

# **SIMULIM Platform**

Simulation, Integration, Modelling at the University of LIMoges

## **System Simulation Integration and Modeling**

S. Mons, A. Beaumont, E. Ngoya

XLIM – UMR CNRS - Université de Limoges, 123  
av. A. Thomas, 87060 Limoges, France

## **Xlim lab**

## **Context - Problematic of RF Frontend simulation**

## **SIMULIM Platform (Xlim lab**

## **SCERNE tool**

Simulation Concept Simulim

Basic functionalities

Architecture

## **VISION tool (Amcad engineering)**

## **Conclusion**

## 6 Research Departments

### 2 Platforms for Optical and Microwave

- Technology & Instrumentation (PLATINOM)
- Modeling & Simulation (SIMULIM)

### 5 Cross-MultiDisciplinary Programs

### 1 Emerging Team

### 4 joints laboratories

- MITTIC (3-5 Lab), AXIS (Thales Alenia Space)
- NXL (NXP), LEV3E (CEA Gramat)

XLIM : Unit created in january 2006

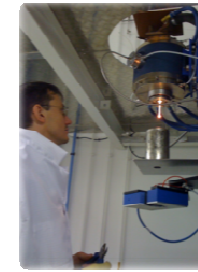
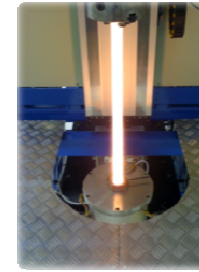


### Since 2004

14 start-ups created

### Since 2009:

scientific production per year  $\approx$  500  
PhD students per year  $\approx$  45



## The strengths of XLIM

Electronics & High Frequency  
Components to sub-systems

Optics  
Photonics

Mathematics  
Computer science  
Image

## Challenges

Communication: Civil, space, military

Autonomous Communicating objects

Secured environments

Bioengineering  
&  
Health

Build a world renowned expertise on numerical techniques for analog and high frequency system modeling

- Mathematical modeling (optimization and nonsmooth analysis)
- Electromagnetic simulation methods (antenna, packages, filters, IC, EMC, ..)
- Multiphysics simulation methodologies for (nanodevices, MEMS, packaging, ..)
- RF Circuit simulation method (Spice, harmonic balance, envelope transient, ..)

Develop top-down design and bottom-up hierarchical behavioral modeling techniques, methodologies and tools for complex systems

Provide internal and external support on simulation and modeling for the optimal design of RF and electro-optical devices and systems

**SIMULIM = Modeling software forge + Modeling tool**

### Inventory, archiving, diffusion and value-adding on calculation codes

<https://forge.xlim.fr/>

it gathers services enabling ones to collaboratively develop informatic projects, with many tools which make it easier to manage projects and improve their visibility.

#### Aims :

- make durable the projects in XLIM and beyond.
- fight again the obsolescence (backup, maintenance, documentation ...)

#### Available tools:

Attached documents (texts, multimedia files ...);

Surveys on the orientations of projects;

Diffusion announces;

A source-code manager (git, mercurial or svn);

A page for downloads (precompiled binaires, etc) ;

A Wiki-style collaborative documentation manager (Mediawiki).

An introduction page;

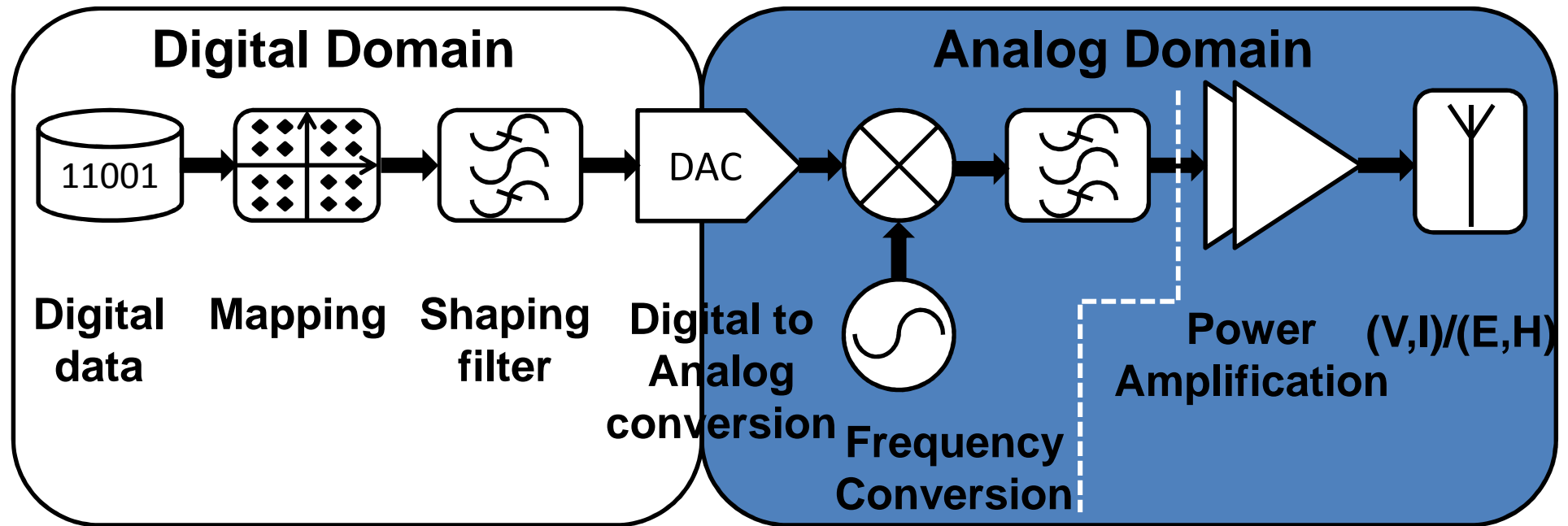
A page displaying activity statistics;

General and thematic forums;

A bug manager; Roadmaps and task-lists; Mailing lists;

# Context

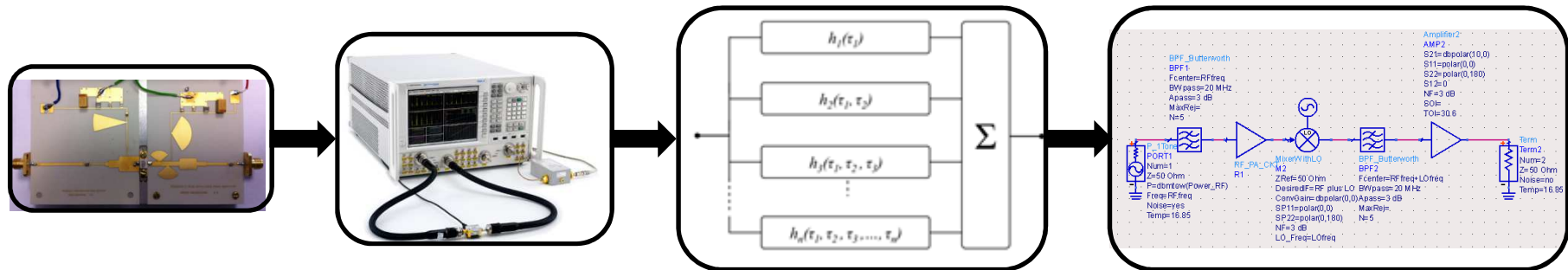
## Schematic block diagram of a transmitter



## Power Amplifier

- Critical element of the transmitter linearity and consumption budgets

## Modeling flow



### Power Amplifier Characterization Module

- Standard
  - Power
  - Bandwidth...
- ### Equipment
- Time domain
  - Frequency domain
  - Bandwidth
  - Cost...

### Power Amplifier Models

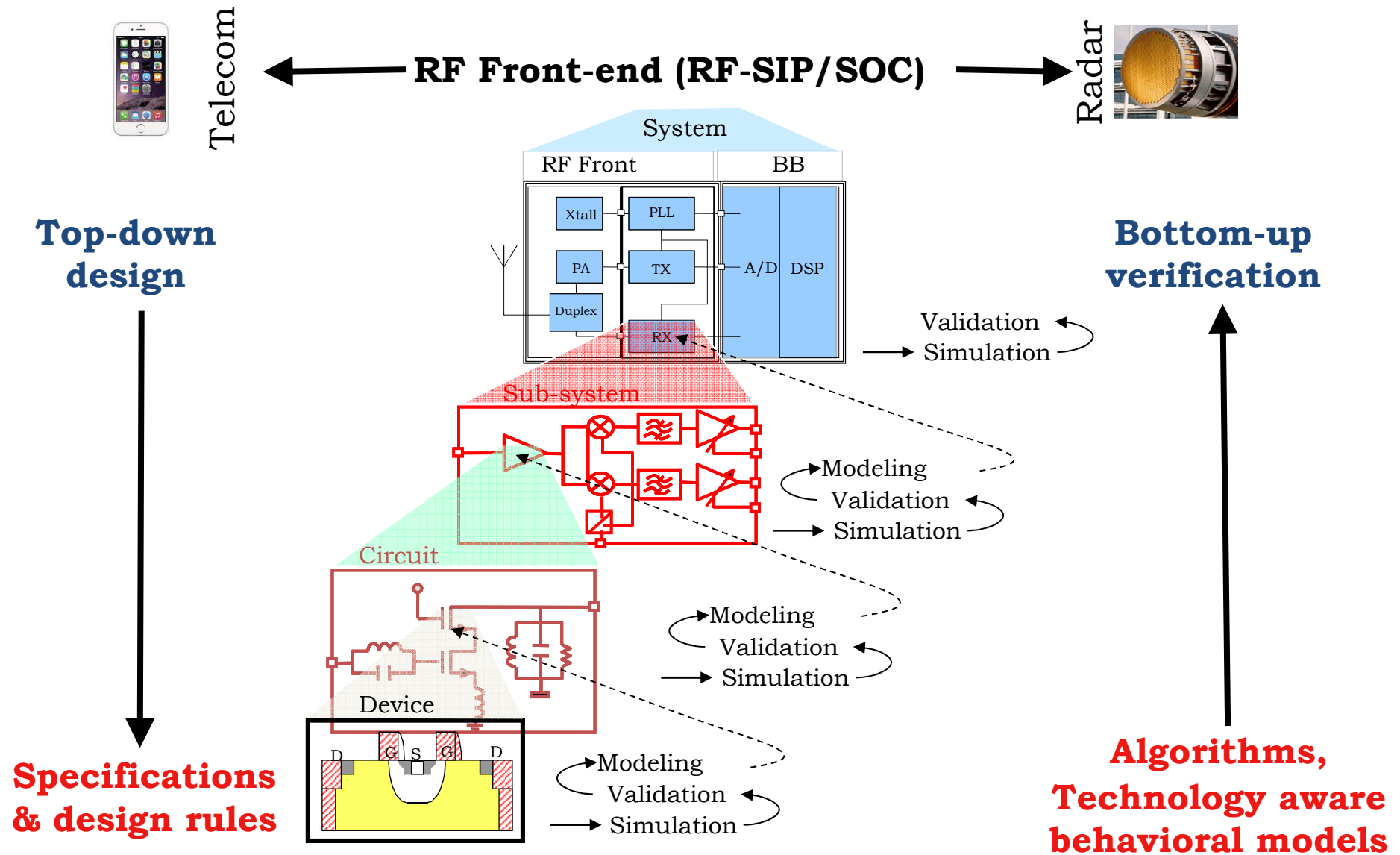
- PHD
- TDNN
- Volterra models...

### System Simulation & Design

- Behavioral model integration
- Validation process...

