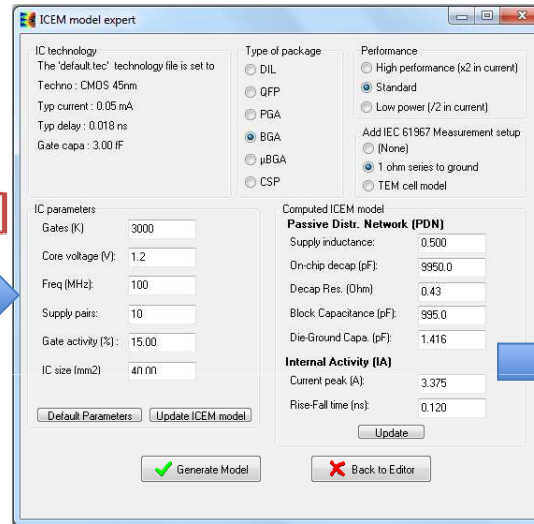
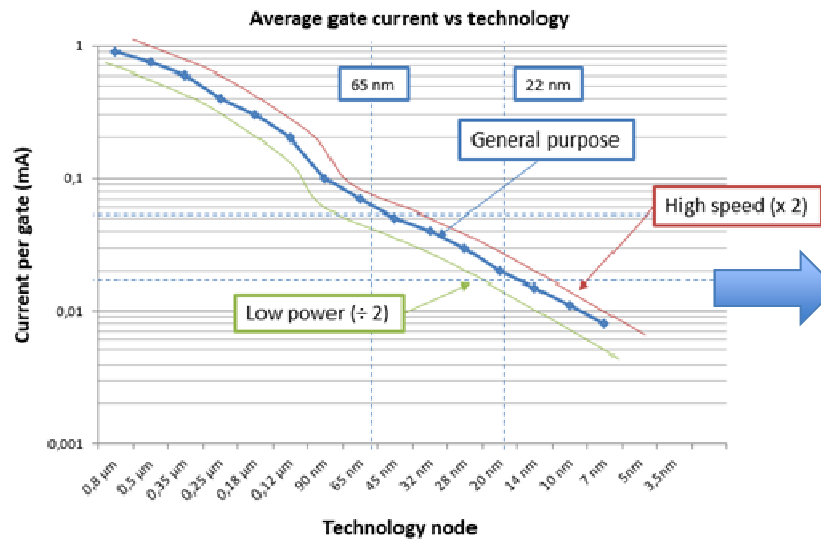
Learning outcomes:

