AMCAD Engineering
Advanced Modeling for Computer-Aided Design

BITS&CHIPS BENELUX RF CONFERENCE

Advanced behavioral modeling for complex front-end system analysis

Presenter
Wissam SAABE
Application engineer

Helping our customers to design smart and safe communication systems !

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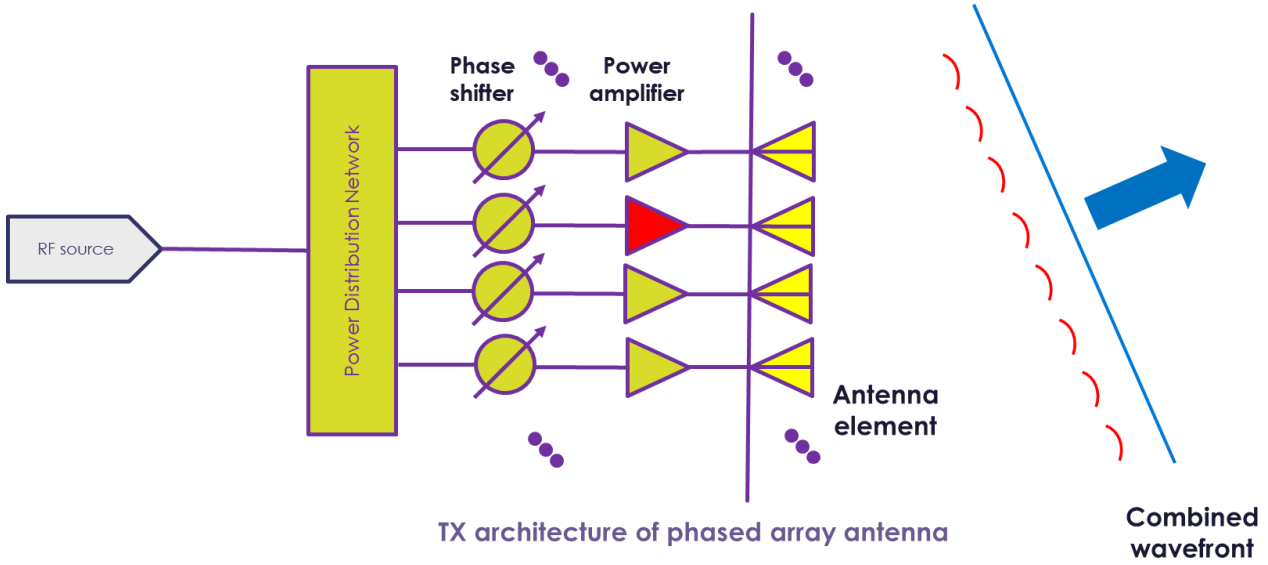
Context

[1]

- Phased-array antenna system
  - 5G basestation
  - Radar
- Main characteristics
  - Independant and simultaneous functions
  - Improved range and reliability
  - High agility of waveforms

- Principle of active antenna
  - Antenna array where each radiating element has its own TRx module
  - Control of the amplitudes / phases of the signals emitted by each sources makes it possible to modify the direction and the shape of the beam



TX architecture of phased array antenna

[1] from https://www.altair.com/newsroom/articles/what-is-5g-and-why-are-there-so-many-new-antennas/

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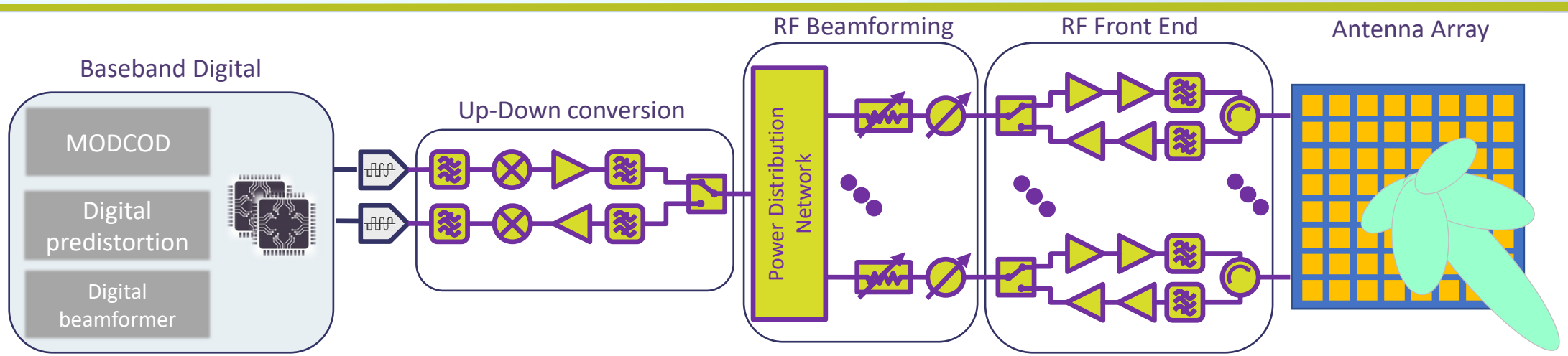
System design challenges



The challenge is to develop complex system that meet specifications in an efficient way

- Digital/Circuit/EM analysis
- Large number of components
- Efficient waveform scheme

- Stakeholder requirement
- Regulation
- System decomposition and definition

- Minimize circuit or subsystem redesign
- Identify impairment early
- Smooth operational communication

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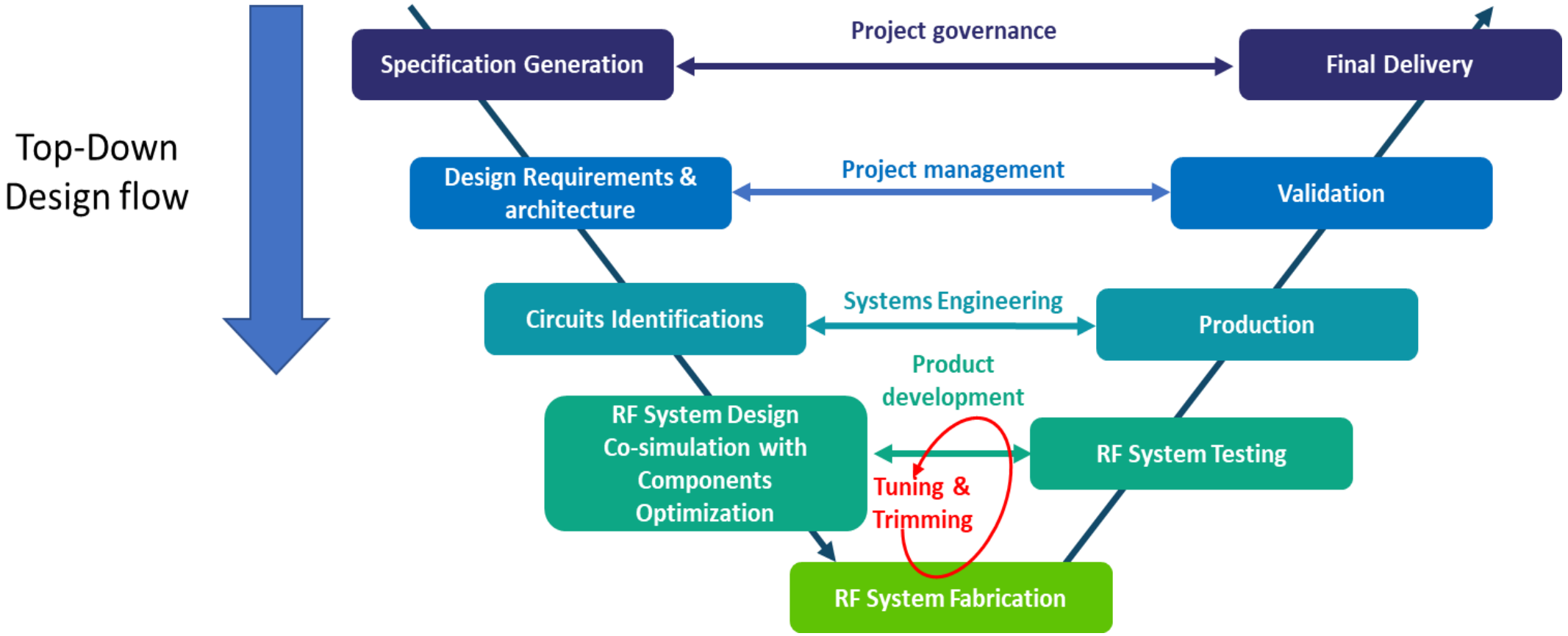
V-model design



