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Instruments  
Company™



## Introduction to AWR Design Flow and New Features for V10

AWR is a National Instruments Company

# What's New with AWR?

- AWR acquired by National Instruments (July 11)
  - AWR a wholly owned subsidiary
  - Will remain independent
  - AWR Brand will continue
  - Backed by \$1B parent
  - RF EDA strategic to NI's long term success
  - Partner with NI for several select accounts





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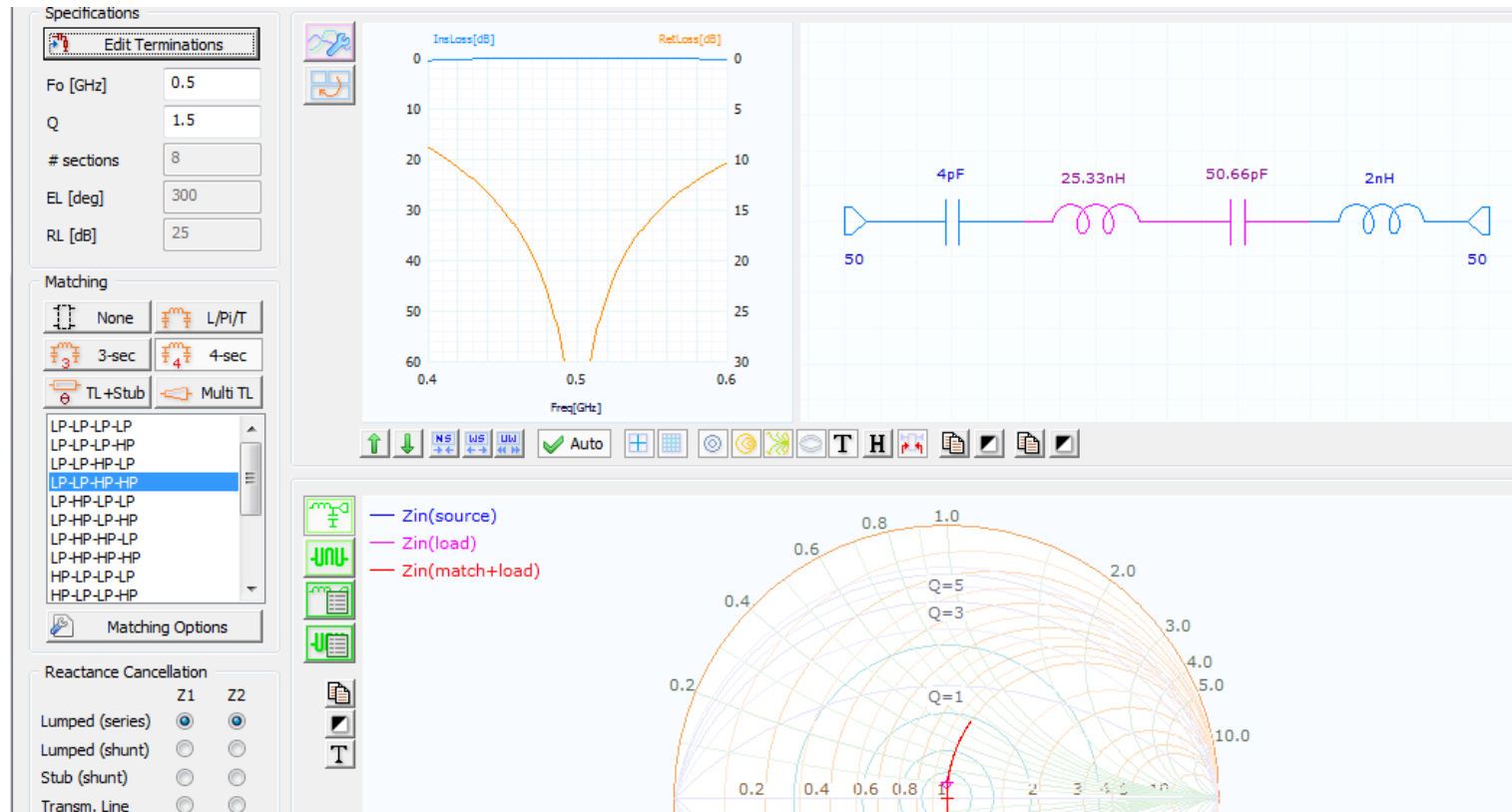