- 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



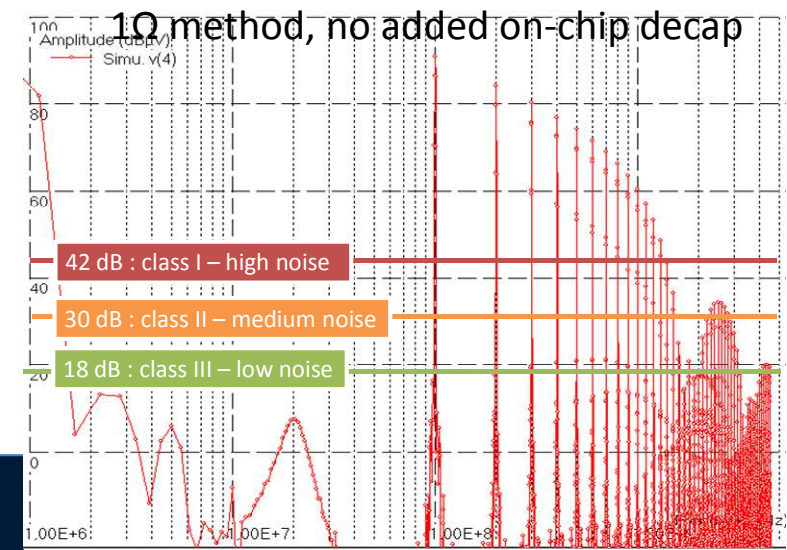
ICEM Expert

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



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



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

~ EXERCISE NO. 5 – SILENTCORE DECOUPLING BUDGET

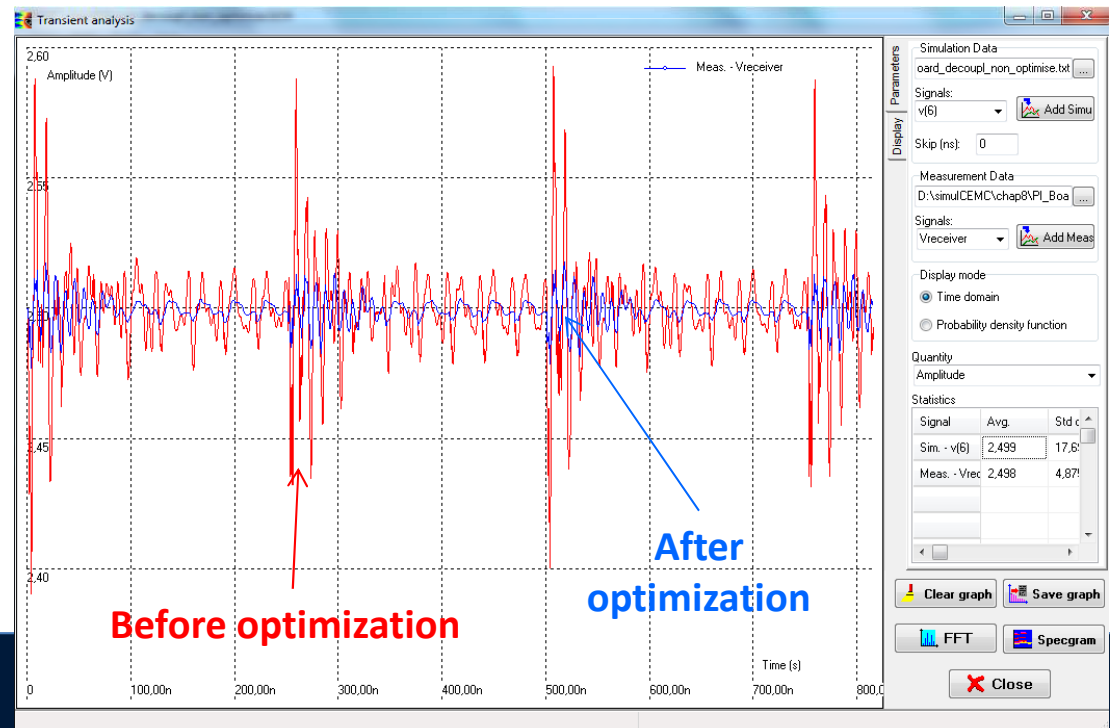
The SilentCore microcontroller is dedicated to high-reliability applications requiring very low electromagnetic noise. The circuit is designed in CMOS 65 nm low-power technology. It includes a 32-bit microprocessing unit. An on-chip PLL provides an internal operating clock running at 80 MHz from an external 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

