

INSA

NATIONAL INSTITUTE
OF APPLIED
SCIENCES
TOULOUSE

DEPARTMENT OF COMPUTER & ELECTRICAL
ENGINEERING

Technology Trends and Electromagnetic Compatibility of Integrated Circuits



Etienne SICARD

Professor

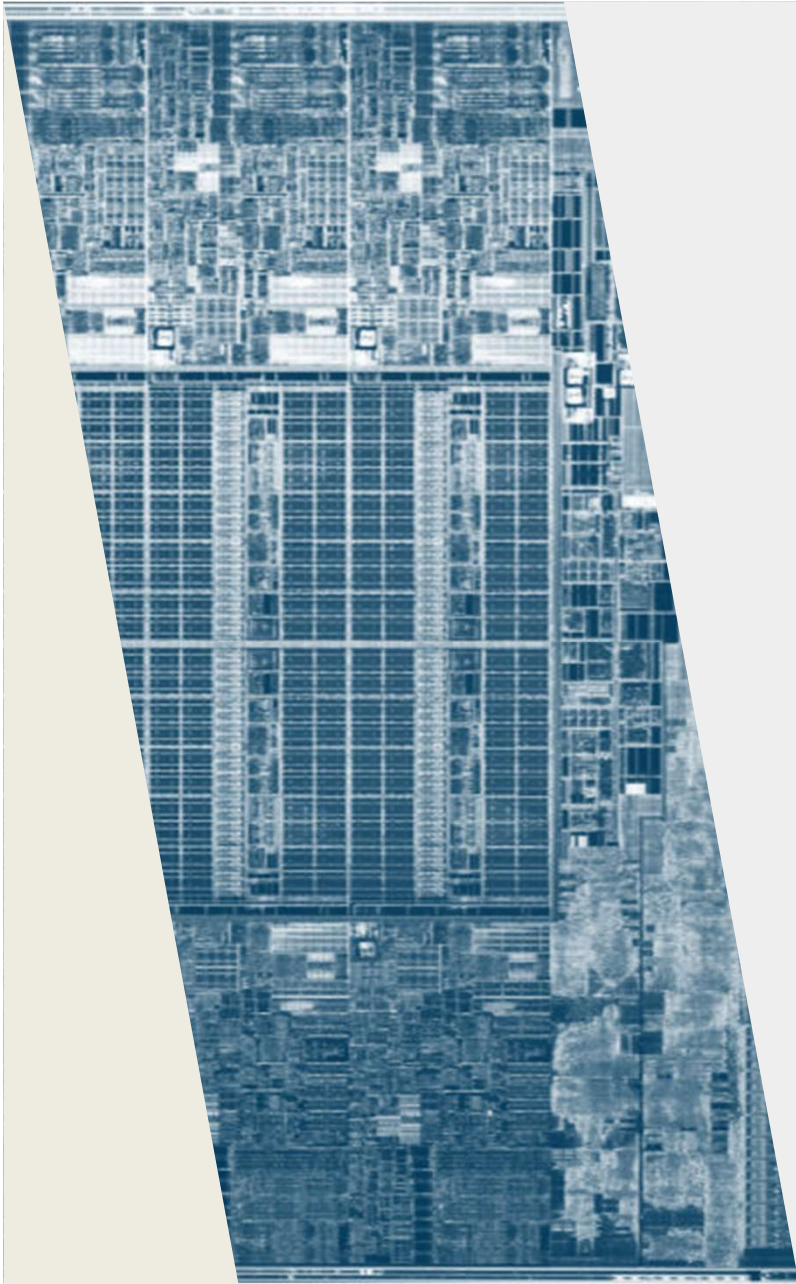
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www.ic-emc.org

- I. A BRIEF HISTORY OF IC EMC
- II. GENERAL TRENDS
- III. TECHNOLOGY TRENDS
- IV. EMC CHALLENGES
- V. GOOD NEWS FOR EMC
- VI. CONCLUSION



A BRIEF HISTORY OF IC-EMC

- Air Force Weapon Laboratory, USA
- SPECTRE : **Simulation software** developed at IBM (Sedore, 1965)
- Effects of the **electromagnetic fields** triggered by nuclear explosions on **electronic devices**
- Correlate **simulations** and experimental **measurements** obtained on an electromagnetic impulse test-bench.
- Ancestor of **SPICE**

SCEPTRE: A Program for Automatic Network Analysis*

Abstract: This paper describes the mathematical formulation of a computer program for automatic transient analysis of electronic networks. The formulation is based on the "state-variable" approach to network analysis and differs from other such programs primarily in the way that the network equations are manipulated to produce a solution. SCEPTRE includes a number of features aimed at providing greater flexibility and convenience for users of the program. Important among these features is that no prescribed equivalent circuit for active elements is required for program operation. Also, linearly dependent voltage and current sources in a network can be handled by the program, and provision has been made to allow a free-form format for input data. The paper includes a discussion of the program's ability to solve networks containing time-varying passive elements, and considers the factors that influence program running time.

* Work supported by the Air Force Weapons Laboratory under contract AF 29(601)-6852. Dissemination of the SCEPTRE program is controlled by the Air Force Weapons Laboratory, Attn: WLRET (Capt. Gary Pritchard), Kirtland Air Force Base, New Mexico 87117.

627

IBM JOURNAL • NOVEMBER 1967

1959

- IEC TC 47 was proposed in 1959 to cope with the needs of industry in **semiconductor devices**.
- Role : preparing **international standards** for the design, manufacture, use, reuse, and **testing** of discrete semiconductor devices, **integrated circuits**, sensors, electronic component assemblies, interface requirements, and micro-electromechanical devices, using environmentally sound practices.




Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

IEEE TRANS ON EMC, 1979

SPECIAL ISSUE ON RF INTERFERENCE IN ICS

- Guest editor: **James J. Whalen**
- Rising **risk of interference** between ICs and electromagnetic sources
- Very High Frequency (30 MHz - 300 MHz)
- Visionary editorial about **future problems** due to higher speed and integration



**IEEE TRANSACTIONS ON
ELECTROMAGNETIC
COMPATIBILITY**

NOVEMBER 1979 VOLUME EMC-21 NUMBER 4 (ISSN 0018-9375)

A PUBLICATION OF THE IEEE ELECTROMAGNETIC COMPATIBILITY SOCIETY

SPECIAL ISSUE ON RF INTERFERENCE EFFECTS IN SEMICONDUCTOR DISCRETE DEVICES AND INTEGRATED CIRCUITS

GUEST EDITORIAL

Predicting RFI Effects in Semiconductor Devices at Frequencies Above 100 MHz *J. J. Whalen* 281

SPECIAL ISSUE PAPERS

Equipment EMC

A Modified Ebers-Moll Transistor Model for RF-Interference Analysis *C. E. Larson and J. M. Roe* 283

Computer-Aided Analysis of RFI Effects in Digital Integrated Circuits *J. J. Whalen, J. G. Tront, C. E. Larson, and J. M. Roe* 291

Computer-Aided Analysis of RFI Effects in Operational Amplifiers *J. G. Tront, J. J. Whalen, C. E. Larson, and J. M. Roe* 297

Modeling of Low-Level-Rectification RFI in Bipolar Circuitry *R. E. Richardson, Jr.* 307

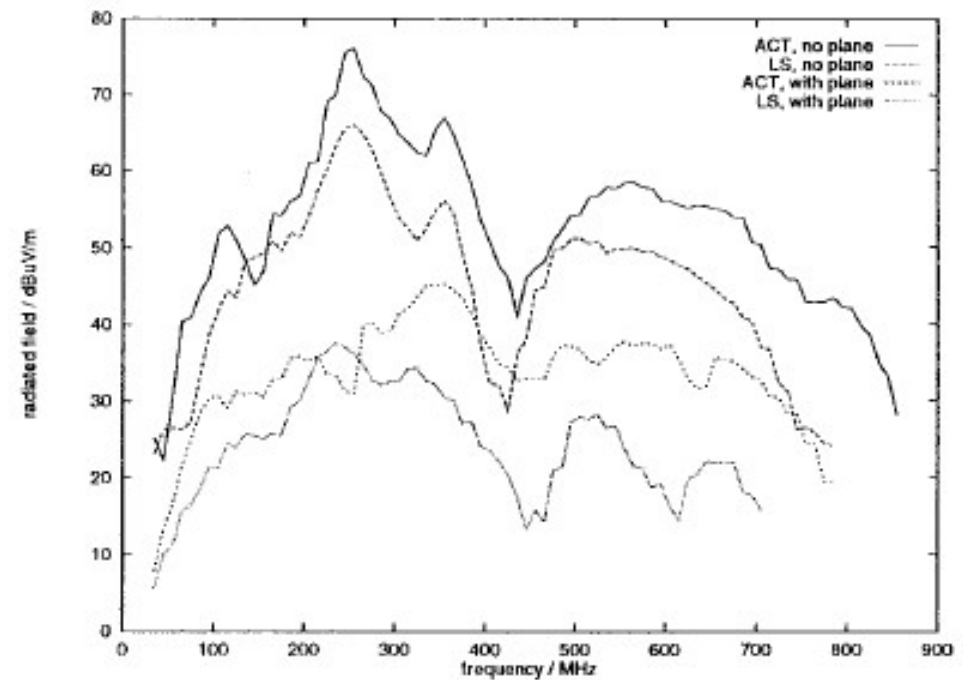
Microwave-Rectification RFI Response in Field-Effect Transistors *M. L. Forcier and R. E. Richardson, Jr.* 312

Response Coefficients of a Double-Balanced Diode Mixer *M. A. Maiuzzo and S. H. Cameron* 316

IEEE TRANS ON EMC, 1998

TECHNOLOGY COMPARISONS (M.P. ROBINSON)

- Robinson (Univ. York) compared the **radiated emissions** produced by **different families** of logic circuits.
- **Significant behavioral differences** were observed
- Upto 1GHz



INTEGRATED CIRCUIT
ELECTROMAGNETIC IMMUNITY
HANDBOOK, BY NASA, USA

- **Comparison between IC families**
(ALS, HC, Regulators)
- **Upto 10 GHz**

NASA/CR-2000-210017



Integrated Circuit Electromagnetic Immunity
Handbook

J.G. Skatze
Boeing Information, Space and Defense Systems, Seattle, WA



Prepared for Marshall Space Flight Center
under Contract NAS8-98217
and sponsored by
The Space Environments and Effects Program

Chart 11. EMI IMMUNITY LEVEL
7805 VOLTAGE REGULATOR

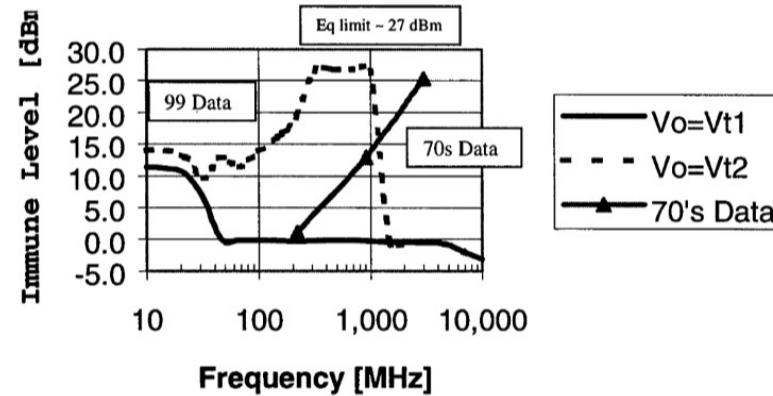
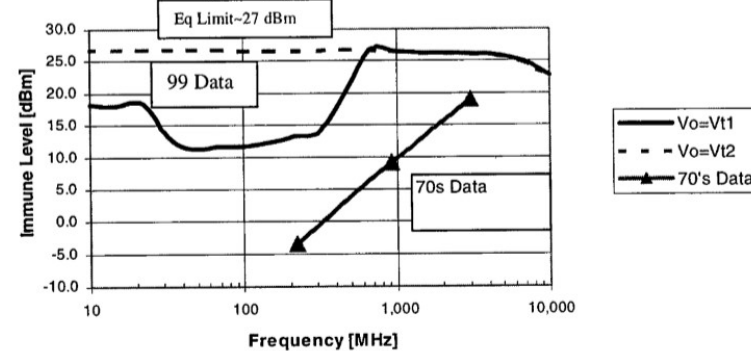


Chart 2. EMI IMMUNITY LEVEL
74ALS00 NAND GATES



FIRST INTERNATIONAL WORKSHOP DEDICATED TO EMC OF ICS (2002)

- Organized by INSA Toulouse France
- 70 attendees
- 30 papers
- Invited guests: **Bob ROSS**, Mentor Graphics & **IBIS**, **Ross CARLTON**, Motorola & **IEC**



3rd International Workshop on Electromagnetic Compatibility of Integrated Circuits

2nd Call for papers

<http://www.insa-tlse.fr/~emccompo>
Hotel ATRIA, Toulouse, France, 14-15 Nov 2002

Context

The progresses in technology, the continuous increase in dock frequencies and circuit complexity lead to complete system-on-chip solutions. However, the level of parasitic emission increases with the technology scale down. Furthermore, the supply reduction and ever smaller noise margins tend to increase the susceptibility of the IC to external electromagnetic aggression.

The purpose of the workshop *EMC Compo 2002* is to address the emission and susceptibility issues for integrated circuits, either logic, analog or mixed logic/analog. The most recent advances in measurement methods, models, standards, tools and design methodologies will be discussed during the workshop.

A technical exhibition will include EMC products and services related to integrated circuits.

Paper submission

Complete papers should be submitted in a A4, 4 pages format, including title, abstract, illustrations and references. Electronic submission is encouraged.

Topics

The workshop is specifically focused on EMC for integrated circuits, with the following sub-topics:

- Measurement methods for emission of integrated circuits
- Measurement methods for susceptibility of integrated circuits
- Models & standards for predicting emission & susceptibility of integrated circuits
- Use of IC models in Printed circuit board simulation
- Education and e-learning related to EMC for ICs
- Design methodologies for improved EMC behavior of ICs
- Tools to handle EMC at IC level
- Prospective aspects of EMC in future generation ICs

Dead-line

Final paper submission
Sept 15th, 2002
Notification of acceptance
Oct 15th, 2002

Program Committee

Sonia Bendhia, *INSA*
Flavio Canavero, *Politecnico Torino*
Christian Carel, *See, Thales*
Mart Coenen, *Philips*
Lionel Courau, *ST Microelectronics*
Bernard Demoulin, *University of Lille*
Jean-Marc Dienot, *IUT Tarbes*
Franco Fiori, *Politecnico Torino*
Hervé Grauby, *Gerac*
Todd H Hubing, *University Missouri Rolla*
Claude Huet, *EADS Airbus*
Werner John, *Mesole*
Elya B. Joffe, *IEEE EMC*
Joachim Kruecken, *Motorola GmbH*
Jean-Luc Levant, *Atmel Nantes*
Marc Lubineau, *Alcatel Space*
Christian Marot, *Siemens VDO*
Jean-Claude Perrin, *Texas Instruments*
Mohamed Ramdani, *ESEO*
Miquel Roca, *University of Balearic Islands*
Anton Sauer, *Lime, Fraunhofer Dresden*
Etienne Sicard, *INSA*
Amaury Soubeyran, *EADS CDR*
Thomas Steinecke, *Infineon*
François Vernieres, *IerSet*
Boris Traa, *Philips*

Contact

Submissions and scientific program
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Local Organizing Committee
Martine Blaimont, *IerSet Toulouse, France*
martine.blaimont@ierset.asso.fr

RELEASE OF IC-EMC MEASUREMENT STANDARDS

- IEC 61967, Integrated circuits
Measurement of **electromagnetic emissions** 150 kHz to 1 GHz, 2002
- Generic **IC EMC Test Specification**,
Version 1.0, Bosch, Infineon, Siemens
VDO, 2004
- IEC 62132, Integrated circuits
Measurement of **electromagnetic immunity** 150 kHz to 1 GHz, 2005



Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

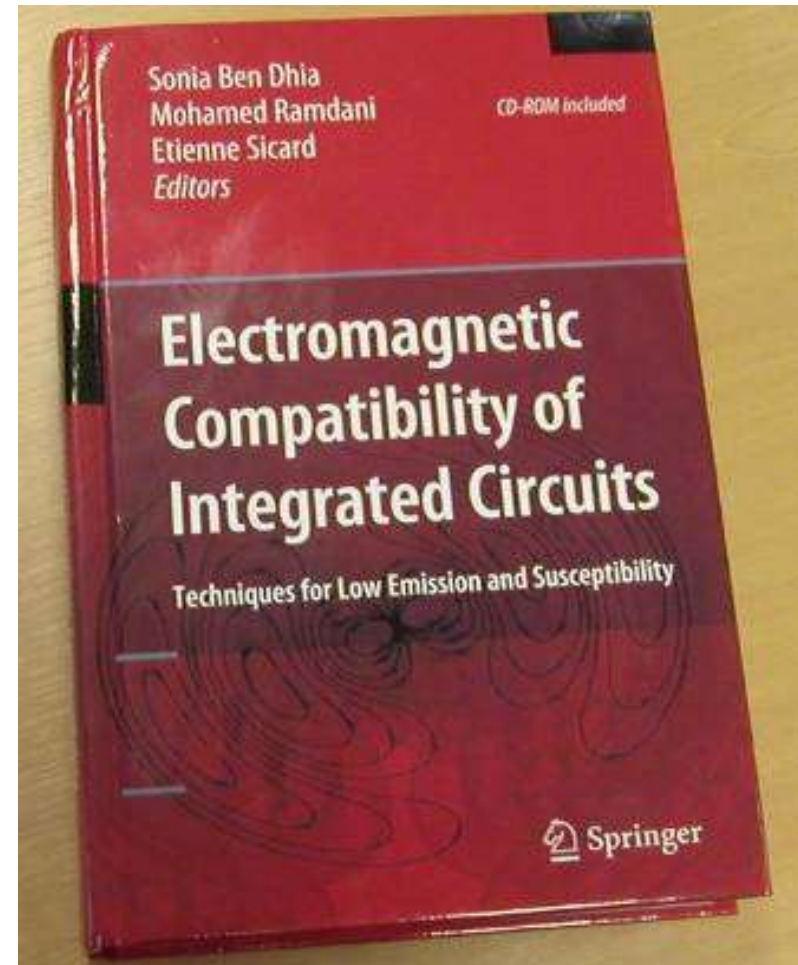
Limit class	150 Ω method		1 Ω method		TEM cell method
	<i>global</i>	<i>local</i>	<i>global</i>	<i>local</i>	
I	8-H	6-F	10-K	8-H	I
II	10-K	8-H	12-M	10-K	L
III	12-M	10-K	14-O	12-M	N
C	<i>Customer-specific</i>				

TABLE II IMMUNITY LIMIT CLASSES

Immunity limit classes	DPI [forward power] dBm		TEM [E-field] V/m
	global pin	local pin	entire IC
I	18	0	200
II	24	6	400
III	30	12	800
C	<i>Customer-specific</i>		

**EMC OF ICS”, SPRINGER, USA,
2006**

- Based on **EMC Compo 2004** contributors
- Ben Dhia, Ramdani and Sicard compile **the first book** only dealing with **EMC at integrated circuit level**.
- The book includes a description of measurement, model standards, techniques for **low emission and susceptibility**



RELEASE OF IC-EMC MODELLING STANDARDS

- **IEC 62433 : EMC IC modelling**
Models of integrated circuits for RF
immunity behavioural simulation

