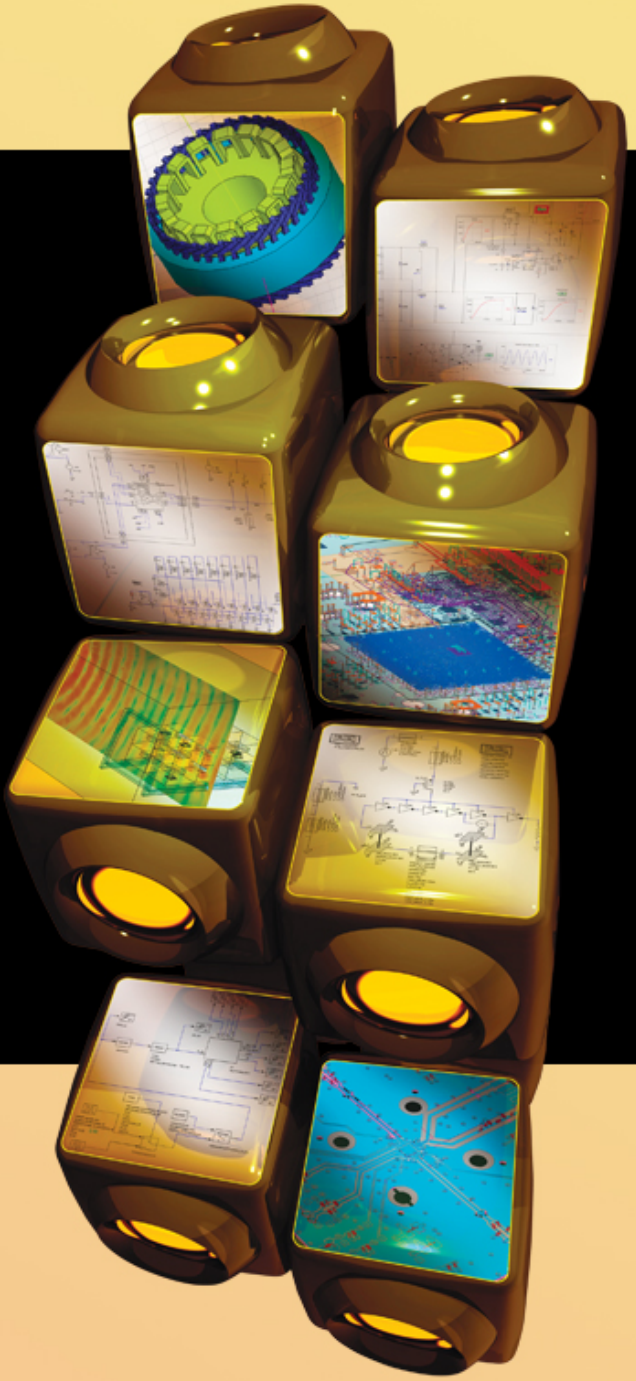

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RF Signal Integrity

Authors: Minhong Mi & Greg Pitner
Ansoft LLC

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Agenda

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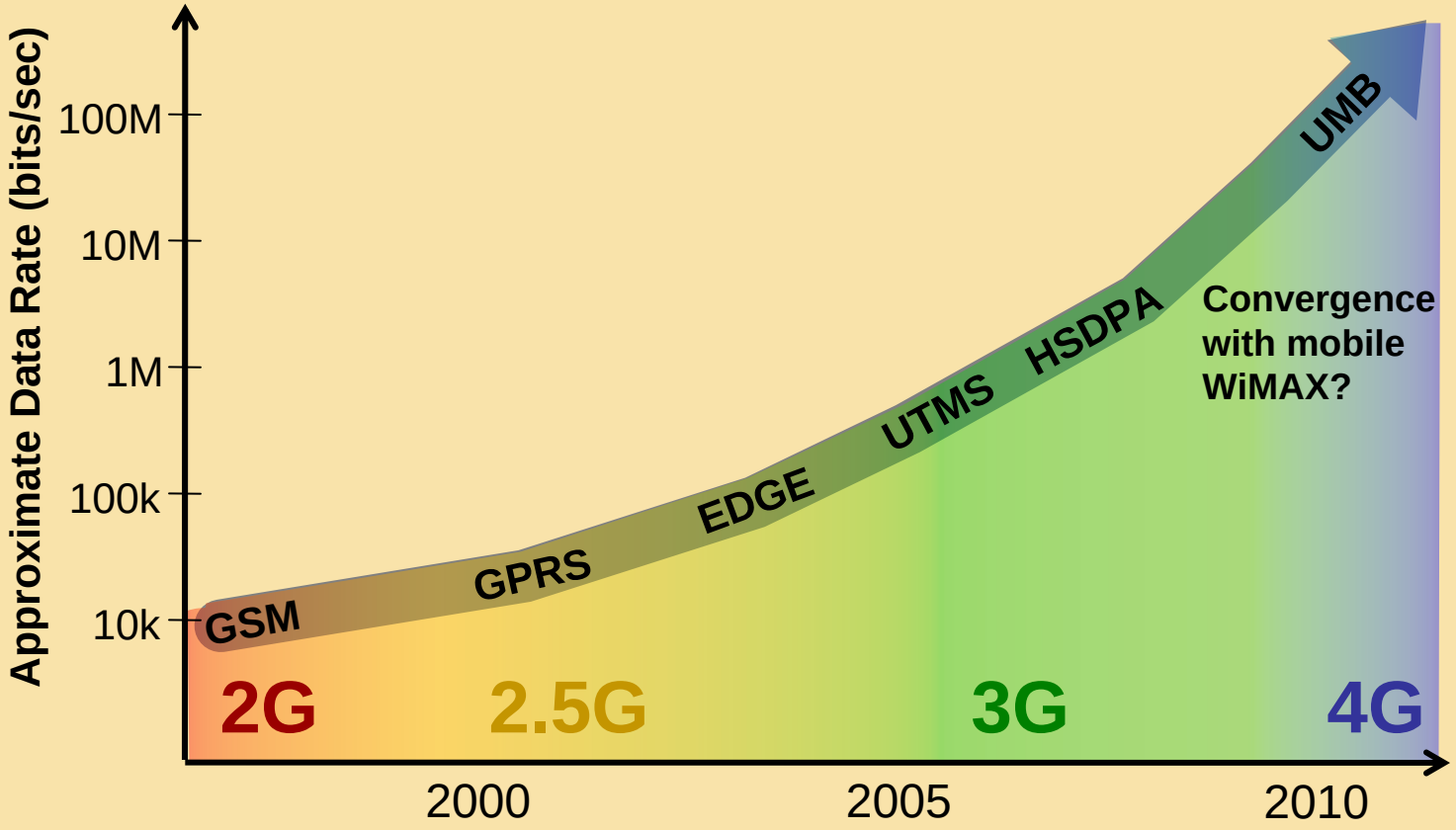
- Wireless technology trends and RF Signal Integrity Challenges
- Electromagnetic Simulation Methodologies
  - Package/Board Co-Simulation Requirements
  - Automation: Hybrid EM SimWizard
- Circuit/System Simulation Methodologies
  - Digital/RF Simulation Divide
  - Bridging the Divide: RF+D Simulation Technique
- UWB Radio Design Example
  - Analyzing the impact of package/PCB parasitics
  - Incorporating digital noise in the RF simulation

