Integrand Software, Inc.

RF Modeling and Characterization at TSMC using Integrand's EMX

Dr. Sharad Kapur, President

Integrand Software, Inc.

EMX

Integrand Software, Inc.

- EMX is a full-wave 3D EM simulation tool
  - Used by TSMC for generation of PDK models
  - Uses TSMC's new iRCX technology file
  - Can be used from within PDK directly
  - RF Reference Design Kit 2.0 for 65nm (VCO)
- Used by several TSMC customers for RFIC and high-speed design

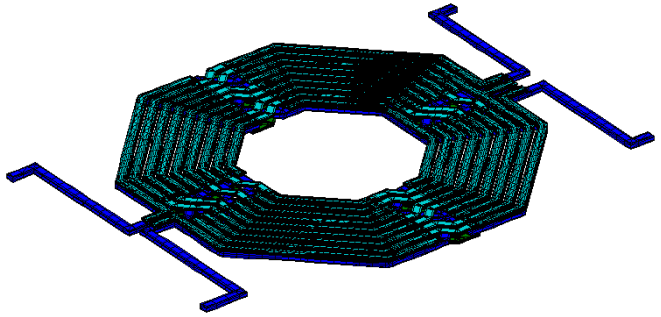
EMX 3D EM simulator

Integrand Software, Inc.

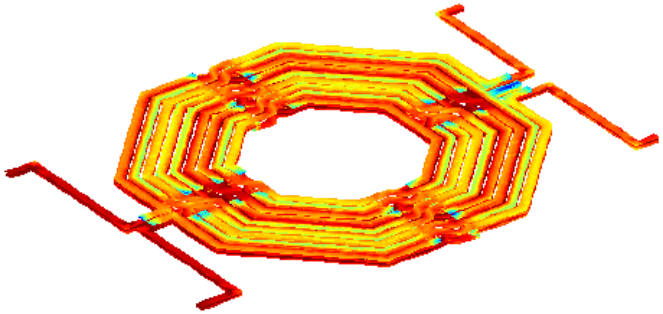
- All physical effects included
  - R, L, C, substrate in a fully coupled manner (solving Maxwell's equations)

$$E_s(r) = \frac{1}{\sigma} J(r) + j\omega A(r) + \nabla \phi(r).$$

- Inductance
  - Distributed 3D volume currents
- Resistance
  - Skin effect and volume loss
- Capacitance
  - Accurate side-wall capacitance
  - MIM and thin-film capacitors
- Substrate



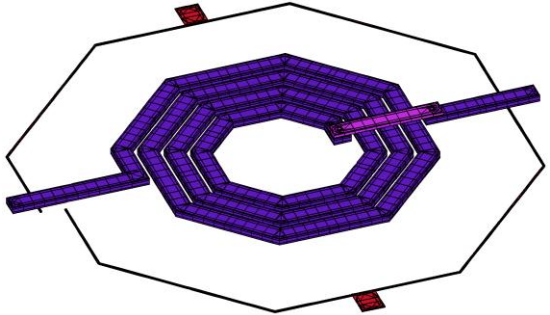
Mesh and current for balun



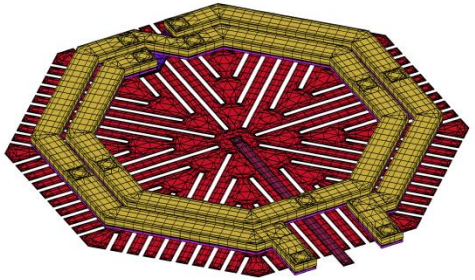
Passive Components

Integrand Software, Inc.

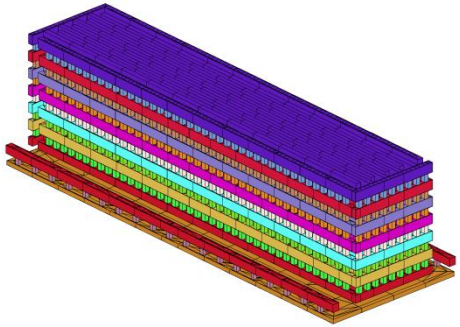
- 3D EM simulation of passive components
- Used for component characterization and scalable model generation for PDKs