General modelling framework : 2011

Conducted immunity modelling (ICIM-CI) :
2016

Conducted emissions modelling (ICEM-
CE) : 2017

Radiated emissions modelling (ICEM-RE) :
2017

Universal data exchange format in XML

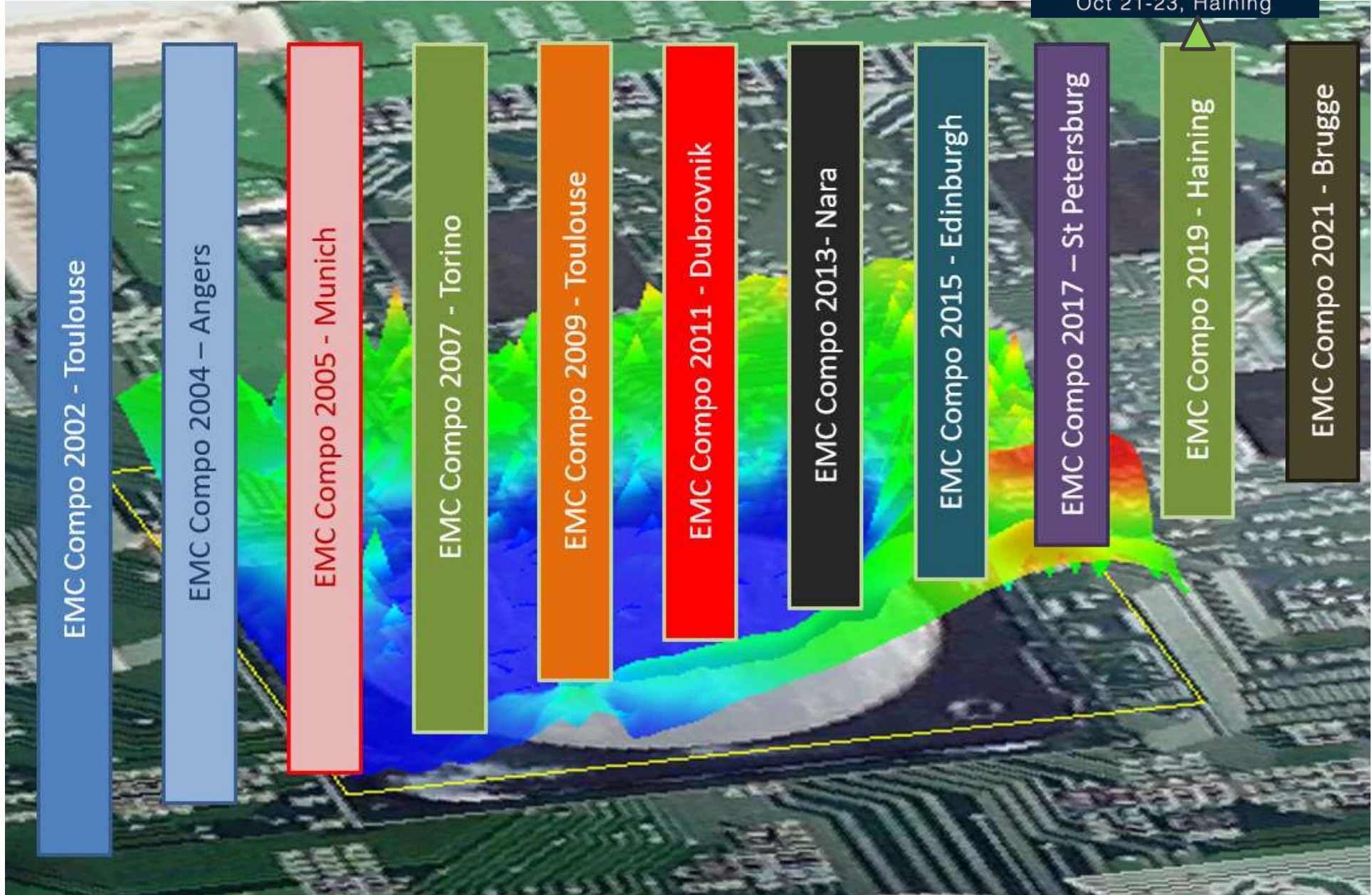
IEC 62433	Conducted mode	Radiated mode
Emission model (ICEM)	ICEM-CE IEC 62433-2	ICEM-RE IEC 62433-3
Immunity model (ICIM)	ICIM-CI IEC 62433-4	ICIM-RI IEC 62433-5
	Impulse immunity IEC 62433-6	



Standard available

Draft of standard

Research ongoing



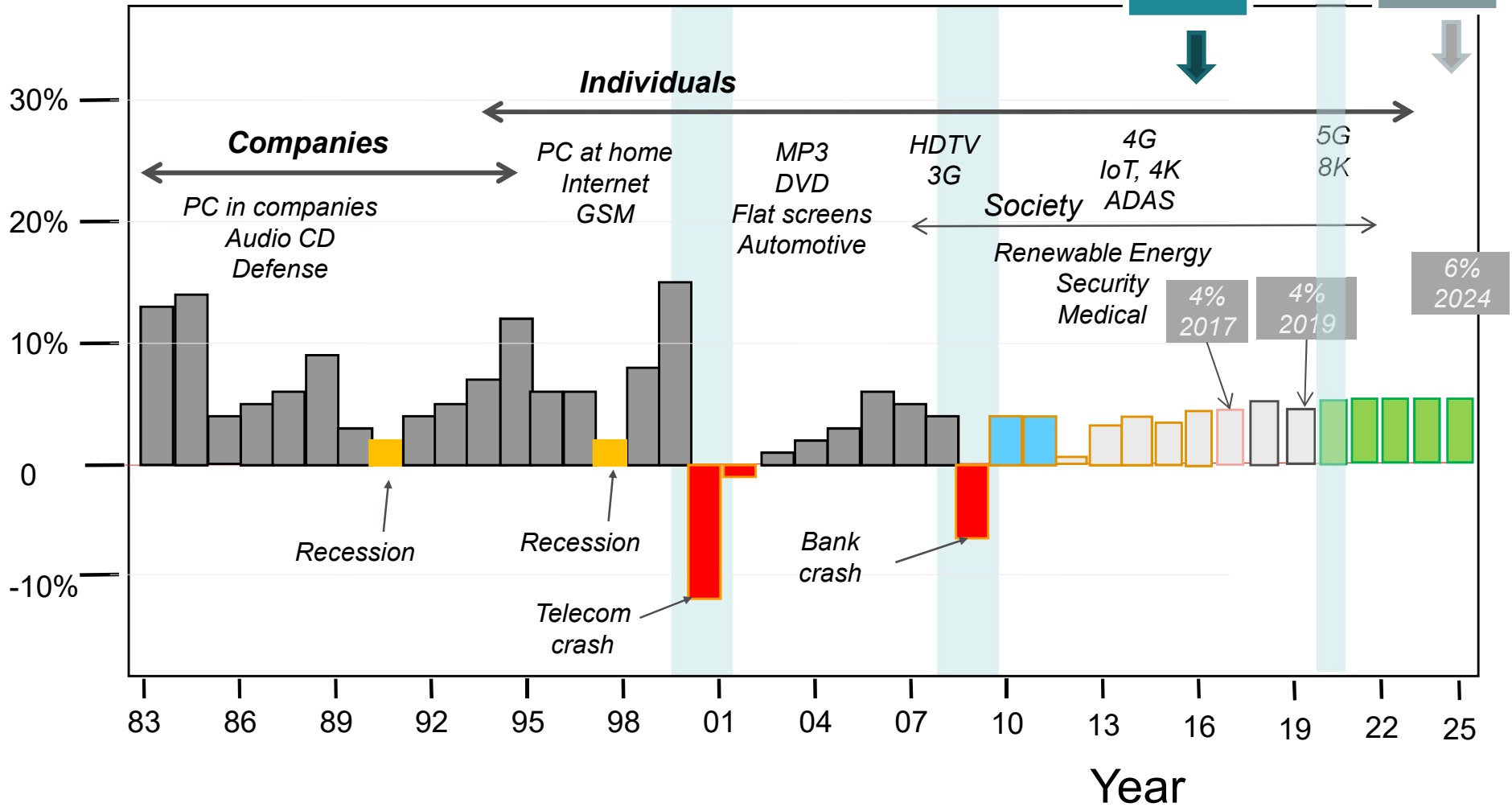


GENERAL TRENDS

THE ELECTRONIC MARKET GROWTH

EMC COMPO 2019
Oct 21-23, Haining

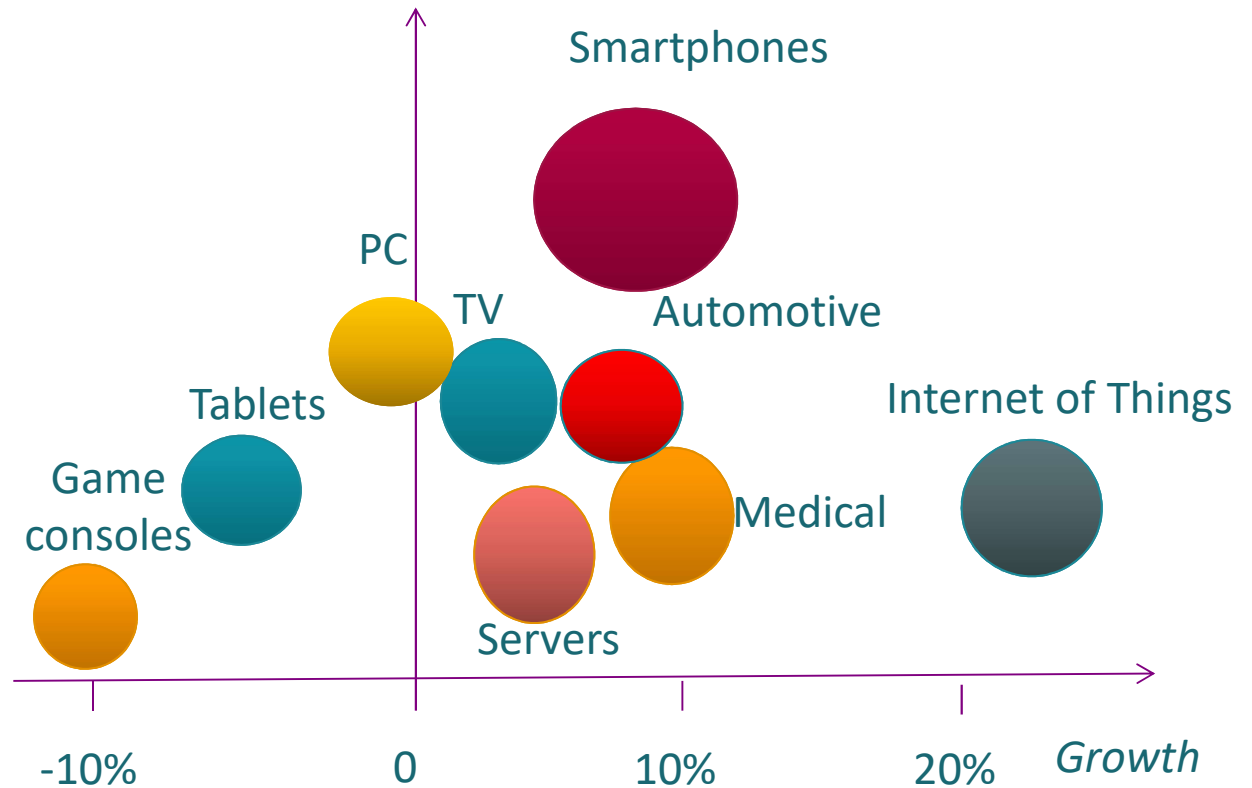
Market Growth



- **Vision 2024**

- Increasing disposable income,
- expanding urban population,
- growing internet penetration and
- availability of strong distribution network

*Share of system sales
2024 vs 2019*



MOBILE SUBSCRIBERS

<https://gsmaintelligence.com/>

Oct. 2019

GLOBAL DATA

Mobile connections, including
licensed cellular IoT Sep 2019

9,319,577,335

▲ 5.5%

Unique mobile subscribers

Sep 2019

5,146,873,987

▲ 2.5%

Revenue/year

FY 2018

\$1.04T

▲ 1.9%

ARPU/month

FY 2018

\$8.45

▼ -0.8%

Source: GSMA Intelligence 2019, current year-end data except interpolated subscribers and connections

.. Oct 2014 (-5 years)

7,180,500,225

▲ 6.21%

3,645,727,439

▲ 7.22%

\$1.13T

▲ 3.75%

\$12.15

▼ -3.97%

Source: GSMA Intelligence 2014, current year-end data except interpolated connections

Technology

130nm

90nm

45nm

28nm

14nm

5nm

Complexity



250M



500M



2G



7G

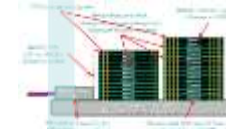
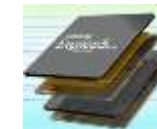
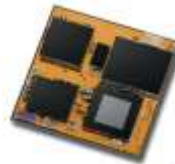


15G



150 G

Packaging



Mobile generation

3G



3G+



4G



4G+



5G



2004

2007

2010

2013

2016

2022

Embedded blocks

Core DSPs
10 Mb Mem

Dual core
Dual DSP
RF
Graphic Process.
100 Mb Mem
Sensors

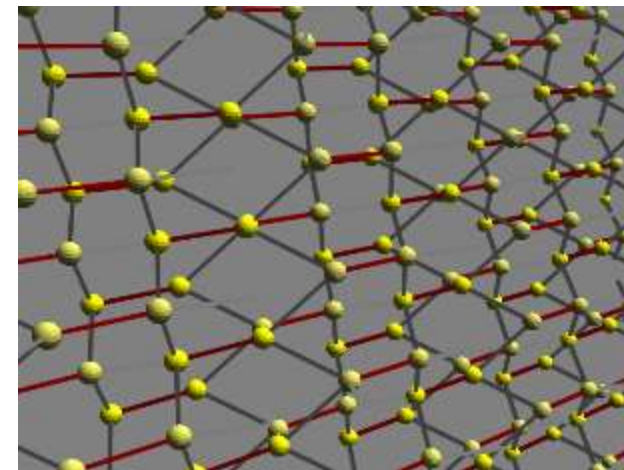
Quad Core
Quad DSP
Image Proc
Crypto processor
Reconf FPGA,
Multi RF
1 Gb Memories
Multi-sensors

Octa Core
Multi DSP
3D 4K
4 GPU
Crypto, sensor,
position processor
Agregated RF
2 Gb Memories

Same +
8K Image
4/8 cameras
16 GPU
Dual IA
Mmw 27 GHz

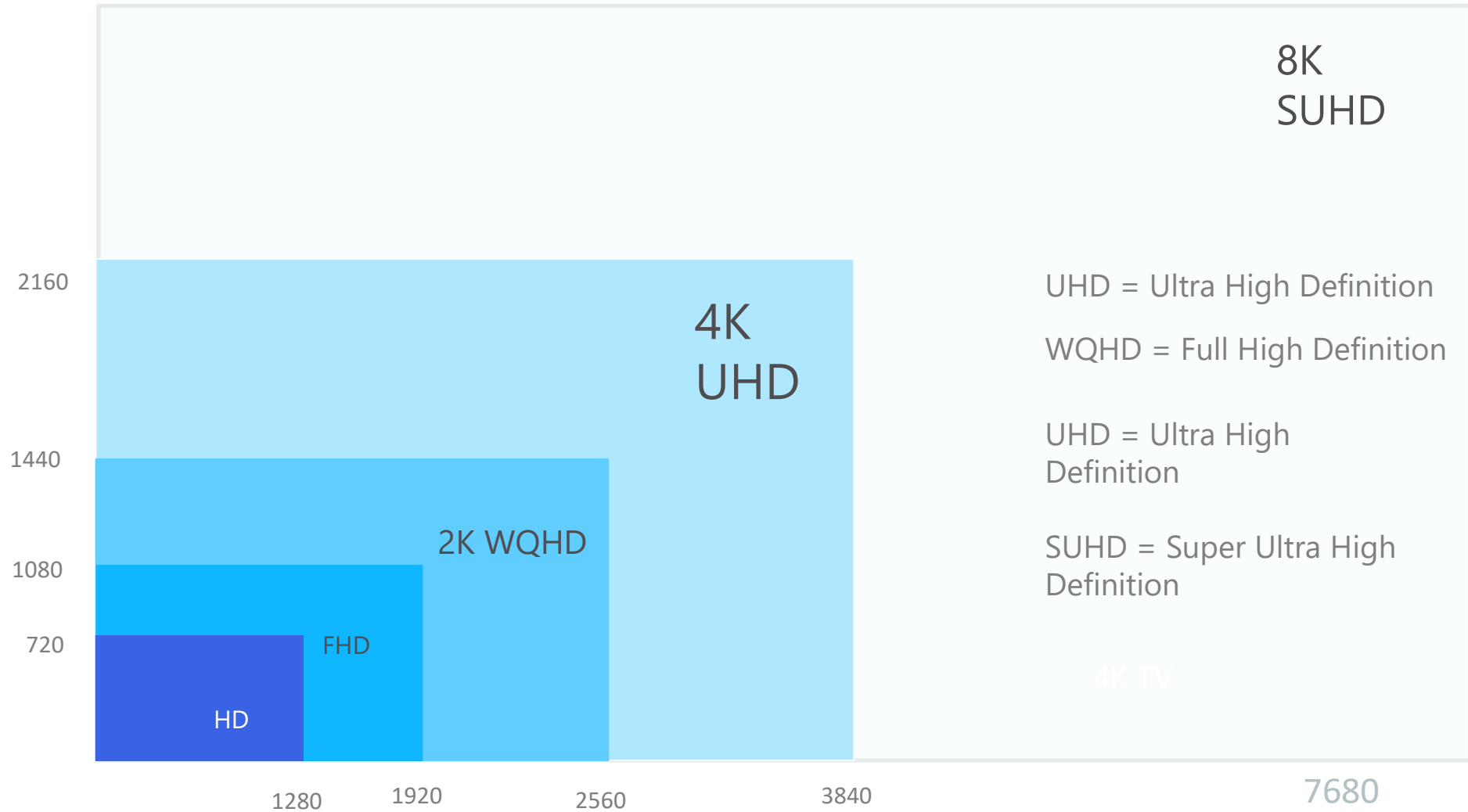
TOWARDS 5G

- Kirin 990 HiSilicon for Huawei
- Octa Processor + Dual IA + 16 GPU + Modem 5G
- 7nm+ process
- Non-Standalone network (now)
- Also support Stand-Alone network
- 10 Billion devices



Silicon lattice: 0.25 nm "7nm"=30 atoms

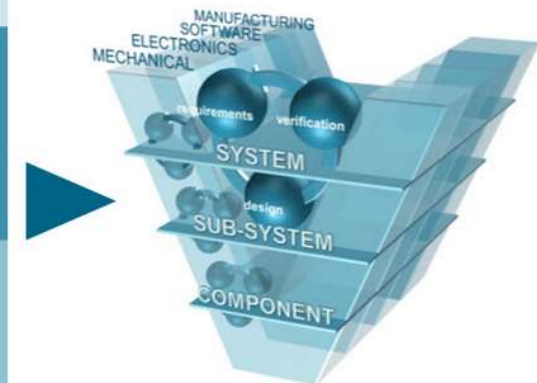
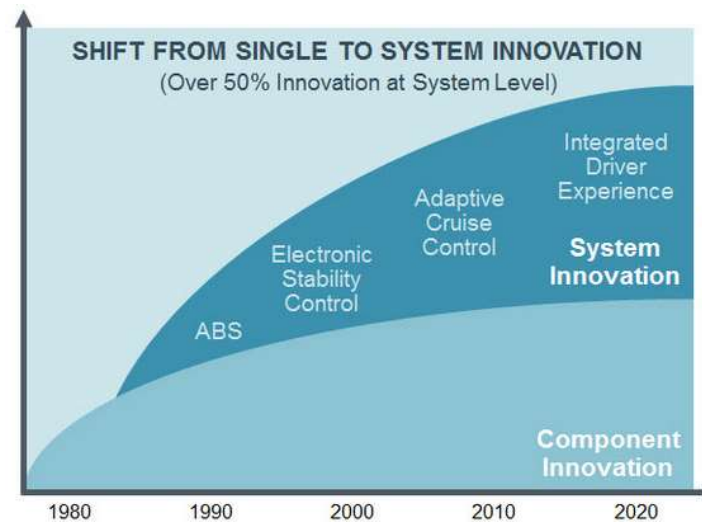
MORE RESOLUTION

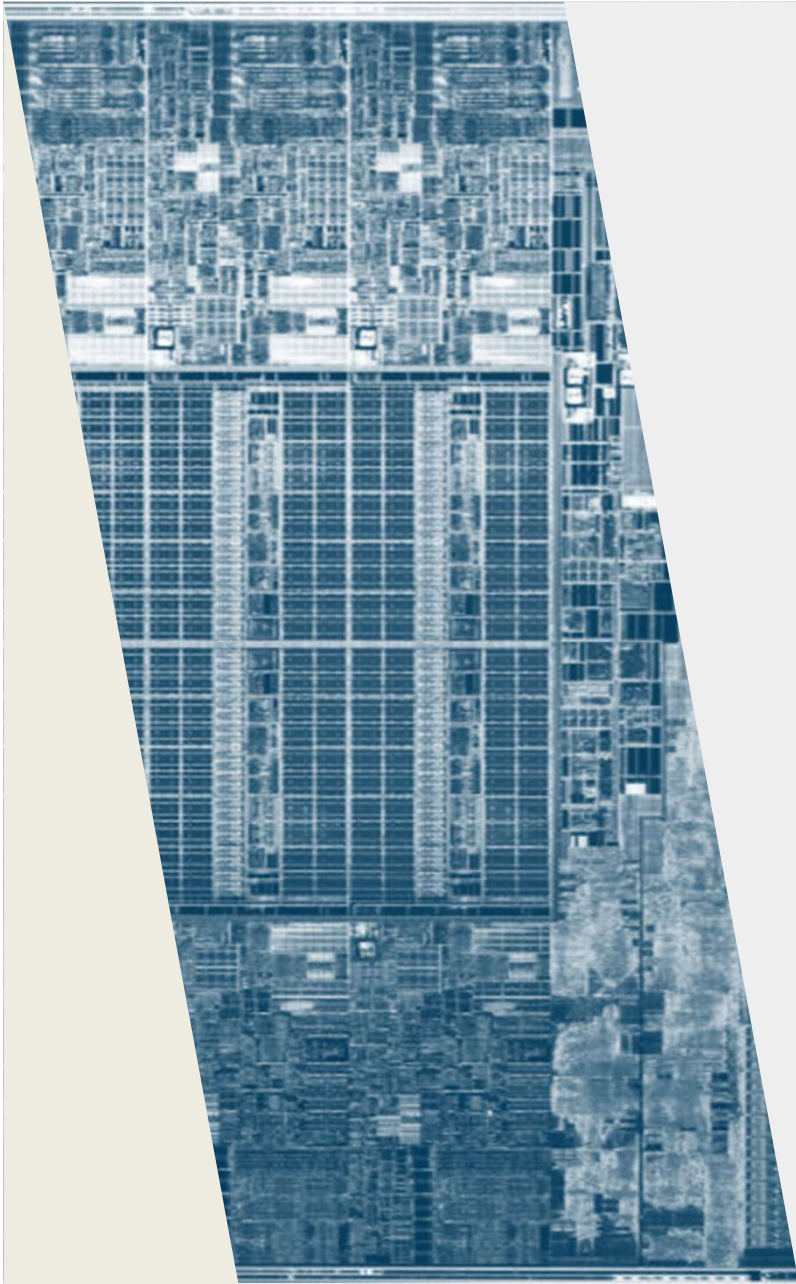


AUTOMATIC DRIVE

Automatic Cars

- require highly intensive and reliable computing
- Trend towards hybrid/electrical car for low carbon emission
- Multi-sensor approach
- A lot of EMC concerns pending