Cellular Data Rates Accelerating



GSM: Global System for Mobile Communication
GPRS: General Packet Radio Service
EDGE: Enhanced Data Rates for GSM Evolution
UTMS: Universal Mobile Telephone Service
HSDPA: High-Speed Downlink Packet Access
UMB: Ultra Mobile Broadband

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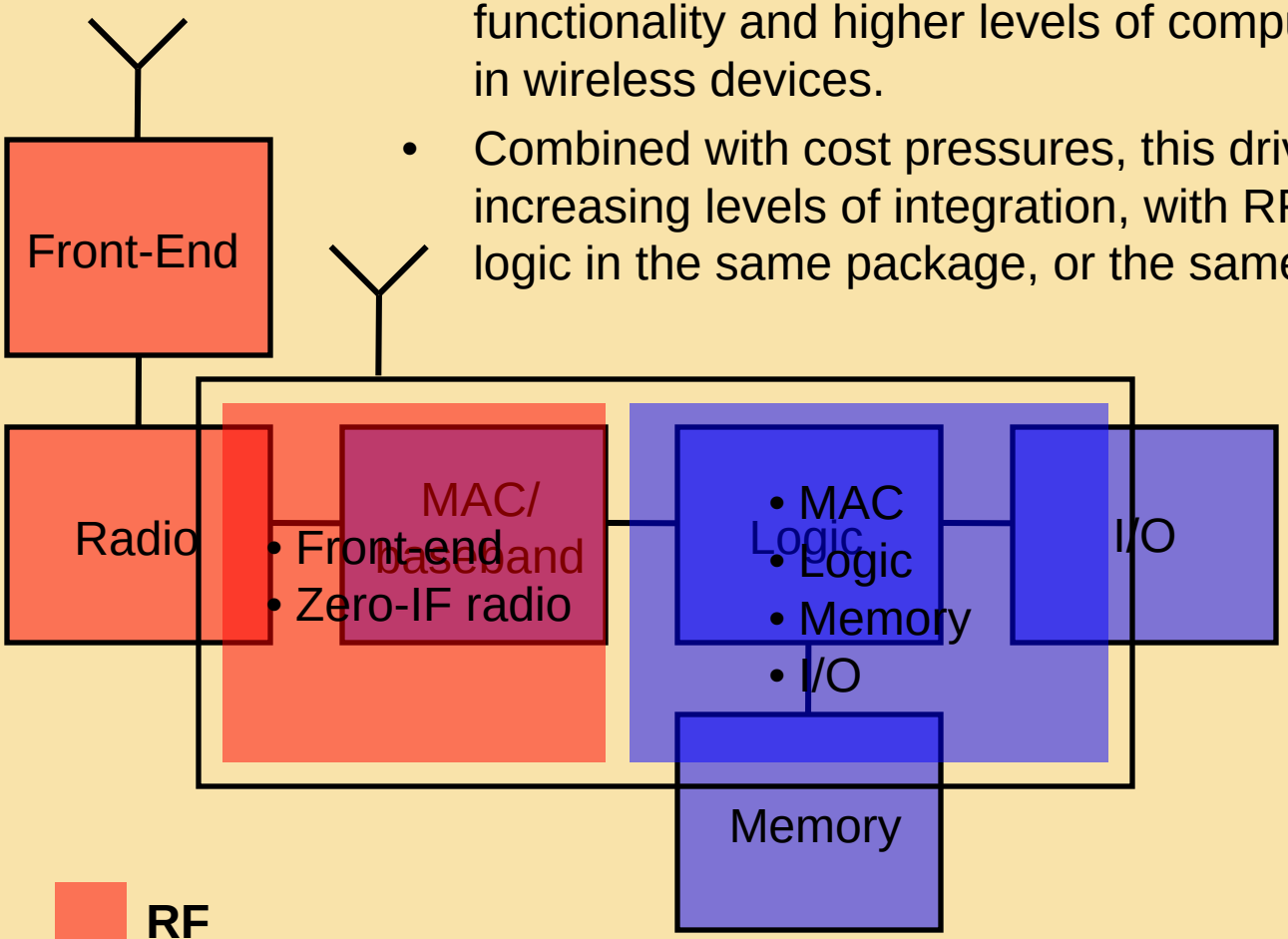
Increasing Integration

- Increasing data rates encourage greater functionality and higher levels of computing power in wireless devices.
- Combined with cost pressures, this drives increasing levels of integration, with RF and digital logic in the same package, or the same die.



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Simulation Requirements

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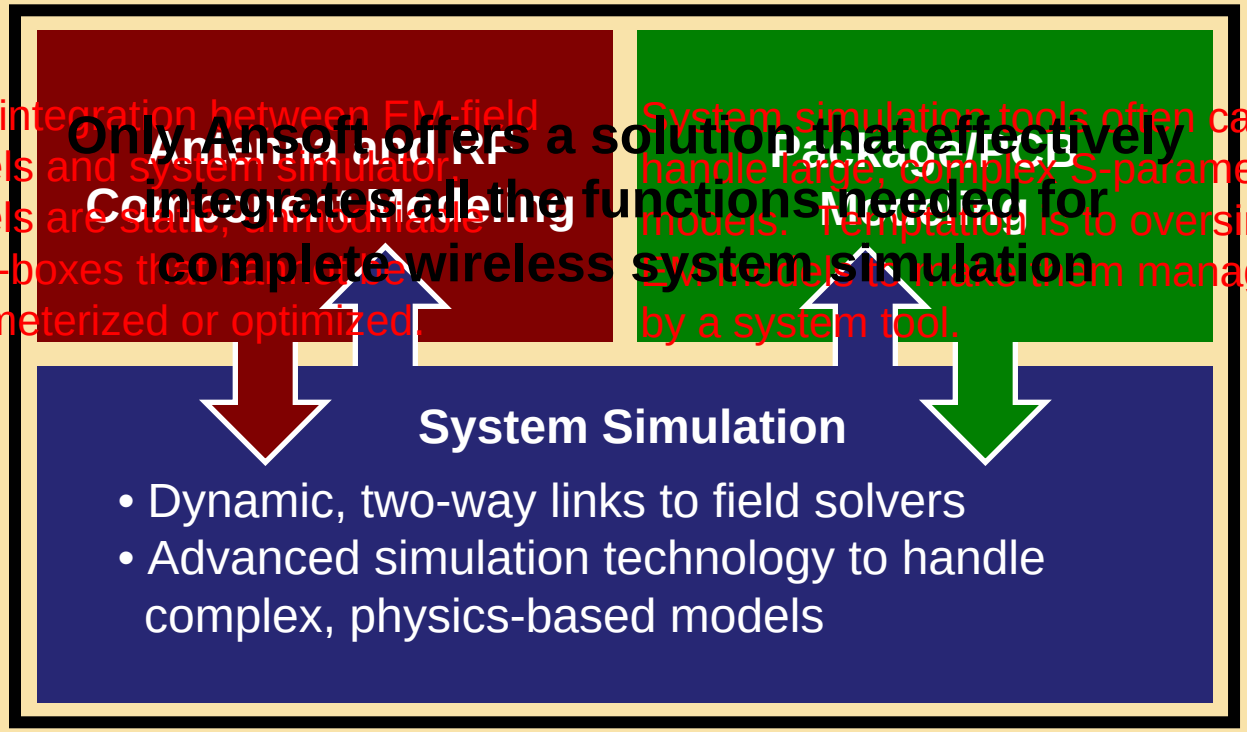
- Simulation environment must encompass multiple domains and types of analysis. For example
  - Accurate EM modeling package/board structures
  - Time- and frequency-domain
  - Analog and digital circuits
- A comprehensive, integrated simulation methodology is needed