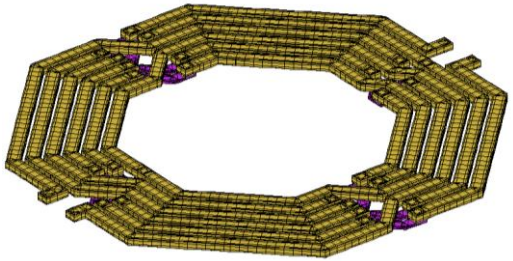
Inductor



Inductor with shield



MOM capacitor

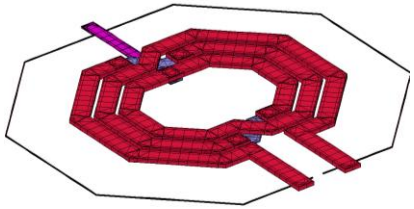


Transformer

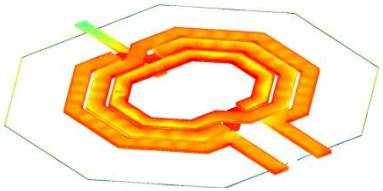
EMX at TSMC

Integrand Software, Inc.

- TSMC uses EMX for
  - Scalable models for PDKs
  - STD/SYM/Stacked inductors
  - RTMOM capacitors
- Verified for 180nm-28nm



Mesh and current for inductor

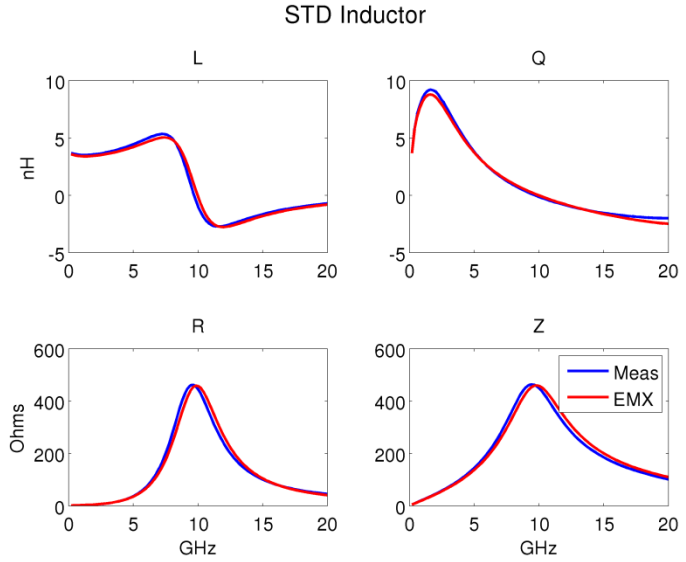


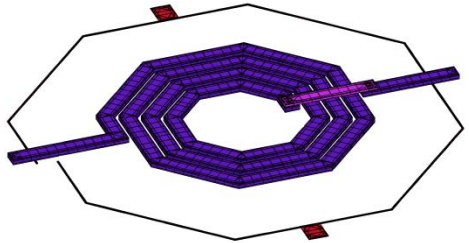
…Extensive verification…for a few generations of technologies, has demonstrated the accuracy and won our confidence in their tools….

- Dr. Sally Liu, Spice Modeling Department

EMX accuracy

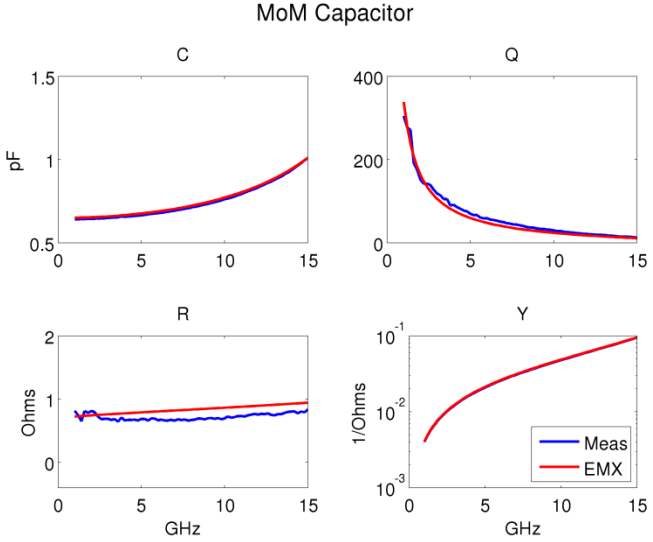
- Very Accurate
  - 3D Conductors and Vias
  - True volume currents
  - Sidewall capacitance
  - Substrate effects
- TSMC uses EMX for
  - Inductor modeling
  - In PDK