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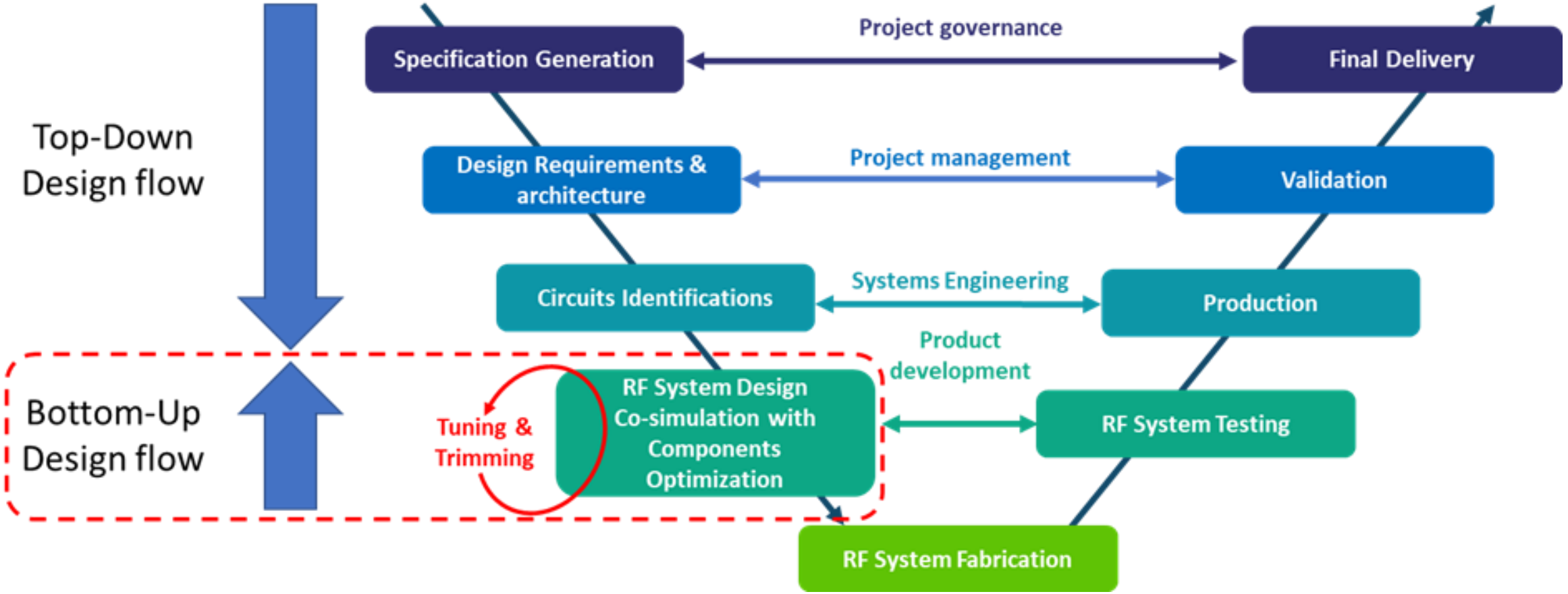
Model-based design approach



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System Design

Bottom-Up Approach

(system design from COTS products)

System

Sub-System

Circuit

Component

VISION

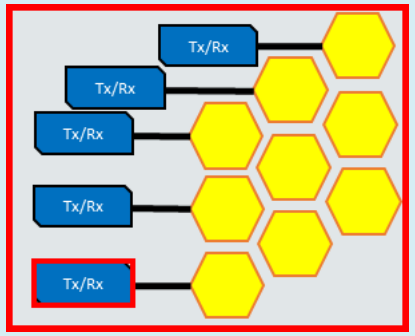
Advanced Design System

cadence | AWR

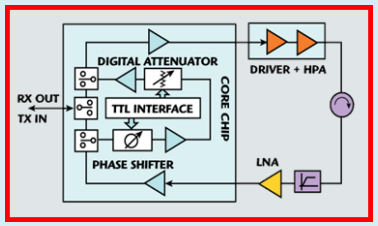
Ansys

SIMULIA

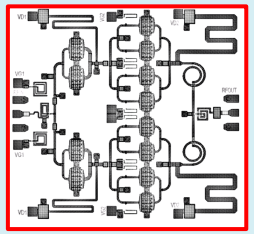
RF FrontEnd



Tx/Rx Module



PA Module



Technology

Top-Down Approach

(design specific components for the project needs)