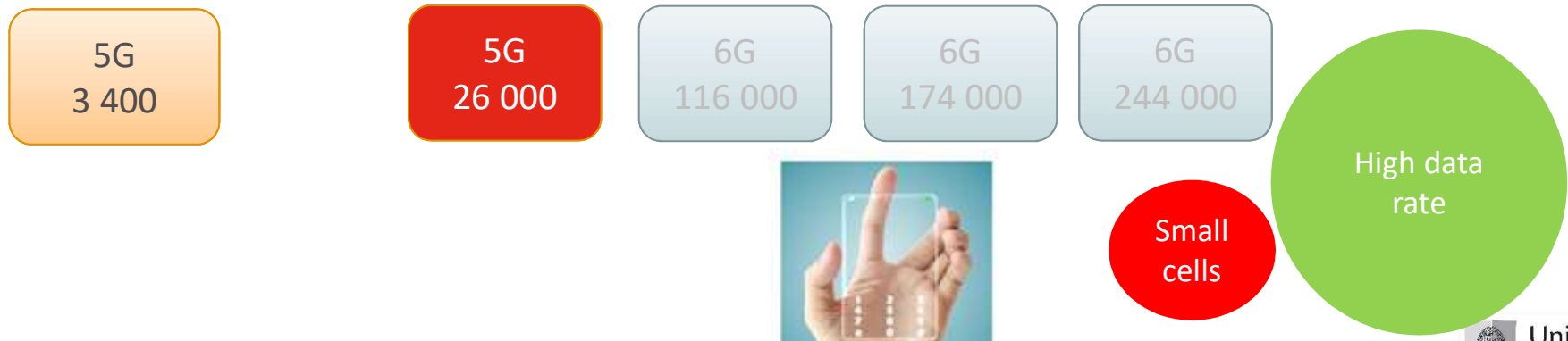
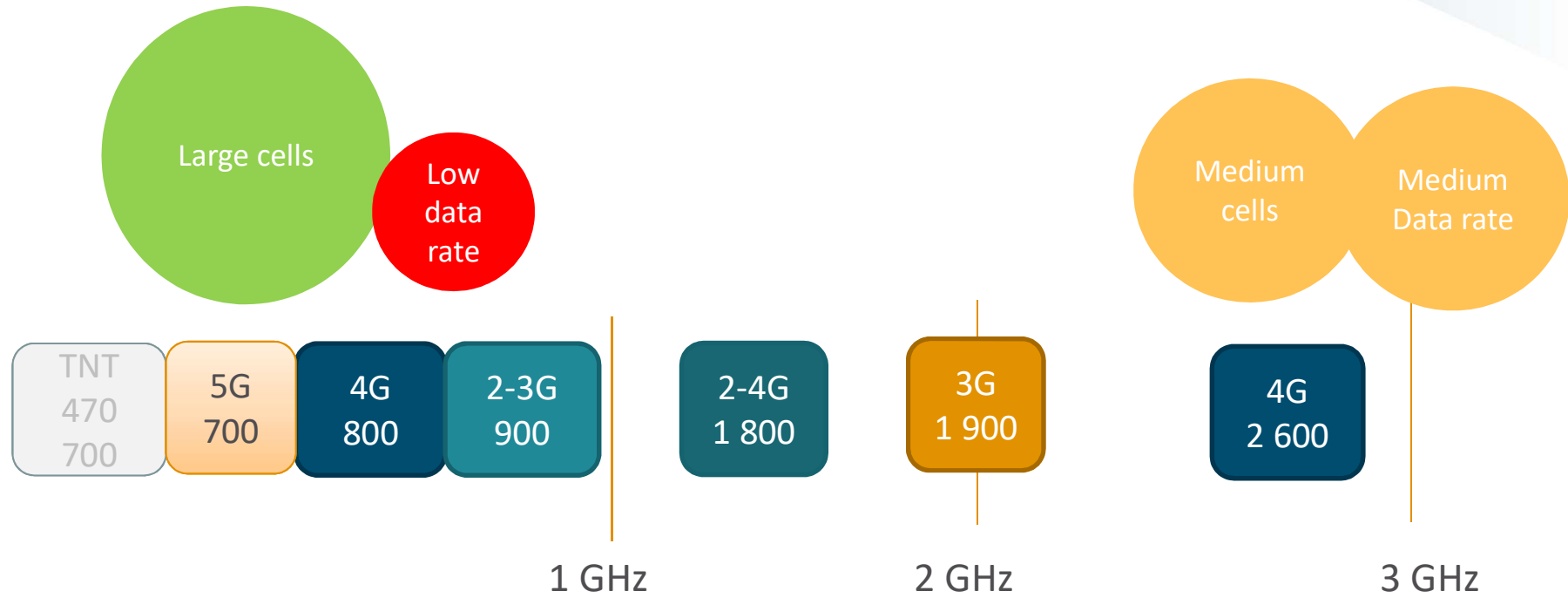




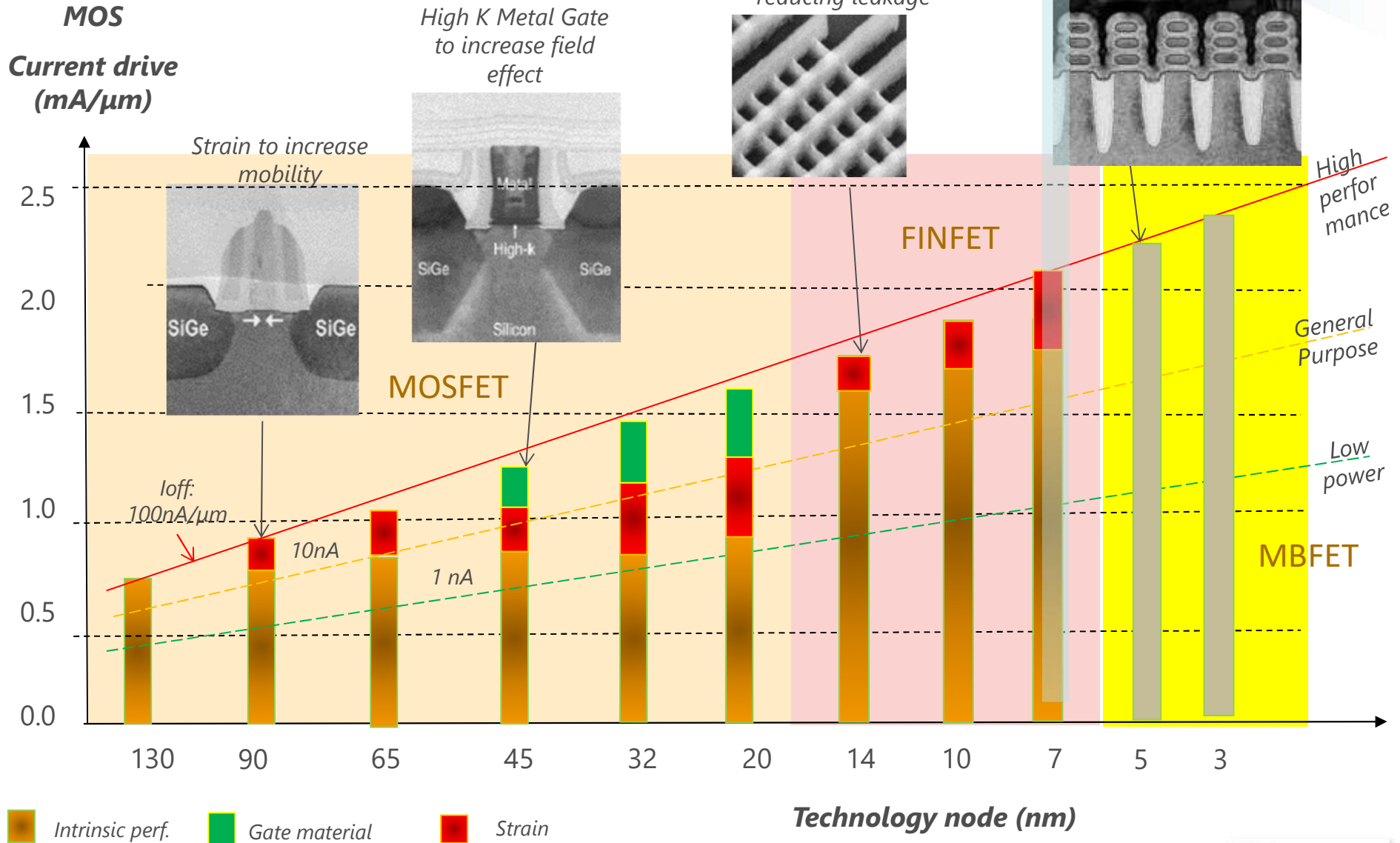
TECHNOLOGY TRENDS

**DEPARTMENT OF ELECTRICAL &
COMPUTER ENGINEERING**

HIGHER FREQUENCIES



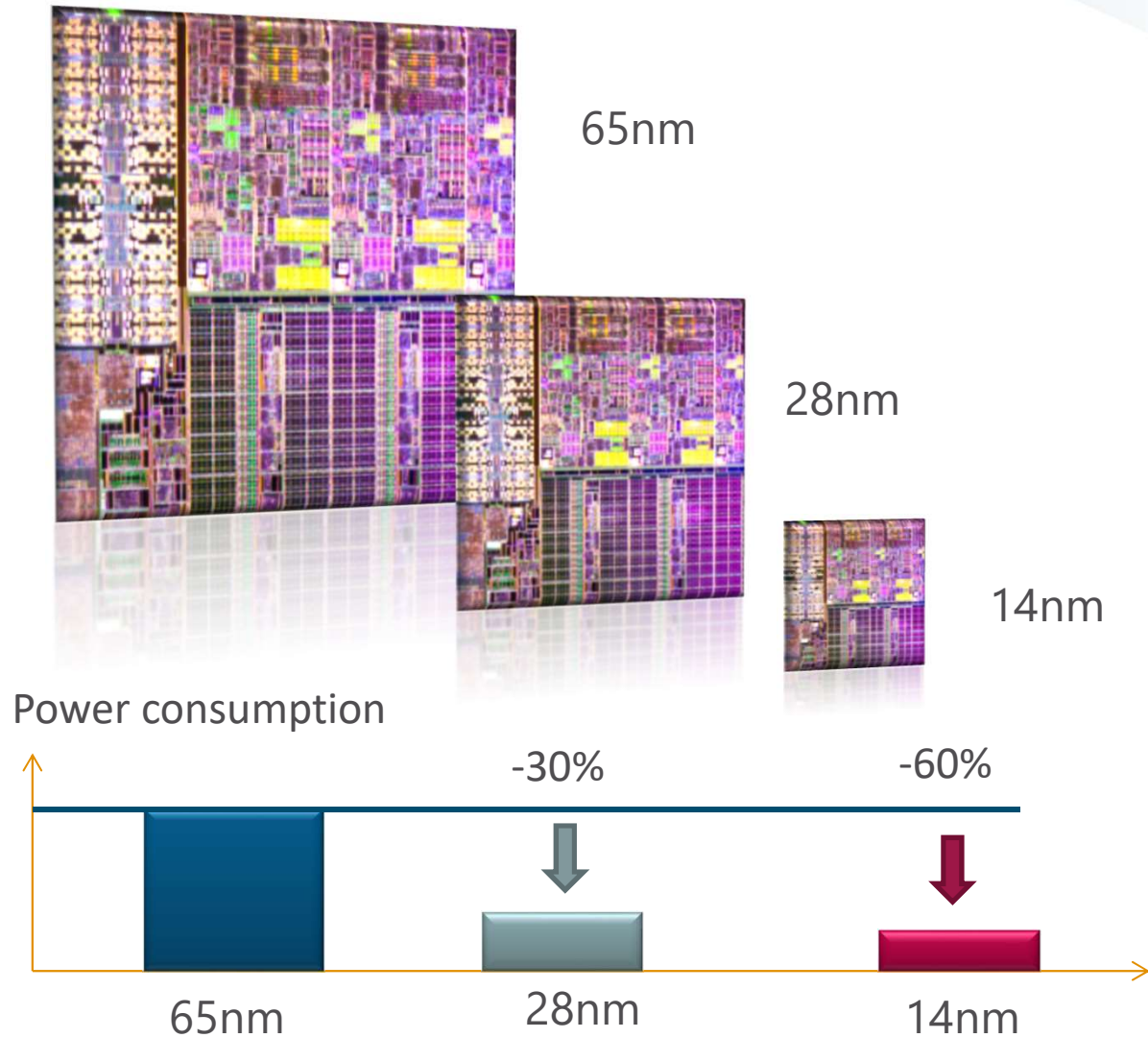
MORE CURRENT DRIVE



LESS POWER

Scale down benefits

- Less power consumption
- More space for integration
- Maybe faster
- Maybe cheaper



MORE MATERIALS

• Screens

50 Sn Tin	49 In Indium	8 O Oxygen
13 Al Aluminum	14 Si Silicon	19 K Potassium
66 Dy Dysprosium	59 Pr Praseodym	
65 Tb Terbium	60 Nd Neodymium	64 Gd Gadolinium
63 Eu Europium	39 Y Yttrium	

Critical !

• Batteries

3 Li Lithium	13 Al Aluminum
6 C Carbon	8 O Oxygen

Very rare!

• Casing

6 C Carbon	12 Mg Magnesium
35 Br Bromine	28 Ni Nickel

• Electronics

22 Ti Titanium	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	28 Ni Nickel
40 Zr Zirconium	41 Ni Niobium	47 Ag Silver	73 Ta Tantalum	79 Au Gold
			66 Dy Dysprosium	59 Pr Praseodym
			65 Tb Terbium	60 Nd Neodymium
				64 Gd Gadolinium
		7 N Nitrogen	8 O Oxygen	14 Si Silicon
				51 Sb Antimony
			33 As Arsenic	15 P Phosphor
				31 Ga Gallium
72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	50 Sn Tin	82 Pb Lead

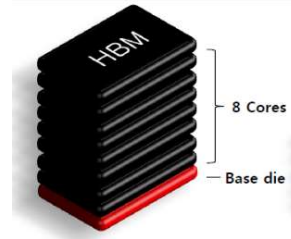
Very rare!

MORE MEMORY BANDWIDTH



- Increased memory/processor bandwidth

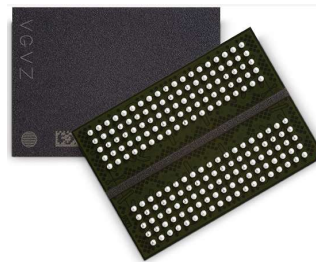
High performance computing & AI
Mobiles & high resolution games
Servers & Security