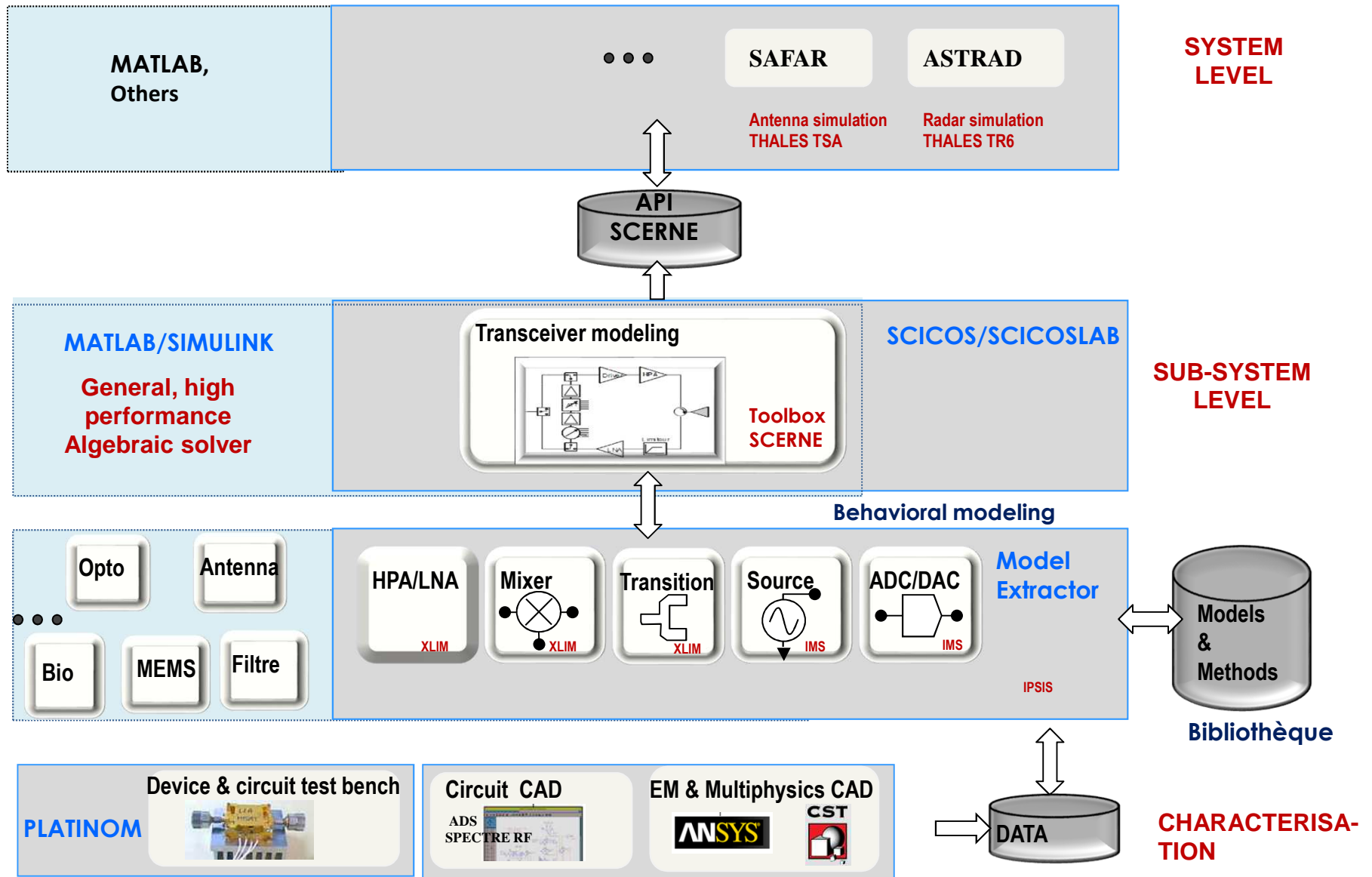


# The hierarchical behavioral modeling concept

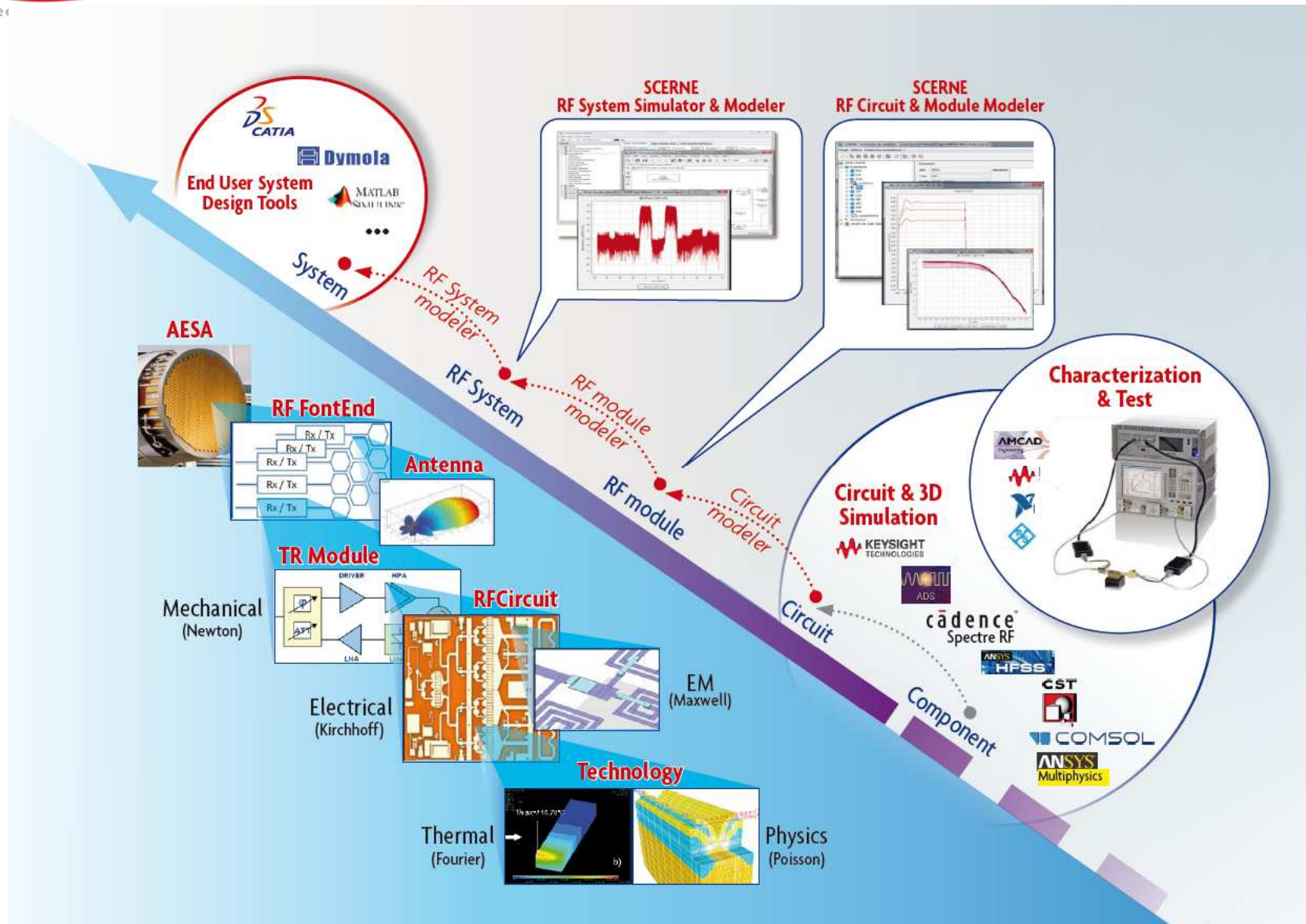


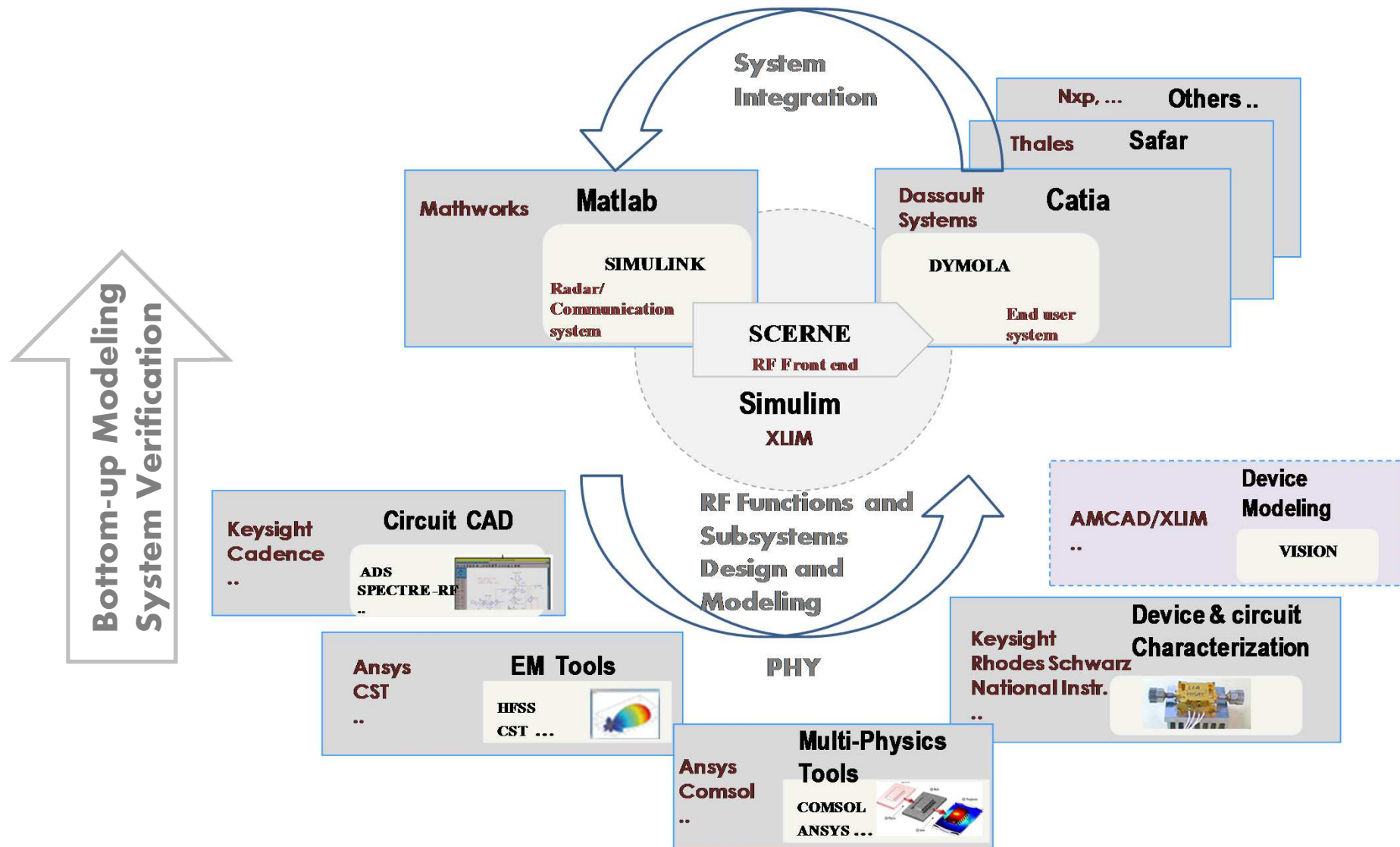
# SCERNE Tool Evolution : Fin PEA-DGA/2013 → 2015

