ICEM based model for IC EMC Analysis

E U R O P E A N I B I S S U M M I T M E E T I N G

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Outline

- Description of the IC
- Circuital model for IC+package+board
- Electromagnetic/circuital model for EM emission
- Validation of the models

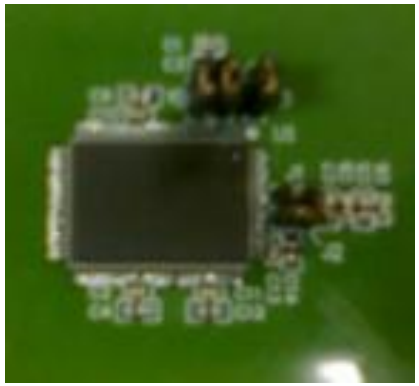
DUT description

Numonyx Flash memories: DUT1 in 150nm and DUT2 (3 different rerevisions) in 110nm.

GOALS:

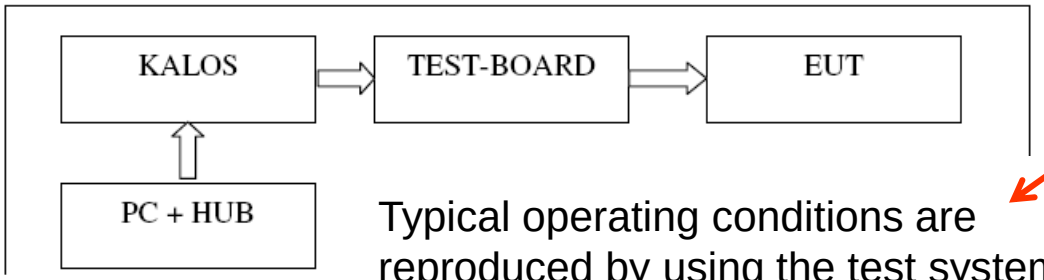
Derive a circuit model for evaluating the currents flowing through the package pins
Derive a model for evaluating the far field emission

Name	*Revision*	*technology*
DUT1		150 nm
DUT2	RevB	110 nm
DUT2	RevC	110 nm
DUT2	RevD	110 nm

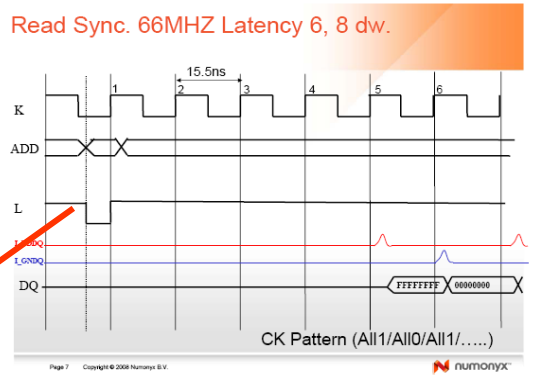


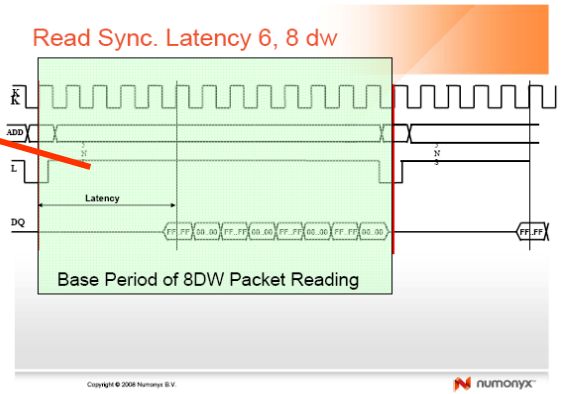
Some DUTs electrical parameters					
DUT	**di/dt(+)**	**di/dt(-)**	**I_{max} [A]**	**I_{rms} [A] [56 MHz]**	**I_{rms} [A] [66 MHz]**
DUT1	1.18	-1.12	0.005	0.113	0.117
DUT2-REVB	44.67	-25.14	0.012	0.155	0.170
DUT2-REVC	3.85	-3.57	0.013	0.120	0.132
DUT2-REVD	1.08	-1.13	0.004	0.098	0.108

DUT test: description



Typical operating conditions are reproduced by using the test system **Credence *Kalos 2* (PK2)**.