High Performance Computing & Networking
High Bandwidth Memory



Mobile
Low Power DDR5

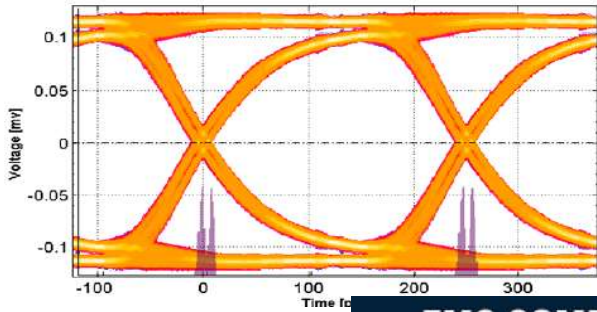


Graphics
Graphics DDR6

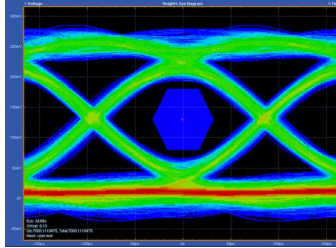


MORE MEMORY BANDWIDTH

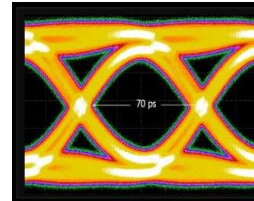
LPDDR4



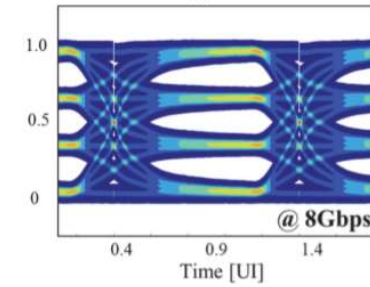
LPDDR5



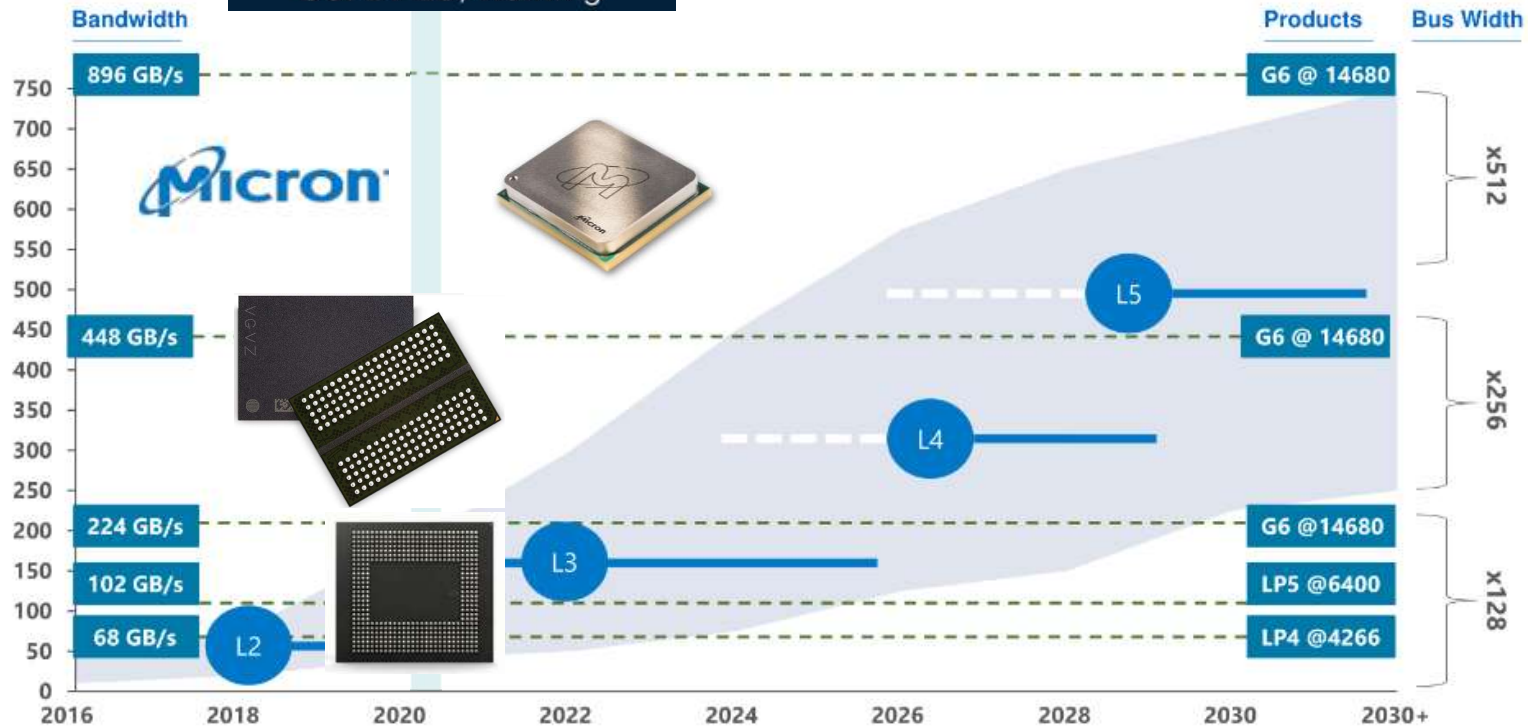
GDDR6



HMC

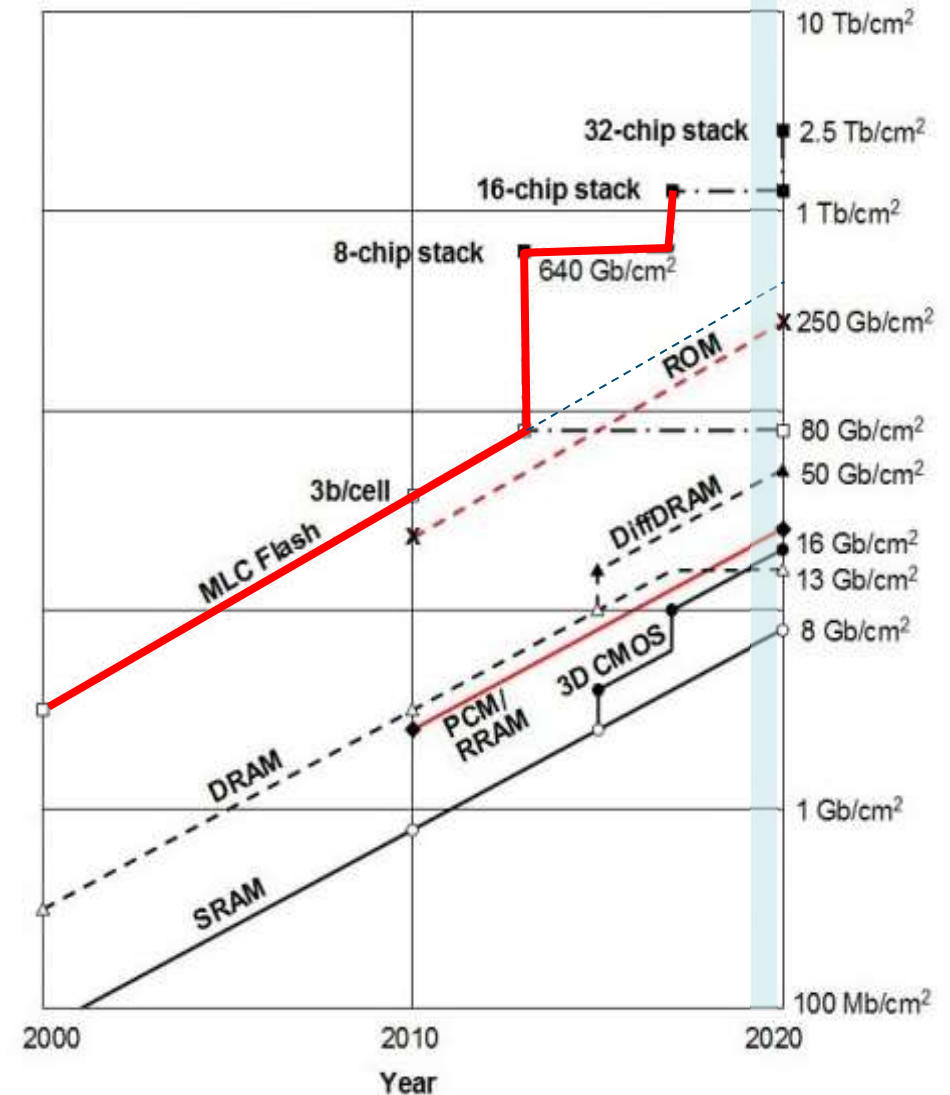
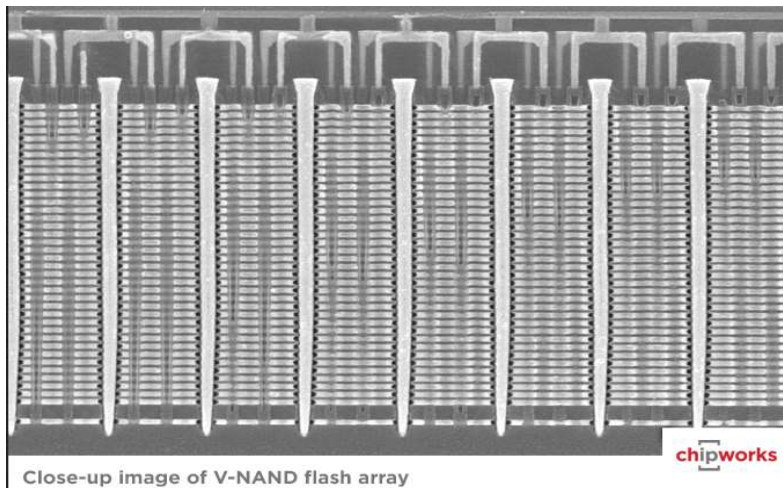


EMC COMPO 2019
Oct 21-23, Haining



Technology

- 2.5D high bandwidth and high density DRAM with TSV and Si Interposer
- 1 tera-bit/cm² achieved 5 years ahead from roadmaps

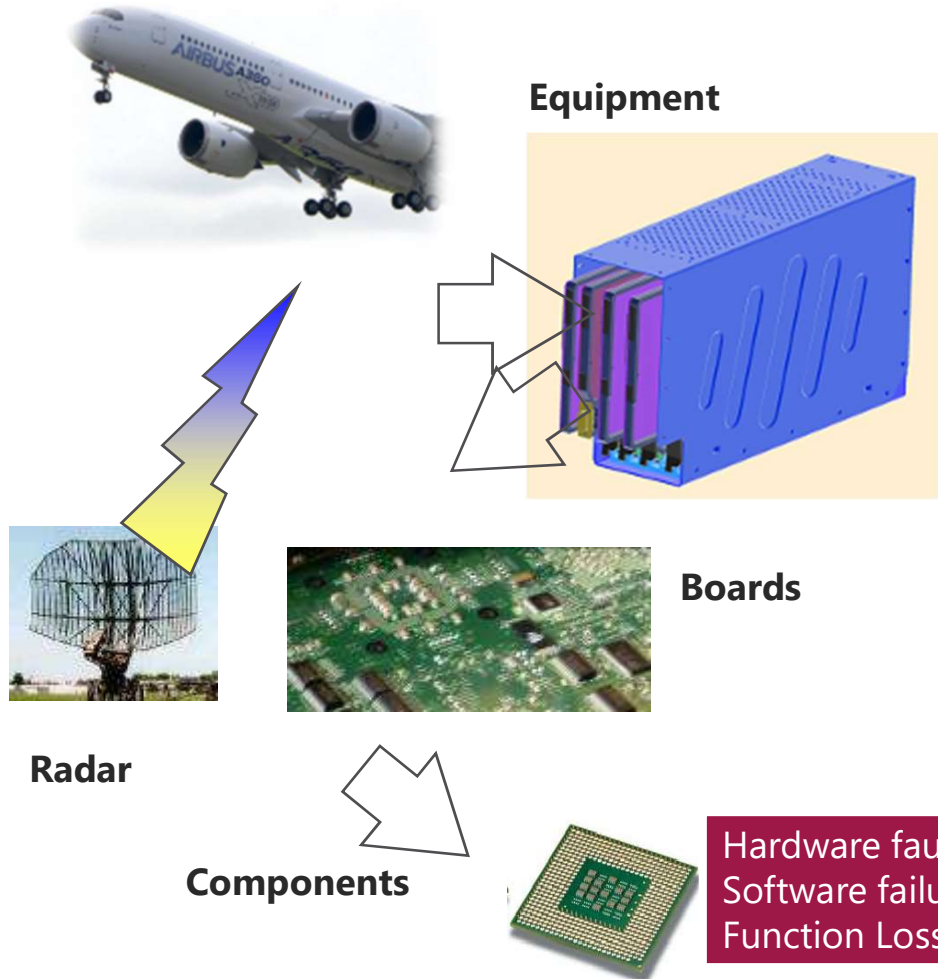




EMC CHALLENGES

EMC – TWO KEYWORDS

- SUSCEPTIBILITY**

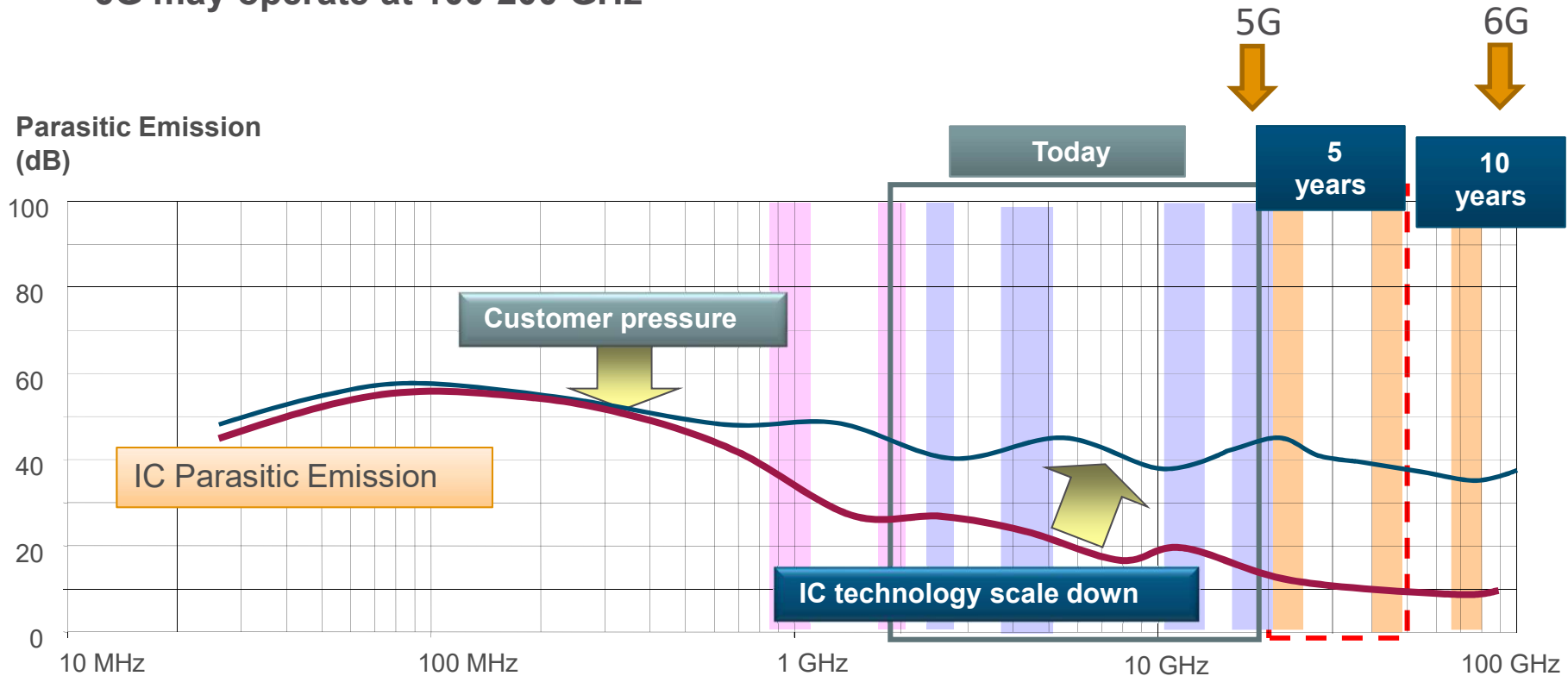


- EMISSION**



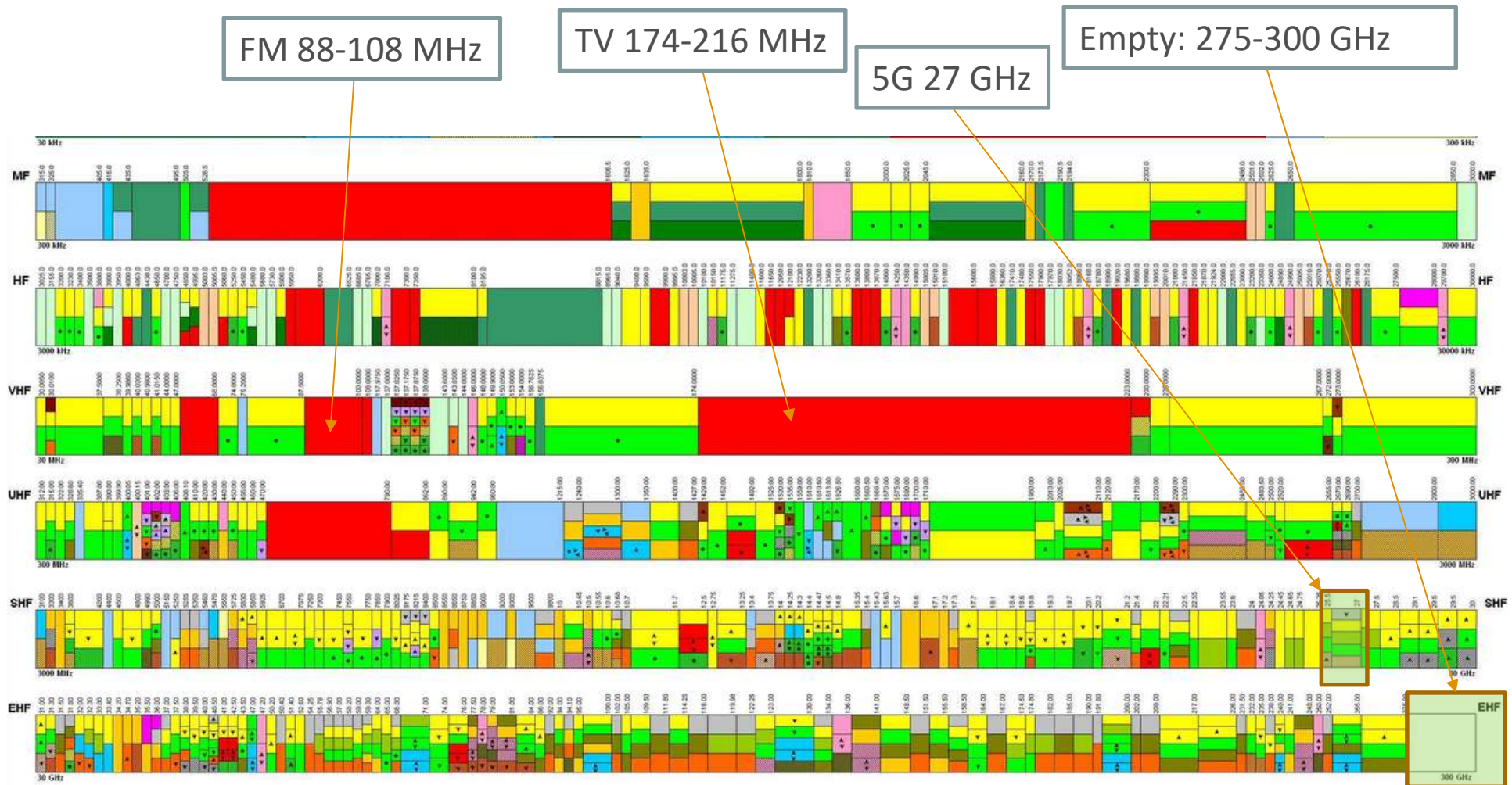
Increased frequencies

- EMC at IC level usually characterized upto 6 GHz
- Millimeter-wave 5G operates at 27 GHz
- 6G may operate at 100-200 GHz



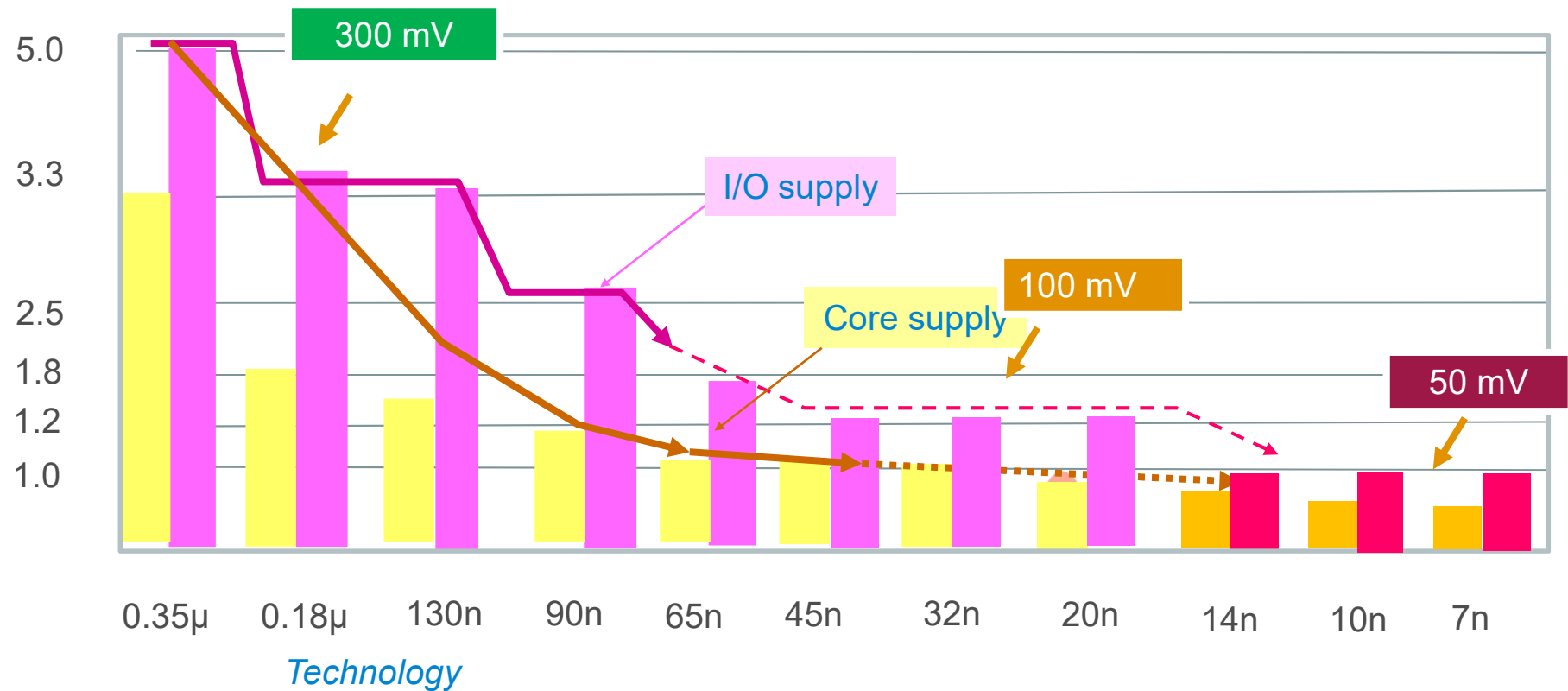
THE FREQUENCY SPECTRUM IS FULL

- Giant number of communication systems upto 275 GHz



- Reduced supply voltage in nano-cmos lcs
- Reduced voltage swing

Supply (V)



Costs

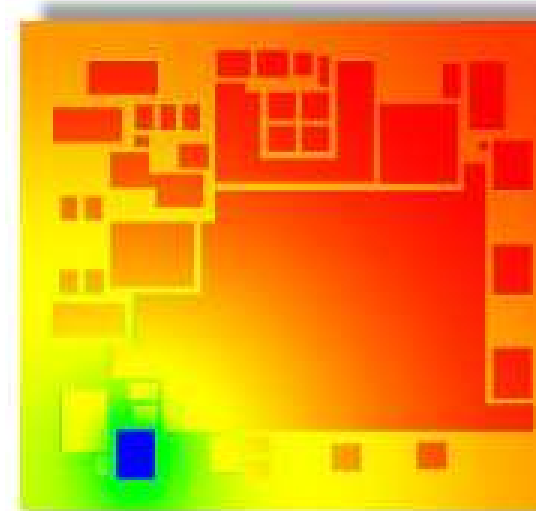
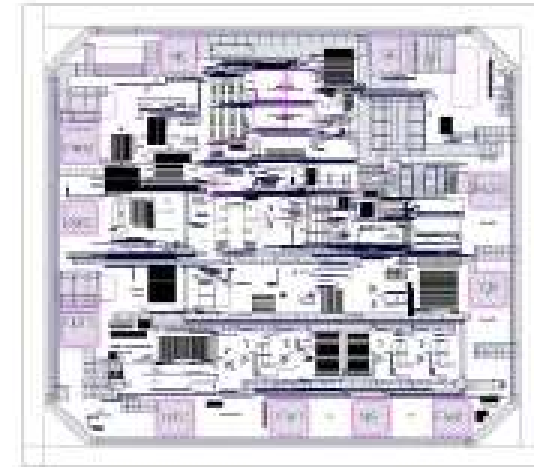
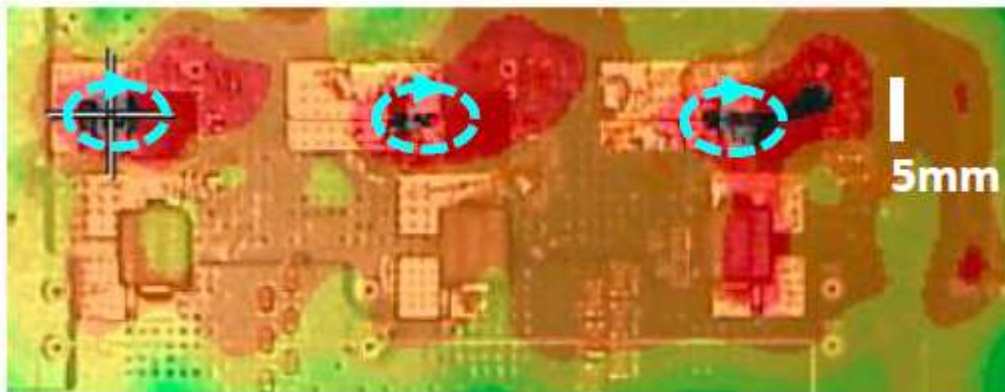
- Pressure for **cost reduction**
- EMC **test costs increased**
- **Late analysis** of EMC usually lead to **extra costs**
- **Off-the-shelf** components are becoming **very popular**, but EMC performances are usually **unknown**
- At best, incomplete **IBIS** models