Extension – Generalization – Openness



## (2) Simulim Platform





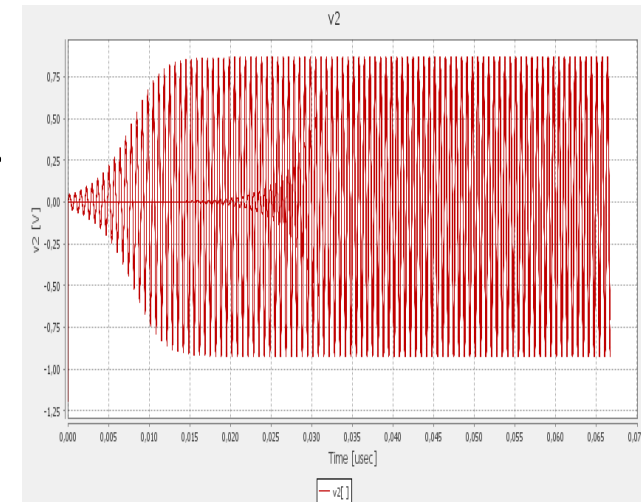
# Scerne tool

$$x(t) = \text{Re}\{\hat{X}(t) e^{j2\pi \int_0^t F_x(t) dt}\}$$

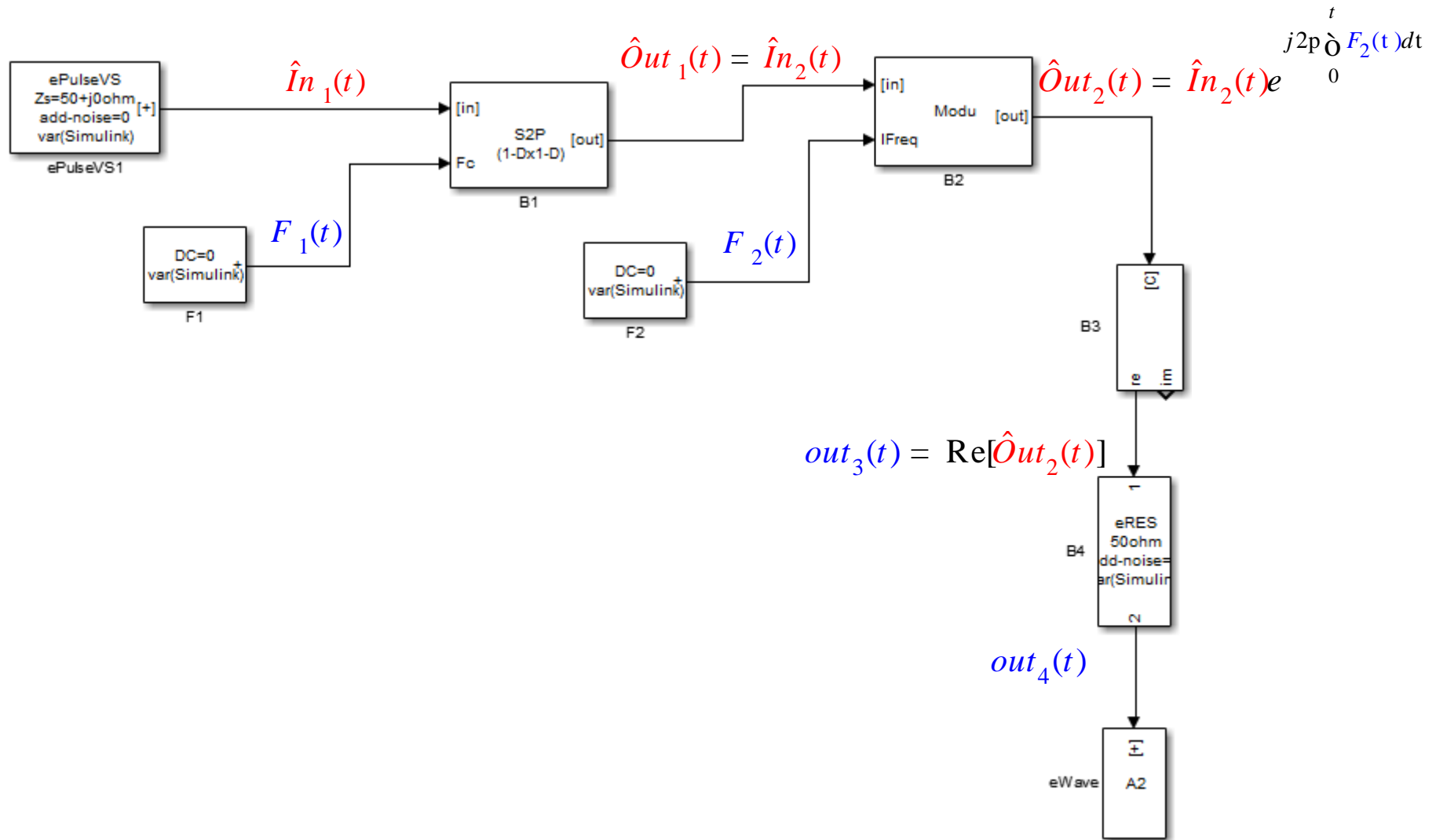
Real Signal

Complex Envelope  
=  
I-Q Modulation

Carrier frequency



Scerne Allows to combine and handle explicitly  $x(t)$ ,  $\hat{X}(t)$  and  $F_x(t)$  within the same simulation, which offers flexibility and efficiency analysis



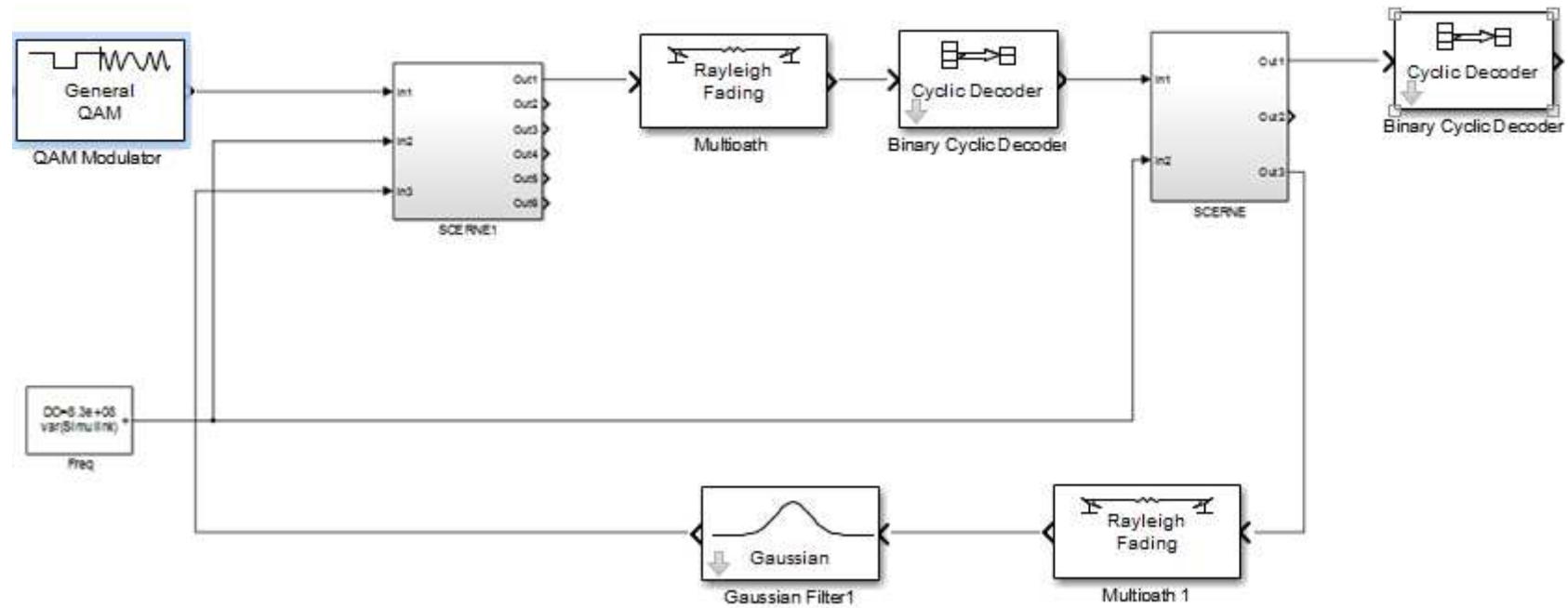
Scerne allows to deal with the concept of impedance  
(current voltage duality)

→ “Circuit” or Algebraic simulation

Scerne can be fitted into the conventional data-flow  
simulation of SIMULINK

In this flow, SCERNE allows the implementation of  
“islands” in which the concept of impedance can be  
taken into account (DAE simulation)





Scerne implements powerful modeling concepts and a toolbox that allows an effective bottom-up modeling

Scerne integrates an efficient DAE solver, allowing the the system simulation of several thousand fonctions.

Scerne offers a large palette of behavioral models with highly effective processes ( ie. multidimensional interpolation functions), particularly useful for behavioral modeling.

Models present today were developed on the basis of radio frequency electronic functions ... but the principles are general and could also be applied to other physicals , including thermal and mechanical, MEMS , optics, enclosures , cooling ...

Scerne gives the opportunity to develop compiled models (C, C ++). Programming templates are available with a Visual Studio project to develop and integrate the DLL model .

There is still “infrastructure” work to do in achieving a professional quality.

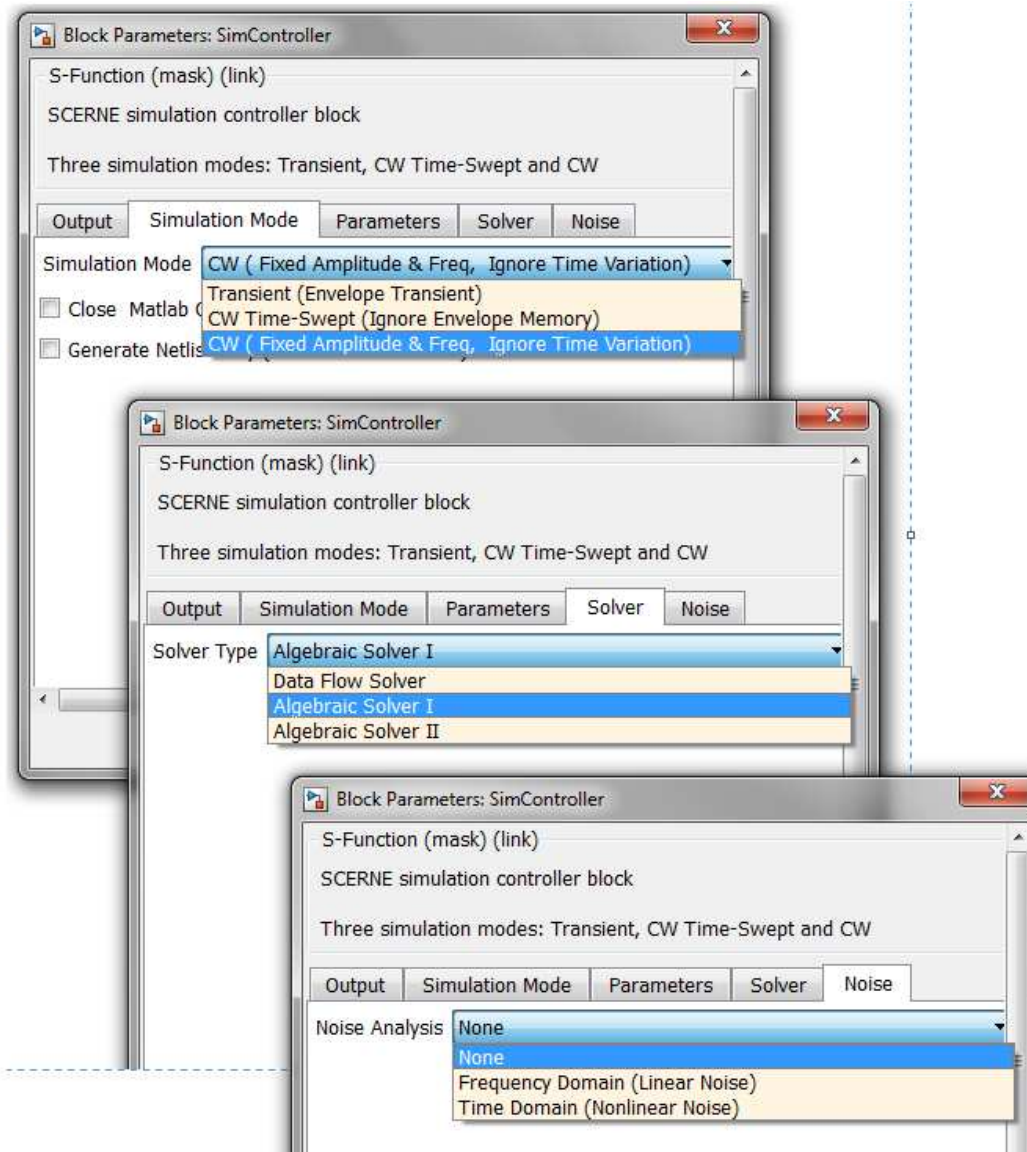
Scerne today offers only a summary documentation  
The help of potential users will be appreciated to enrich this documentation !

We have a RAPID ongoing project in collaboration with AMCAD company that will provide professional graphics solution treatment in one or two years .

RAPID-DGA “VISION” (AMCAD ENGINEERING / XLIM)

# Basic fonctionnalités

SCERNE  
Algebraic Solver I  
CW Time-Swept  
Result=twoport\_pade\_sweep22  
SimController



# Design Controller (Nomin, sweep, statis, optim)

Parameter definition and optimization specification may be entered using external file edition.  
Use `setenv('SCERNE_TEXT_EDITOR','myEditor')` in matlab command window to specify the desired editor. The default editor is Notepad++.

Type: Performances Design Parameters Optim Specs Result Print Netlist

Analysis Type: Nominal Analysis

Switch On/Off: Sweep Analysis, Statistical Analysis, Optimization

Complex Type Performances: Number  
2

Complex Type Performances: Names List  
GAIN, ROS

Real Type Performances: Number  
1

Real Type Performances: Names List  
PadEff

Time-Average Type Performances: Number  
1

Time-Average Type Performances: Names List  
ACPR

Type: Performances Design Parameters Optim Specs Result Print Netlist

Design Parameters Number  
10

Parameter Definition Mode: Direct Form Fill

Design Parameter 1 ( name [unit] = nominal value , range or list )  
Alpha[]=1.0, range (1.0, 4.0, 4), dispersion(uniform, 0.2)

Design Parameter 2 ( name [unit] = nominal value , range or list )  
Beta[]=2.0, range (1, 2.0, 3), dispersion(uniform, 0.2)

Design Parameter 3 ( name [unit] = nominal value , range or list )  
bandwidth [G] = 1 range\_log(0.01, 10, 10)

Design Parameter 4 ( name [unit] = nominal value , range or list )  
gama [f] = 10.