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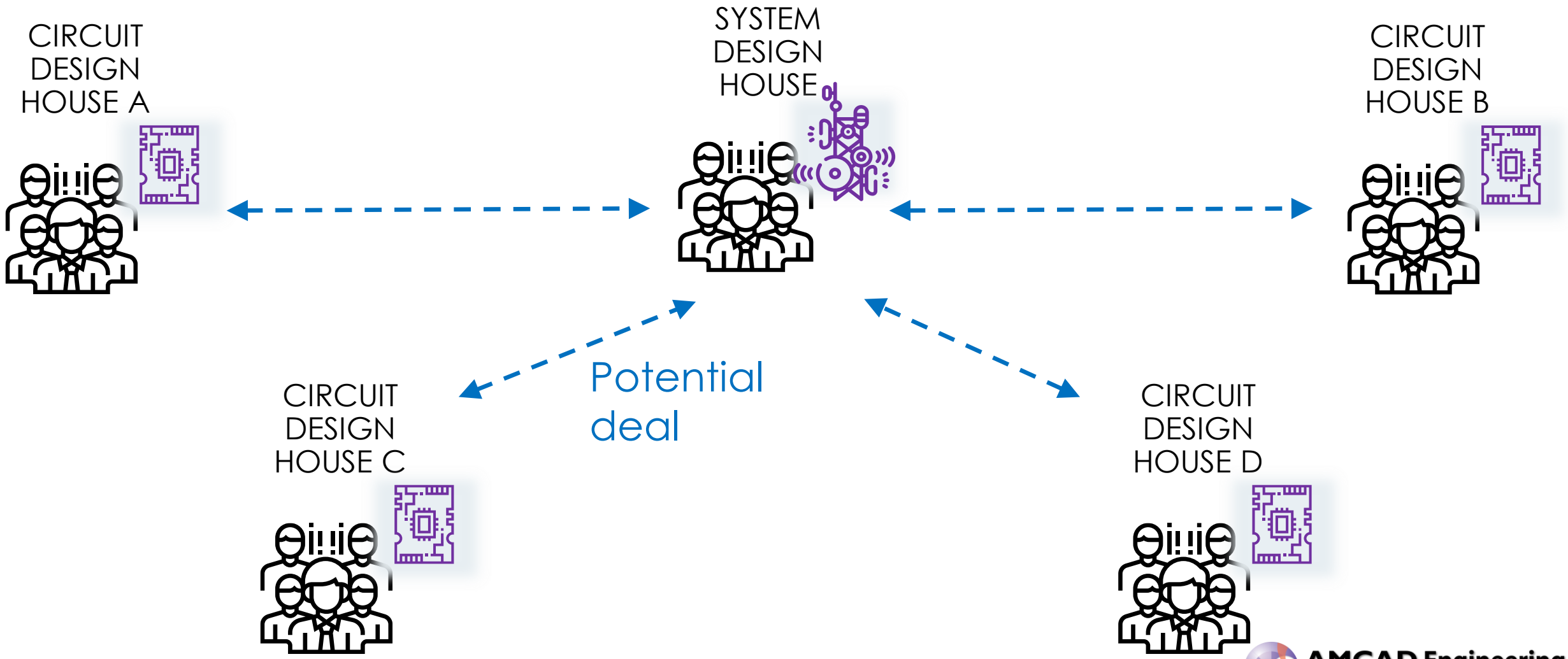
Current challenges for circuit vendor

Strong competition



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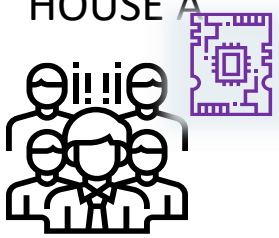
Circuit Behavioral Model for System Design

CIRCUIT DESIGN HOUSE A

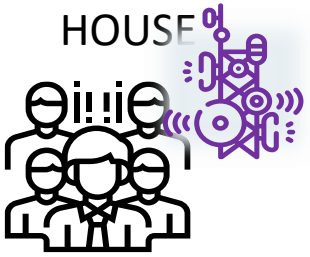


Datasheet

Look-up table

Circuit design

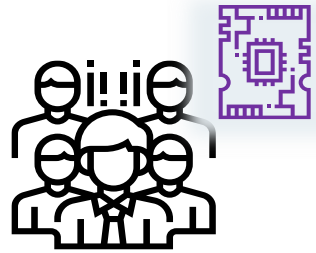
SYSTEM DESIGN HOUSE



Behavioral model

Key competitive advantage for both

CIRCUIT DESIGN HOUSE B



Lack of information

Time consuming task

Convergence issue

Sensitive IP

Heavy co-simulation

Requirements

- Protected IP
- Wide domain of validity
- Data extraction from circuit simulation or measurement
- Fast simulation
- Integration in system simulator

=> Provide a comprehensive process is a challenge !

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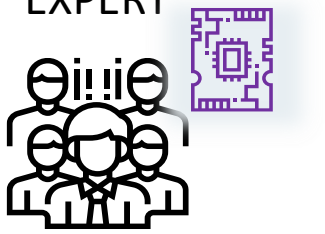
Circuit Behavioral Model for System Design

Behavioral models are useful because we can execute them in system simulation and learn faster than we can with product datasheet

SYSTEM EXPERT

- Analysis & Simulation
- Test & Verification
- Communication

CIRCUIT EXPERT



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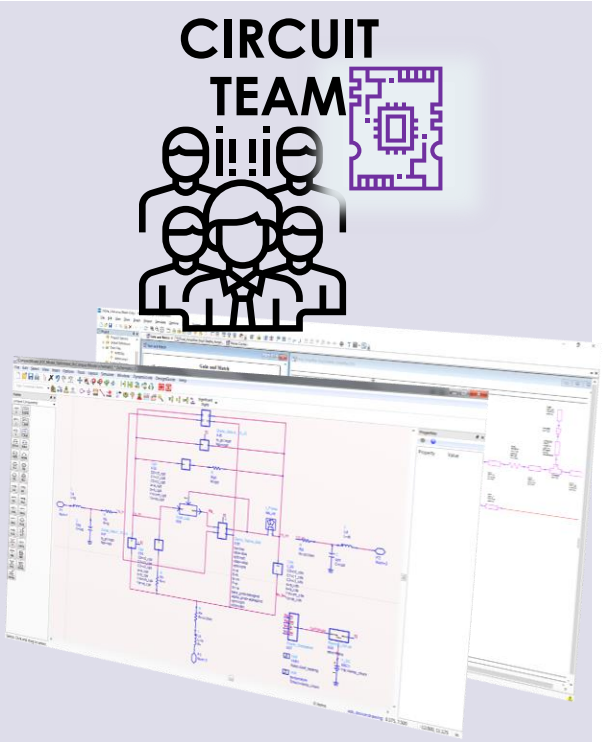
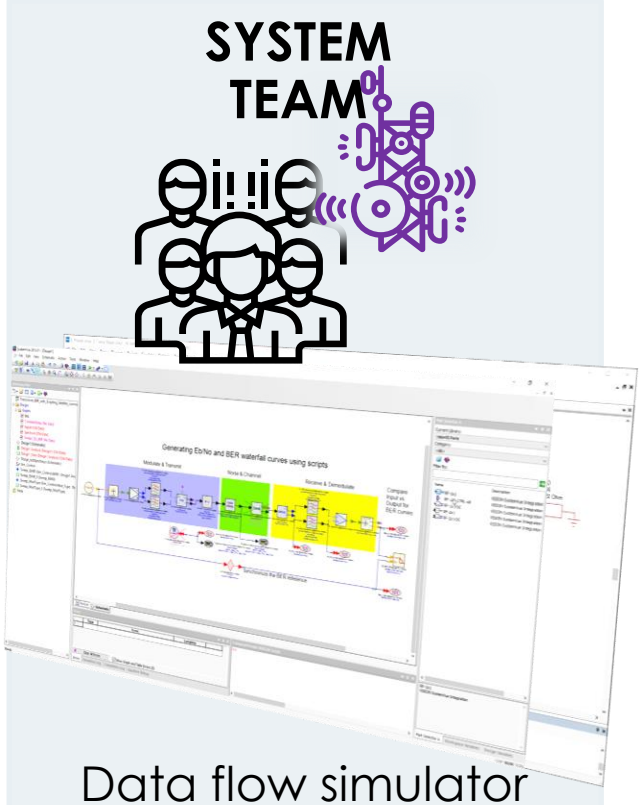
Behavioral modelling solution

How to bridge the gap ?