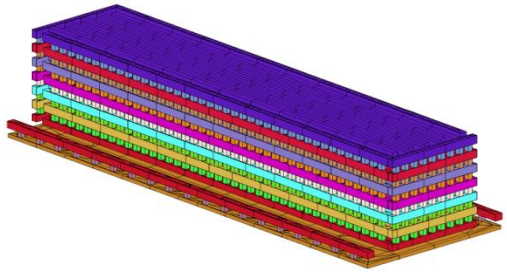




EMX accuracy

- Very Accurate
  - 3D Conductors and Vias
  - True volume currents
  - Sidewall capacitance
  - Substrate effects
- TSMC uses EMX for
  - RT MOM modeling
  - In PDK

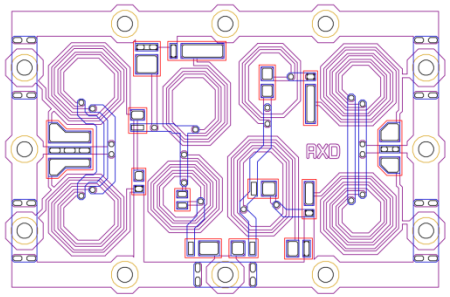




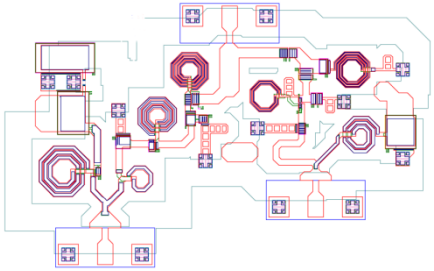
EMX for large circuits

Integrand Software, Inc.

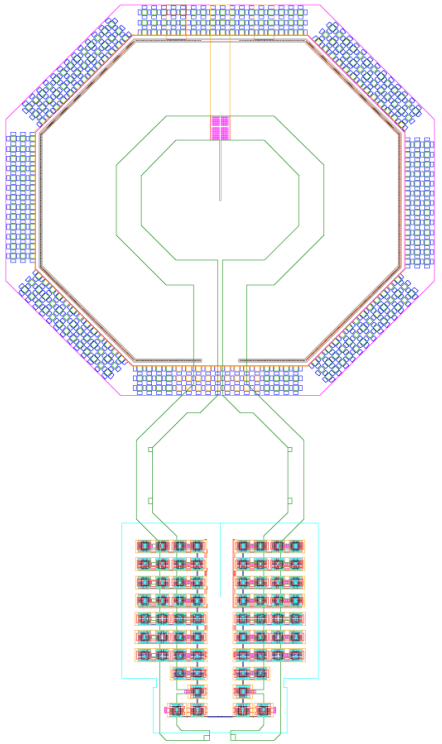
- 3D Full-wave EM simulation tool
- Applications
  - VCOs, LNAs
  - Diplexers