Design Parameter 5 ( name [unit] = nominal value , range or list )

Type: Performances Design Parameters Optim Specs Result Print Netlist

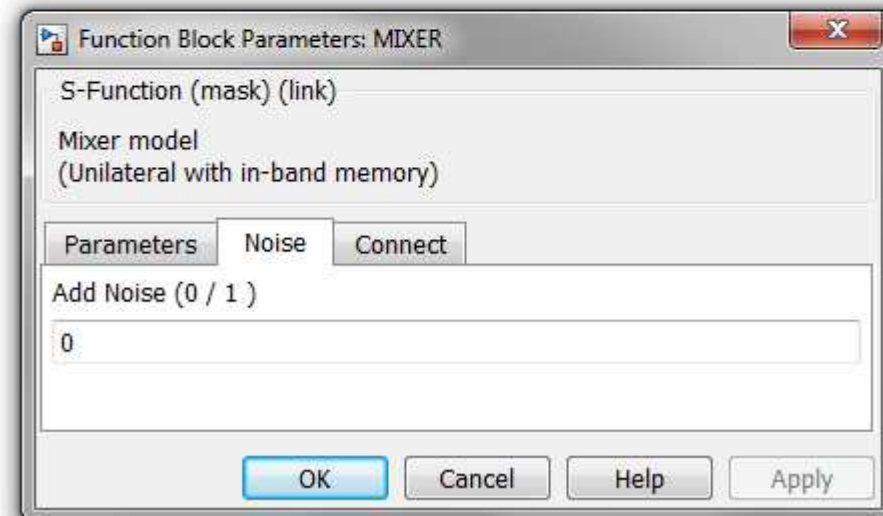
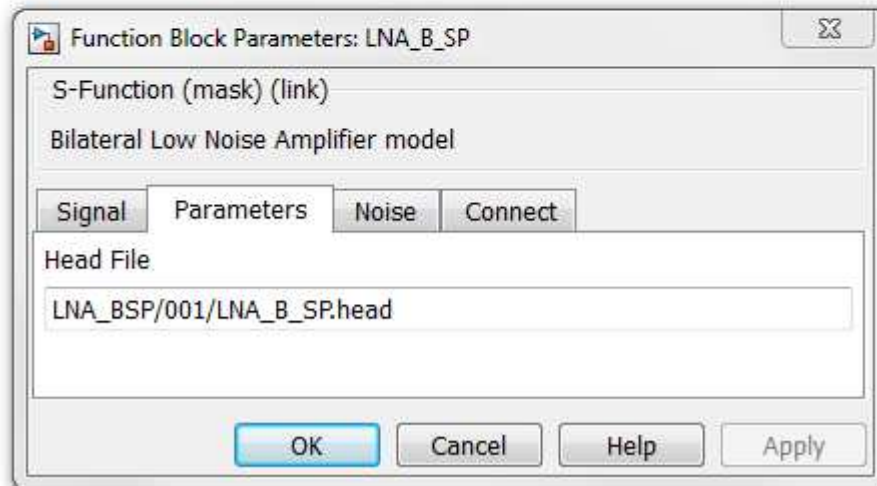
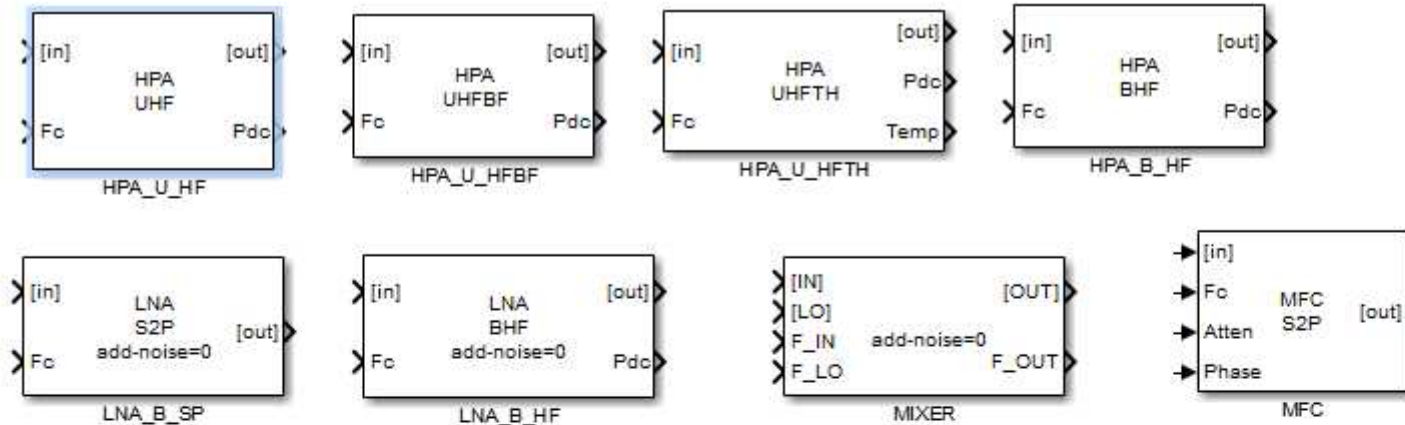
Optimization Objective Definition File

☐ Edit Objective Definition File

OK Cancel Help Apply

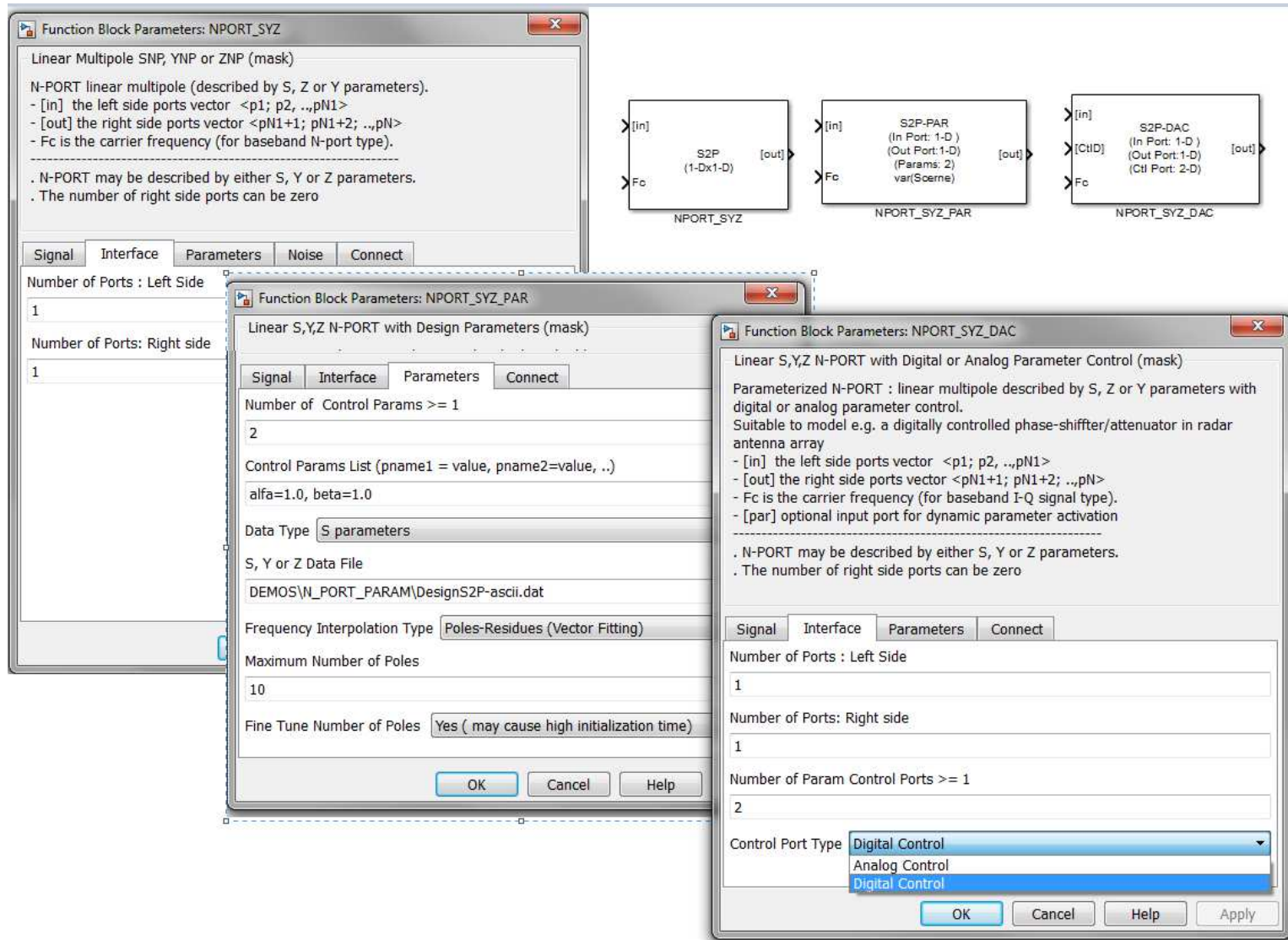
SCERNE  
Design Specs  
cmplx Perfs: 1  
real Perfs: 1  
avrg Perfs: 1  
Statistical Analysis  
Params: 10  
DesignController

# Basic nonlinear models (Volterra)





# Linear Multipole (SNP, YNP, ZNP)



The image shows three overlapping dialog boxes for configuring linear multipole blocks in a Simulink model. The background shows a block diagram with three blocks: NPORT\_SYZ, NPORT\_SYZ\_PAR, and NPORT\_SYZ\_DAC.

**Function Block Parameters: NPORT\_SYZ**

- Linear Multipole SNP, YNP or ZNP (mask)
- N-PORT linear multipole (described by S, Z or Y parameters).
  - [in] the left side ports vector <p1; p2, ..,pN1>
  - [out] the right side ports vector <pN1+1; pN1+2; ..,pN>
  - Fc is the carrier frequency (for baseband N-port type).
- N-PORT may be described by either S, Y or Z parameters.
- The number of right side ports can be zero

Number of Ports : Left Side: 1  
Number of Ports: Right side: 1

**Function Block Parameters: NPORT\_SYZ\_PAR**

- Linear S,Y,Z N-PORT with Design Parameters (mask)
- Number of Control Params >= 1: 2
- Control Params List (pname1 = value, pname2=value, ..): alfa=1.0, beta=1.0
- Data Type: S parameters
- S, Y or Z Data File: DEMOS\N\_PORT\_PARAM\DesignS2P-ascii.dat
- Frequency Interpolation Type: Poles-Residues (Vector Fitting)
- Maximum Number of Poles: 10
- Fine Tune Number of Poles: Yes ( may cause high initialization time)

**Function Block Parameters: NPORT\_SYZ\_DAC**

- Linear S,Y,Z N-PORT with Digital or Analog Parameter Control (mask)
- Parameterized N-PORT : linear multipole described by S, Z or Y parameters with digital or analog parameter control.
- Suitable to model e.g. a digitally controlled phase-shifter/attenuator in radar antenna array
- [in] the left side ports vector <p1; p2, ..,pN1>
- [out] the right side ports vector <pN1+1; pN1+2; ..,pN>
- Fc is the carrier frequency (for baseband I-Q signal type).
- [par] optional input port for dynamic parameter activation
- N-PORT may be described by either S, Y or Z parameters.
- The number of right side ports can be zero

Number of Ports : Left Side: 1  
Number of Ports: Right side: 1  
Number of Param Control Ports >= 1: 2  
Control Port Type: Digital Control

# Polynomial Filter (S, Z, Y)



Function Block Parameters: POLY\_FILTER

Linear Reciprocal and Symmetrical 2-PORT Filter described by Polynomial (mask) (link)

2-PORT linear multipole (described by S, Z or Y parameters polynomial)

$s_{11} = s_{22} = r(w)/q(w)$   
 $s_{12} = s_{21} = p(w)/q(w)$   
 - Fc is the carrier frequency (for baseband I-Q signal type).

-----

Make sure polynomial coefficients are entered in increasing rank order, starting 0, 1, ..,  
 e.g. q0=1.0, q1=2.0, q2=2.0, q3=1.0  
 r0=0.0, r1=0.0, r2=0.0, r3=0.0  
 p0=1.0, p1=0.0, p2=0.0, p3=0.0

Coefficient value can be a variable expression, e.g. p1=1.0[ A\*B ], where A and B are SCERNE variables