<u>HB & Circuit envelope simulator</u>
Taking into account the parasitic effects



<u>Data flow simulator</u>
Processing a large volume of data

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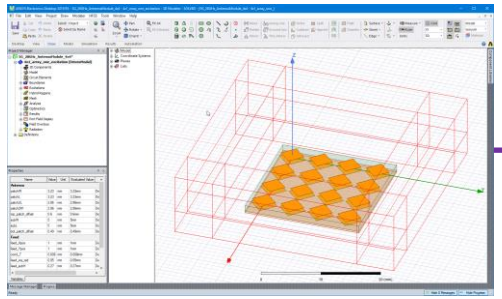
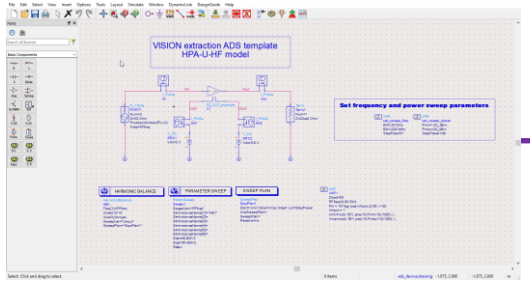
VISION Behavioral Modeling Workflow

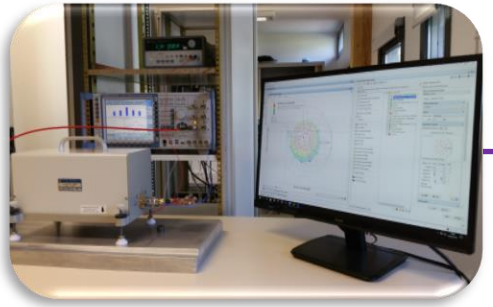
EM Simulation



Circuit level Simulation



Test bench Control



Data IN

Mixer

P. SHIFTER

PA

VISION

VISION DEVICE MODELER

Black-box Model

Black-box Model

Black-box Model

Black-box Model

VISION SYSTEM ARCHITECT

IRF Mixer IRF P. SHIFTER VGA PA

Transient simulation

Export feature

Subsystem Macro-model in external Data Flow Simulator

Macro-model = design + models + solver

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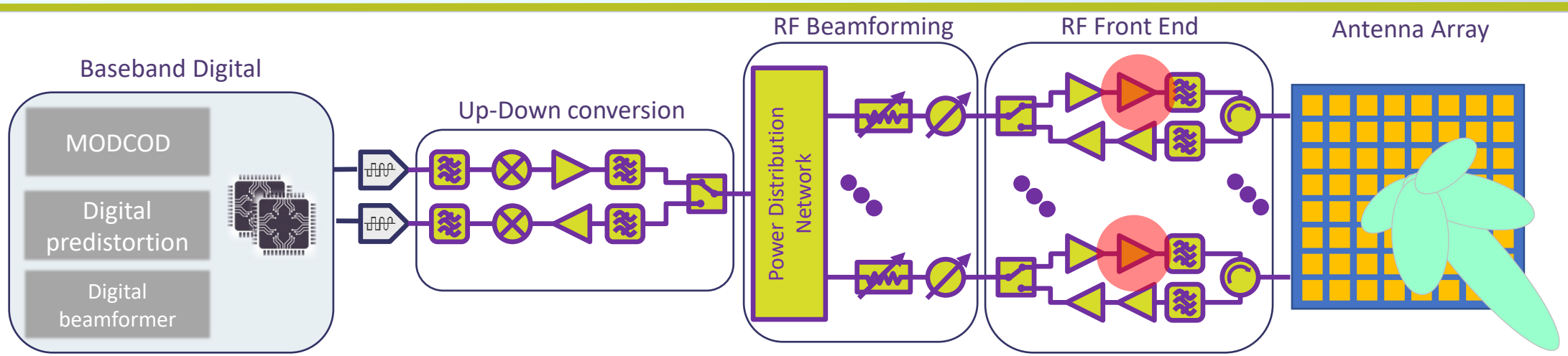
VISION Behavioral Modeling Workflow



Application examples focused on power amplifier:

- VISION model with load-pull effects => interaction between RF front-end and Antenna
- VISION model with memory effects => DPD evaluation in simulation

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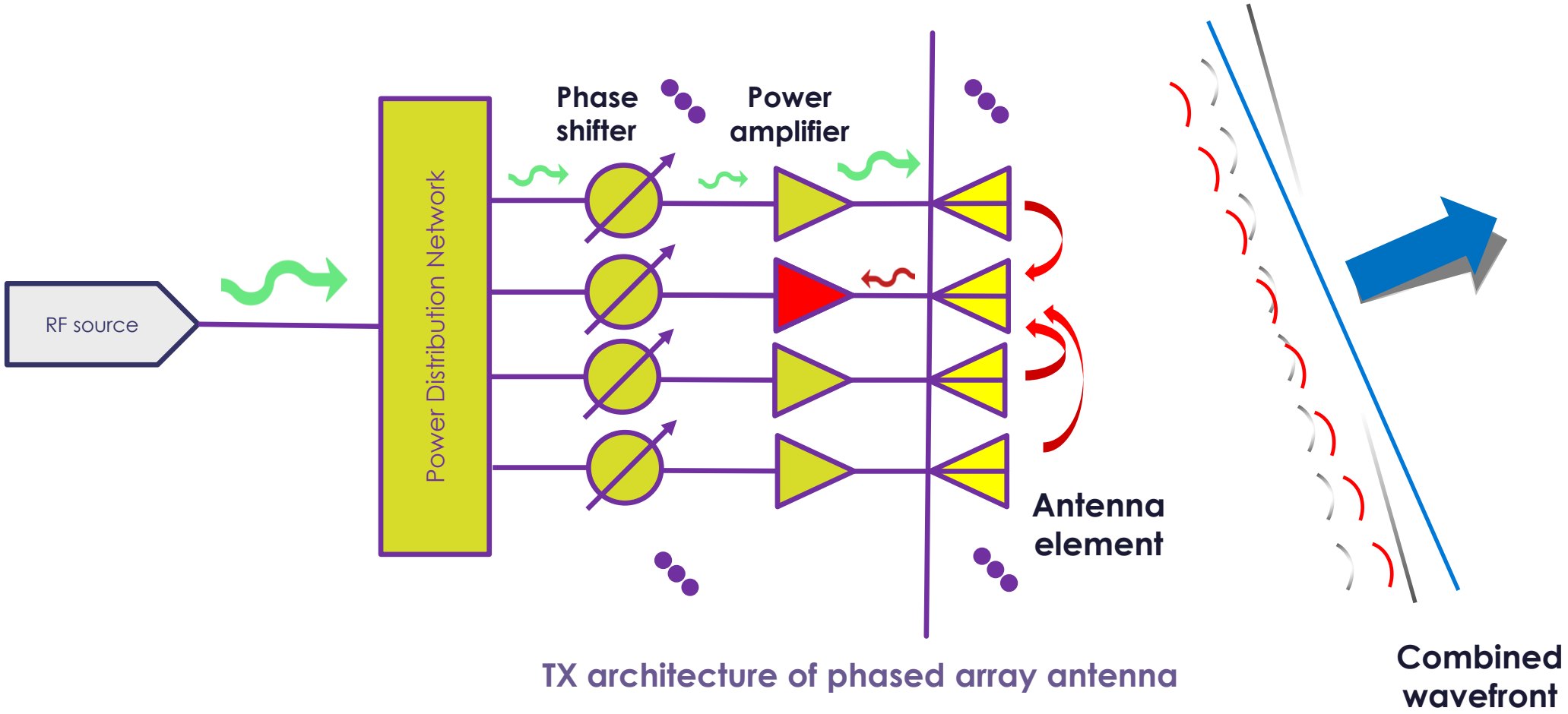
VISION model with load-pull effects