Diplexer



Full circuit

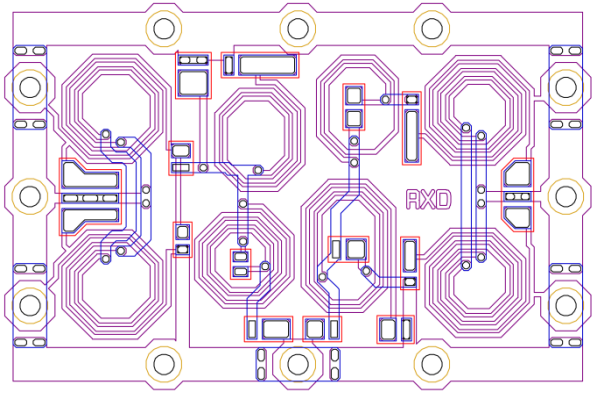


VCO

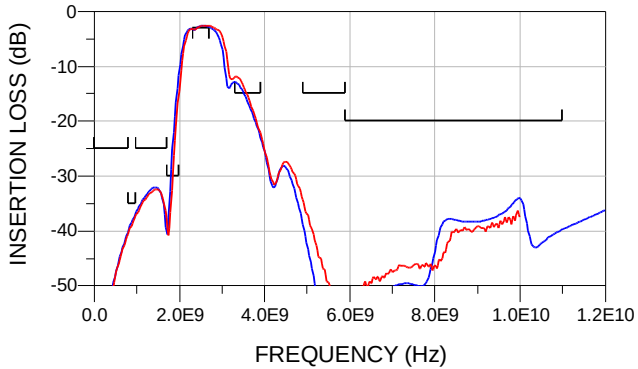
EMX distinguishing features

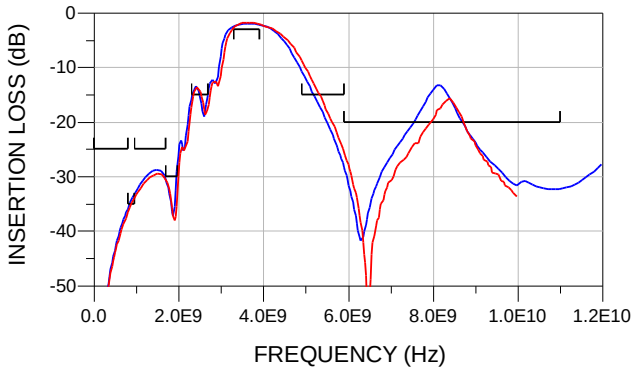
Integrand Software, Inc.

- Speed and capacity
  - 10-50X faster than other EM tools
  - **10X larger problems**