PROS	CONS
No development time required; The product is available as soon as it is purchased	No competitive advantage since it is available to all competitors
Gain cost efficiencies with a mass market product	Custom functionality not available; You conform to the app rather than the app conforming to you
Upgrades and enhancements provided by the app owner, oftentimes at no additional charge	App support is contingent on the developing company's viability

More Electric Systems (cars, airplanes)

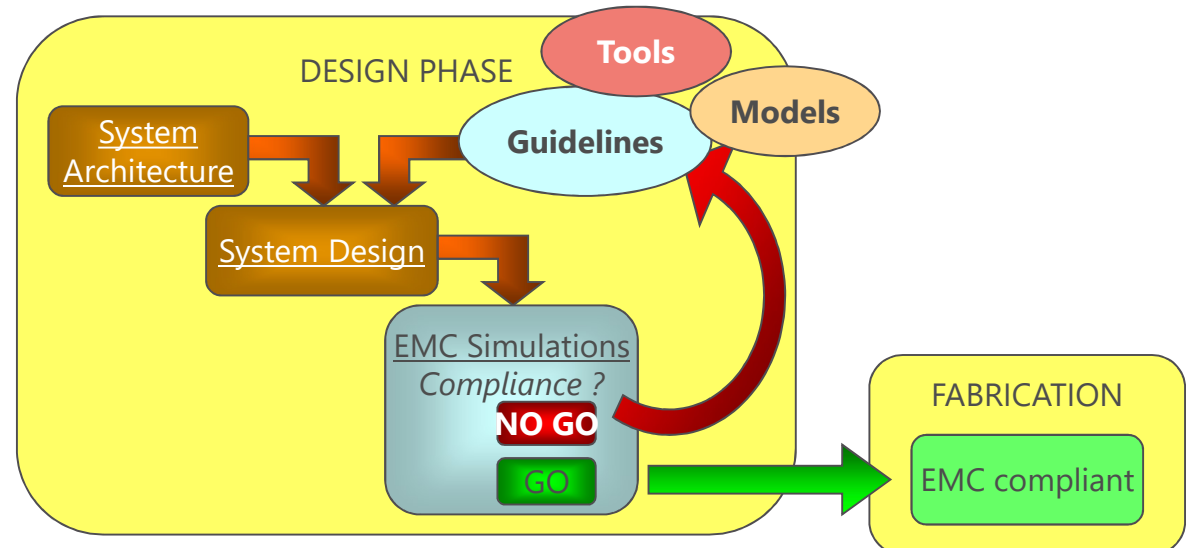
- Power IC contains **100+ pockets** and 10+ **power domains**
- Standard TCAD tools **cannot** cope with chip complexity and dimensions
- Simulation of EMC requires simplification & approximations for **model-order-reduction**



MORE ANTICIPATION

Design

- EMC concerns move from **system-level to IC-level**
- EMC/interference is taken into account from the very **early design phases**
- Increased use of simulation & modeling
- Measurement should (preferably) only **confirm a good EMC modeling / simulation work**



People

- **Lack of EMC engineers** with knowledge on ICs
- Not enough engineers who can design and simulate **chip-package-board** together
- Not enough engineers who can handle **signal & power integrity** together
- Non-EMC aware **project management**



Tool Efficiency

- Communication and data sharing between IC, package, and PCB design level **very difficult**
- Limits of CAD and **computational resources**
- Efficient modeling and simulation methods simulating “**Tera-device**” problems not available





GOOD NEWS FOR EMC

Improve IC EMC

At source

Defensive software

Spread Spectrum

Thermal
management

Optimize Power
Delivery

Better layout

Identify failures

Novel materials

Anticipate failures

Along the path

Filtering

Shielding

Better Layout

More accurate
Measurements

Impedance
Matching

Anticipate emission

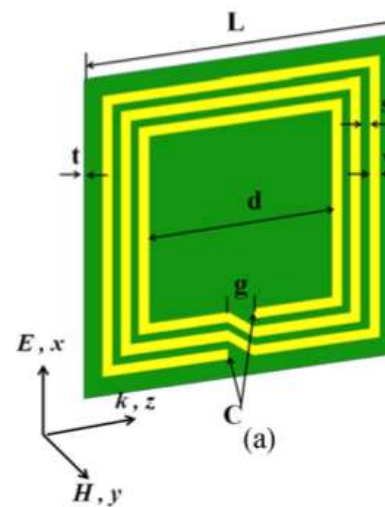
Choice of
components

Anticipate
susceptibility

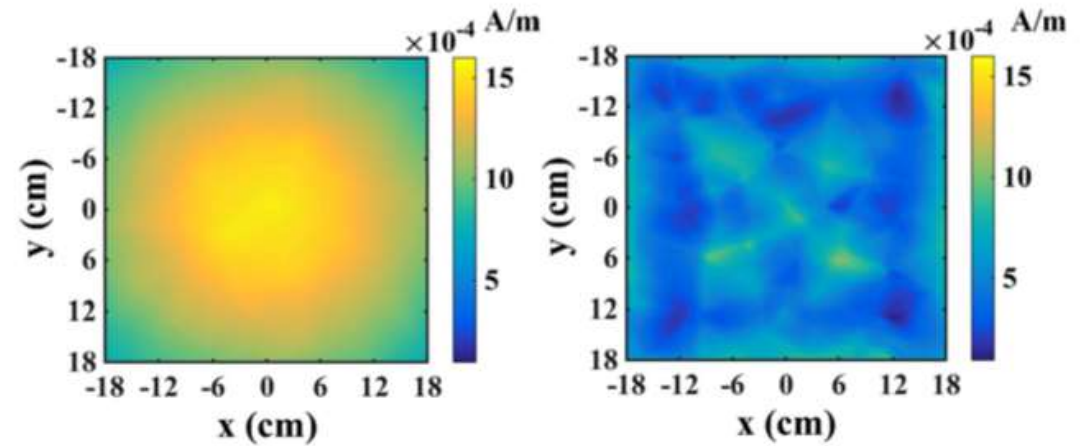
- Selection of papers published in 2018, 2019 in IEEE Transaction on EMC

Shielding

- Investigation of Negative and Near-Zero Permeability Metamaterials, Conghui Lu, IEEE Trans. EMC, 2019
- Reduction of 15 dB thanks to meta-materials



(b)



Shielding

- Flexible, Thin Composite Film to Enhance the Electromagnetic Compatibility of Biomedical Electronic Devices Vikas Rathi, 2019
- Electromagnetic Shielding Effectiveness: 20-30 dB

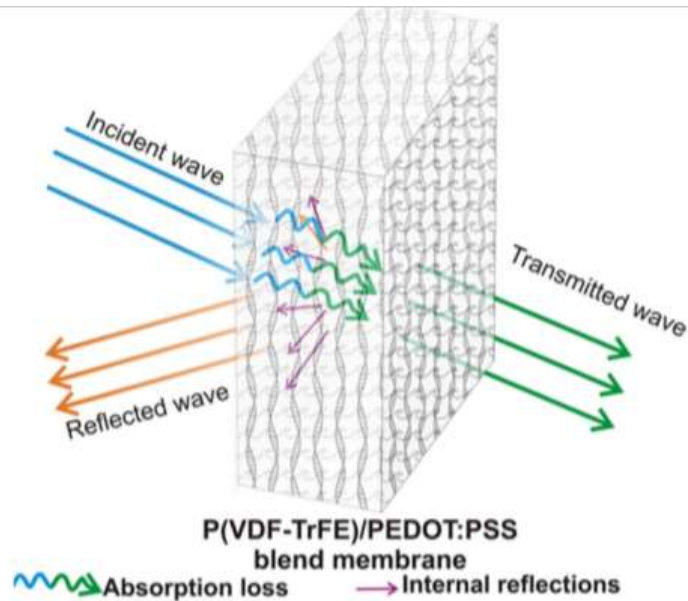


TABLE I
EMI SHIELDING PERFORMANCE OF SOME OTHER FILMS

Material	Mechanical Property	Thickness (mm)	EMISE(dB)	Reference
MWCNT/polyurethane	flexible	1.5	29	25
PVDF/CNT/graphene	flexible	0.1	27.58	2
poly(propylene)/polystyrene	hard	2	20	26
P(VDF-TrFE)/PEDOT:PSS	flexible	0.08	35	This work

Novel materials

Shielding

- Efficient Passive Shielding of Multi-Wire Carbon Nano-Tube Interconnects to Reduce Crosstalk Effects, M. H. Moaiyeri, 2019
- More compact pitch, less crosstalk with CNT as compared to Copper

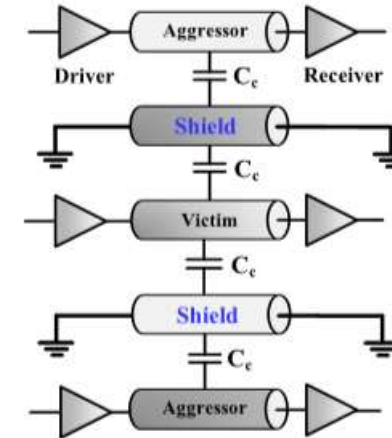
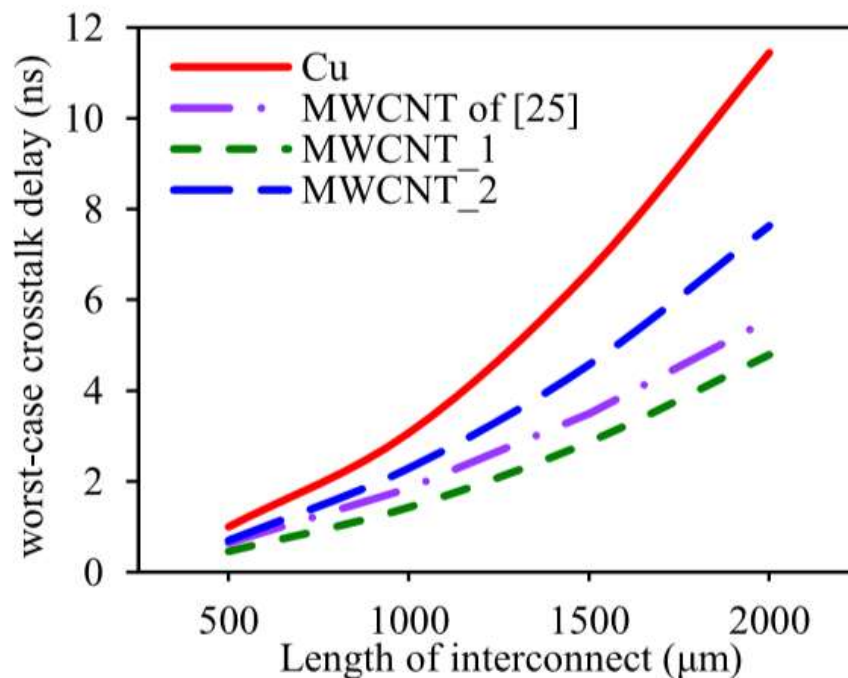
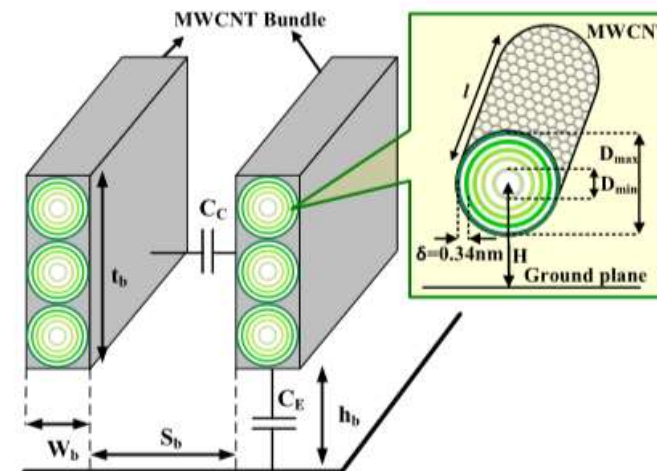
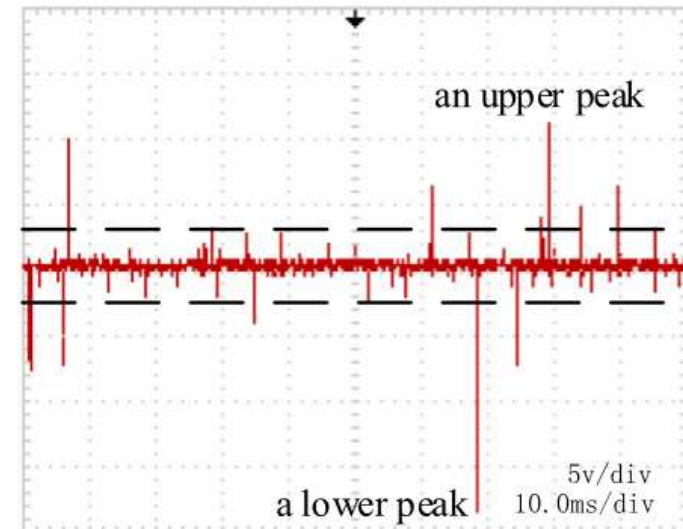
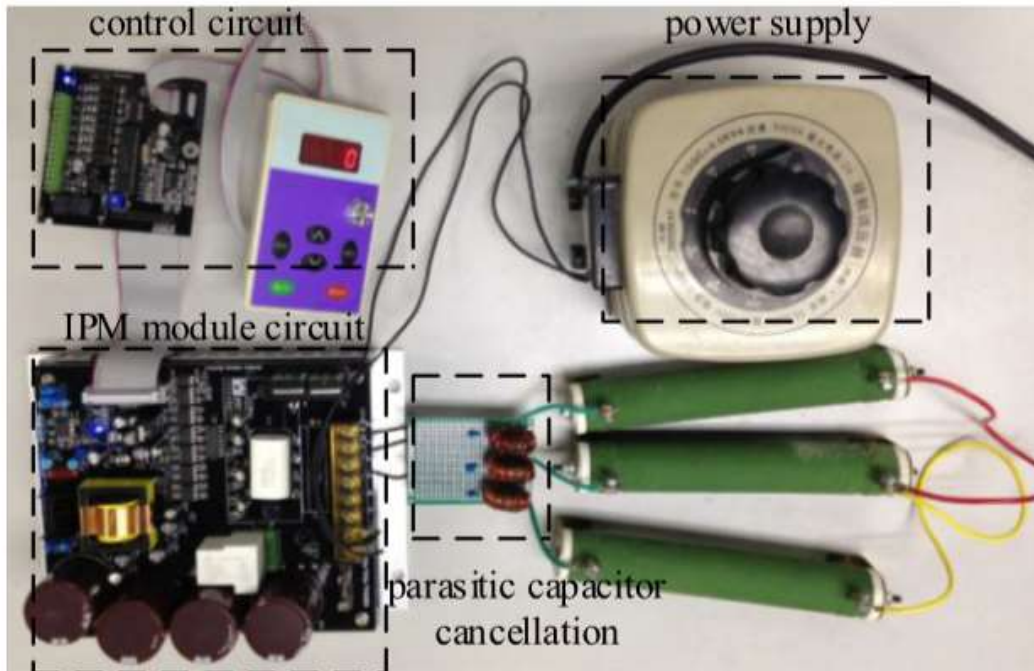


Fig. 1. Schematic of the bus used for investigating the crosstalk effects.

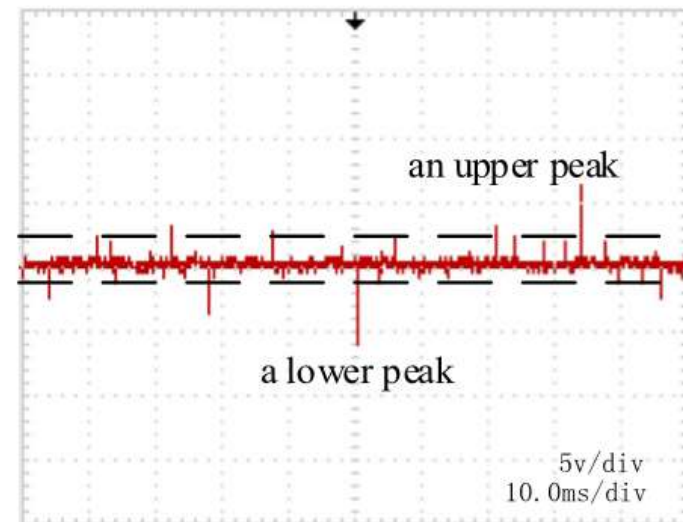


Filtering

- Common-Mode Noise Reduction by Parasitic Capacitance Cancellation in the Three-Phase Inverter Haiwei Zhang, 2019
- Devices for solar panels



(a)



(b)

Anticipate failures

- **A New Methodology for EMC Prediction of Integrated Circuits**
After Aging, Chaimae Ghfiri, 2019
- Degradation of **Ring Oscillator frequency**
- **Reduction of conducted emission**

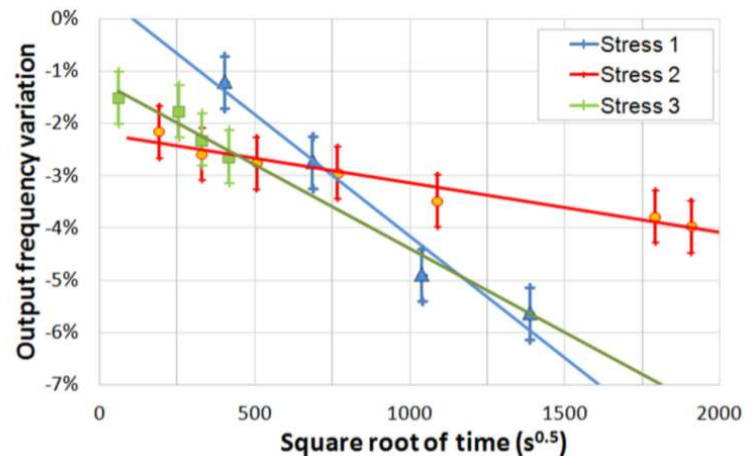


Fig. 3. Evolution of the output frequency of the ring oscillator for each stress condition.