Load pull effect in phased-array antenna systems



TX architecture of phased array antenna

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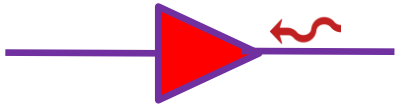
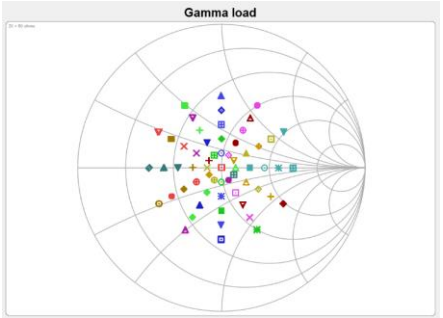
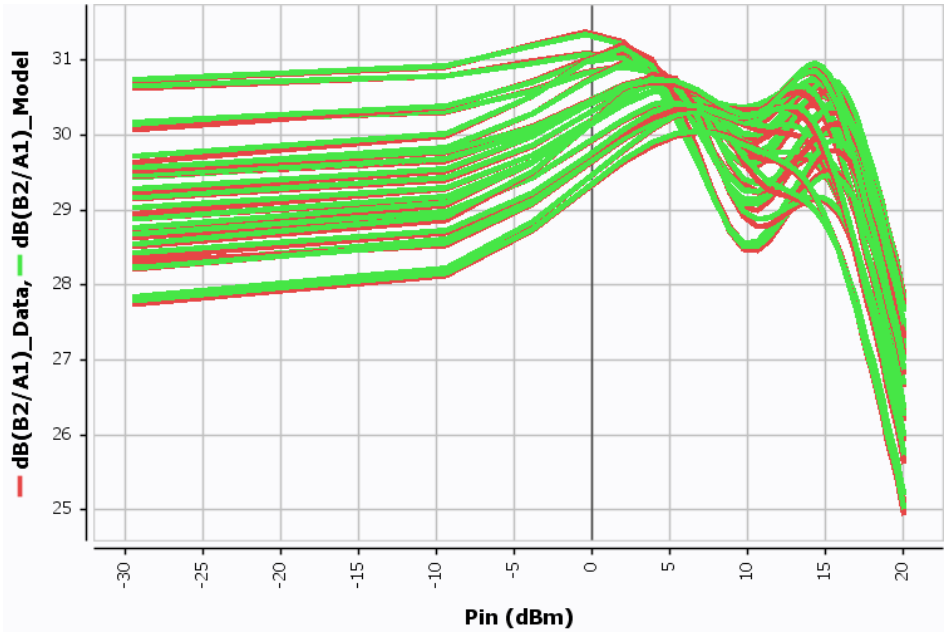
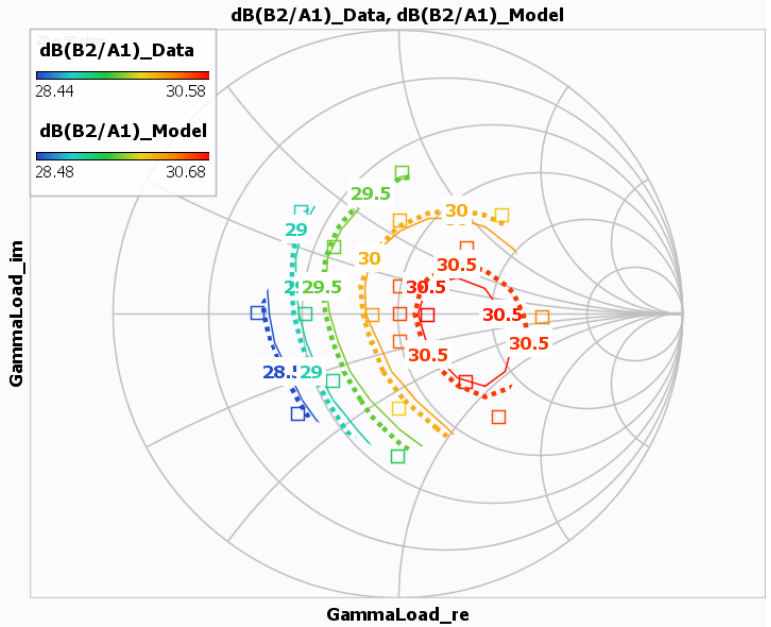
VISION model with load-pull effects





- PA load-pull characterization from measurement or circuit simulation
- Frequency, power and impedance sweep
- Continuous-time model used in in-house envelop transient simulator





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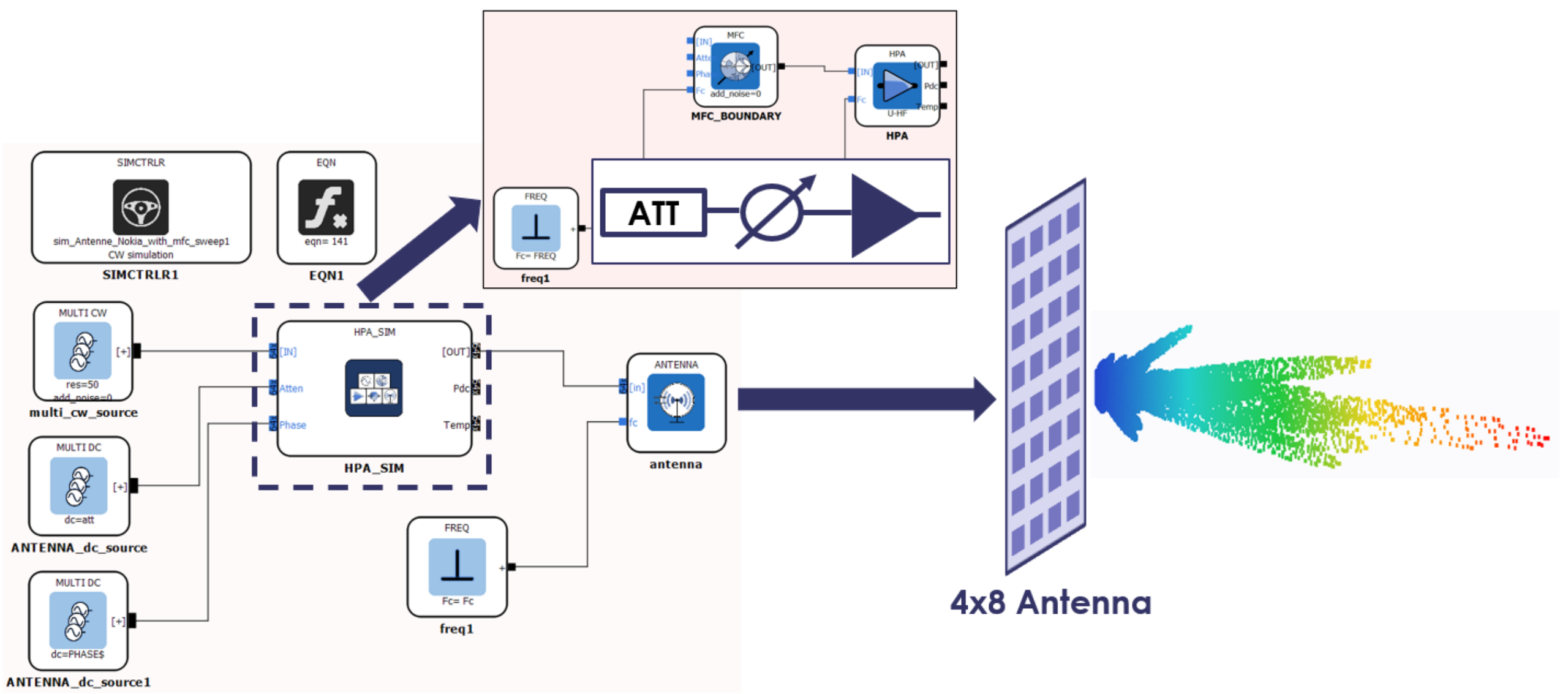
VISION model with load-pull effects