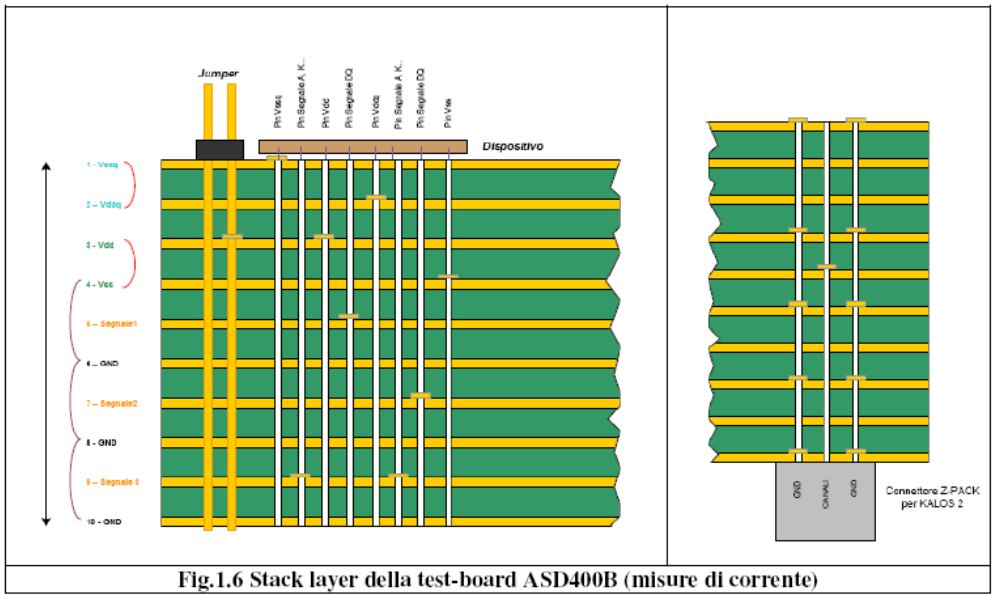
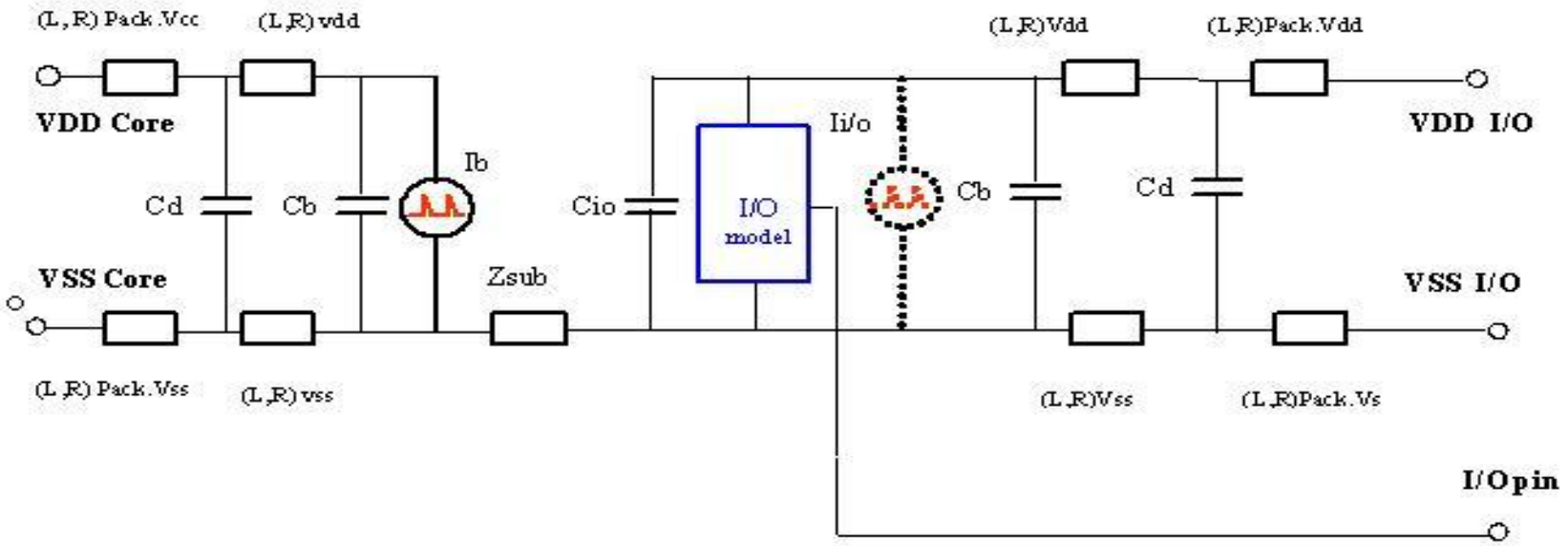