TABLE II
SELECTED STRESS CONDITIONS FOR THE M-HTOL TEST

Stress N°	VCCINT (V)	VCCO (V)	T _j (°C)
1	2,3	4,1	115
2	2,3	4,8	135
3	2,8	5,2	115

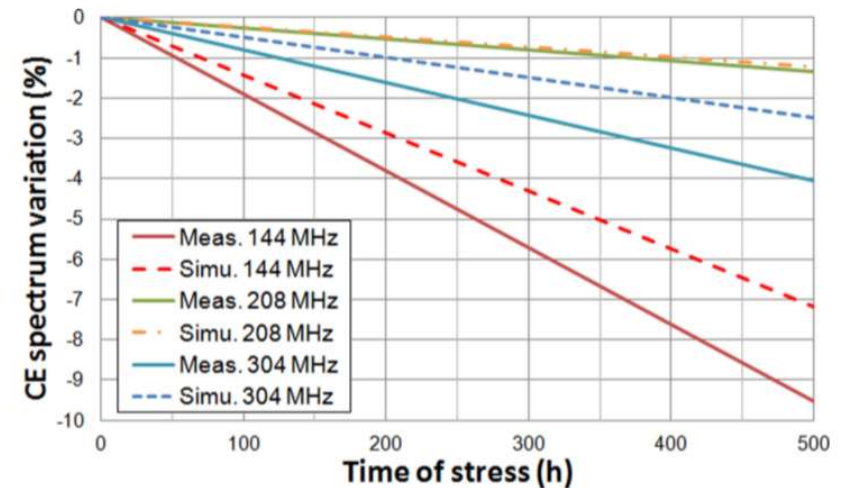
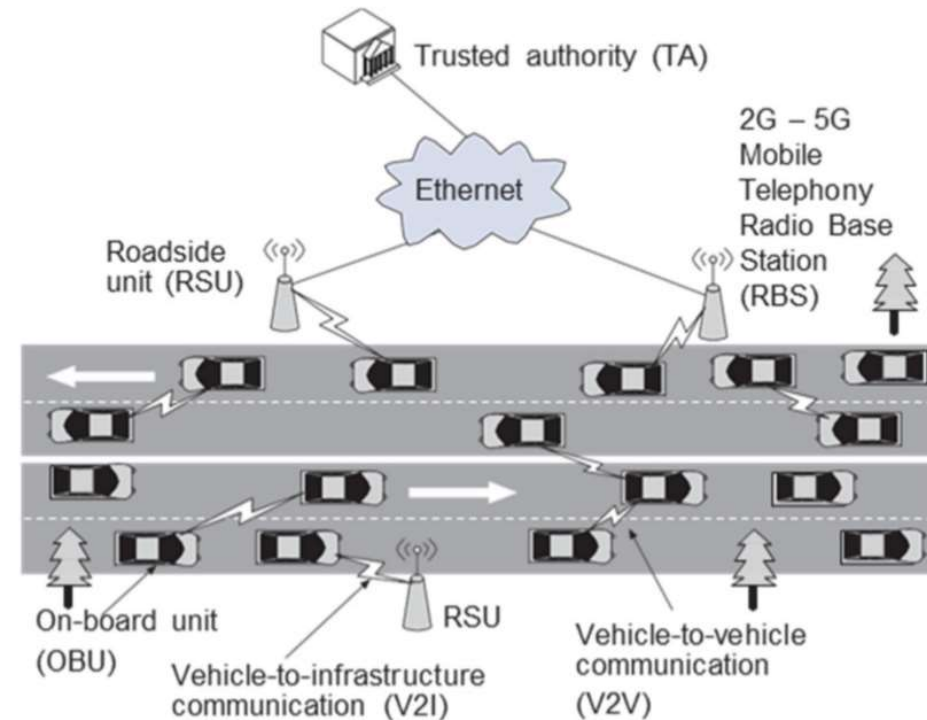


Fig. 7. Comparison between the variation of the measured and simulated CE spectrum from the initial state and after 500 h aging.

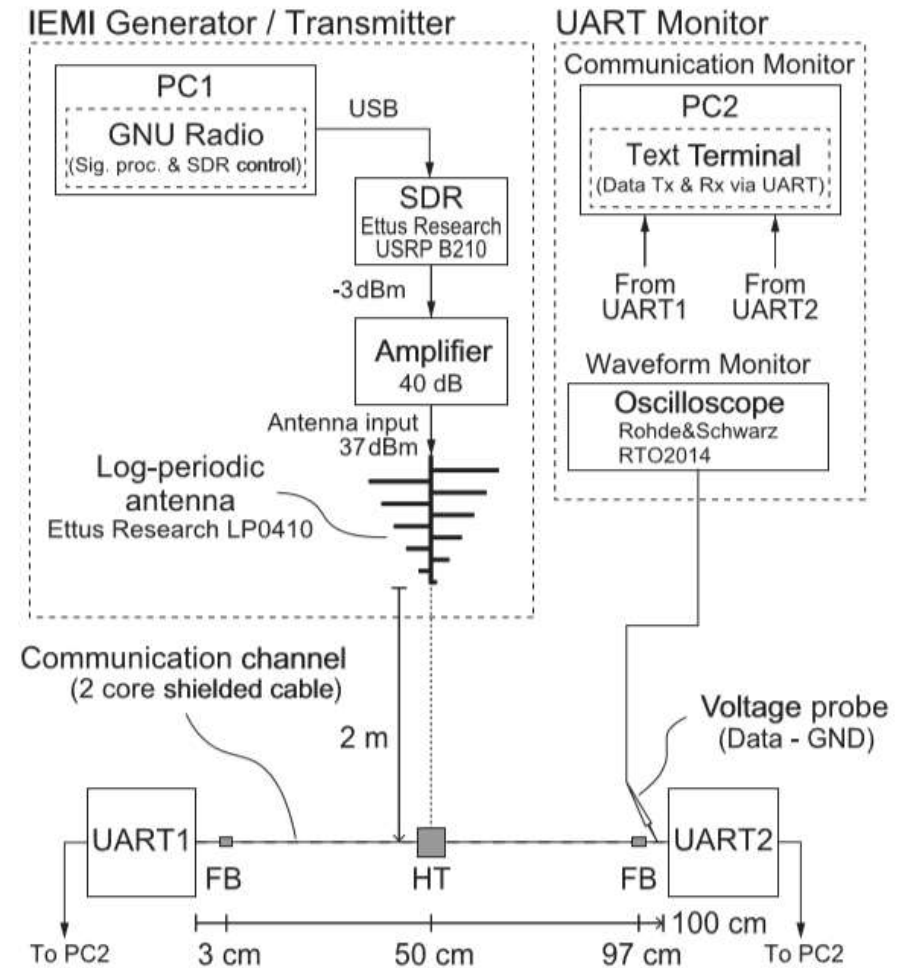
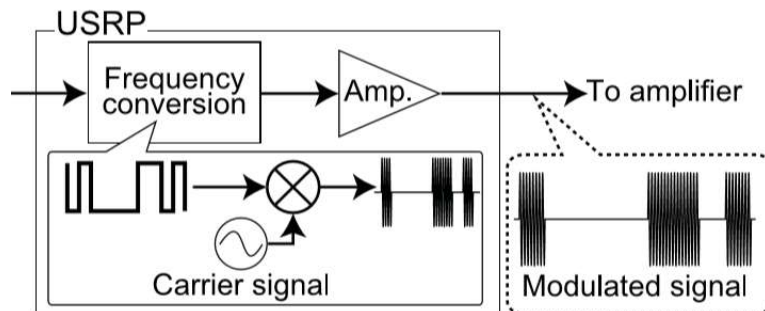
Anticipate failures

- Resilience to Intentional Electromagnetic Interference Is Required for Connected Autonomous Vehicles, Per Angskog, IEEE EMC 2019
- Analyse vulnerability of critical Active Road Safety warnings
 - approaching emergency vehicle warning
 - intersection collision warning
 - stop-sign violation warning
 - wrong-way driving warning
 - collision risk warning
 - road-work warning
 - road condition warning



Identify failures

- **Data Injection Attack Against Electronic Devices With Locally Weakened Immunity Using a Hardware Trojan** Shugo Kaji, 2019
- **Changes in electrical signals equivalent to the communication between UARTs are obtainable by data injection attacks**



Identify failures

- Identification of Soft Failure Mechanisms Triggered by ESD Stress on a Powered USB 3.0 Interface, Sebastian Koch, 2019

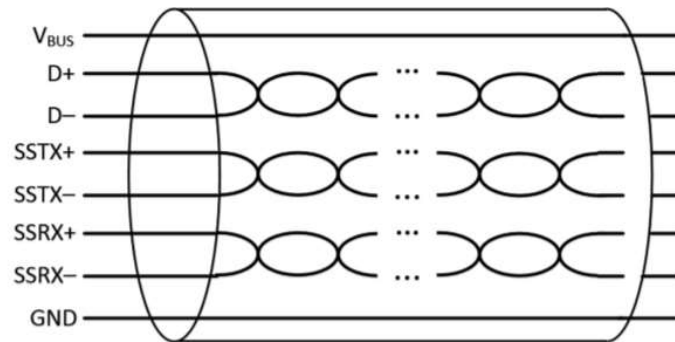
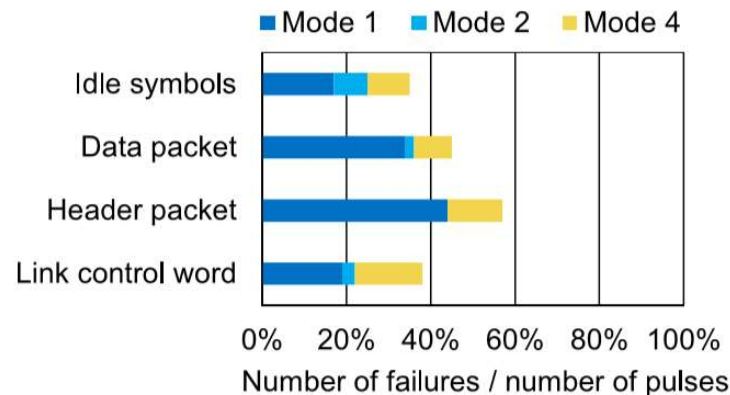
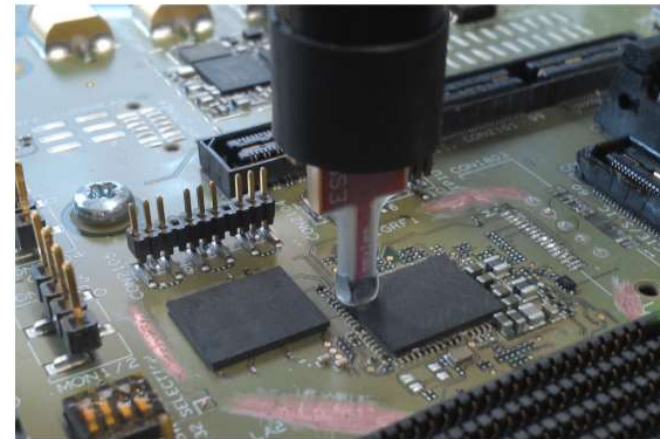


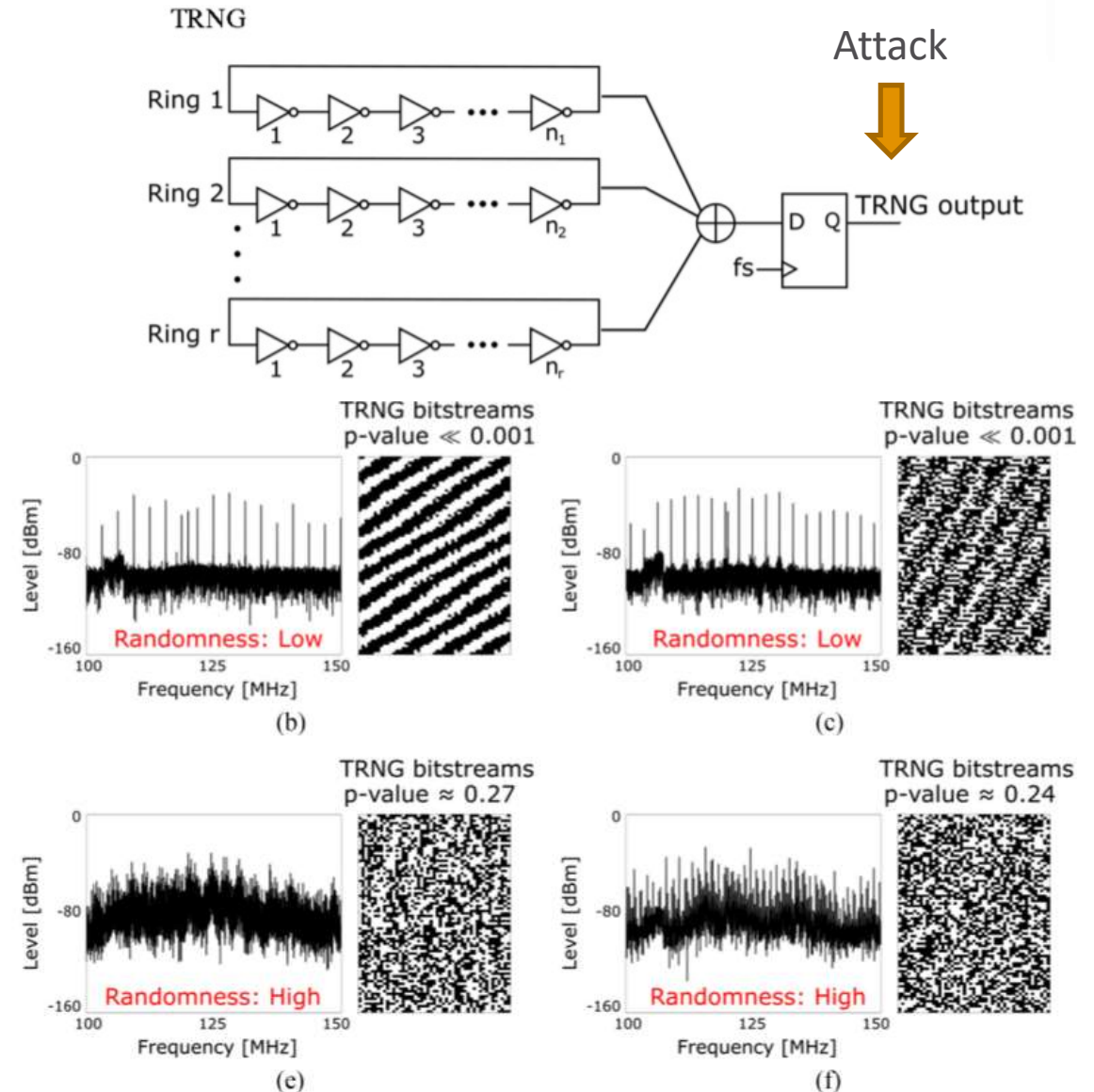
Fig. 1. USB 3.0 interface with its three differential signaling pairs, 5 V V_{BUS} , and GND pin.



ATTACK ON RANDOM NUMBER GENERATOR

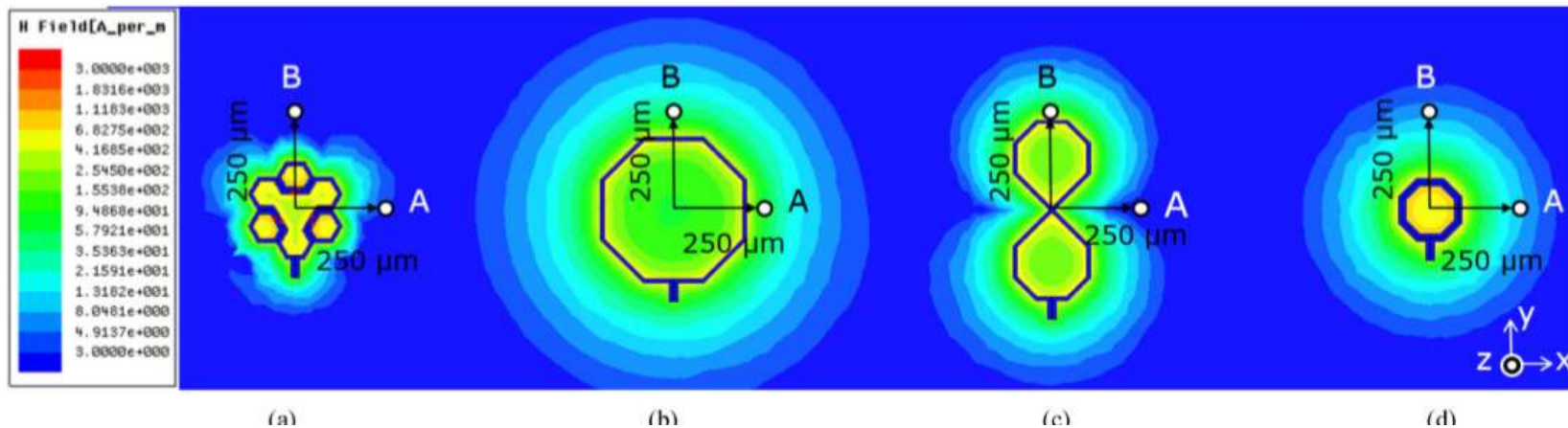
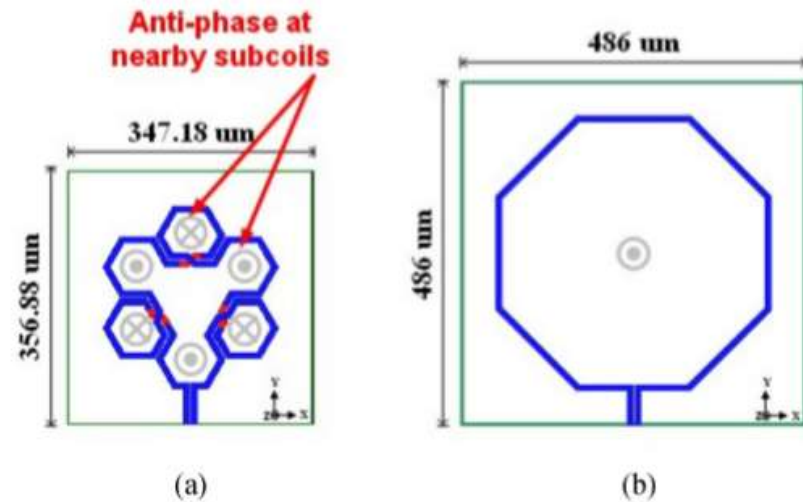
Identify failures

- EM Information Security Threats Against Ring-Oscillator-Based True-Random Number Generators, S. Osuka, 2019
- The disturbance frequency could be kept out of the IC by dynamically controlling the load impedance
- EMC countermeasures, such as ferrite cores, may be able to prevent interference



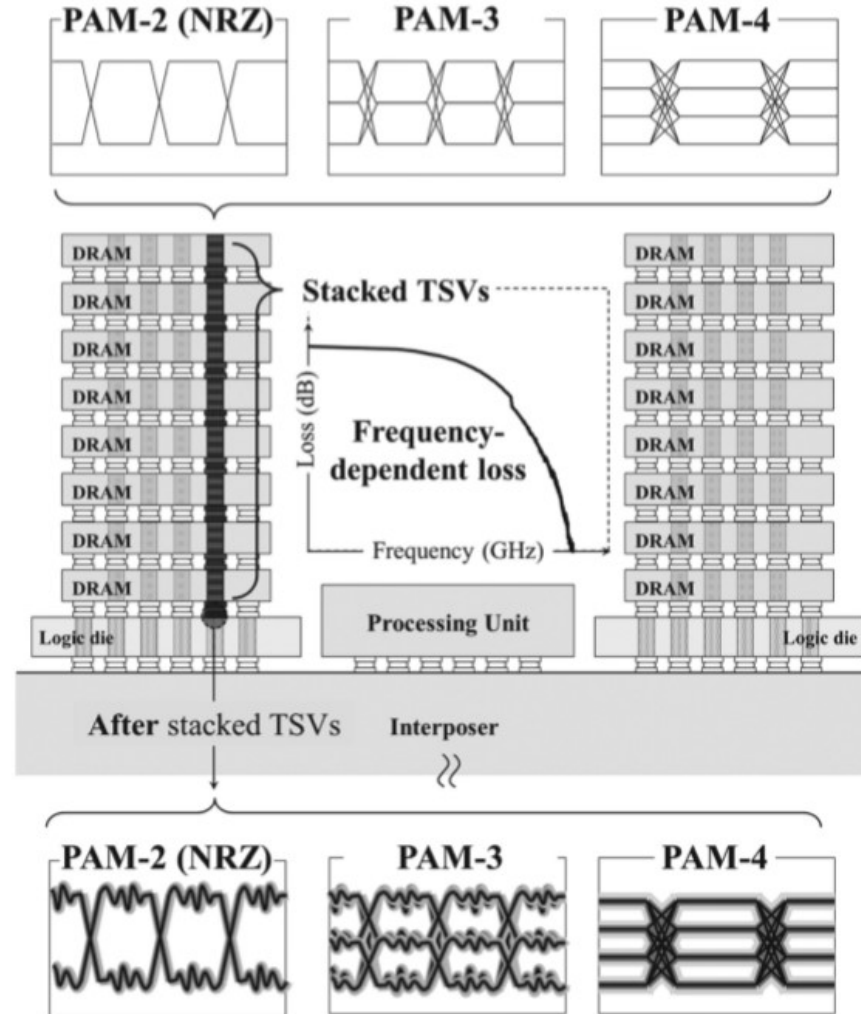
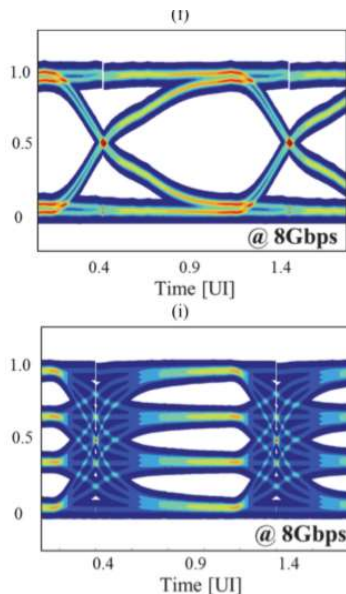
Better layout