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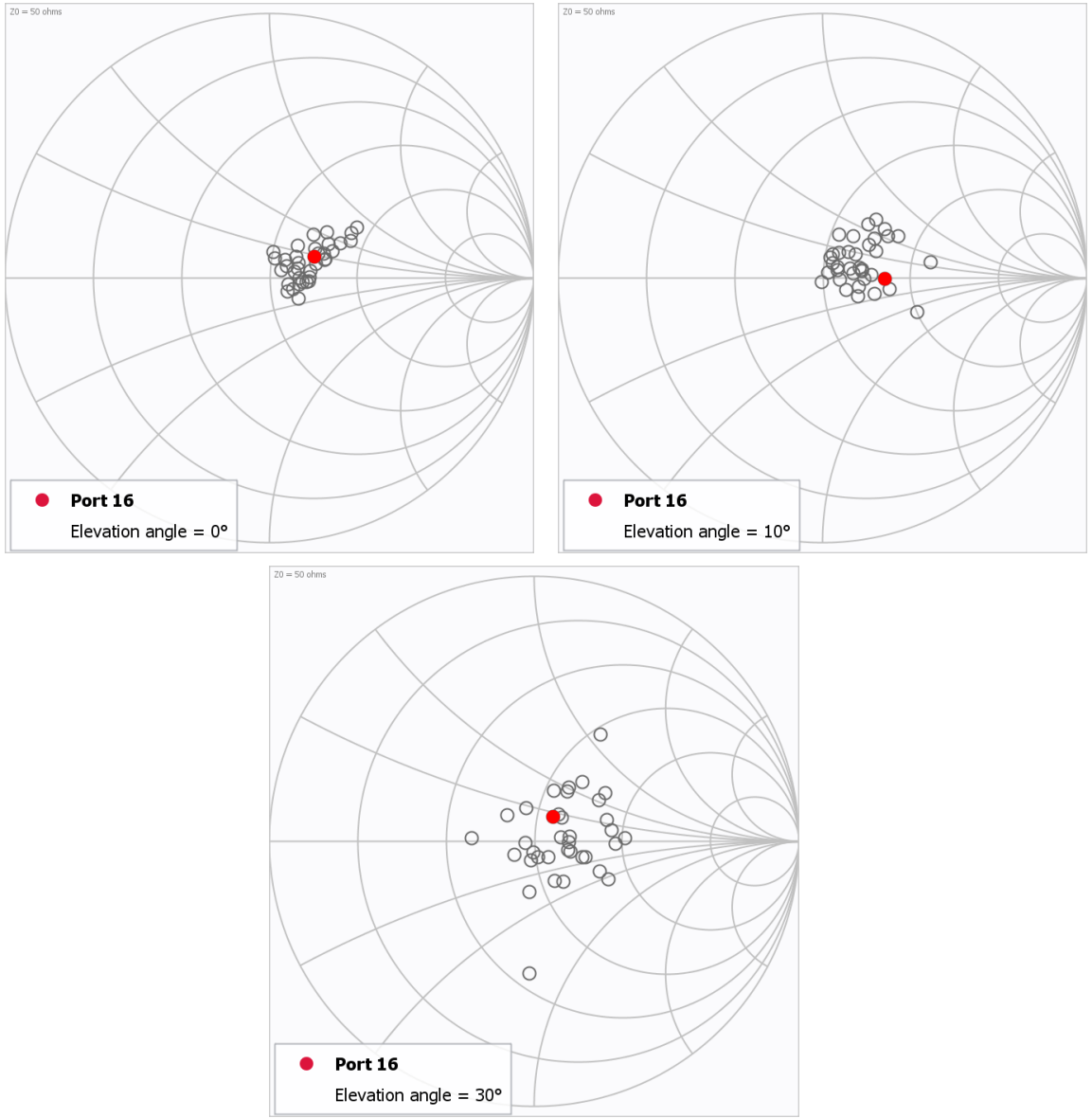
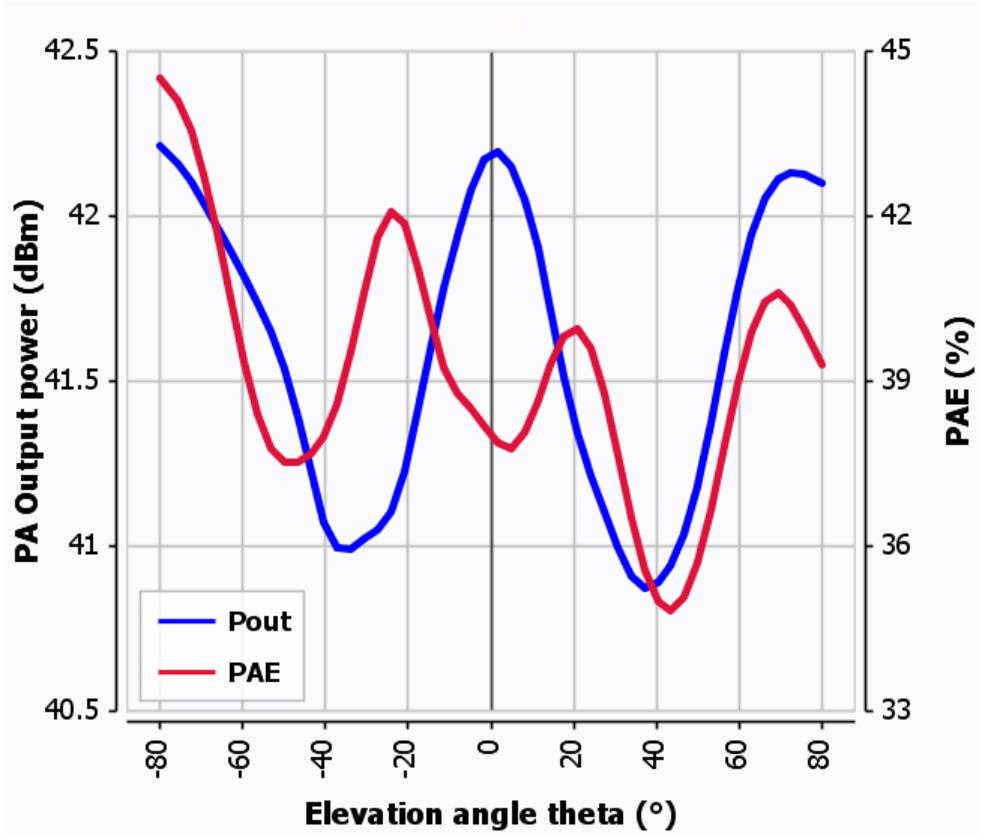
VISION model with load-pull effects