Fig.1.6 Stack layer della test-board ASD400B (misure di corrente)

An ad-hoc test board has been designed and realized for the measurement setup, optimized to:

- minimize the radiation from the board;
- guarantee Signal Integrity

Circuit model: modeling IC + package (ICEM)



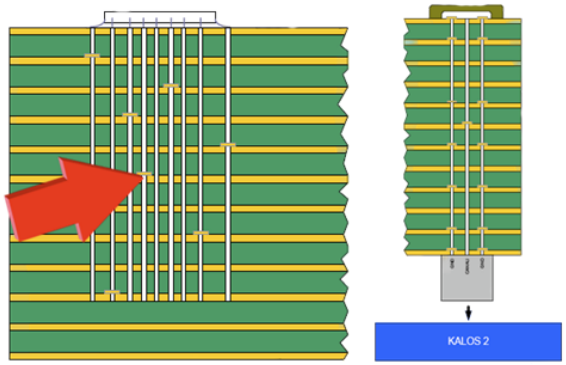
The model is based on the IEC ICEM approach.
It simulates the **switching activity**, including the load effects and the package parasitics.
In the ICEM model the current flowing through the IC core circuitry, during 1→0 and 0→1 transitions, is represented through an equivalent current source I_b, whereas the I/O buffers are modeled through conventional SPICE elements.

Circuit model: modeling the board

Circuit model for the test-board

The test board structure is rather complex, since it shows an high number of layers and signal traces.

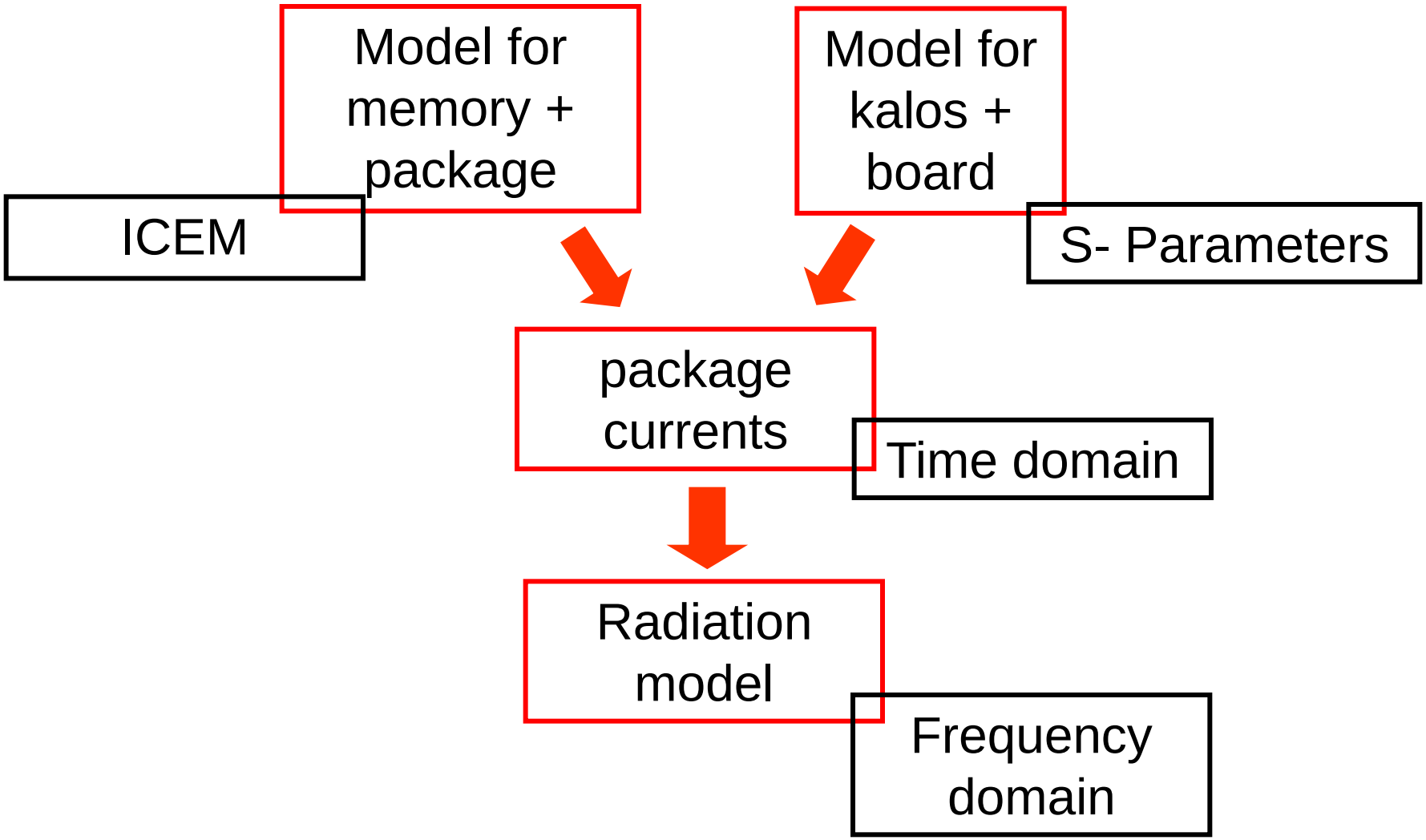
The board is connected at one end to the Kalos testing machine.