Dual Band WiMax Diplexer

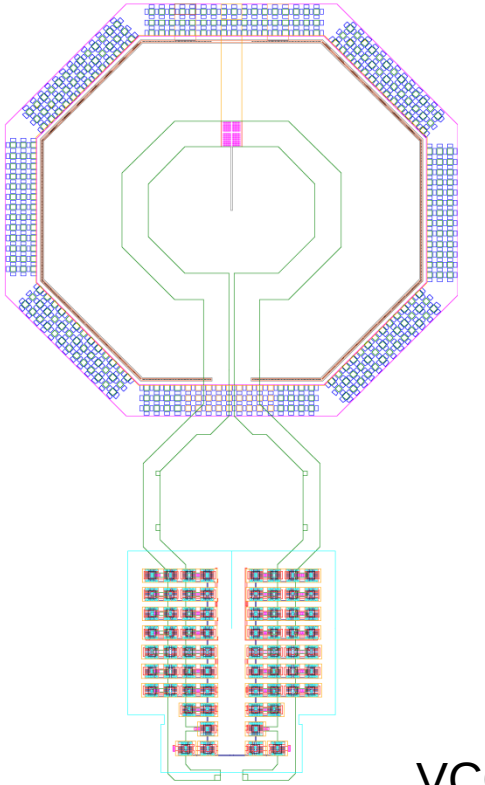




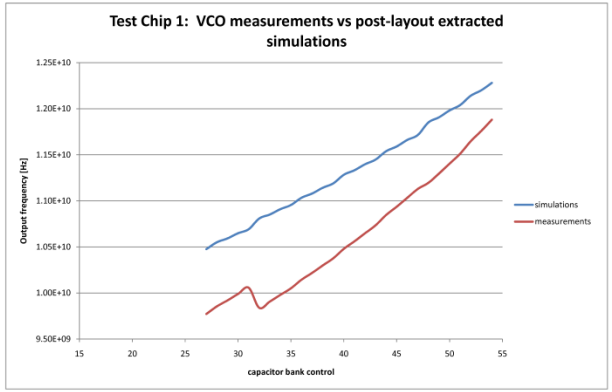
STATSChipPAC

90nm VCO using iRCX

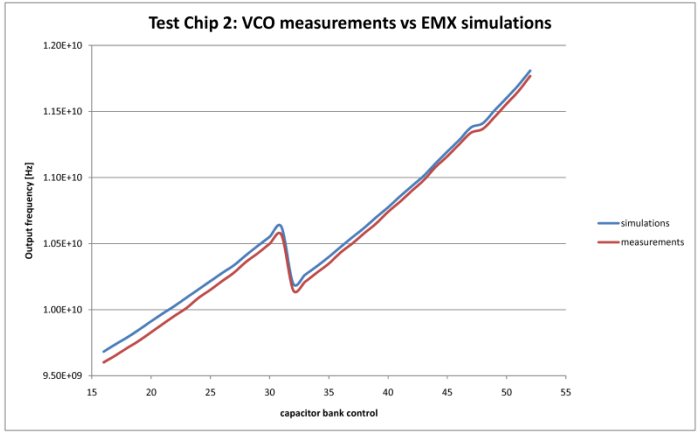
Integrand Software, Inc.



VCO



Before EMX



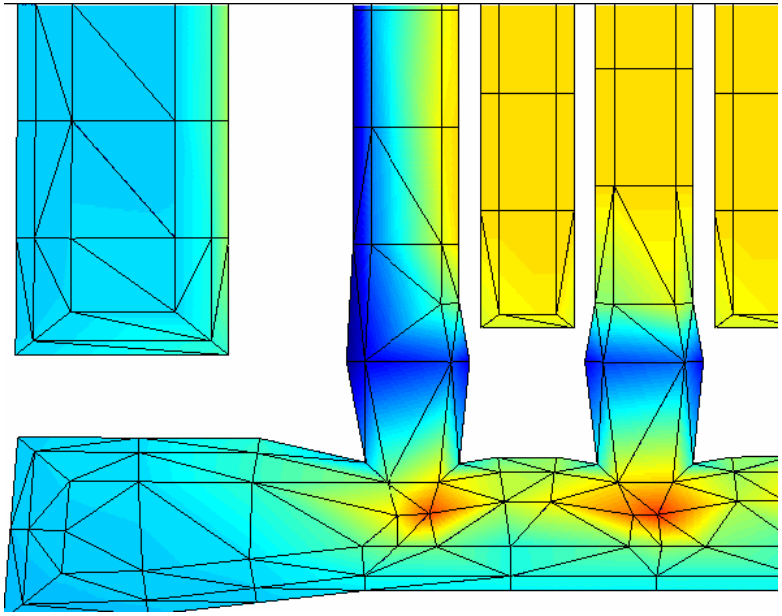
EMX+iRCX

WIPRO
Applying Thought

EMX and TSMC's iRCX

Integrand Software, Inc.

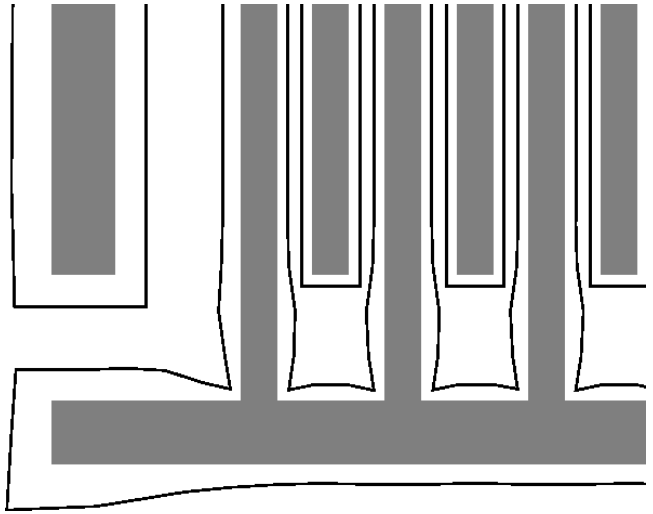
- TSMC iRCX
  - Technology properties
  - Width/spacing dependence
  - Sheet resistance variation
  - Metal width and bias variation
  - Parser converts iRCX to EMX process file
  - Paper at RFIC 09



EMX and TSMC's iRCX

Integrand Software, Inc.

- Drawing vs Fabrication
  - EMX mimics actual fabrication



Drawn vs Fabricated Layout

…Several mutual customers that use EMX+iRCX and have achieved first pass silicon success….

- Dr. Pike Chang, PDK Department

TSMC Customers using iRCX+EMX

Integrand Software, Inc.