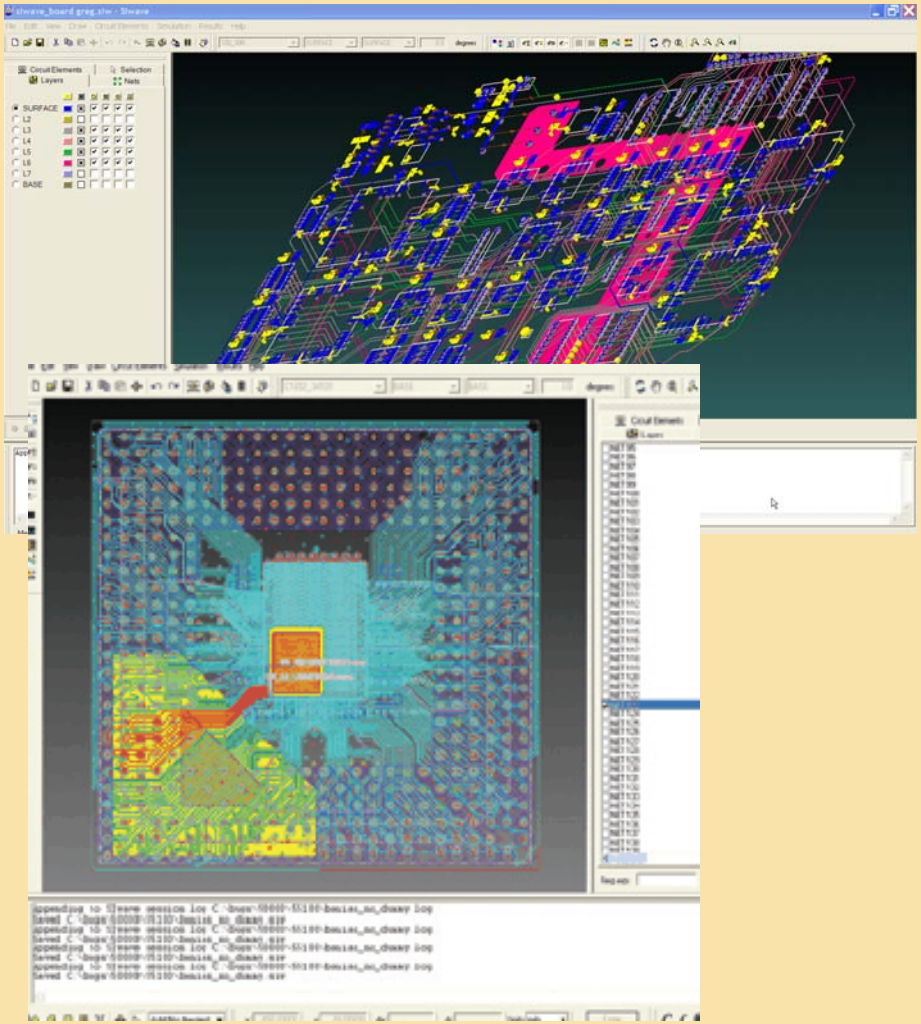
RF System Simulation

Complete wireless system simulation relies on multiple functions. Interoperability between functions is critical.



Package and PCB Modeling

- Full-wave modeling of packages and PCB's
- Need to capture extremely low level of coupling
- Use of cheap packages mandates arbitrary 3D solvers (HFSS)
- Complex board structures are more suitable to be analyzed with SIwave



Hybrid EM Simulation Wizard

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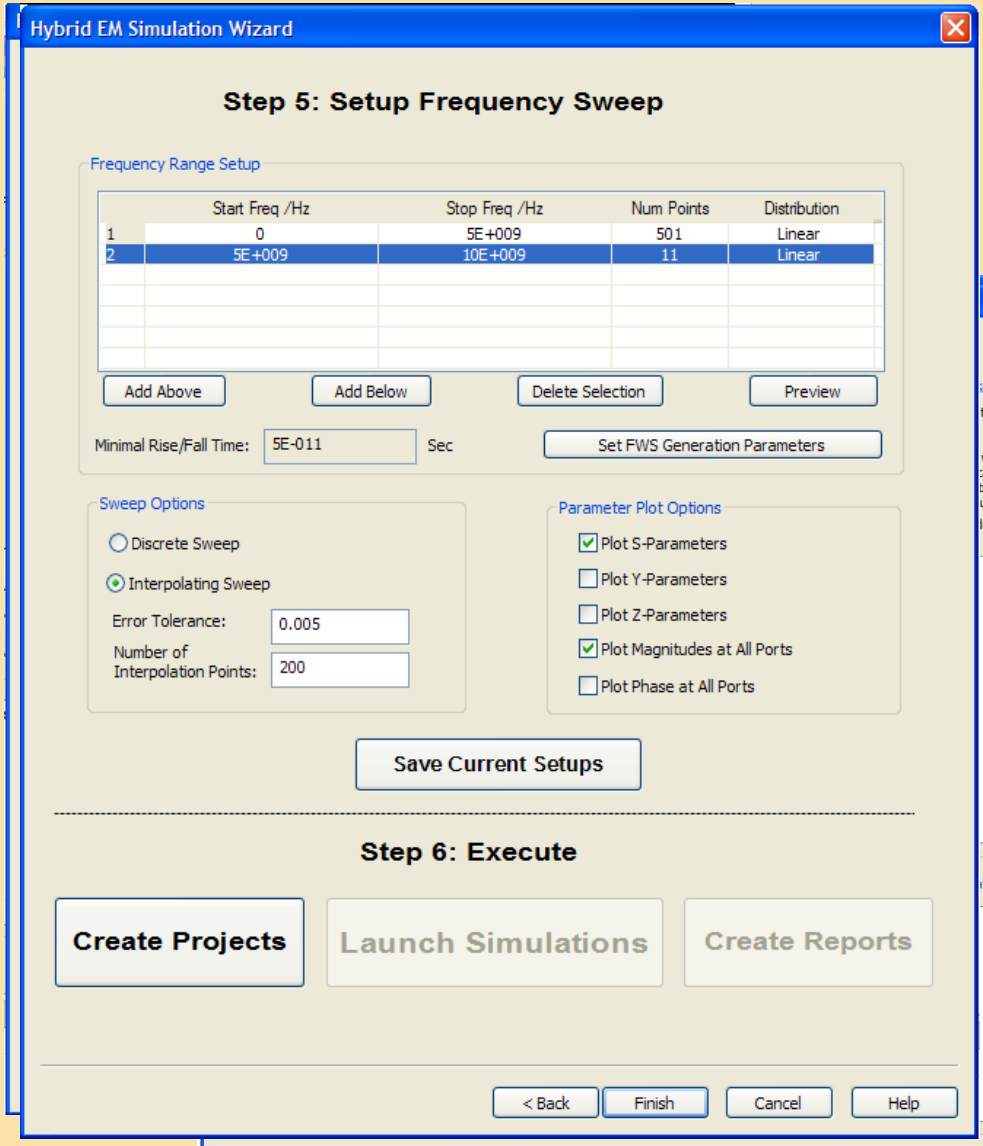
- Automates the whole EM Simulation Process
- Reduces the simulation setup time from hours to minutes
- Minimize the possibility of errors
- Easy to use for IC designers