Signal Parameters Connect

Bandwidth Min Frequency (Hz)  
 1e6

Bandwidth Max Frequency (Hz)  
 1e9

Model Polynomial Order  
 3

Normalization Frequency of Polynomial Coeffs (Hz)  
 1e8

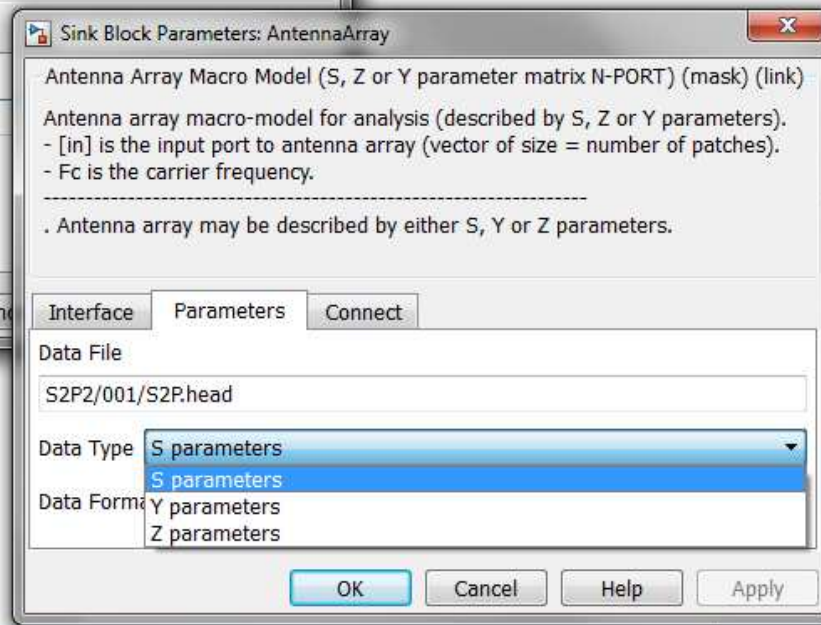
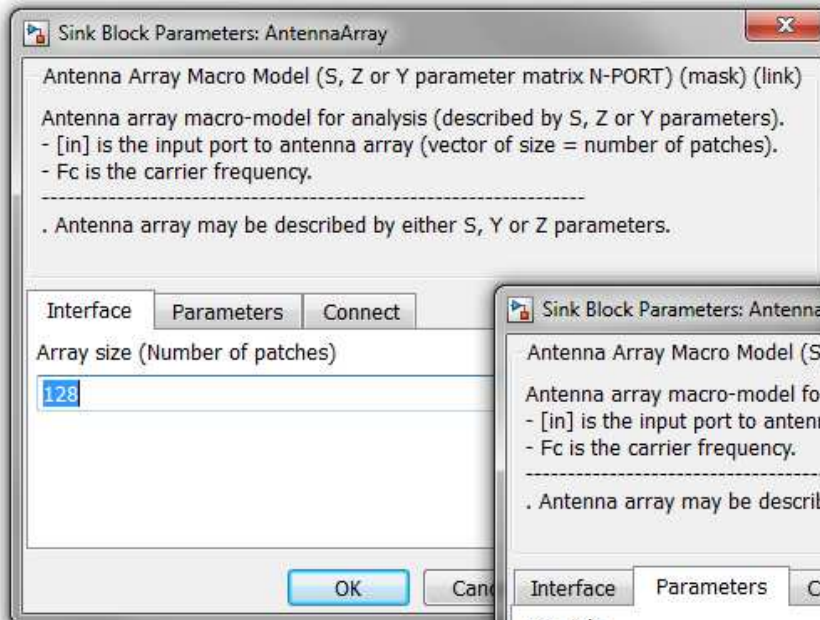
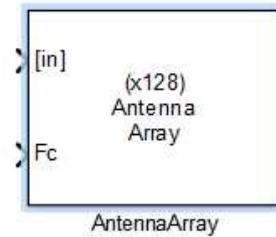
Demoninator Poly Coeff List - normalized (q0 = value, q1=value, ..)  
 q0=1.0, q1=2.0[Beta], q2=2.0, q3=1.0

Numerator Poly Coeff List for S11, S22 - normalized ( r0 = value, r1=value, ..)  
 r0=0, r1=0, r2=0, r3=0

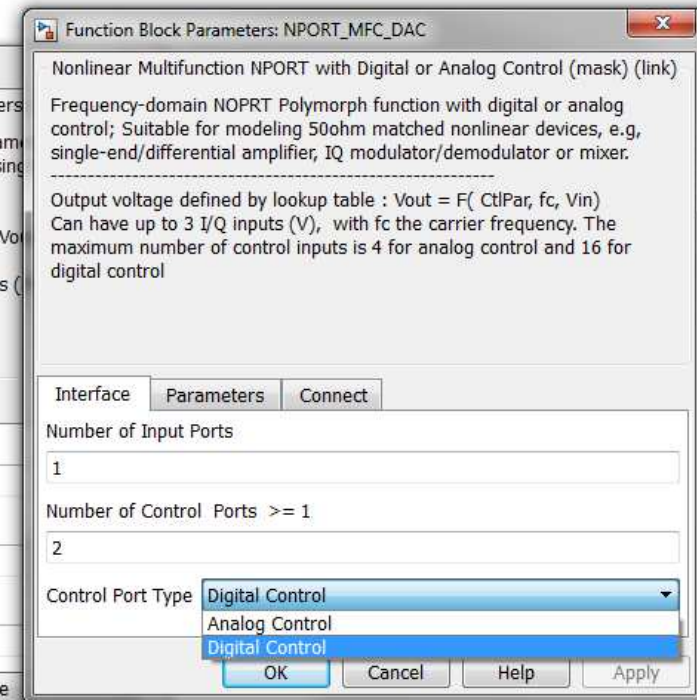
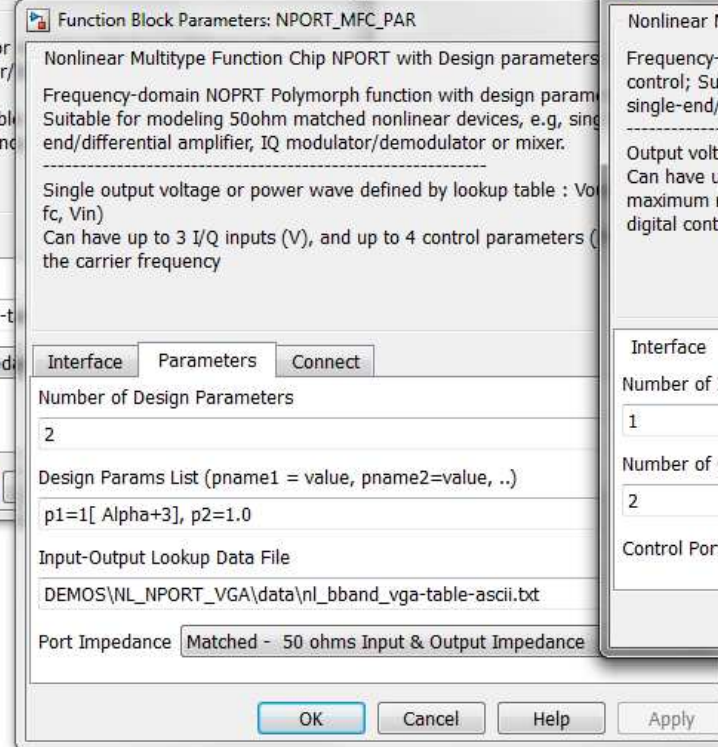
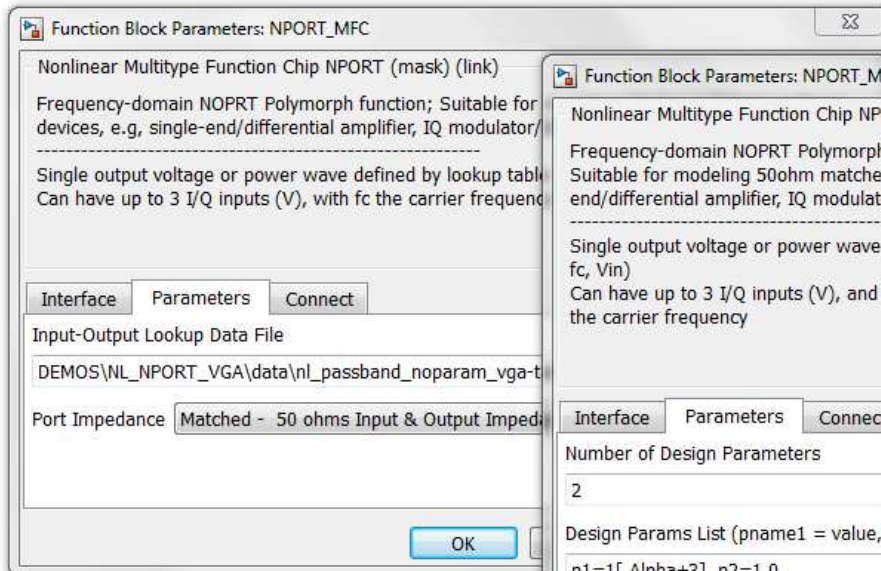
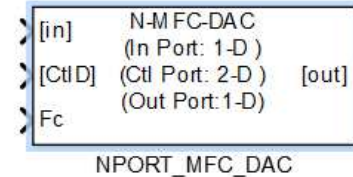
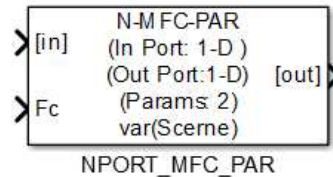
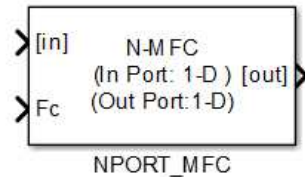
Numerator Poly Coeff List for S12, S21 - normalized ( p0 = value, p1=value, ..)  
 p0=1[2\*Alpha], p1=0, p2=0, p3=0

OK Cancel Help Apply

# Antenna Array Model (S, Z, Y)

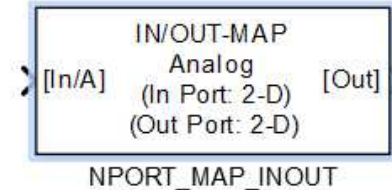
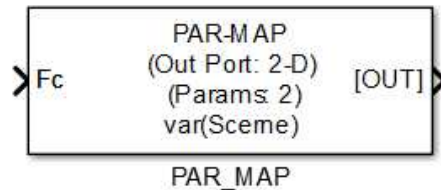


# Nport Nonlinear Generic MFC (HF memory)





# Generic Map Table (EXCEL)



Function Block Parameters: PAR\_MAP

Generic Design Parameters Map table (mask) (link)

Generic map table; suitable for modeling design specifications using lookup table data

Nota:  
The mapping may set a function of frequency

-----

The number of parameter including frequency may not exceed 6.  
The number of output is unlimited  
Parameter value can be a variable expression, e.g. par1=1.0[ A\*B ], where A and B are SCERNE variables

Interface

Number of Outputs  
2

Number of Design Params >= 1  
2

Design Params List (pname1 = value, pname2=value, ..)  
par1=1[2\*Alpha], par2=0[Beta]

☒ Frequency Dependence

Lookup Table Data File  
DEMOS\LUTABLE\LUT-ascii-table.dat

OK Cancel Help Apply

Function Block Parameters: NPORT\_MAP\_INOUT

Generic Input-Output Map table (digital or analog signal converter) (mask) (link)

Generic Lookup table map block; may process input data in two modes: analog or digital

- Analog mode: continuous input signal (maximum number of input = 6)
- Digital mode: discontinuous input signal (maximum number of input = 16)

Nota:  
The input-output mapping may set a function of frequency

Interface

Number of Outputs  
2

Number of Inputs >= 1  
2

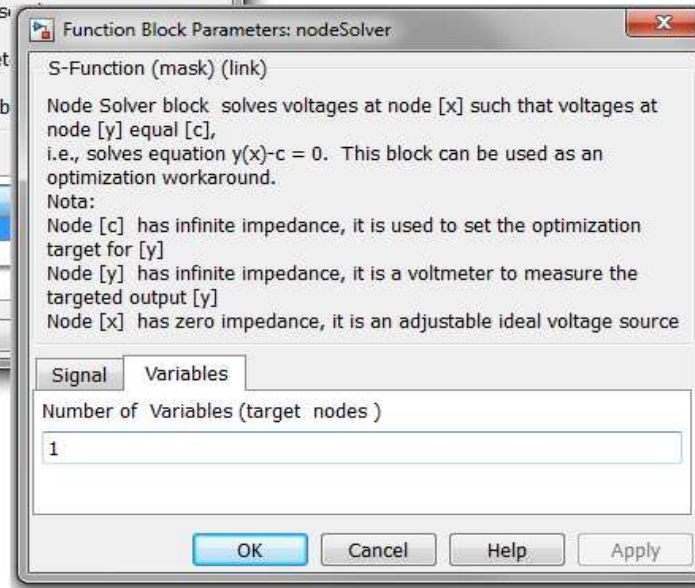
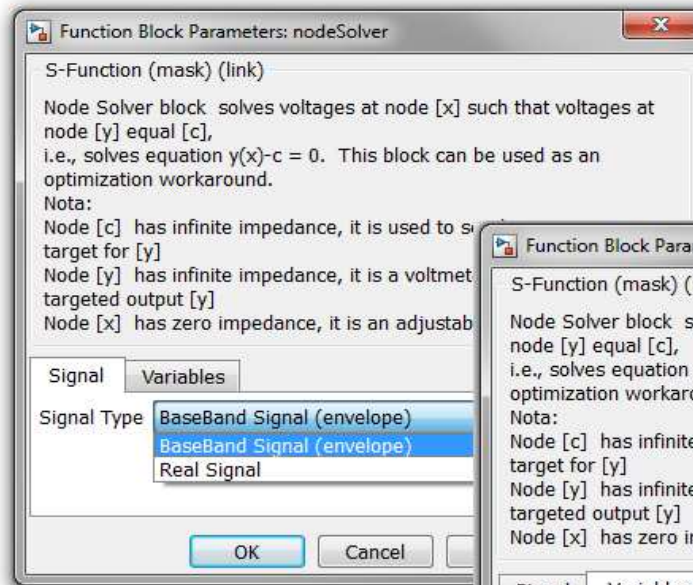
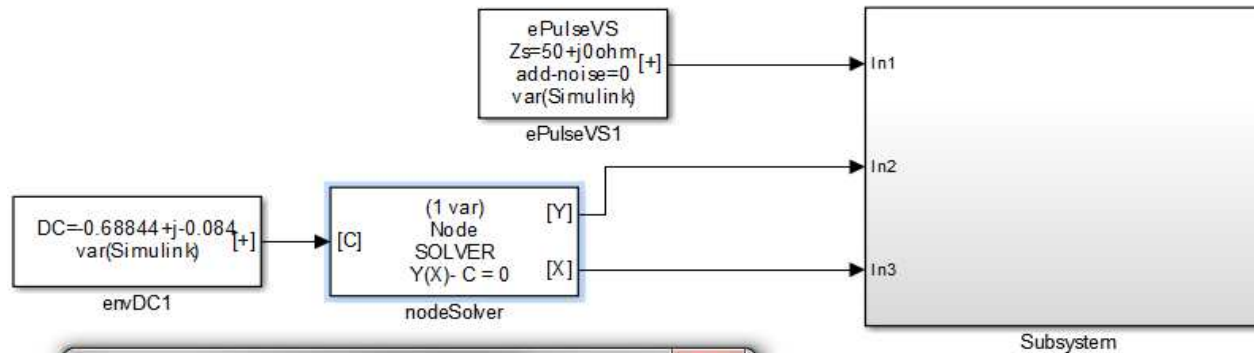
Input Signal Type: Analog (selected), Analog, Digital