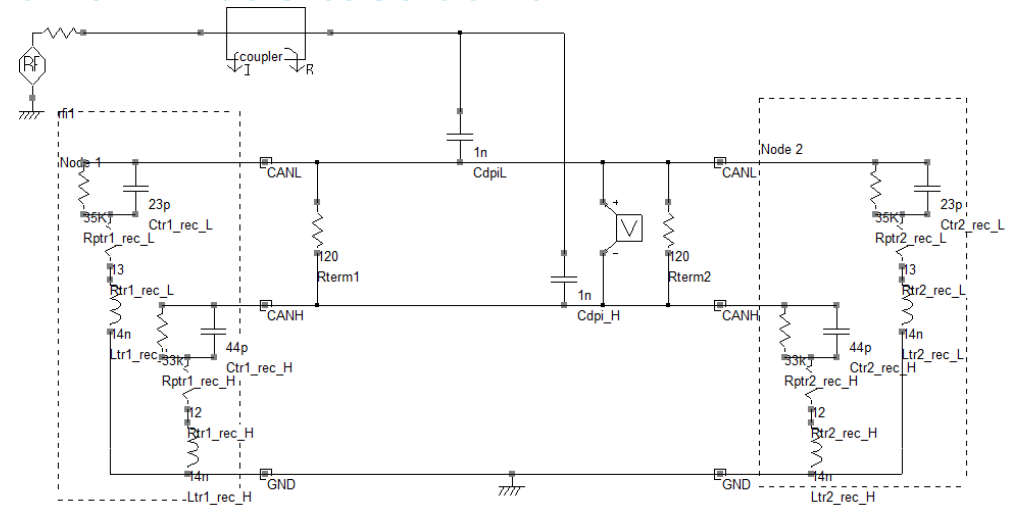
Learning outcomes:

- 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



RF susceptibility simulation: Virtual CAN bus test bench

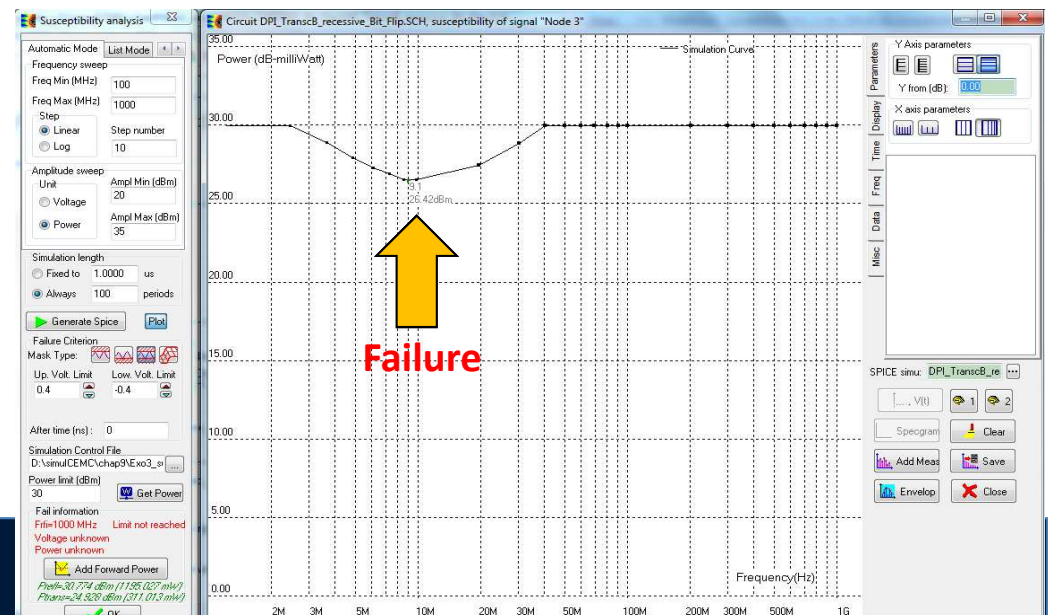
- ✓ Build simple IC susceptibility model including PDN, non-linear elements, failure detection
- ✓ Simulate susceptibility to harmonic disturbance
- ✓ Examples of practical works: Simulation of DPI/BCI of CAN bus

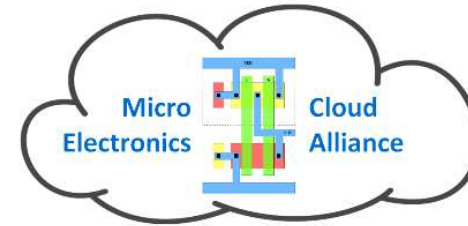


Model of DPI on CAN bus interface

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





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



Thank you for your attention