- Characterization of a Planar Honeycomb-Based Inductor on Crosstalk/EMI Suppression
Tzuen-Hsi Huang, 2019
- Honeycomb shape: 15–30 dB reduction
- Same 1nH inductor



Impedance Matching

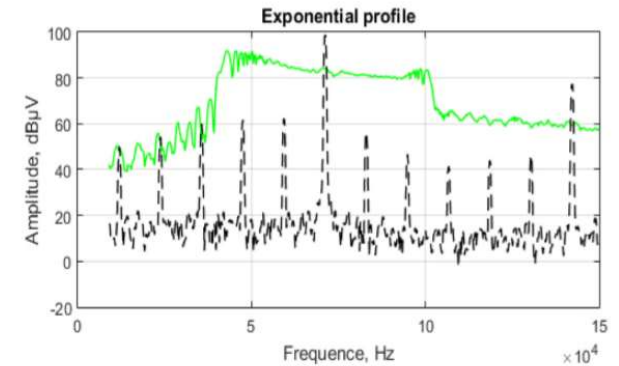
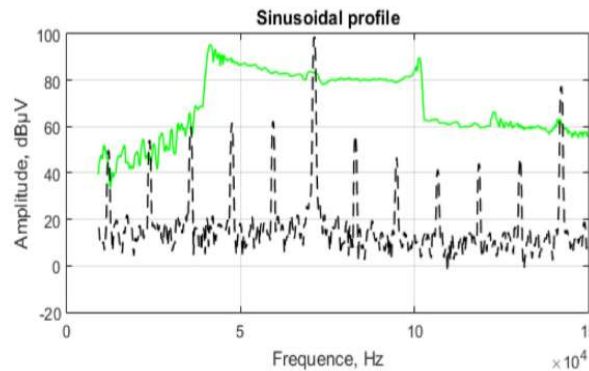
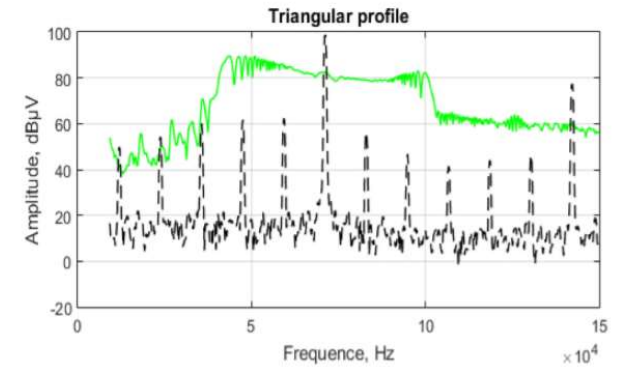
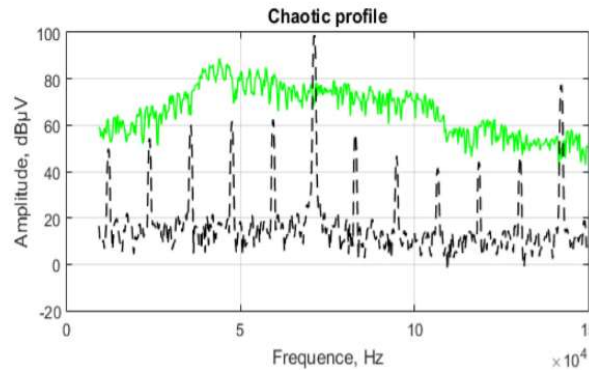
- A Novel Eye-Diagram Estimation Method for Pulse Amplitude Modulation With N-Level (PAM-N) on Stacked Through-Silicon Vias
Junyong Park, 2019



REDUCING NOISE BY PEAK REDUCTION

Spread Spectrum

- **A Review of Spread-Spectrum-Based PWM Techniques—A Novel Fast Digital Implementation**
Rabiah Gamoudi,
2018
- **Optimal spread of Energy by chaotic profile**



Anticipate emission

- A New Methodology to Build the **Internal Activity** Block of ICEM-CE for Complex Integrated Circuits
Chaimae Ghfiri, 2018
- Deterministic** vs **statistical** model of a FPGA IA

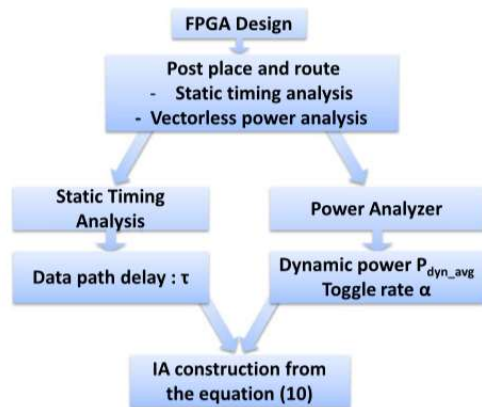


Fig. 3. Construction workflow of the IA block for FPGA circuit following deterministic approach.

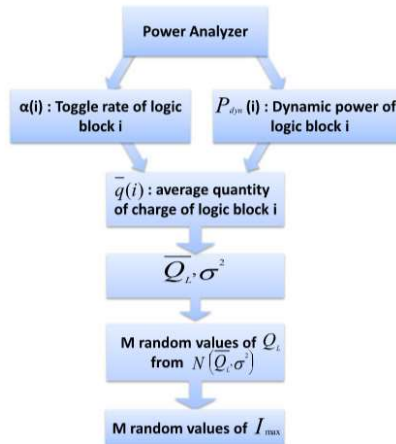


Fig. 4. Workflow of the IA construction using the statistical approach.

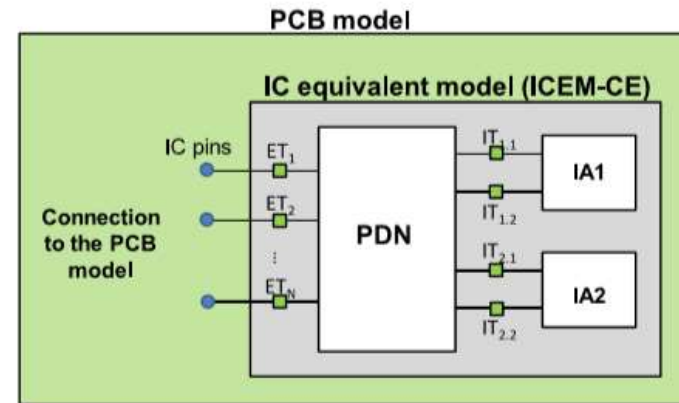


Fig. 1. Structure of ICEM-CE model.

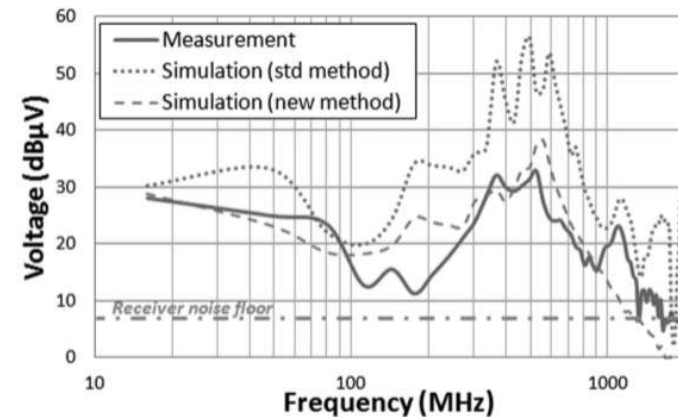
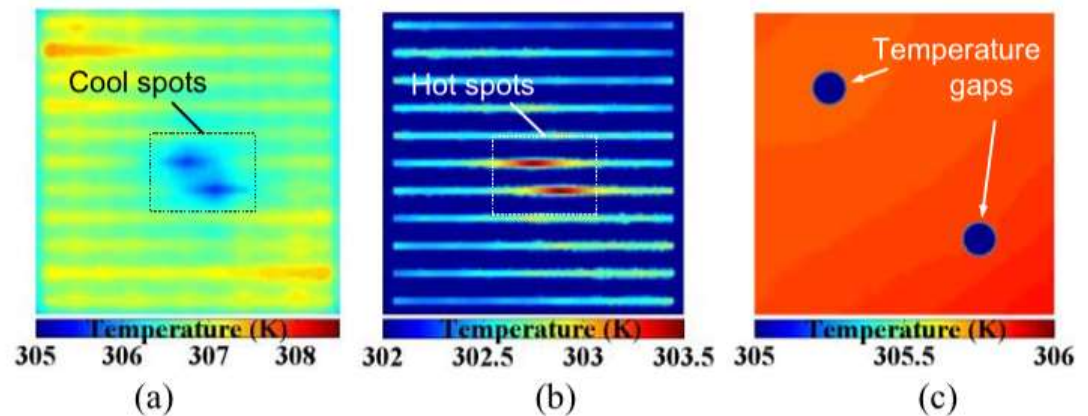
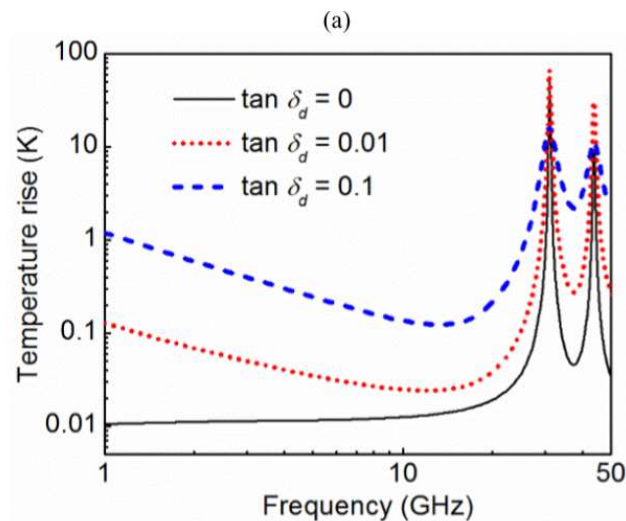
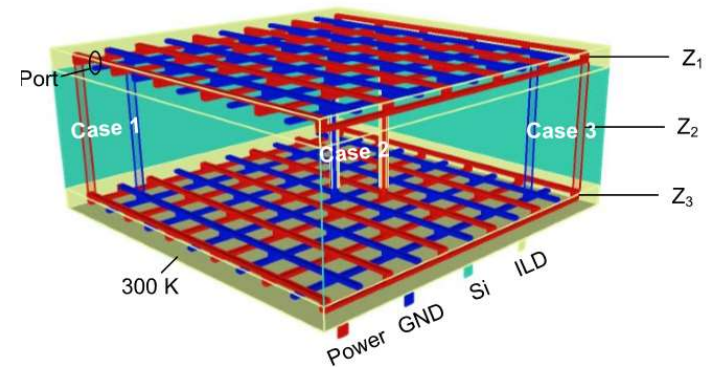


Fig. 23. Comparison between the measured and simulated spectral envelope CE with a 150 Ω probe according to the standard and new IA extraction method (delay Line configuration).

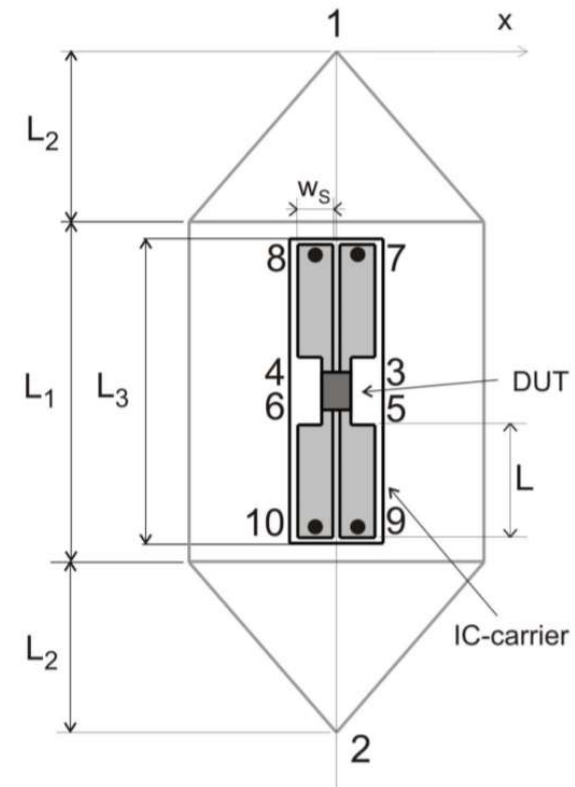
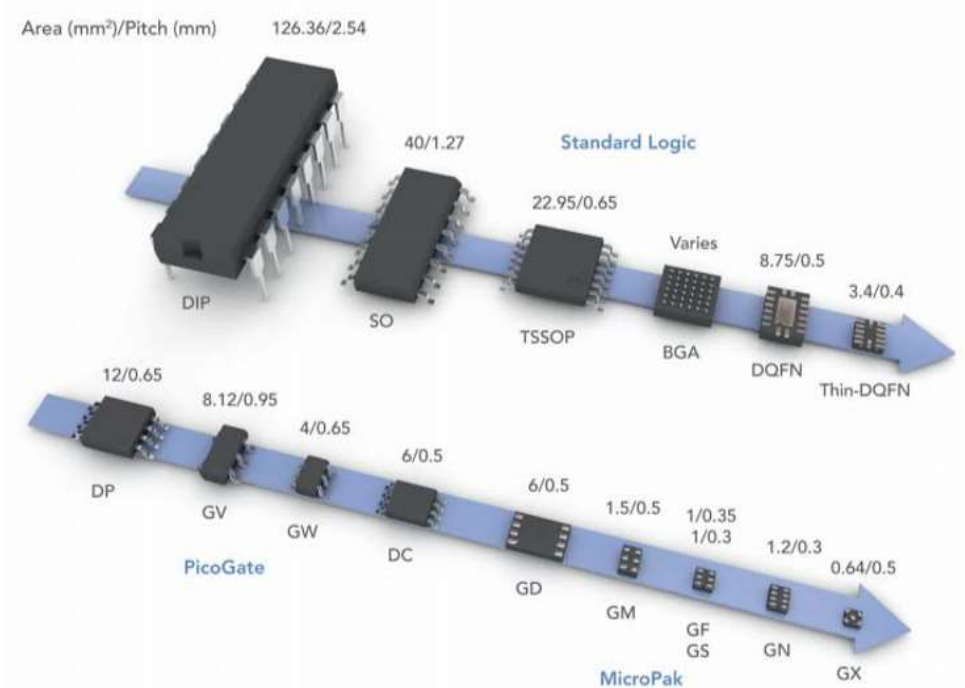
Thermal management

- LI et al.: HIGH-FREQUENCY ELECTROTHERMAL CHARACTERIZATION OF TSV-BASED PDN
- Effects of 20-40 GHz resonance of local hot spots



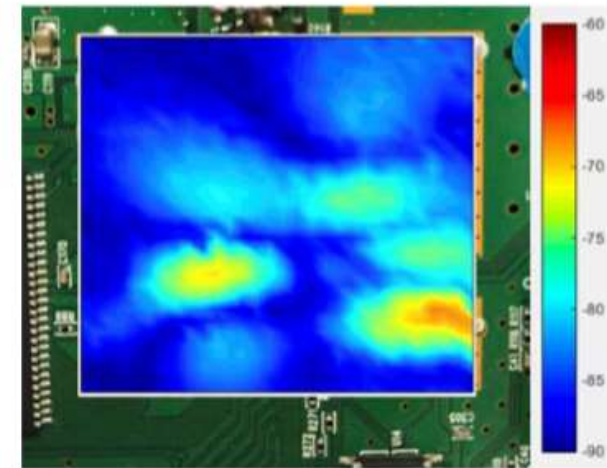
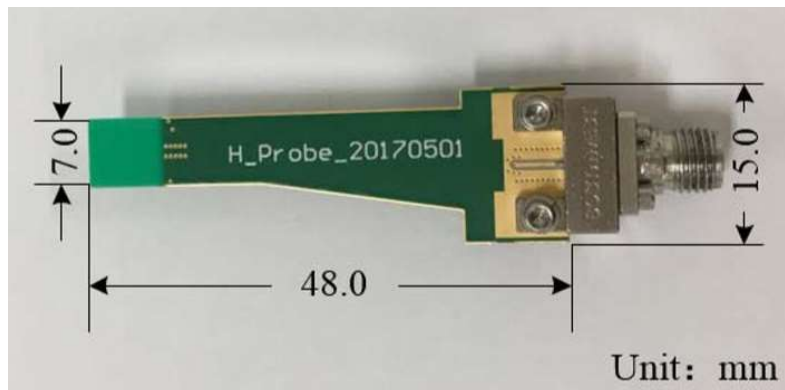
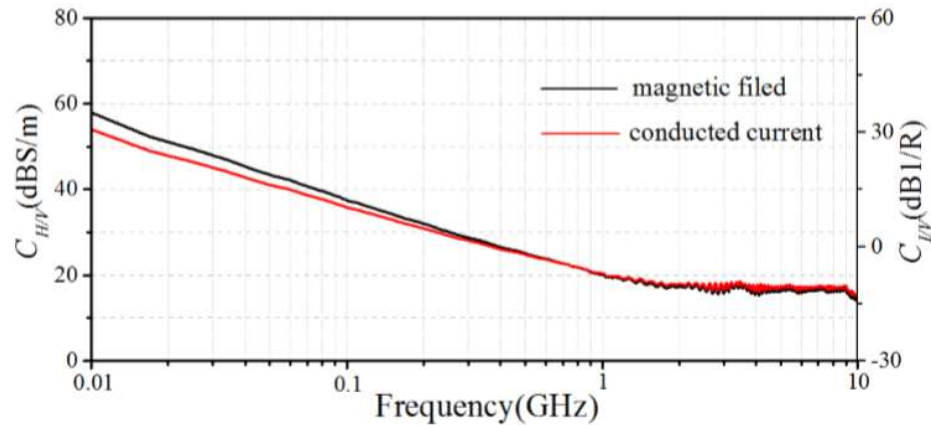
More accurate
Measurements

- A Test Structure for the EMC Characterization of Small Integrated Circuits, Michele Perotti, 2019
- Stripline method adaptation to very small ICs

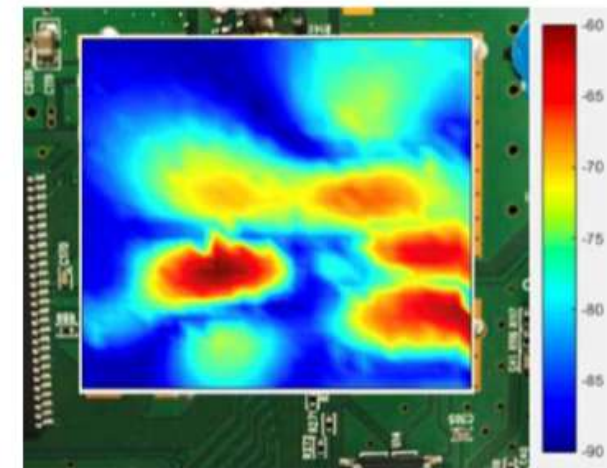


More accurate
Measurements

- YAN et al.: NONCONTACT WIDEBAND CURRENT PROBES, IEEE EMC 2018
- More precision, more resolution, upto 10 GHz



(a)