The model is described in terms of S parameters, by modeling the paths between test machine and memory module, including:

- Vias
- PCB traces
- bends

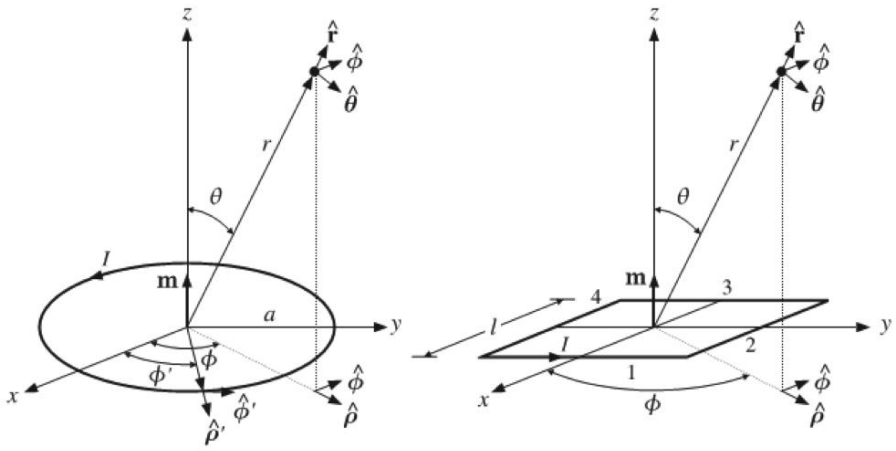
Electromagnetic/circuital model for the radiated emission



Model for the far-field radiated emission

The physical dimensions of the package are short compared to the smaller wavelength (at 1GHz = 30 cm.): each current path may be then represented by a current loop

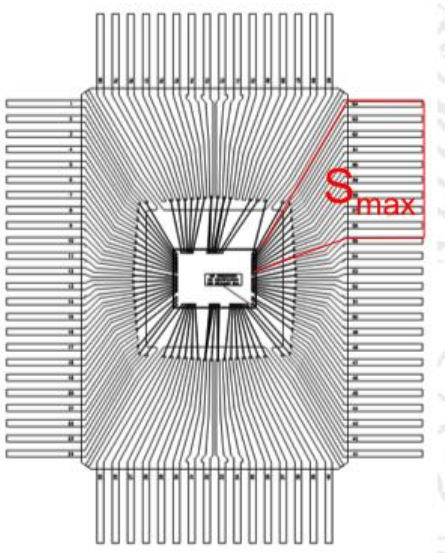
The measurements have been carried out at 3 m: for such frequencies this distance falls into the far-field region, where the field emitted by a current loop is given by:



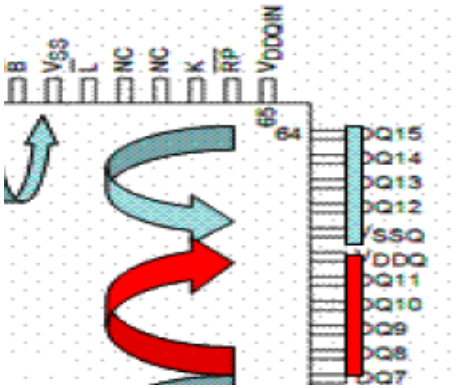
$$|E(\mathrm{r},\mathrm{f})| \cong Z_0 \pi f^2 \frac{S}{\mathrm{r}\mathrm{c}^2} I(\mathrm{f})$$

S = loop area
r = distance
c = propagation velocity
I(f) = loop current

Model for the far-field radiated emission



S_{max}= 57.7 mm^2



To account for the external layer (grounded) the radiation model describes the current loops above a conducting ground, therefore the field is produced by the loops and their imagines with respect to such plane.

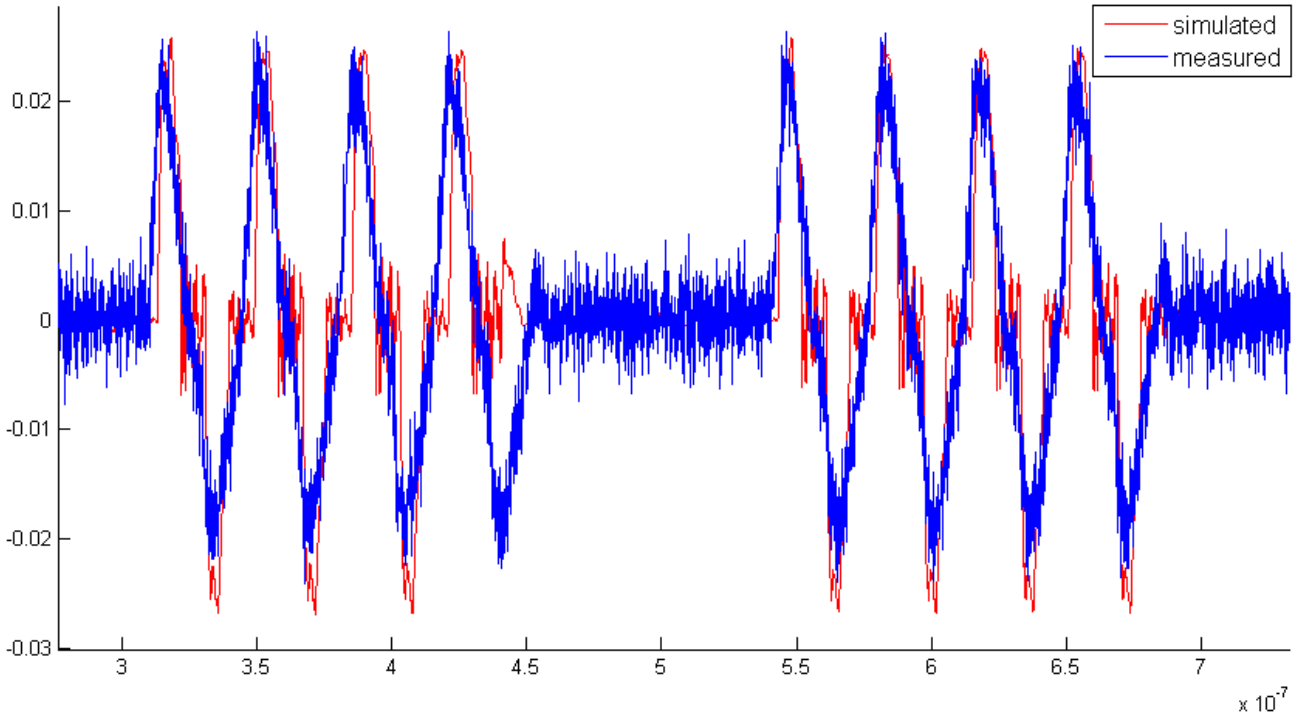
The effect of inner layers is negligible, since they can be assumed to be shielded by the grounded external ones. The effect of the dielectric in the package is not taken into account since in this model the source is of magnetic type.