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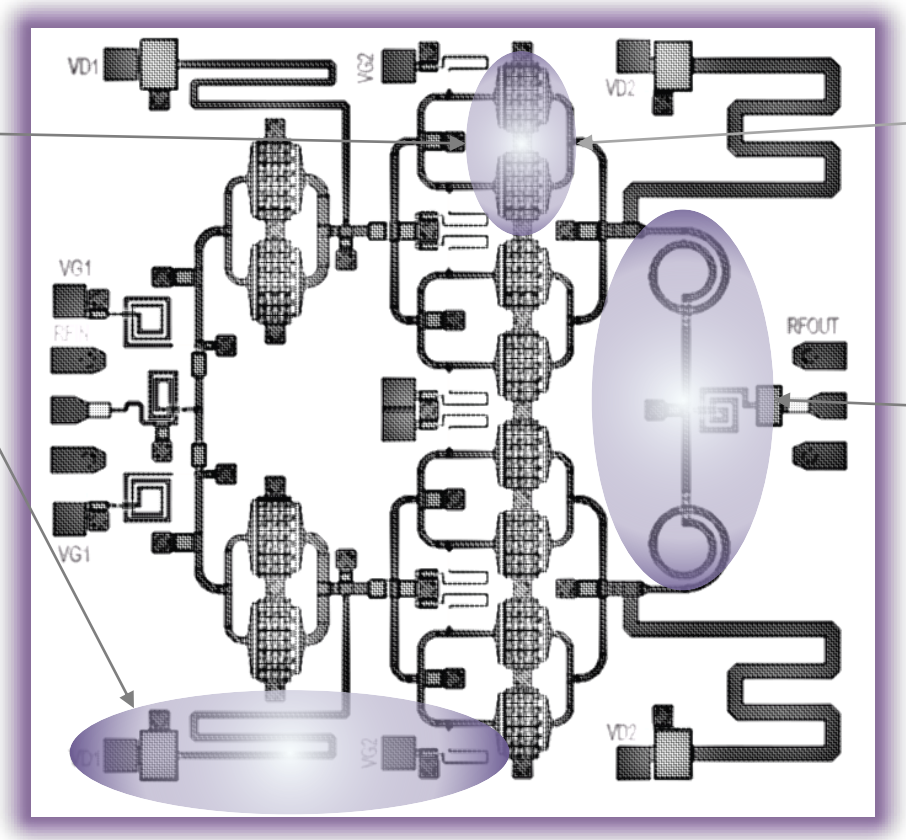
VISION model with memory effects

Self-Heating
Trapping effects
(Transistors)

Biasing Circuits
AGC Loops



Transit-time
(Transistors)

Band-pass, High-pass
Filters
(Matching networks)

Long term memory response
(µs to secs)

Short term memory response
(ns to µs)

Nonlinear coupling

Severely affects wideband modulation signal

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VISION model with memory effects

Behavioral modeling challenge : increase model robustness

- Extract model coefficients once for all (similar to transistor level modeling)
- Guaranty good model accuracy in an extended signal space
  - ✓ **Average signal power variation:** from small signal linear regime to large gain compression
  - ✓ **Signal bandwidth variation:** from KHz to GHz
  - ✓ **Signal time statistics variation:** all communications, single and multi-mode protocols

Model Features	Common models	Desired model
Equation type	Full Black-box	Grey-box (physics based equivalent network)
Memory processing	Mixed long-term and short-term memory contributions	Separated long-term and short-term memory contributions
Identification mode	Discrete- time kernel identification	Continuous-time kernel identification

A candidate model → Non-linear integral Two-Path-Memory model (TPM)