☐ Frequency Dependence

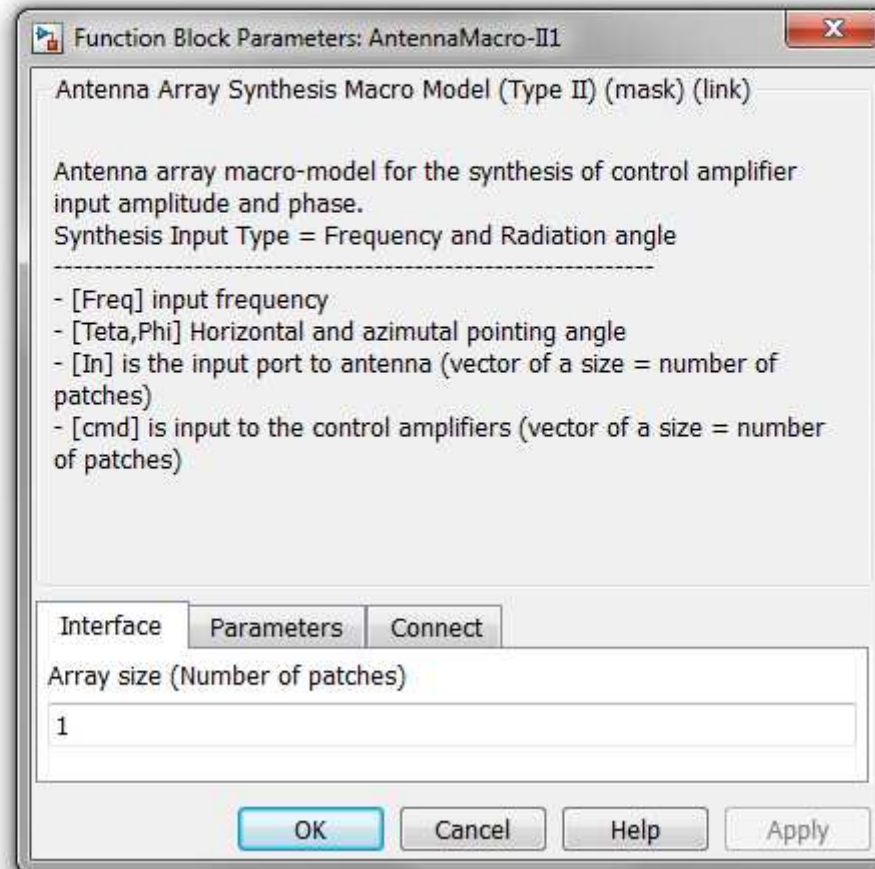
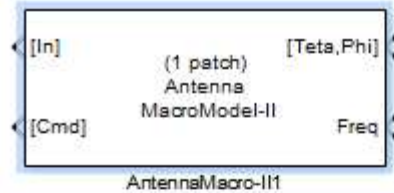
Lookup Table Data File  
DEMOS\LUTABLE\LUT-binary.dat

OK Cancel Help Apply

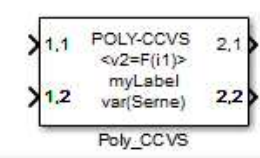
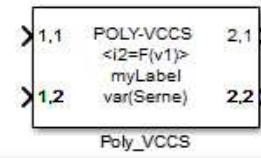
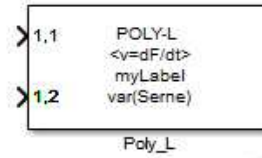
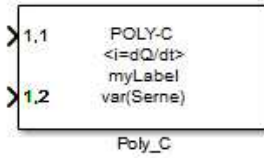
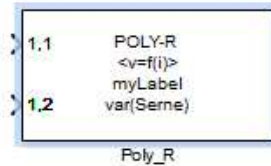
# Node Solver (synthesis)



# Antenna Array Synthesis Macro Model



# Common Components : Res, cap, ind, I(V), Q(V)



Sink Block Parameters: Poly\_R

Polynomial or Piecewise-linear Resistance or Conductance (mask) (link)

2 possible views:

Resistance view: voltage response  
 $v(t) = c_0 + c_1 \cdot i(t) + c_2 \cdot i(t)^2 + c_3 \cdot i(t)^3 + \dots$   
 $v(t) = \text{piece-wise-linear}(i(t))$

Conductance view: current response  
 $i(t) = c_0 + c_1 \cdot v(t) + c_2 \cdot v(t)^2 + c_3 \cdot v(t)^3 + \dots$   
 $i(t) = \text{piece-wise-linear}(v(t))$

Only the non zero polynomial coefficients need be indicated  
 Maximum of order of polynomial is 19.

Interface Parameters Label Connect

Response Type Voltage:  $V(t_n) = f(I(t_n))$

Port Type Two terminal nodes

Expression Type Polynomial  
 Polynomial  
 Piece-wiseLinear

OK Cancel Help Apply

Function Block Parameters: Poly\_VCCS

S-Function (mask) (link)

Polynomial or Piecewise-linear Voltage Controlled Current Source Model

Defined by output current response  
 $i_2(t) = c_0 + c_1 \cdot v_1(t) + c_2 \cdot v_1(t)^2 + c_3 \cdot v_1(t)^3 + \dots$   
 or  
 $i_2(t) = \text{piecewise-linear}(v_1(t))$

Only the non zero polynomial coefficient need be indicated  
 Maximum polynomial order is 19.

Interface Label Connect

Port Type Two terminal nodes

Expression Type Polynomial

Polynomial Coefficients ( non-zeros coeffs only, e.g:  $c_0=1e-6$ ,  $c_1=5$ ,  $c_3=-0.01, \dots$ )

OK Cancel Help Apply



# Nonlinear Nport - AM/PM complex envelope table



Sink Block Parameters: Rdut

Nonlinear Resistance (or Conductance) NPORT (mask) (link)

NPORT model defined by lookup table

2 possible views:

- current response type (resistance) :  $i_p(t) = F(v_1(t), \dots, v_N(t))$ ,  $p = 1, \dots, N$
- voltage response type (conductance):  $v_p(t) = F(i_1(t), \dots, i_N(t))$ ,  $p = 1, \dots, N$

-> Describing function  $F(x_1, \dots, x_N)$  is defined by lookup table

Interface Label Connect

Response Type Voltage:  $V(tn) = f(I(tn))$

Port Type Two terminal nodes

Number of Left Side Ports

1

Number of Right Side Ports

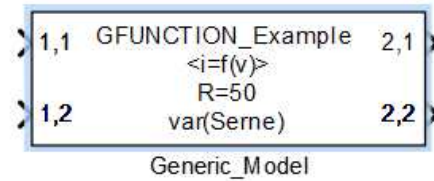
0

Data File

G:\GranBois3\U\Debug\test\CR\Tunnel\data\vo2\_grd11\_I\_nl\_nport\_table.bt

OK Cancel Help Apply

# Generic Nport



Function Block Parameters: Generic\_Model

Dynamic nonlinear model equation

-> can use real or baseband(complex I/Q) input/output signal

For real signal:

- current response type:  $i(t)=f(v(t),dv/dt,...,di/dt,...)$
- voltage response type:  $v(t)=f(i(t),di/dt,...,dv/dt,...)$

For baseband signal:

- current response type:  $I(t)=F(V(t),dV/dt,...,dI/dt,...,Fc(t),dFc/dt,...)$
- voltage response type:  $V(t)=F(I(t),dI/dt,...,dV/dt,...,Fc(t),dFc/dt,...)$

FC(t) is the carrier time varying carrier frequency

Interface Parameters Label Connect

Generic Function Name

GFUNCTION\_Example

Signal Type Real Signal

Equation Type Current:  $I(tn) = f(V(tn), V(tn-1), ..., V(tn-M), I(tn-1), ..., I(tn-M))$

Port Type Two-node Ports

Number of Left Side Ports

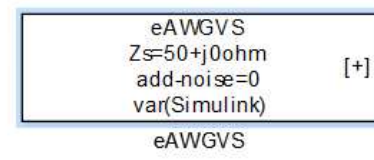
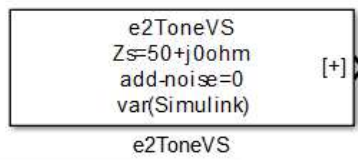
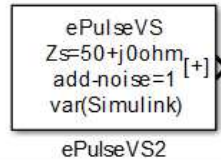
1

Number of Right Side Ports

1

OK Cancel Help Apply

# Signal generators



Source Block Parameters: ePulseVS2

S-Function (mask) (link)

User defined Pulse voltage source

Signal Parameters Noise Params Conn

Variables Type Scerne

Period (sec)  
 $1e-6[\text{Clock}*2]$

Delay (sec)  
 0

Duty Cycle (% period)  
 0

Rise Time (% period)  
 0

Fall Time (% period)  
 0

Modulation Freq Start value (Hz)  
 0

Modulation Freq End value (Hz)  
 0

Pulse Start Amplitude (dBm or Volt)  
 Pin-3

Pulse End Amplitude (dBm or Volt)  
 Pin+15

OK Cancel

Source Block Parameters: e2ToneVS

S-Function (mask) (link)

Two-tone voltage source

Signal Parameters Noise Params

Variables Type Simulink

Baseband Tone Freq 1 (Hz)  
 0

Amplitude Tone 1 (Unit)  
 0

Phase Tone 1 (deg)  
 0

Baseband Tone Freq 2 (Hz)  
 0

Amplitude Tone 2 (Unit)  
 0

Phase Tone 2 (deg)  
 0

Internal Impedance: Real Part (ohm)  
 50

Internal Impedance: Imag Part (ohm)  
 0

OK Cancel

Source Block Parameters: eAWGVS

S-Function (mask) (link)

Arbitrary wave signal generator  
 (User data file defined)

Signal Parameters Noise Params Connect

Variables Type Scerne

Data File  
 AWG/EAWG.wcdma.dat

Average Power (for dBm and Volt unit), or Mult Factor (for Free unit)  
 0

Data Time Step [ 0 = read from file ] (sec)  
 0

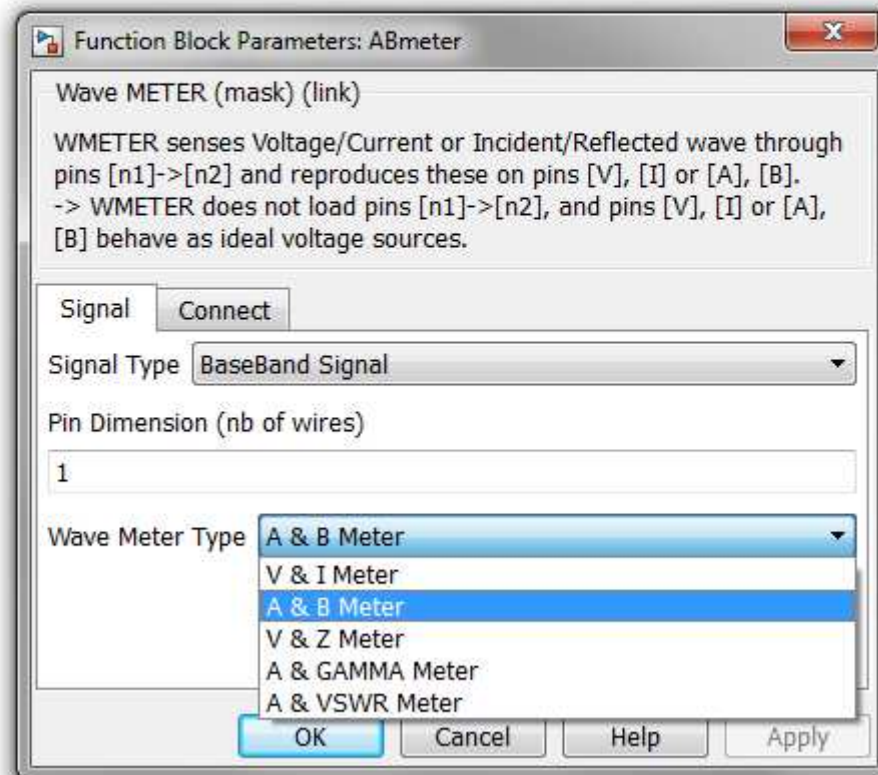
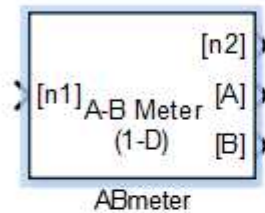
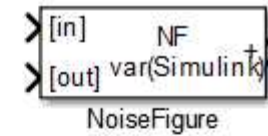
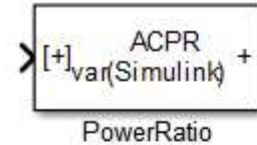
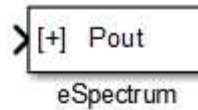
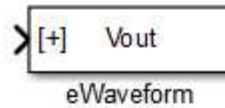
Maximum Number of Samples [ 0 = All ]  
 0