MEDIATEK LSI SILICON LABS REALTEK HUAWEI

MARVELL® Ralink ST ERICSSON JAVELIN SEMICONDUCTOR WIPRO Applying Thought

MARVELL®

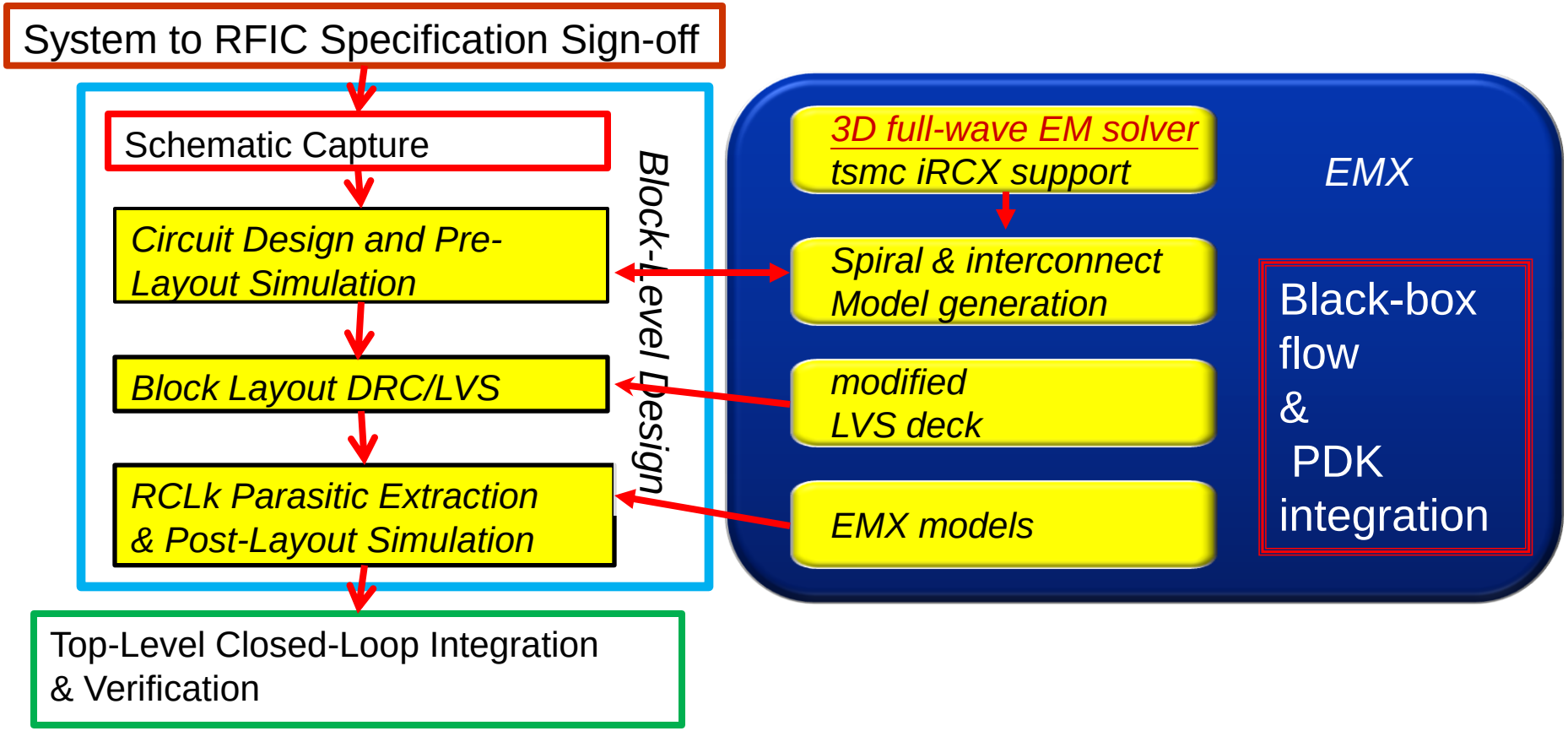
The iRCX flow with EMX is very useful to us…it has enabled us to achieve the best die size/performances of analog RF circuit and achieve first pass success at 55nm and 65nm nodes.– ***Dr. Cao Thong Tu, Design Manager, Marvell***

WIPRO Applying Thought

Since we have started using EMX+iRCX, high frequency design is no longer Russian Roulette– ***Dr. Carla Ghidini, Newlogic, Wipro***