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S-Parameter Analyzer

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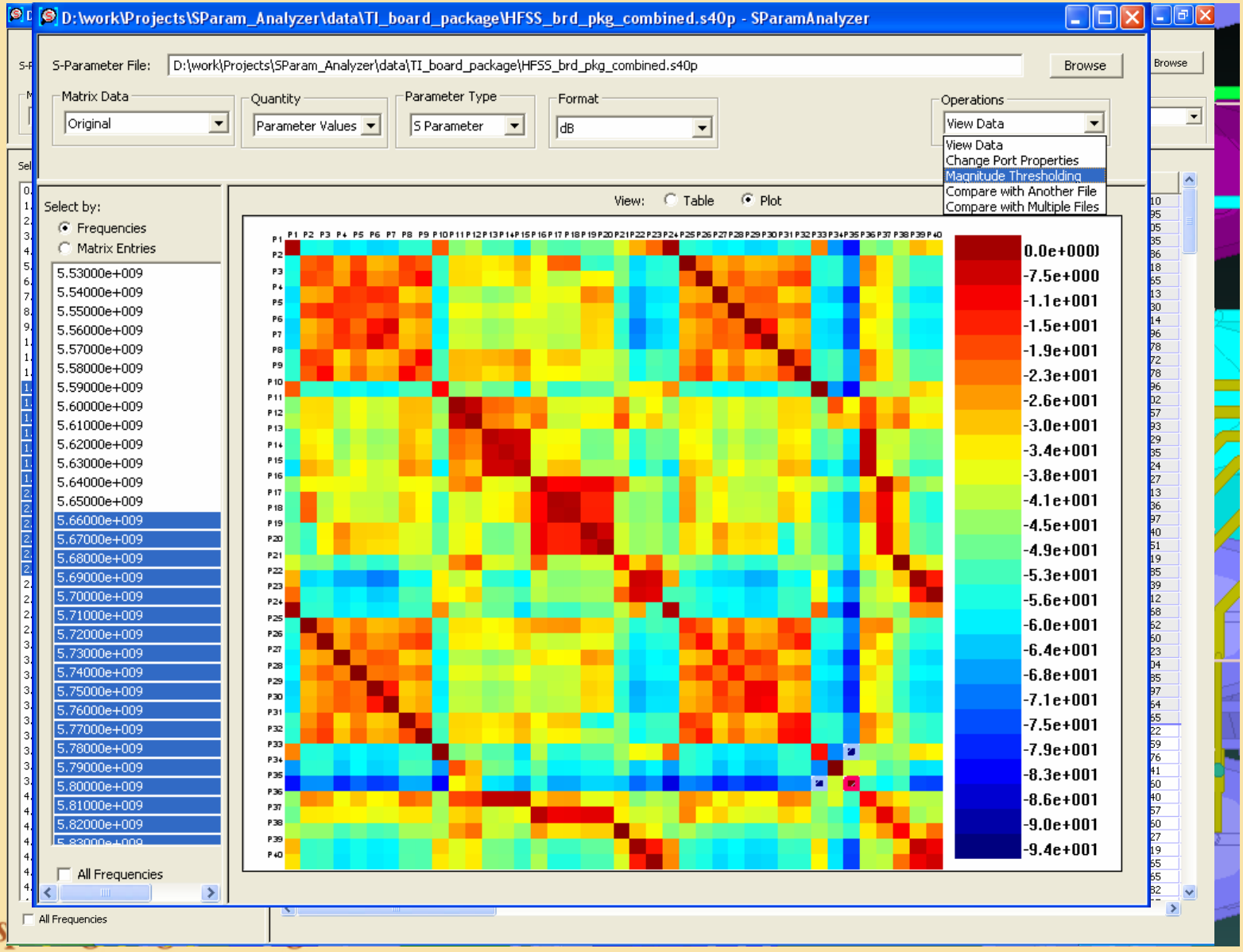

The Digital / RF Simulation Divide

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Digital Circuits

✗ Harmonic Balance

✓ Transient

The harmonic balance method is not well-suited to circuits that are both very large and highly nonlinear.

RF Circuits

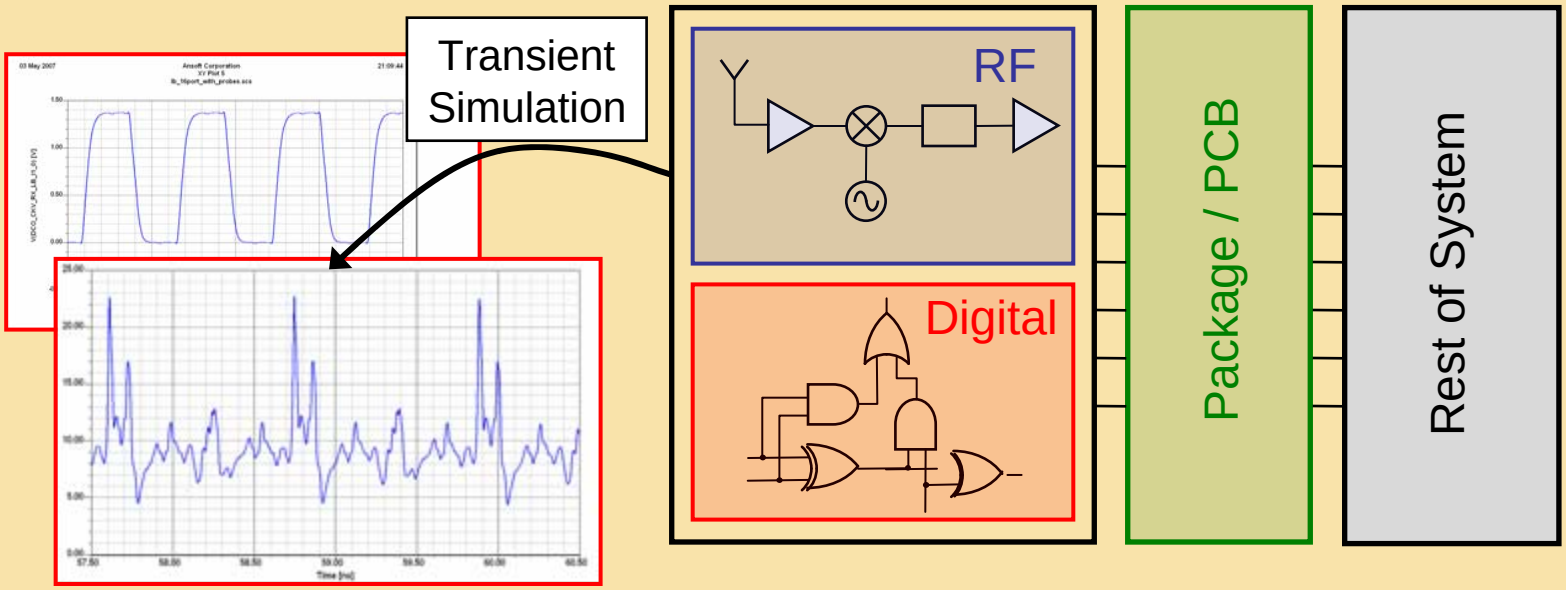
✓ Harmonic Balance

✗ Transient

Transient simulations are often impractical. A very large number of carrier wave cycles must be simulated to capture the lower-frequency modulation.