Experimental validation of the circuit model

DC component (VDD pin)

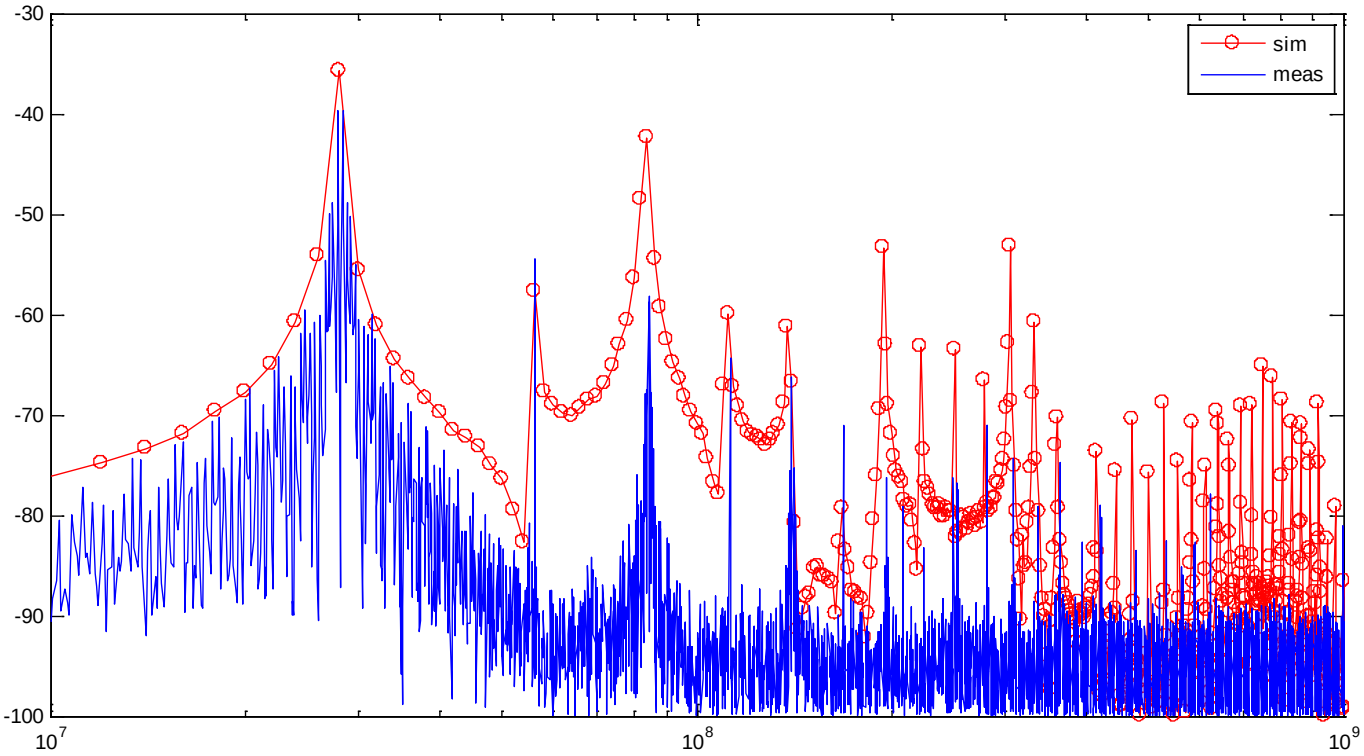
Measured	expected
30 mA	< 50 mA

AC waveform (a signal pin)