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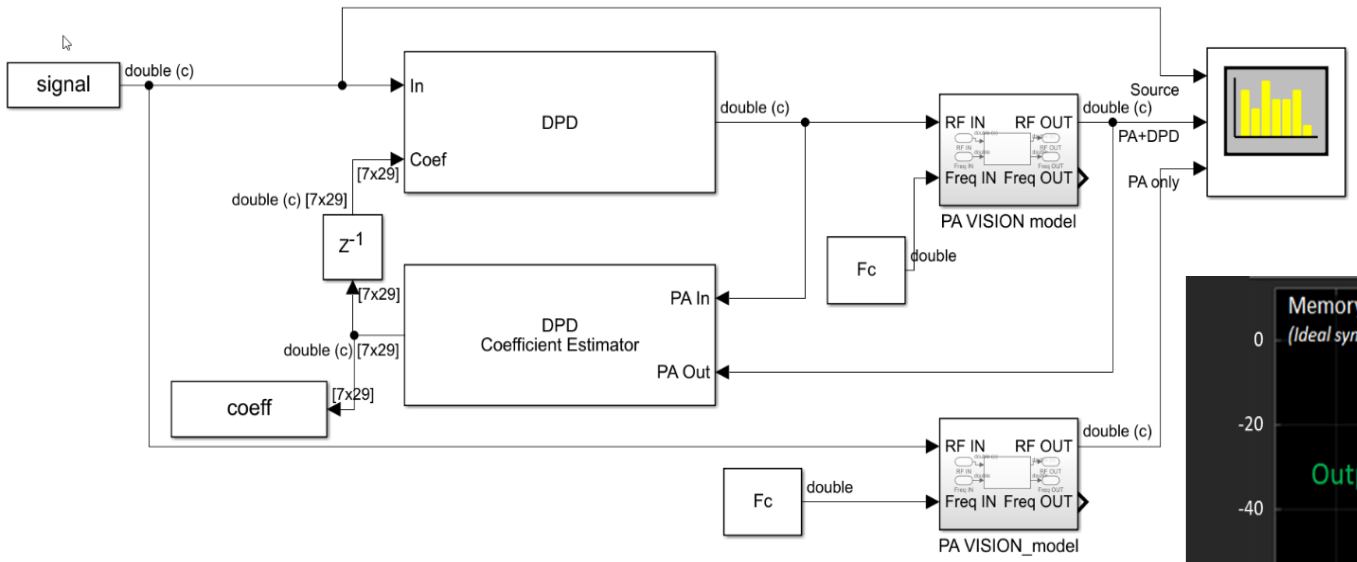
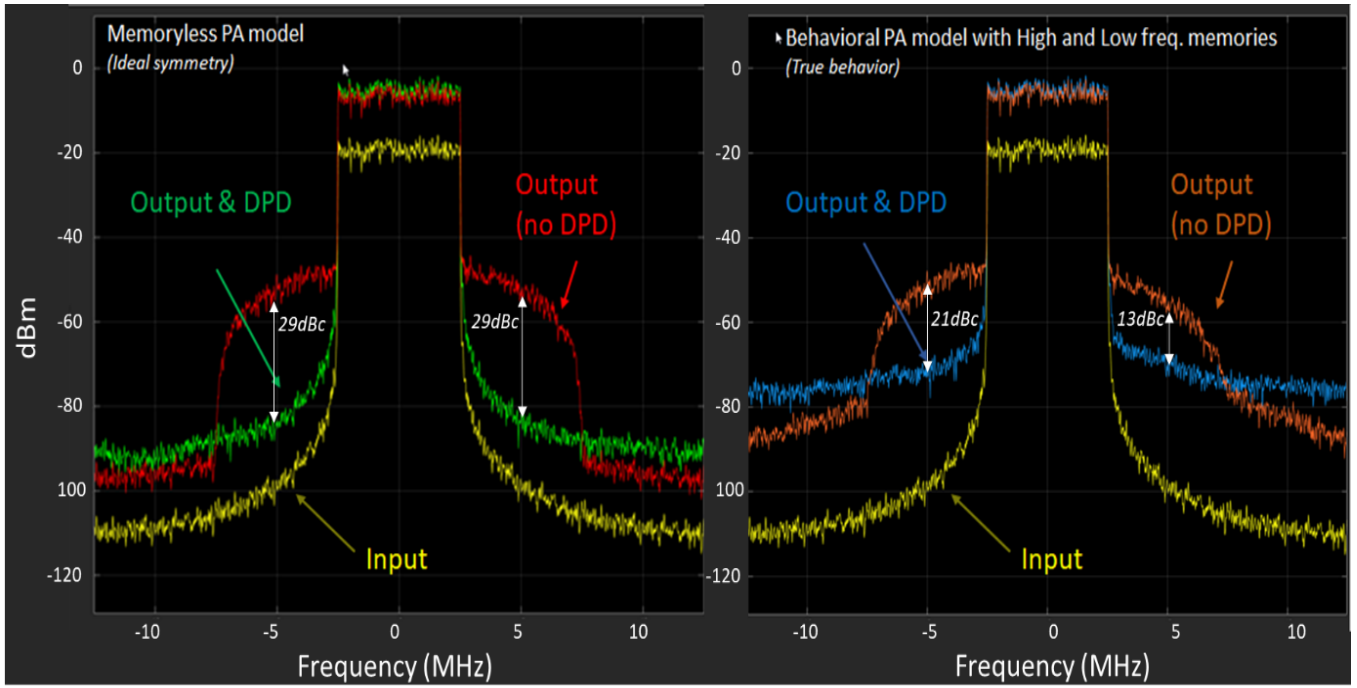
VISION model with memory effects

DPD evaluation in dataflow simulator





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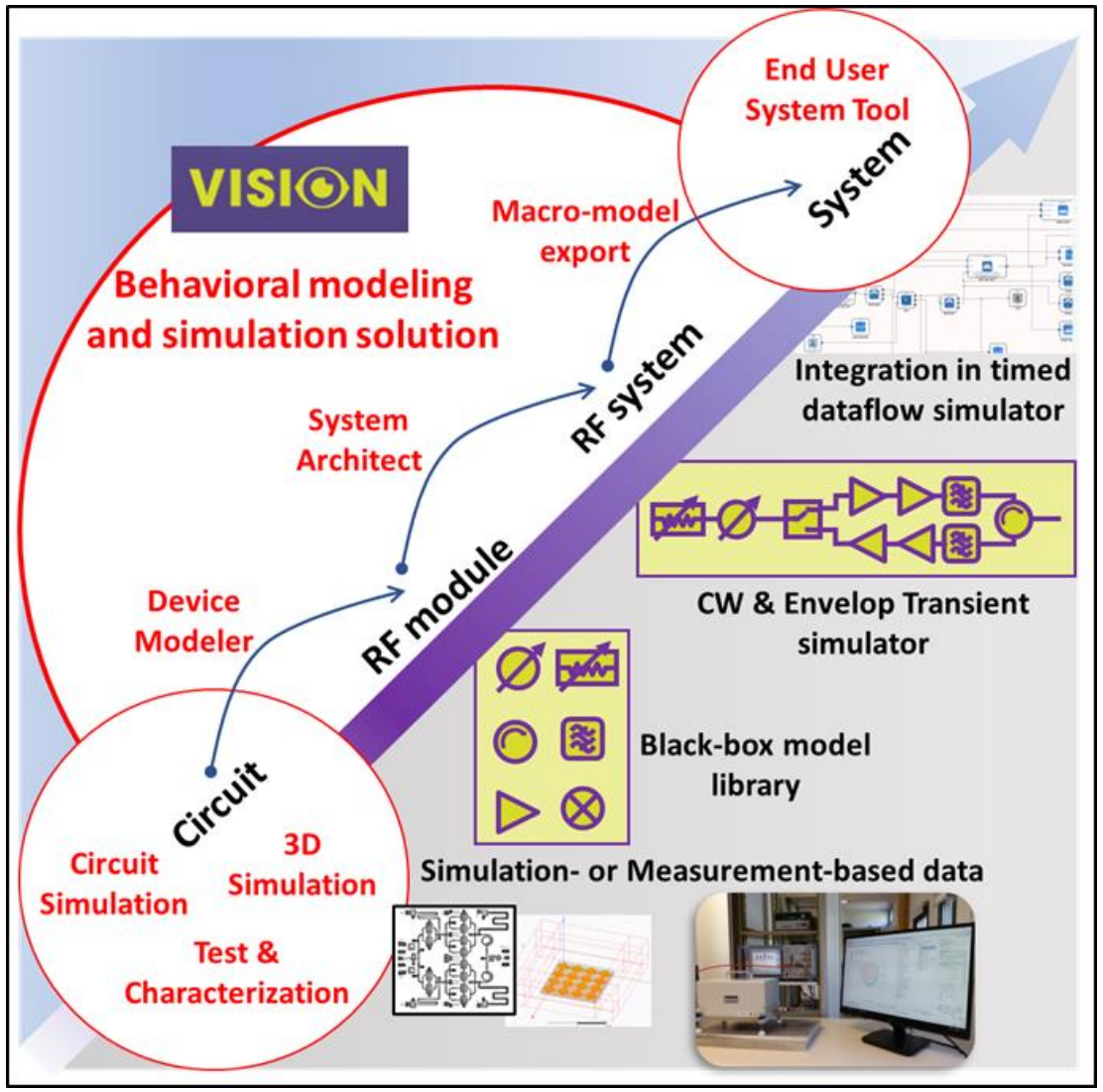
Conclusion



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