EMX design flow for RDK 2.0

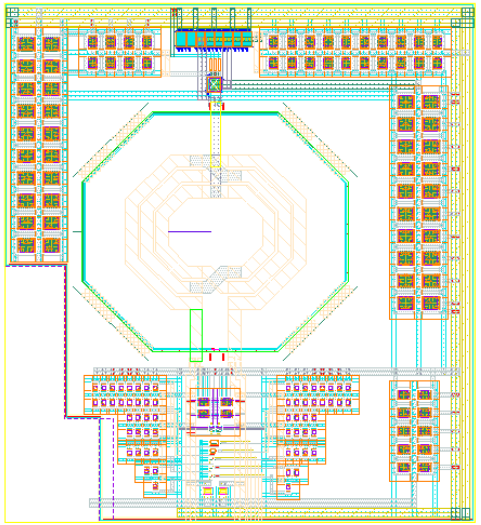
Integrand Software, Inc.



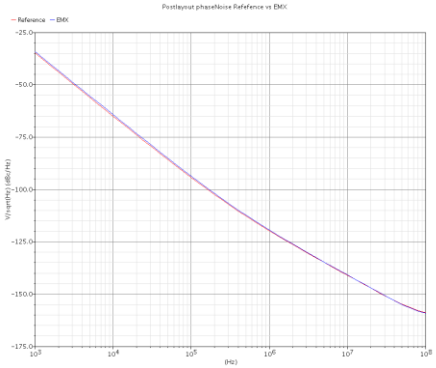
RF RDK 2.0 65nm VCO

Integrand Software, Inc.

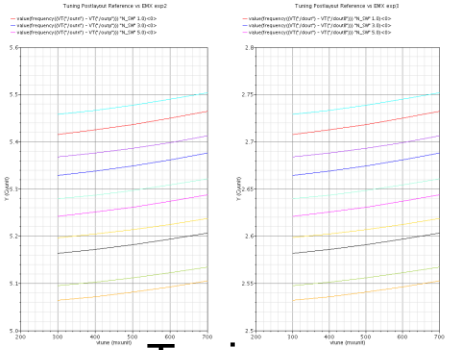
- TSMC provides a RF Reference Design Kit (RF RDK 2.0) 65nm
- VCO design
- Pre and Post-layout simulation
- Excellent agreement with reference



65nm VCO



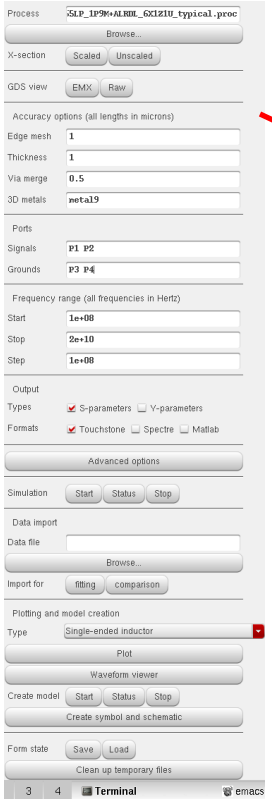
Phase Noise

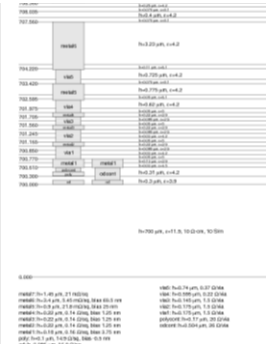


Tuning

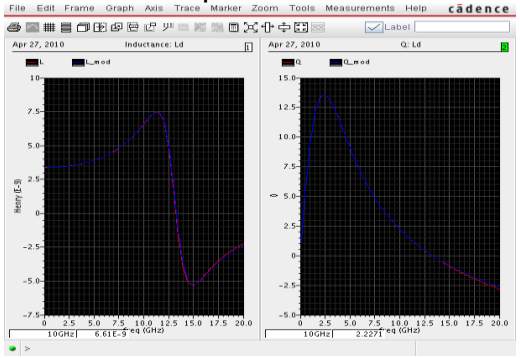
EMX in Cadence/TSMC RDK

Integrand Software, Inc.





iRCX process file



From layout to model in seconds

Simulation, modeling and plotting