Bridge the Divide: RF+D

- Run a transient simulation of the system for enough time to obtain representative “aggressor” digital waveforms.
  - We do not need the long run times that would be required to characterize the RF circuit using transient analysis
  - S-parameter models can optionally be simplified before state-space fitting since we are only seeking the aggressor waveforms at this point. Full coupling not necessary



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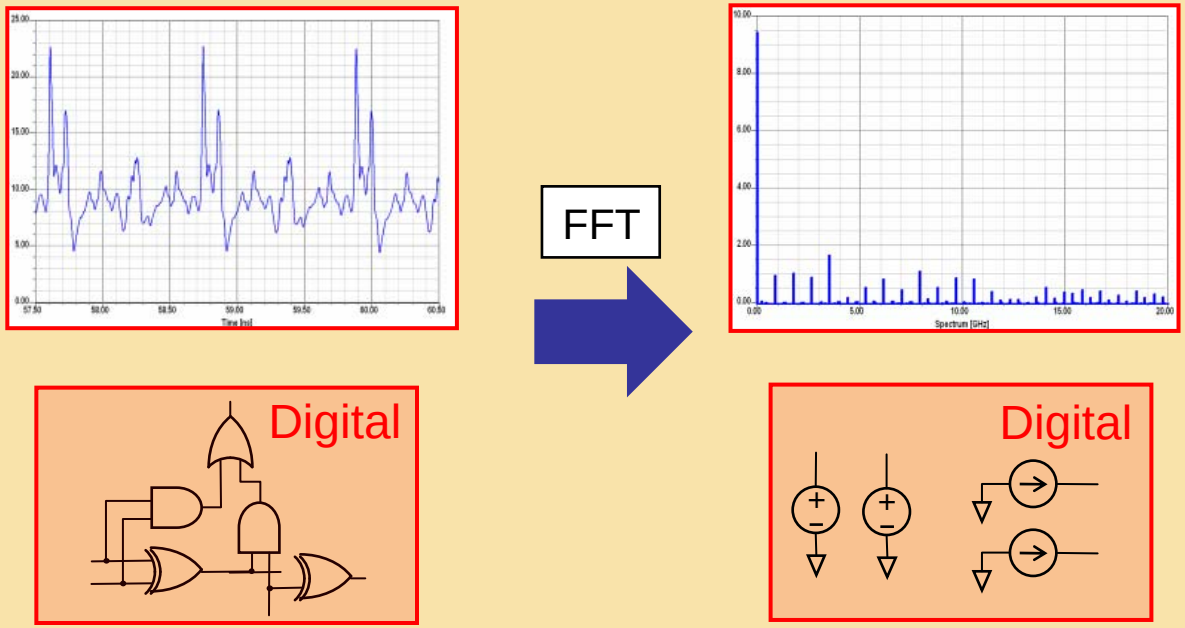
Bridge the Divide: RF+D

- FFT digital aggressor waveforms to the frequency domain to prepare for HB simulation
- Represent digital sources as frequency-domain sources
  - Periodic time-domain sources (such as piece-wise linear or pulse sources) can be directly included in an HB simulation. Simulator calculates Fourier spectrum automatically.



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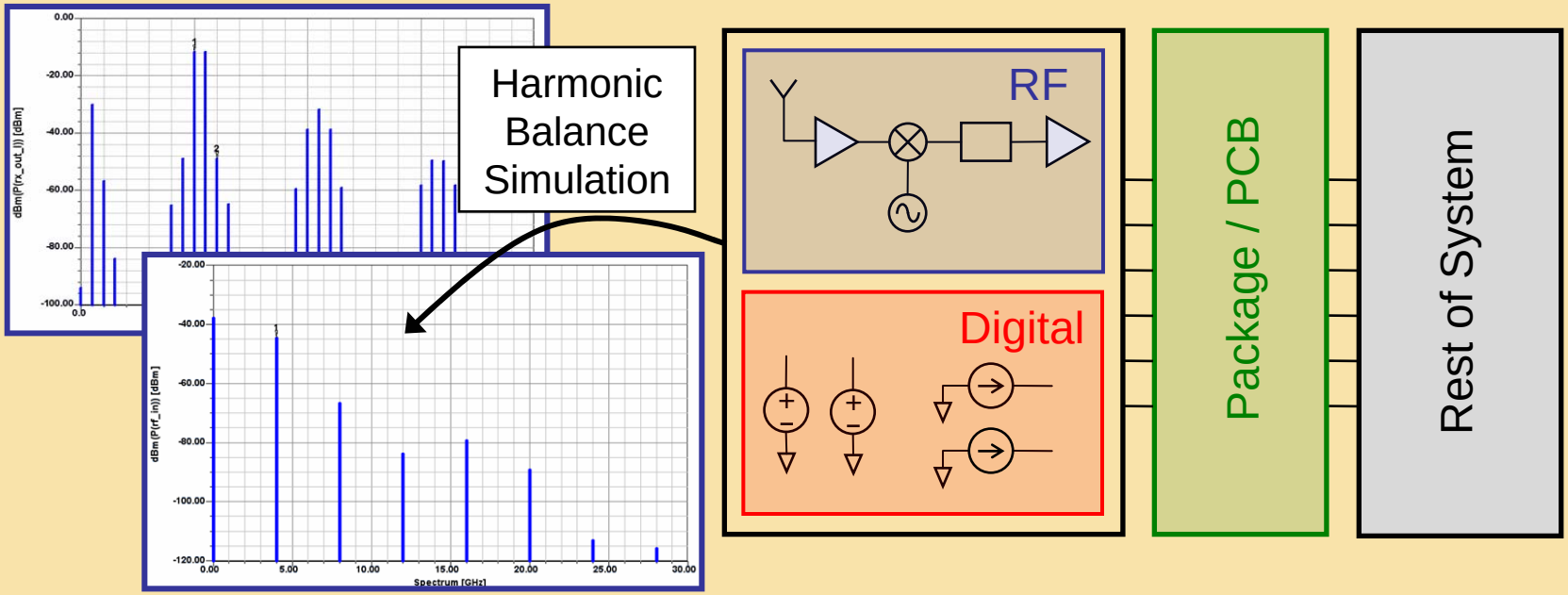
Bridge the Divide: RF+D

- Run HB simulation with frequency domain digital sources and complete S-parameter models to find the system RF performance in the presence of digital noise



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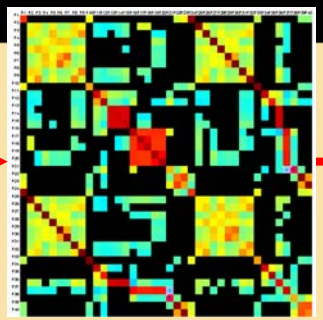
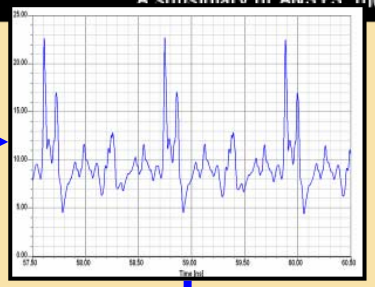
RF+D Summary