Delay factor (fraction of Max sample number: 0 -> 1.0)  
 0

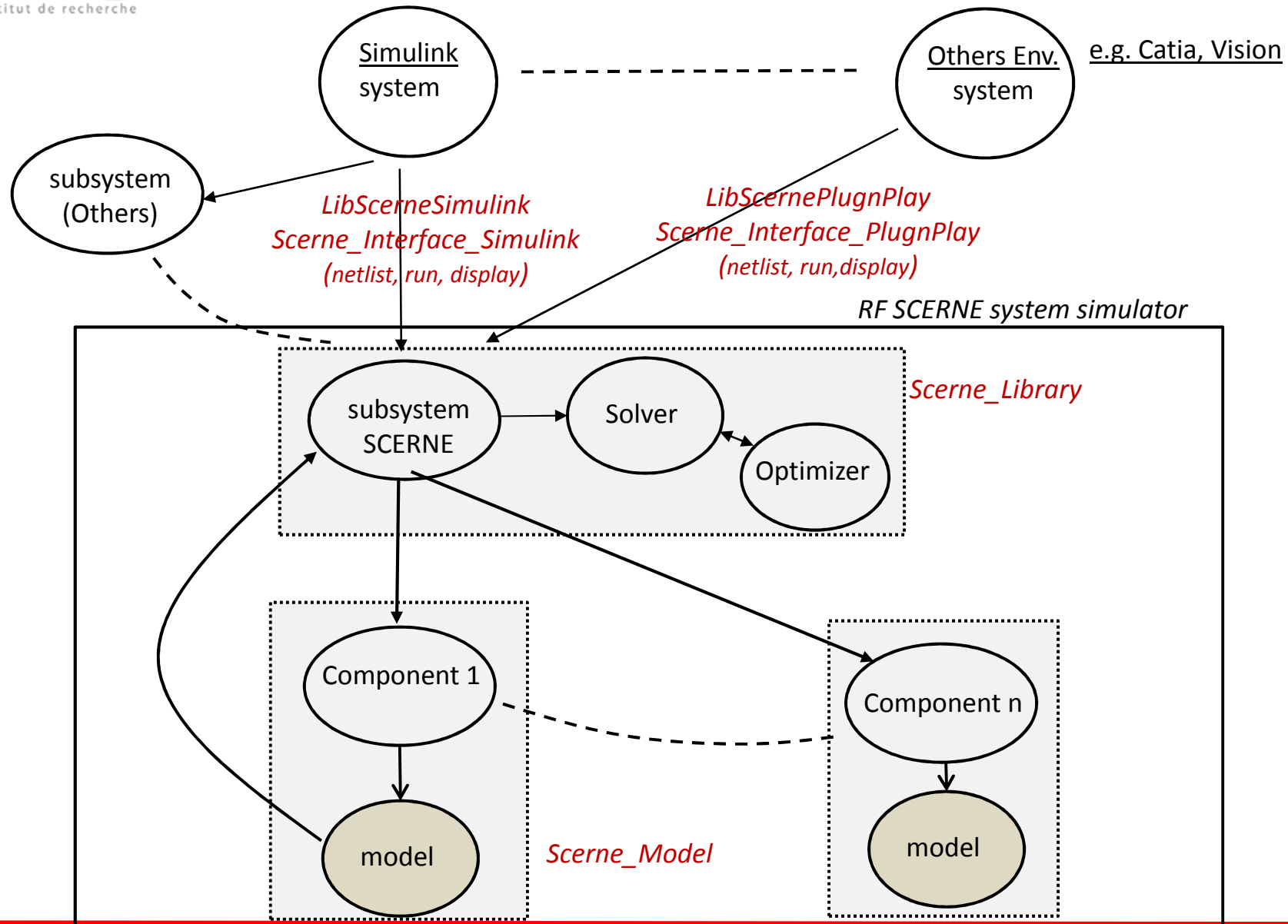
Internal Impedance: Real Part (ohm)  
 50

Internal Impedance: Imag Part (ohm)  
 0

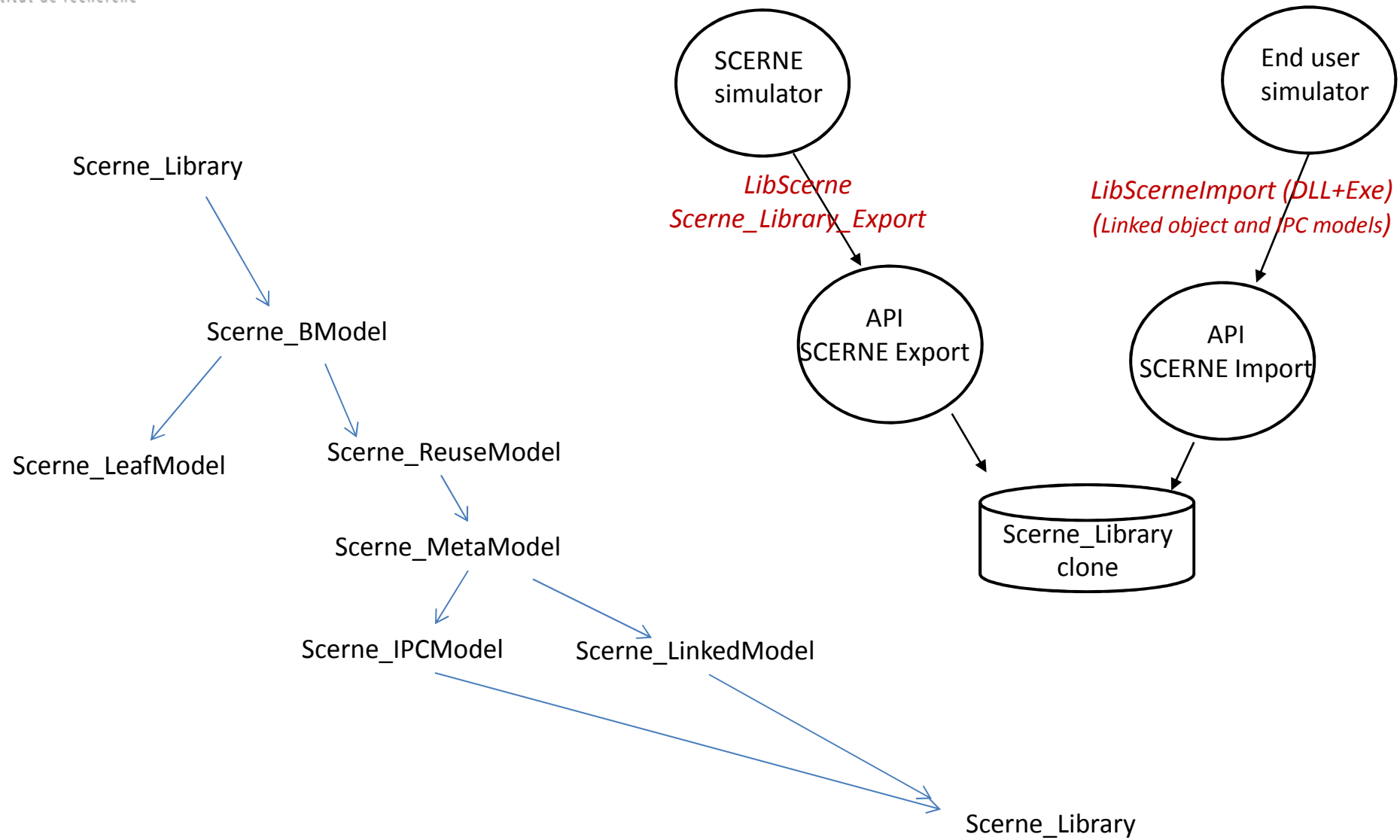
OK Cancel Help Apply



# Scerne Architecture



# Export functionalities

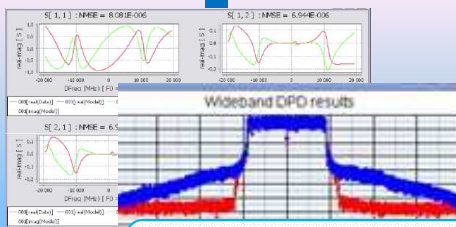


# Vision tool

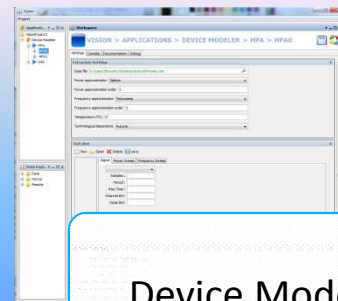


## 3 Applications

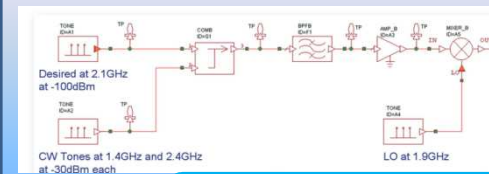
Logiciel  
VISION



Visualization



Device Modeler



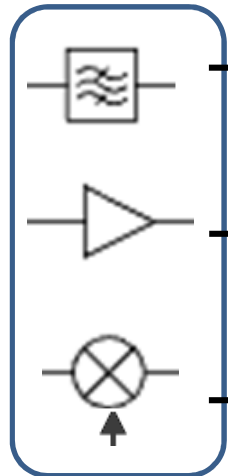
System Modeler

❑ Outil qui permet de Visualiser et mettre en forme la visualisation des résultats obtenus via le Device Modeler et le System Modeler.

❑ Outil qui réalise l'extraction de modèles de composants à partir de mesure ou de simulation.

❑ Outil qui réalise la concaténation de modèles de composants afin d'embarquer leurs interactions dans un modèle système autonome.