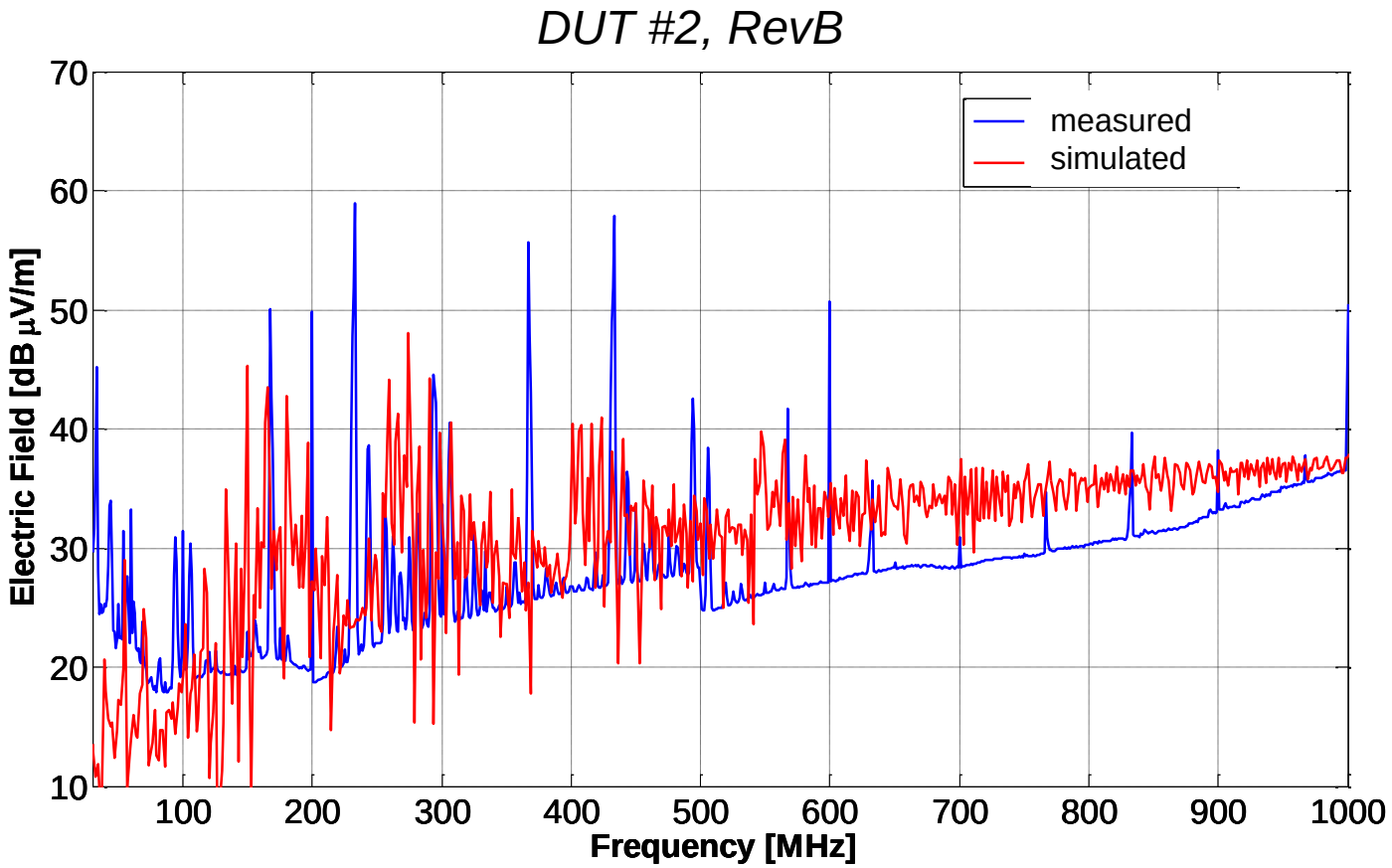


Experimental validation of the circuit model

Frequency spectrum of currents (in dBA): signal pin (IDQ16)