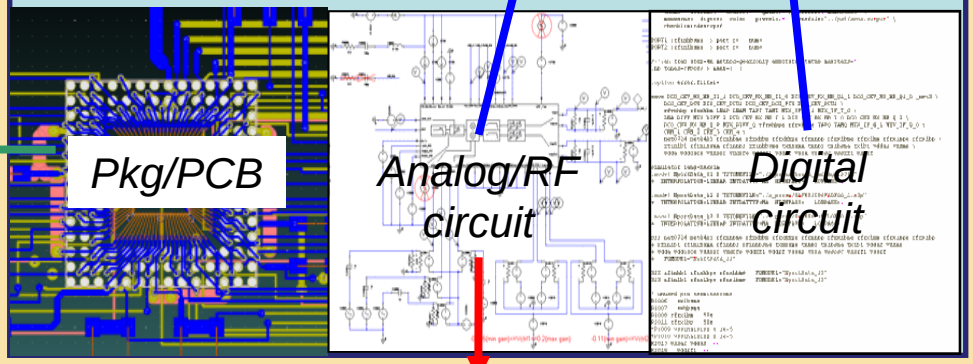


State-Space Fitting

2 Transient simulation



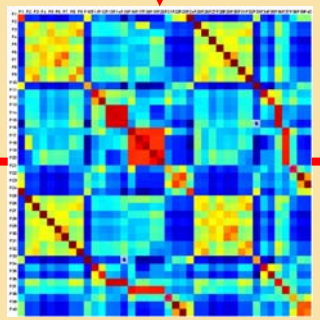
Wireless System Design



MOR

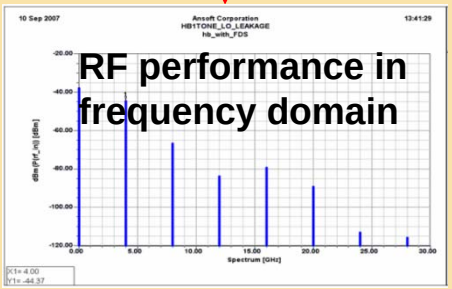
1 EM Modeling

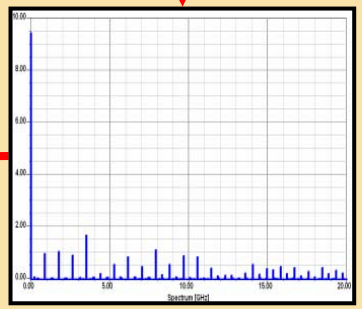
FFT



Full S-parameter model

3 Harmonic balance simulation





Frequency domain sources

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Design Example: UWB Radio

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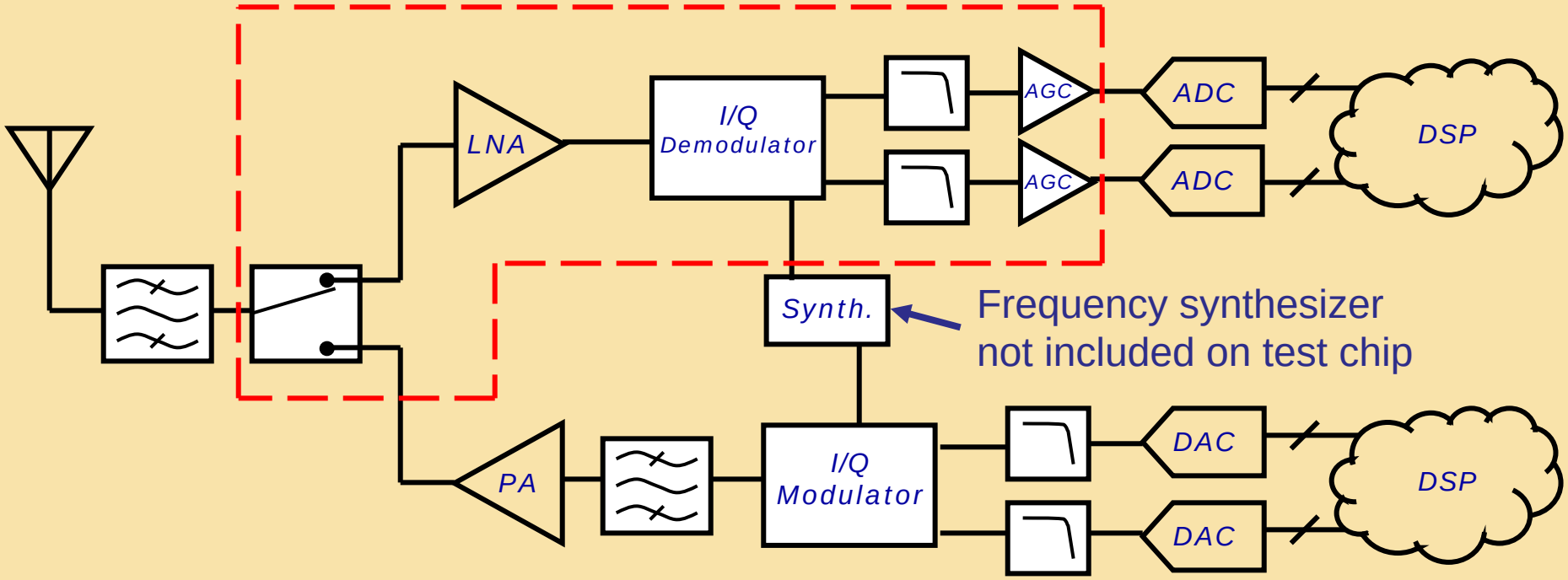
- Test chip of the receiver was fabricated in 0.13μm CMOS process
- Packaged in a 32-pin QFN package
- Demonstrated to work on a test board



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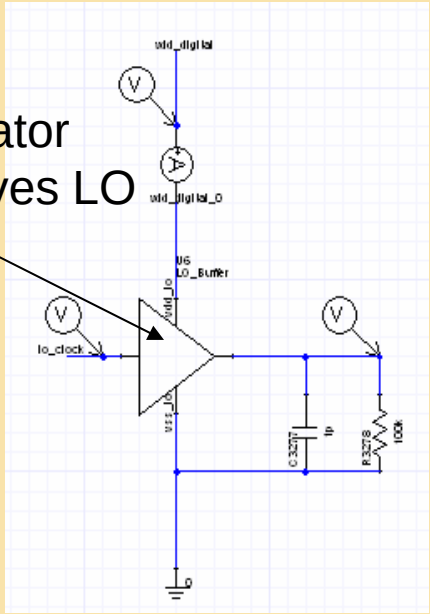
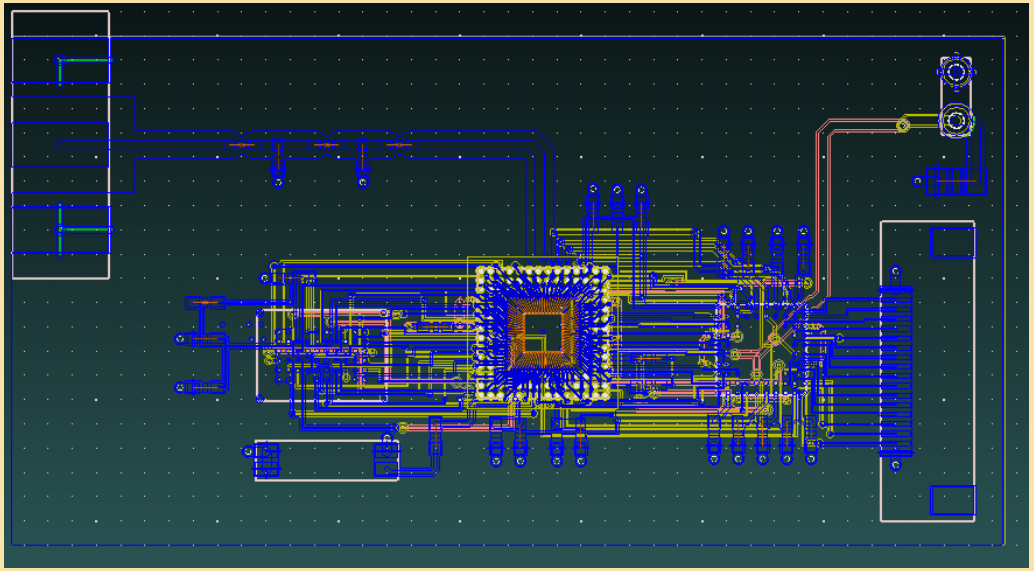
RF+D Methodology Validation