Data IN



Circuit Modeler

Circuit Modeler

Circuit Modeler

• Circuit Models

## VISION SYSTEM MODELER

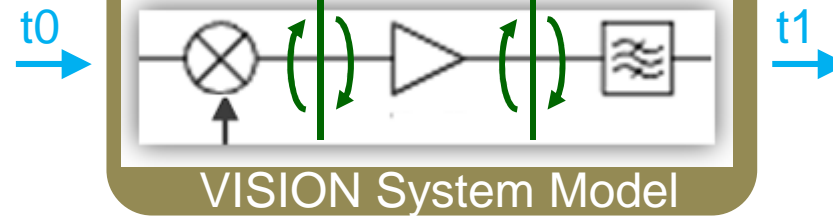
Schematic Editor

• Circuit Models  
• Schematic equations

System Modeler

• System Model  
• Solver

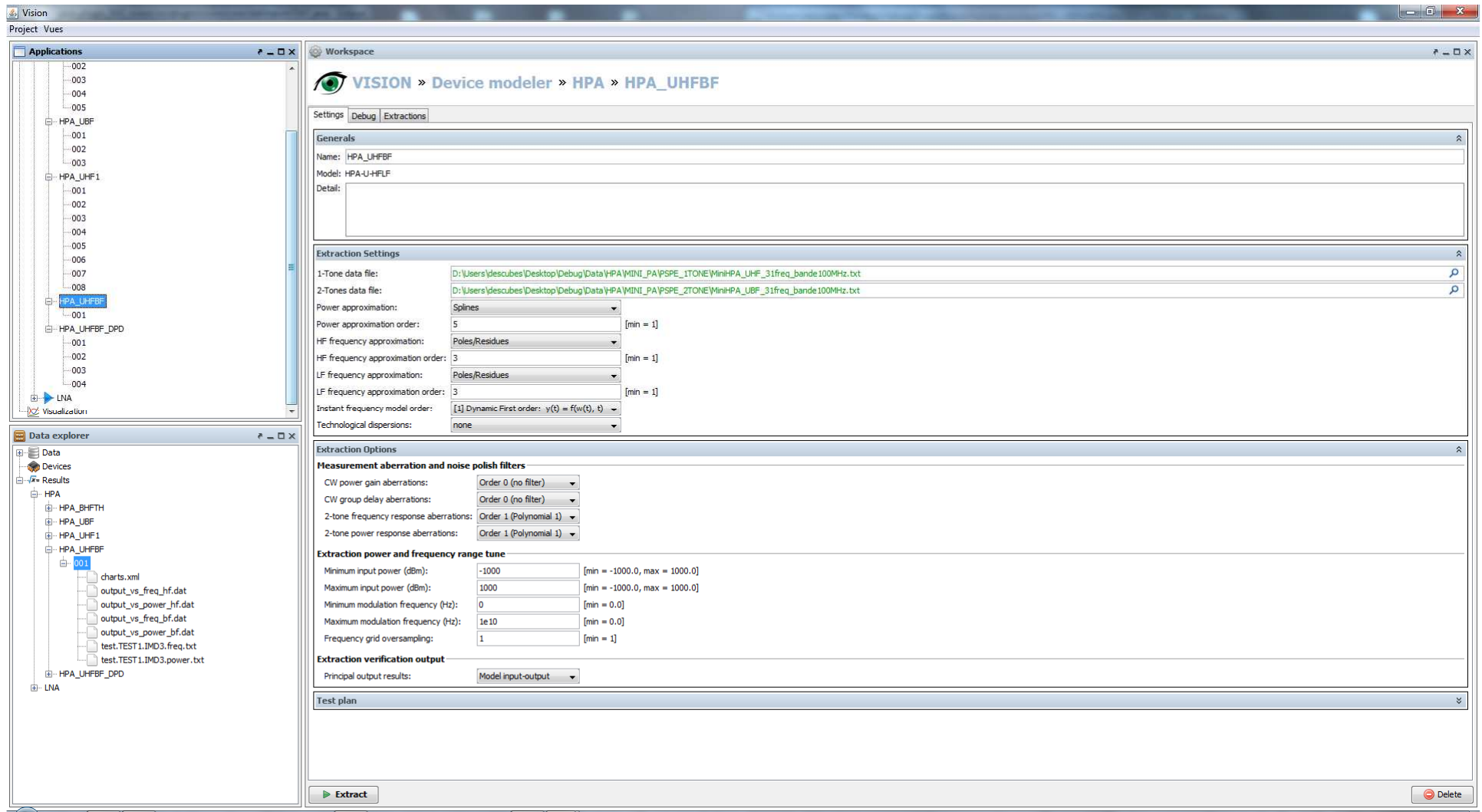
### TR module model



Inclusion of mismatches between bloc 1,2,3, & memory effects

FMI,  
Dymola

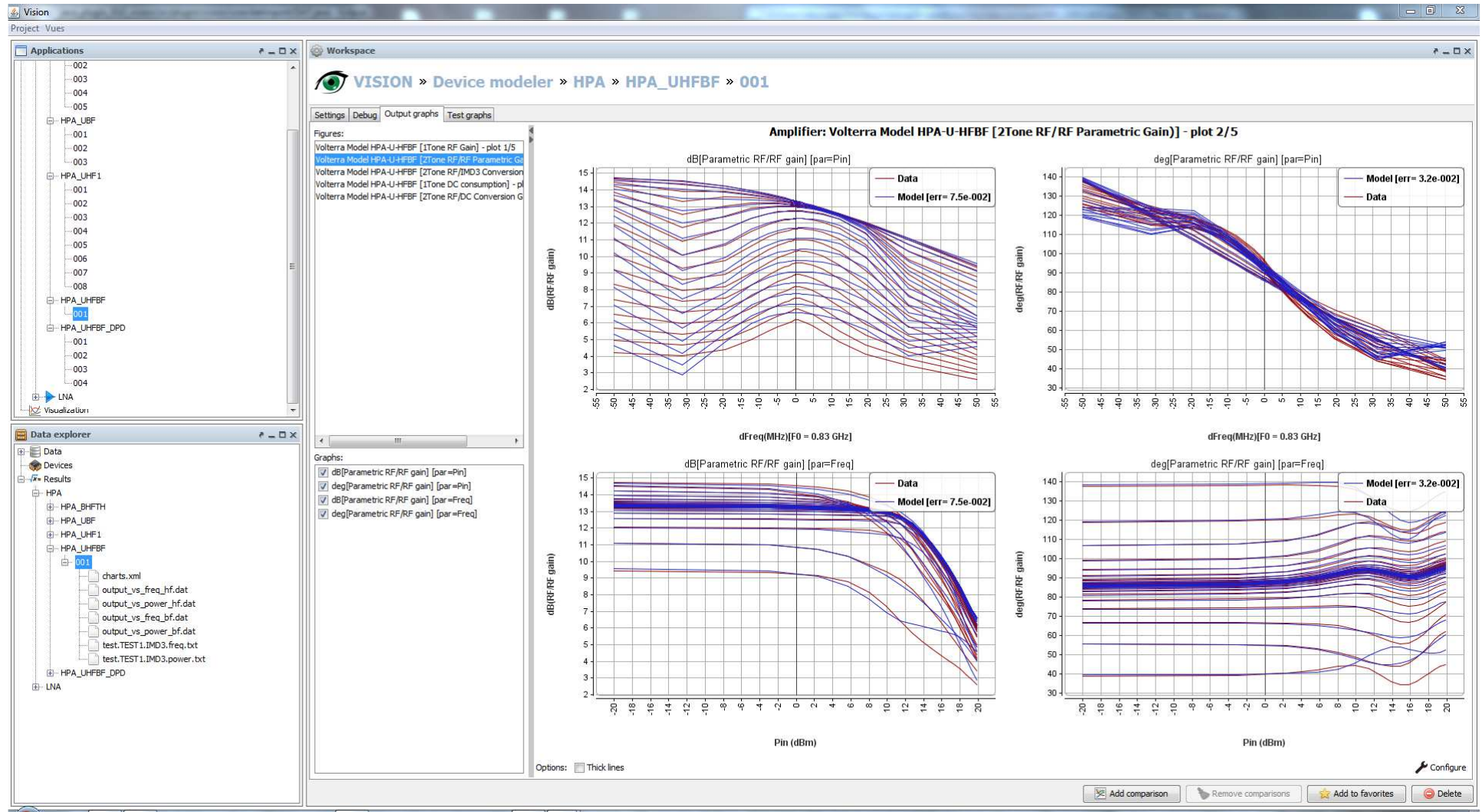
# VISION – IHM Device Modeler (settings)



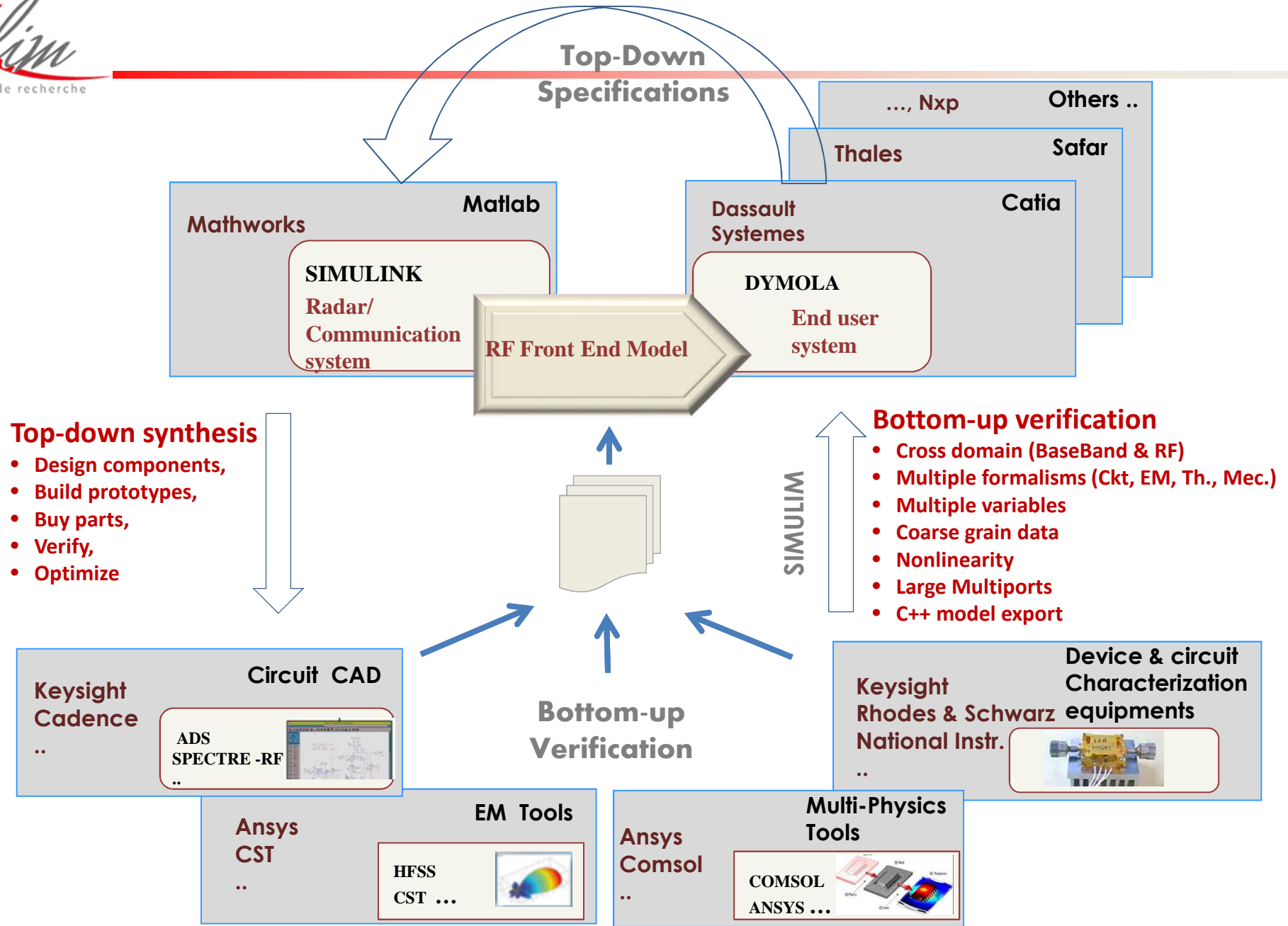
The screenshot shows the VISION Device Modeler interface with the following components:

- Project Vues:** A tree view on the left showing the project structure. The 'Applications' folder is expanded, showing a hierarchy of components including HPA\_UBF, HPA\_UHF1, HPA\_UHFBF, and HPA\_UHFBF\_DPD. The 'Data explorer' folder is also expanded, showing various data files like charts.xml, output\_vs\_freq\_hf.dat, and test.TEST1.IMD3.freq.txt.
- Workspace:** The main area on the right, titled 'VISION » Device modeler » HPA » HPA\_UHFBF'. It contains several tabs: 'Settings', 'Debug', and 'Extractions'. The 'Settings' tab is active, showing the following sections:
  - Generals:** Name: HPA\_UHFBF, Model: HPA-U-HFLF, Detail: (empty).
  - Extraction Settings:**
    - 1-Tone data file: D:\Users\descubes\Desktop\Debug\Data\HPA\MINI\_PA\PSPE\_1TONE\MINIHPA\_UHF\_31freq\_bande100MHz.txt
    - 2-Tones data file: D:\Users\descubes\Desktop\Debug\Data\HPA\MINI\_PA\PSPE\_2TONE\MINIHPA\_UBF\_31freq\_bande100MHz.txt
    - Power approximation: Splines
    - Power approximation order: 5 [min = 1]
    - HF frequency approximation: Poles/Residues
    - HF frequency approximation order: 3 [min = 1]
    - LF frequency approximation: Poles/Residues
    - LF frequency approximation order: 3 [min = 1]
    - Instant frequency model order: [1] Dynamic First order:  $y(t) = f(w(t), t)$
    - Technological dispersions: none
  - Extraction Options:**
    - Measurement aberration and noise polish filters:**
      - CW power gain aberrations: Order 0 (no filter)
      - CW group delay aberrations: Order 0 (no filter)
      - 2-tone frequency response aberrations: Order 1 (Polynomial 1)
      - 2-tone power response aberrations: Order 1 (Polynomial 1)
    - Extraction power and frequency range tune:**
      - Minimum input power (dBm): -1000 [min = -1000.0, max = 1000.0]
      - Maximum input power (dBm): 1000 [min = -1000.0, max = 1000.0]
      - Minimum modulation frequency (Hz): 0 [min = 0.0]
      - Maximum modulation frequency (Hz): 1e10 [min = 0.0]
      - Frequency grid oversampling: 1 [min = 1]
    - Extraction verification output:** Principal output results: Model input-output
  - Test plan:** A section at the bottom of the workspace area.
- Buttons:** An 'Extract' button is located at the bottom left of the workspace, and a 'Delete' button is at the bottom right.

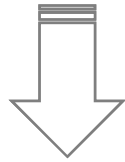
# VISION – IHM Device Modeler (graphics results)



# Conclusion



## Higher functional complexity



- Heterogeneous technologies
- Multiple standards
- Higher data rate
- Larger bandwidths
- Carrier aggregation
- Low RF to Millimeter wave carriers
- Device to device communication

## Co-design paradigm



- RF-Baseband
- Antenna and Circuit

## Flexible and accurate Bottom-up modeling methods and tools of the RF Link

- Model, combine and export lower-level data from
- Heterogeneous simulation tools and environments
- Diverse test and characterization equipments