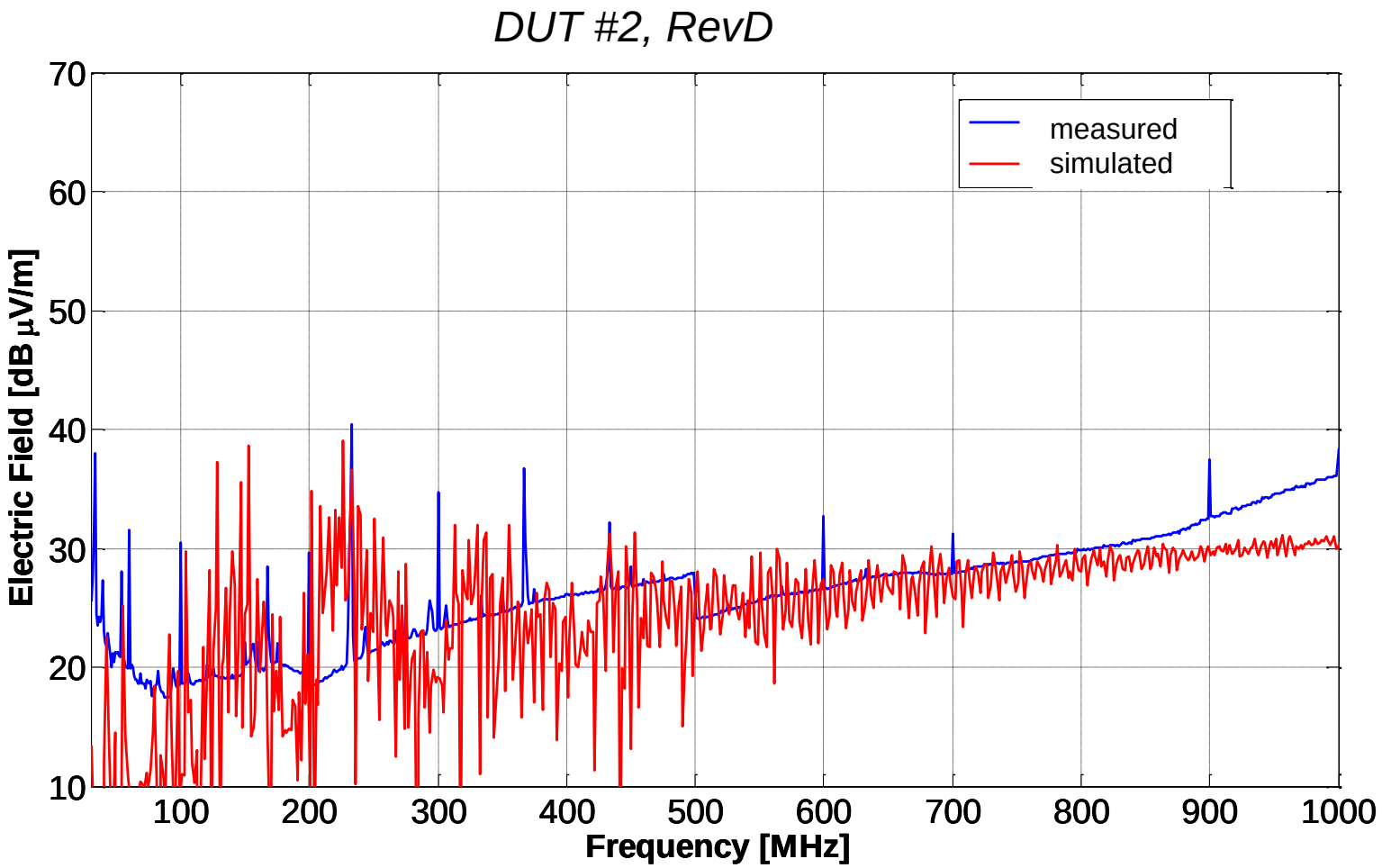


Experimental validation of the emission model



Far field emission (at 3m) measured in anechoic chamber

Emitted fiels: simulation vs measurements



Simulation vs measurements

$$\|X\| = \sqrt{\sum_n (X_n \cdot X_n^*)}$$

X_n = measured (or simulated) sample

n = number of samples in the frequency band

This parameter is the euclidean norm, taken as an index describing the global emission in the considered frequency range

DUT comparison, norm value				
EUT	**[dBμV/m] (meas.)**	**[dBμV/m] (simul.)**	**normalized (meas.)**	**normalized (simul.)**
DUT2-REVB	70,11	77.97	1	1
DUT2-REVC	67,63	73.37	0.96	0.94
DUT2-REVD	58,85	59.14	0.84	0.77

Conclusions

Modeling

The sub-system memory+package has been modeled by using an ICEM model, which includes the switching activity and the load effects, including the packages parasitics.

The emission model is based on different models for the subsystems:

- IC + package is described by the ICEM model;
- test board and test machine are described by an S-parameter distributed model
- the overall circuital model provides the currents flowing into the package
- the far-field (at 3m) radiated emission is based on the superposition of the contributions coming from each current loop in the package

Validation

An excellent agreement has been found between measured and simulated time-domain waveforms of the currents. The analysis of the spectral components of such currents highligths that the main harmonics are catched

A good agreement is found with respect to emission measured in anechoic chamber

The model has been proven to be reliable to compare EMC performance of DUTs