- To validate RF+D we will add some digital components to the UWB receiver, as in a system-on-a-chip, with a new package and PCB model.
- But we will intentionally keep the total system small enough that it can be simulated unmodified using HB.
- Then compare unmodified HB results with the RF+D results.

Local oscillator buffer redrives LO signal





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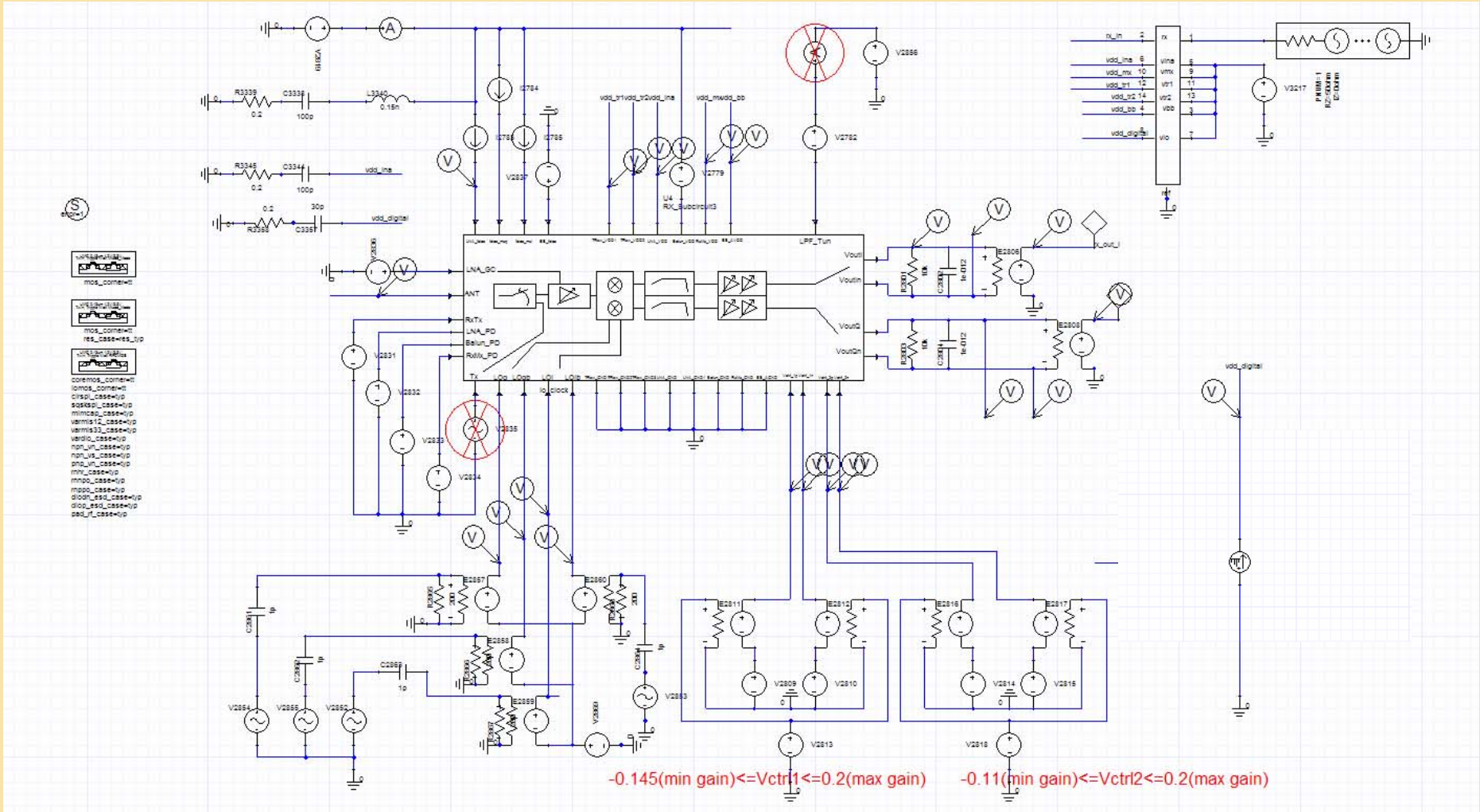
RF+D Methodology Validation