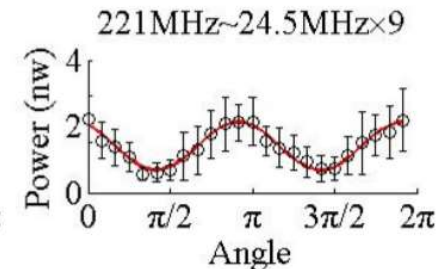
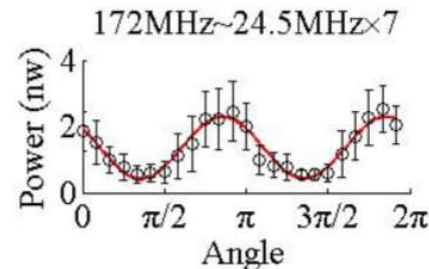
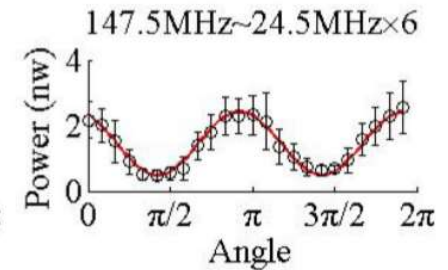
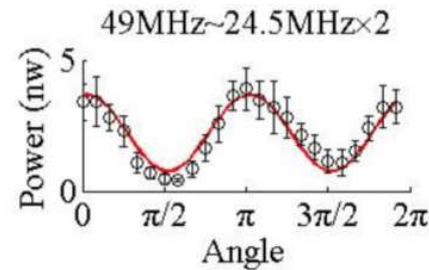
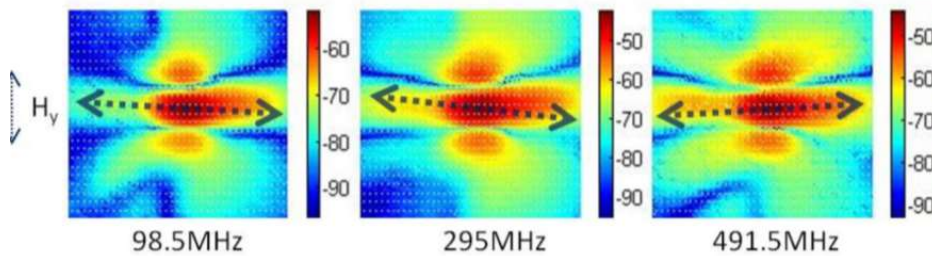
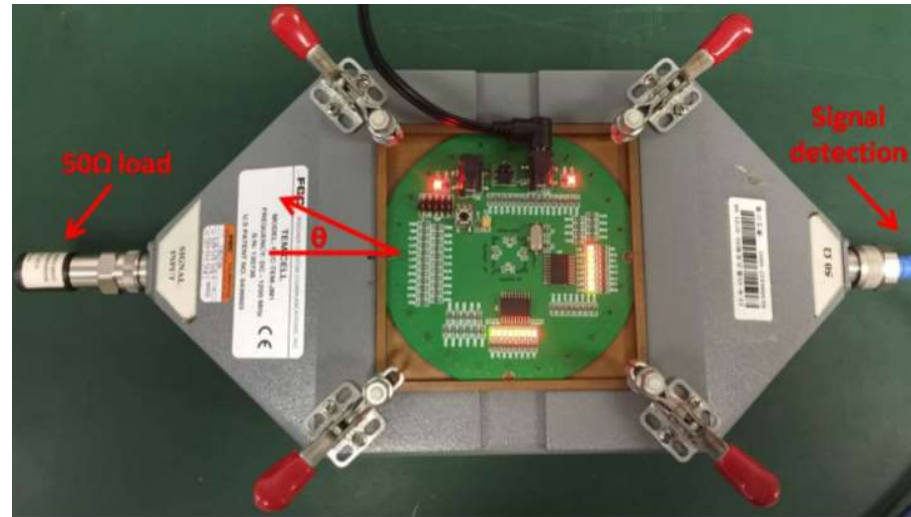


(b)

ROTATING TEST BOARD

More accurate
Measurements

- Extracting the Electromagnetic Radiated Emission Source of an Integrated Circuit by Rotating the Test Board in a TEM Cell Measurement Wenxiao Fan, 2019
- Maximum power is not always matched to 0, 90, 180 or 270°
- Verified using near-field scan



Choice of components

- Modeling and Analysis of Large-Signal RFI Effects in MOS Transistors Clovis Pouant, 2019
- 2 MOS references BSS83 and 3N170 compared in terms of rectifying effects with RFI 1 MHz – 3GHz

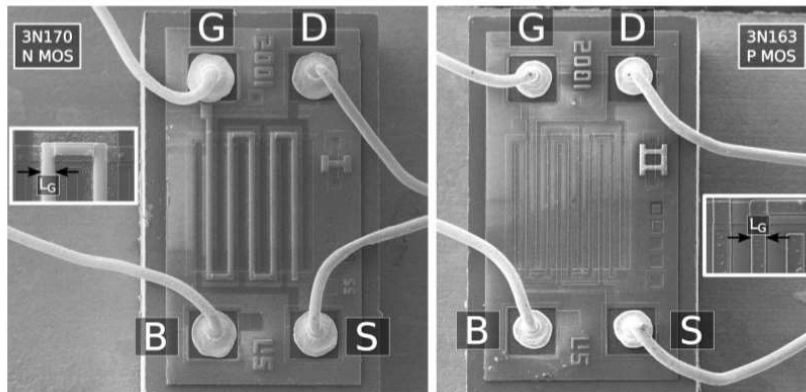


Fig. 6. 3N170 (left) and 3N163 (right) dies pictures obtained with a SEM and geometrical parameter measurement.

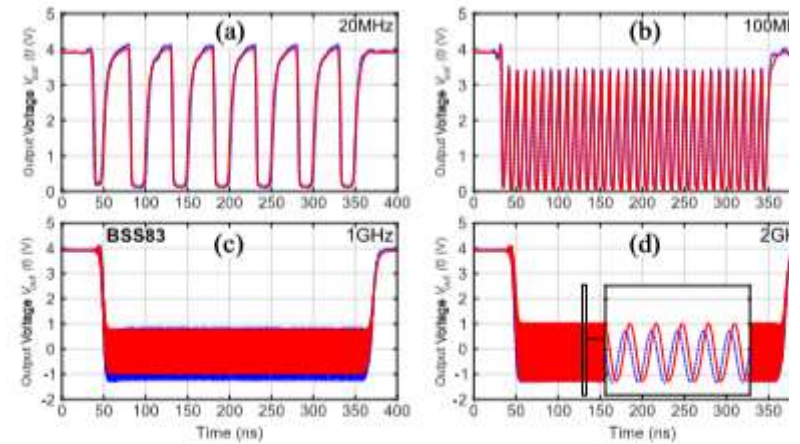


Fig. 12. Measured (dashed blue line) and simulated (solid red line) B3 output voltages $V_{out}(t)$ for an input signal of 4-V peak. (a) Response at 20 MHz, (b) 100 MHz, (c) 1 GHz, and (d) 2 GHz. $R_L = 1 \text{ k}\Omega$ and $V_{DD} = 4 \text{ V}$.

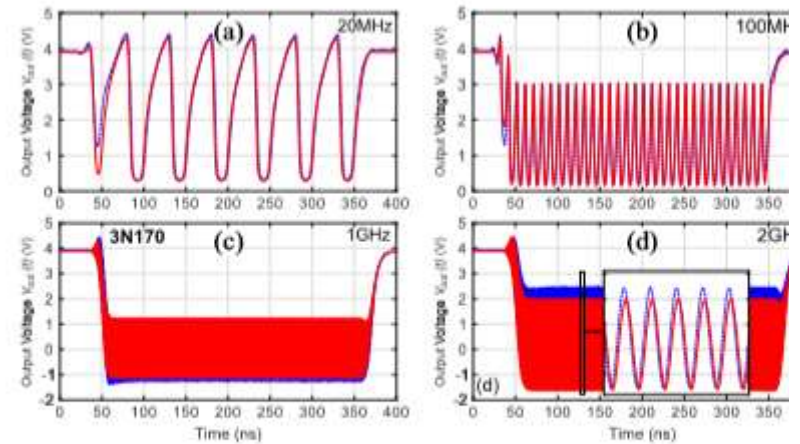
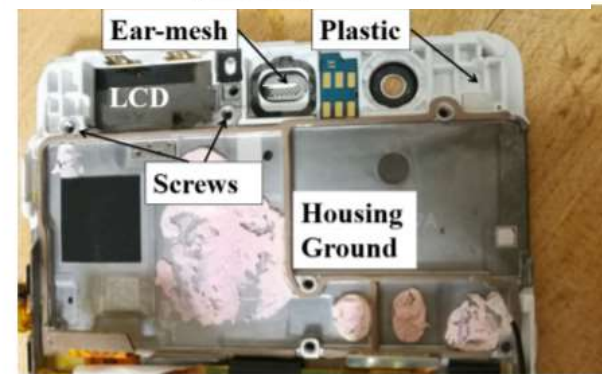
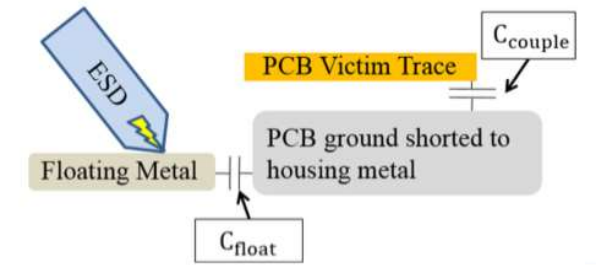
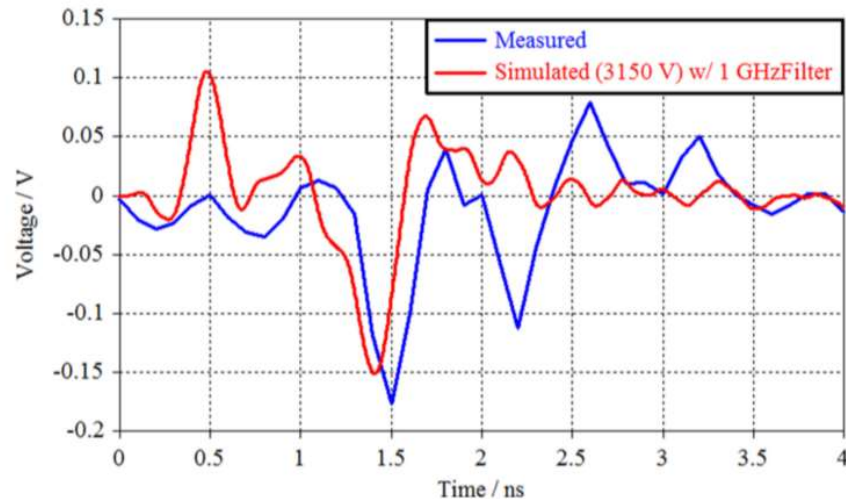


Fig. 13. Measured (dashed blue line) and simulated (solid red line) 3N170 output voltages $V_{out}(t)$ for an input signal of 6-V peak. (a) Response at 20 MHz, (b) 100 MHz, (c) 1 GHz, and (d) 2 GHz. $R_L = 1 \text{ k}\Omega$ and $V_{DD} = 4 \text{ V}$.

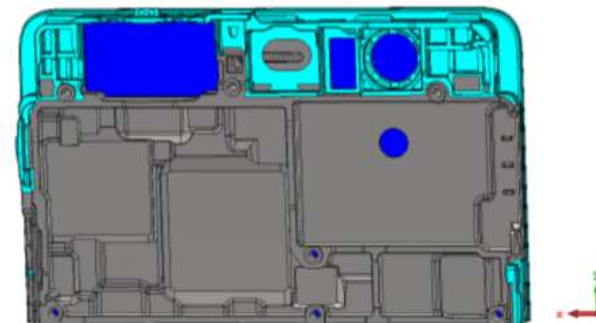
ESD ON SMARTPHONE – FULL WAVE SIMULATION

Anticipate
susceptibility

- Full-Wave Simulation of System-Level Disruption During Secondary ESD Events in a Smartphone, Darwin Zhang Li, 2019
- 5 billion initial mesh, reduced to 8 million
- Prediction of discharge current & victim noise



(a)



Anticipate susceptibility

- Analysis of the Coupling Capacitance Between TSVs and Adjacent RDL Interconnections Zheng Mei, 2019
- Analysis of coupling & noise for different situations

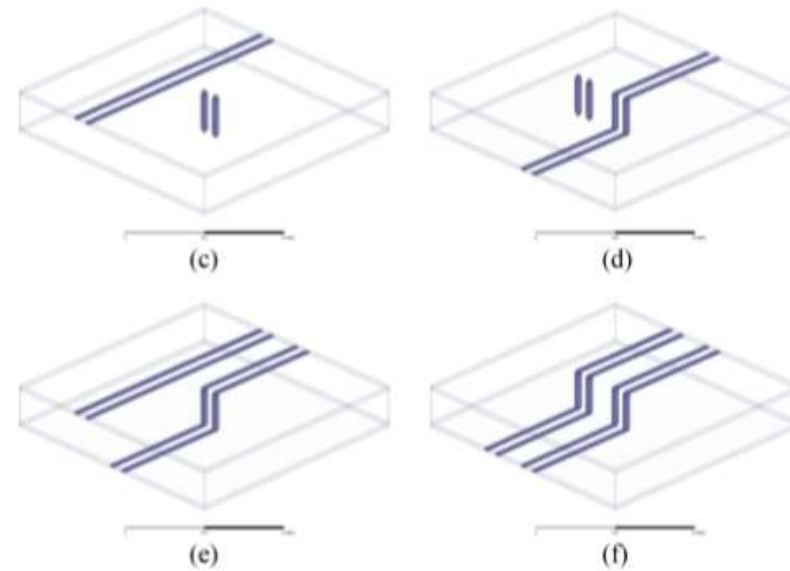
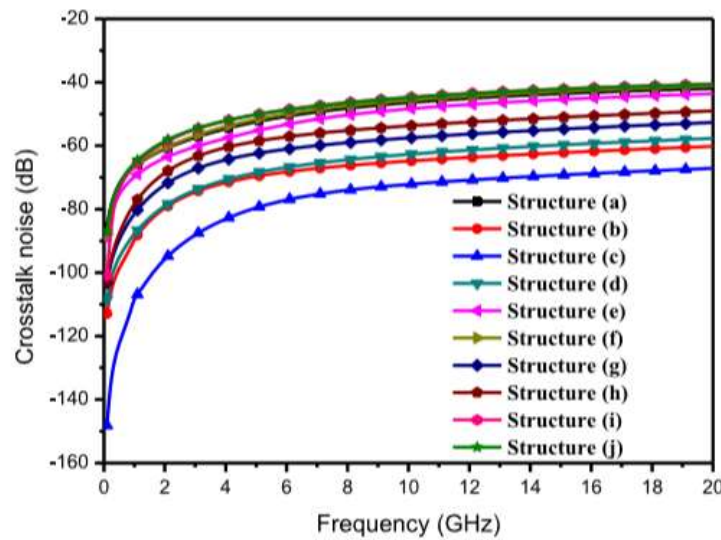
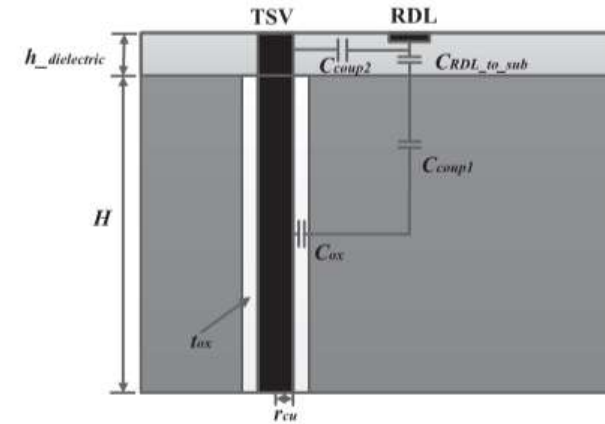
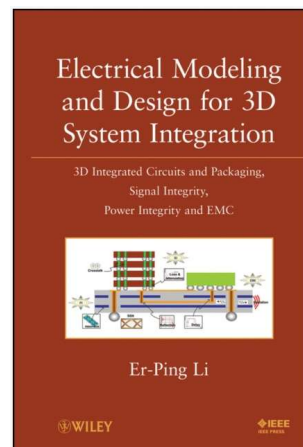
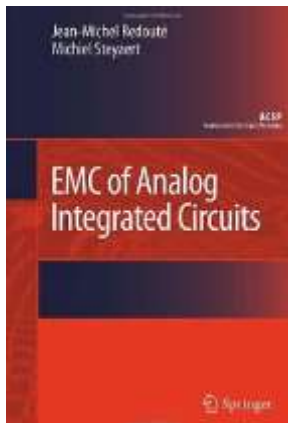
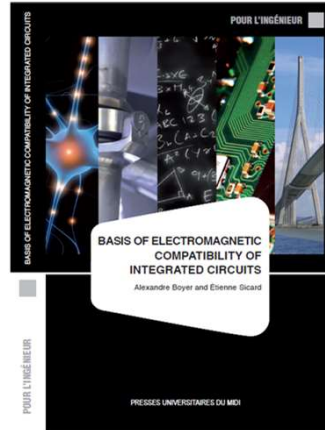
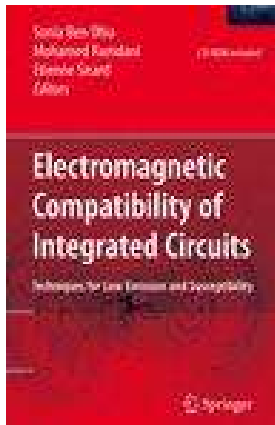


Fig. 9. Crosstalk noise of different types of TSV structures.

CONCLUSION

- **Steady growth of the electronics market**
- **5G, autonomous drive, ultra high resolution screens**
- **Technology trends towards nm-scale, 10-100 giga transistors**
- **Numerous EMC challenges**
- **Active EMC-IC community**
- **Many improvements in emission & immunity**
- **Anticipation of EMC risk in many domains**

Books

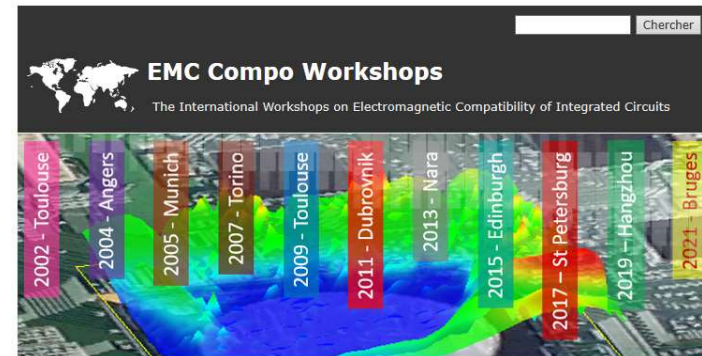


Freeware



www.ic-emc.org

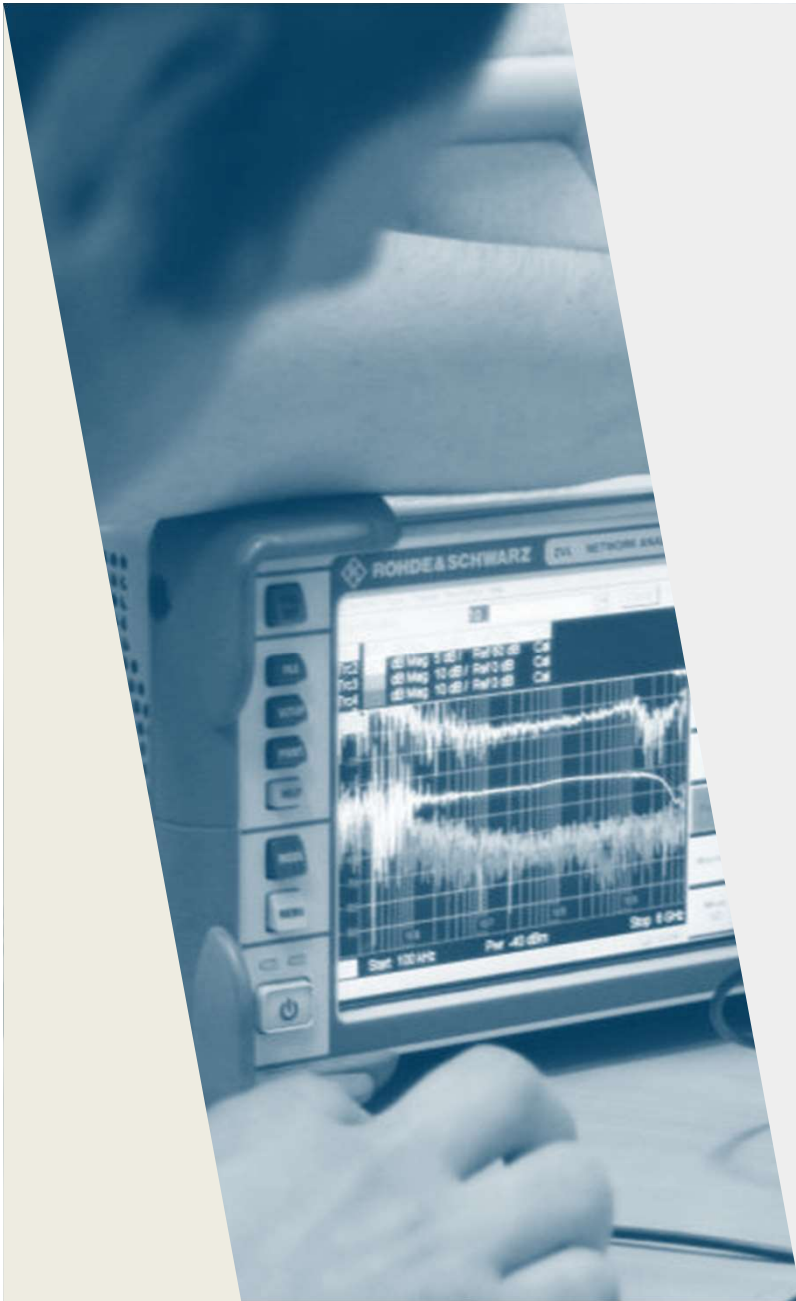
Workshops



www.emccompo.org

Standards www.iec.ch

- IEC 61967, 2001, Integrated Circuits Emissions
- IEC 62132, 2003, Integrated circuits Immunity
- IEC 62433, 2008, Integrated Circuit Model



Thank you for your
attention

非常感謝您的邀請
to Prof. Erping Li