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Result Comparison

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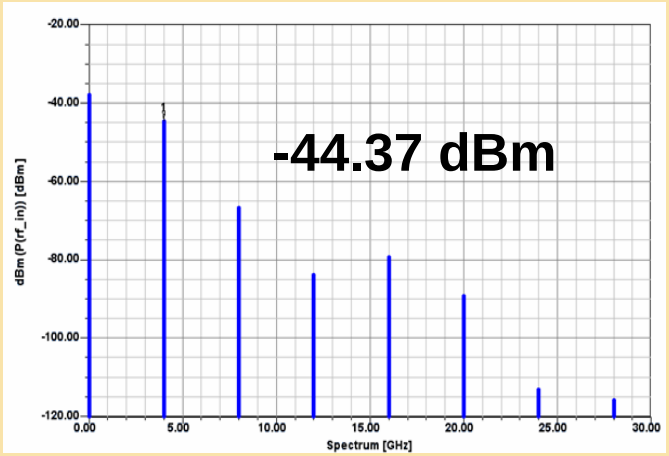
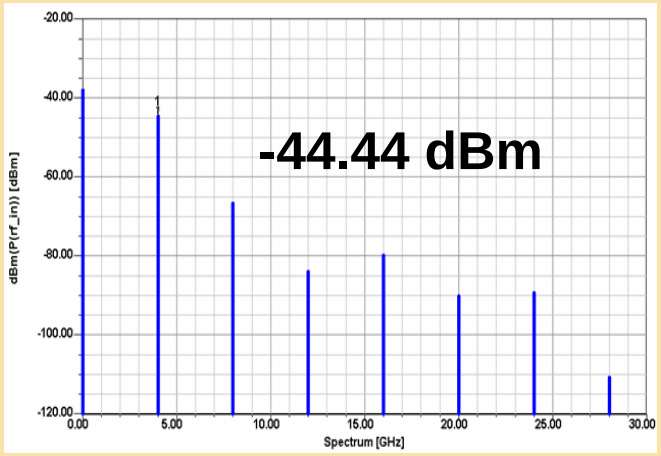
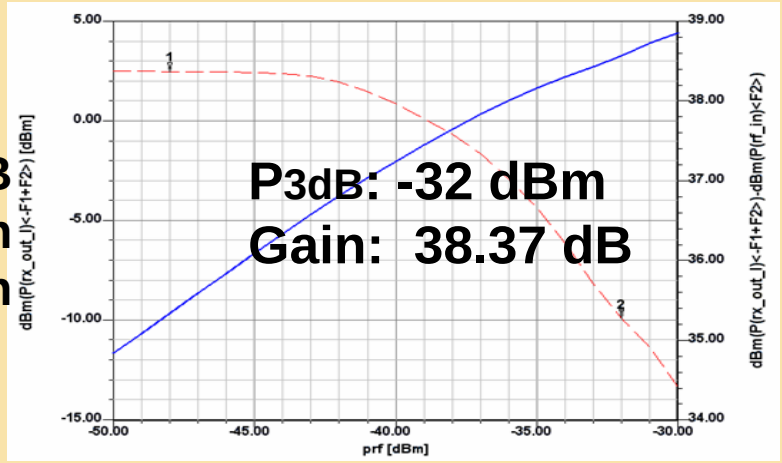
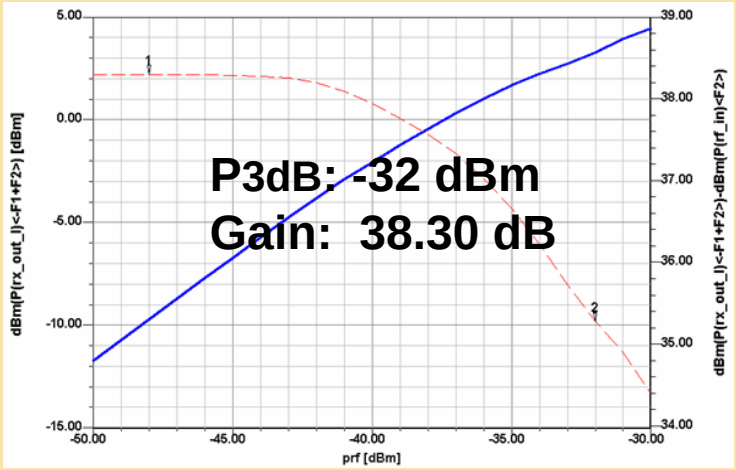
	RF+D	Unmodified HB
LO leakage power		
3dB compression and gain		

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Result Comparison

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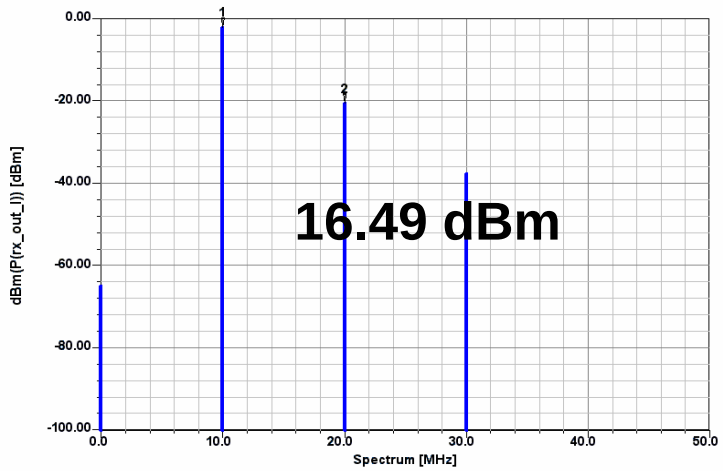
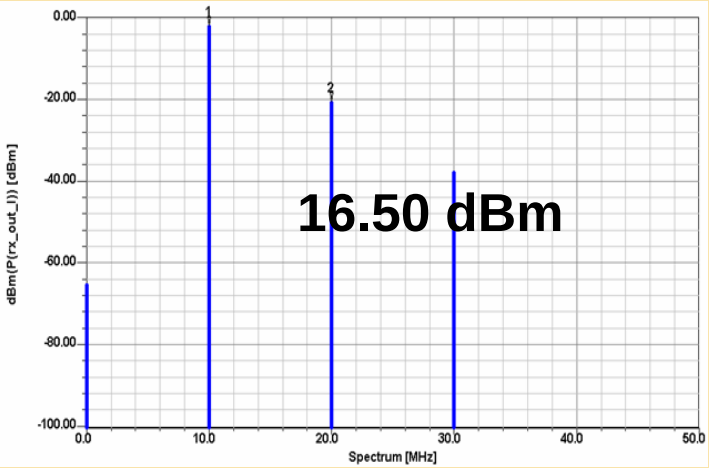
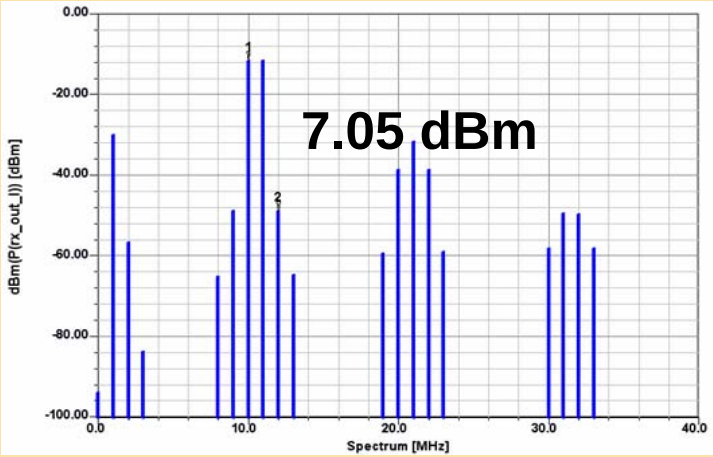
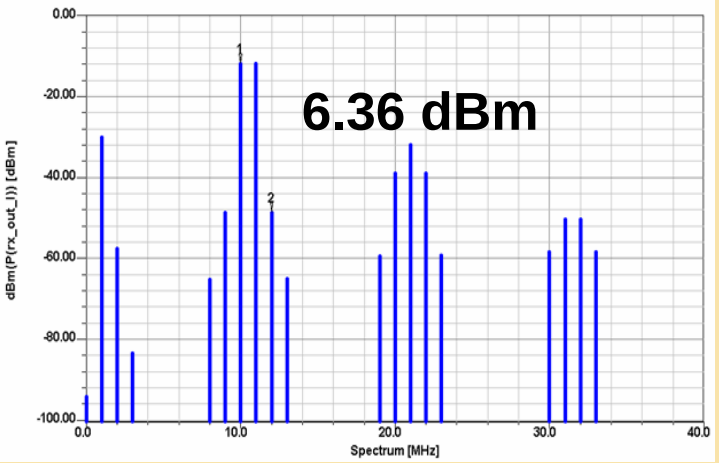
	RF+D	Unmodified HB
IP2		
IP3		

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Conclusions

- The difficult problem of RF Signal Integrity is solved with the combination of and interoperability between
  - Best-in-class electromagnetic model extraction
  - Powerful and flexible system simulation
- Ansoft provides the breadth of expertise needed to address the multi-disciplinary nature of modern wireless design