## What's New In Version 10

AWR is a National Instruments Company

# iMatch – Matching Network Synthesis

- Matching Network Synthesis
  - Tight integration with AWR tools
  - Excellent starting point for further AWR analysis –
    - EM verification and EM synthesis



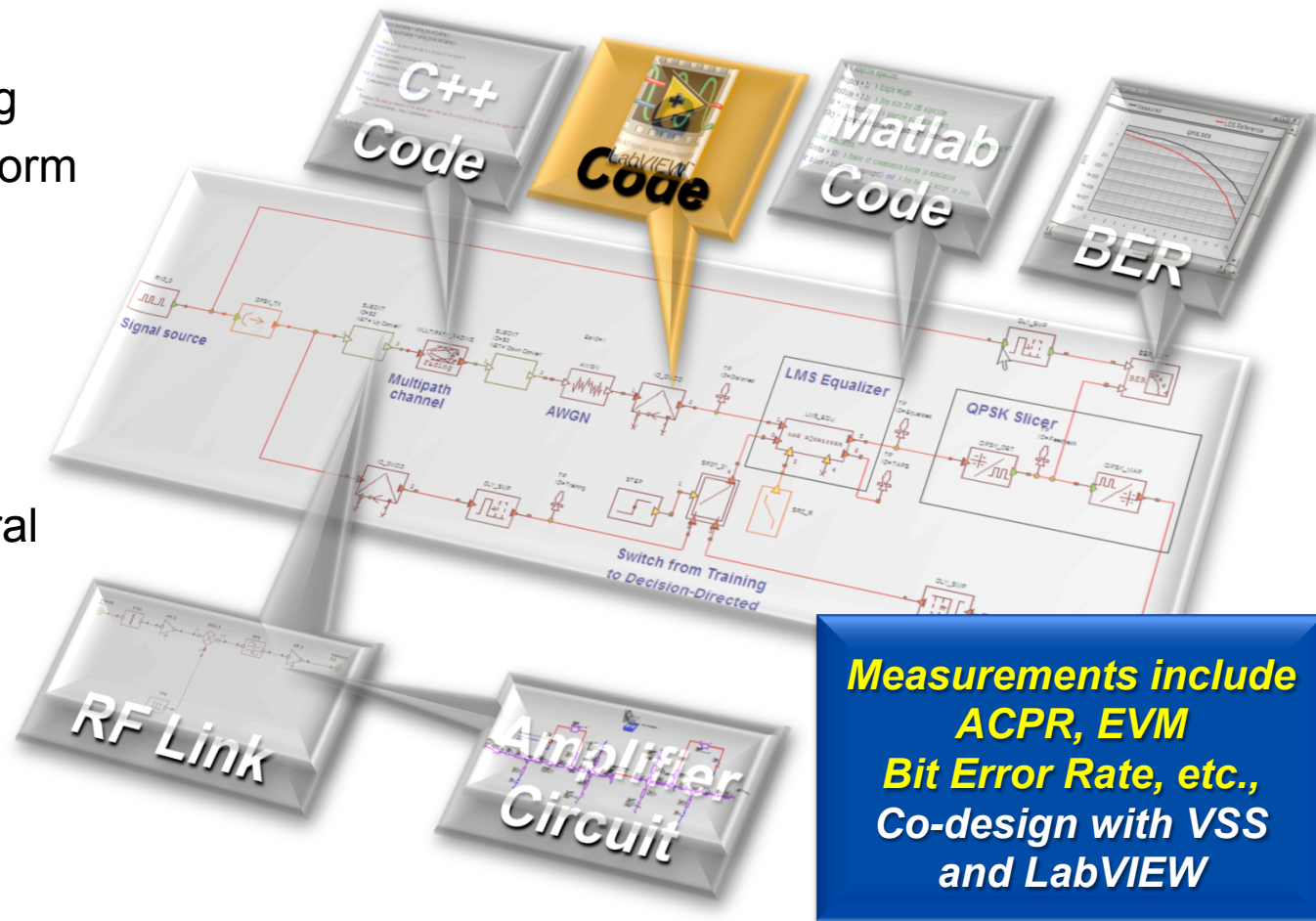


# VSS / LabVIEW Integration

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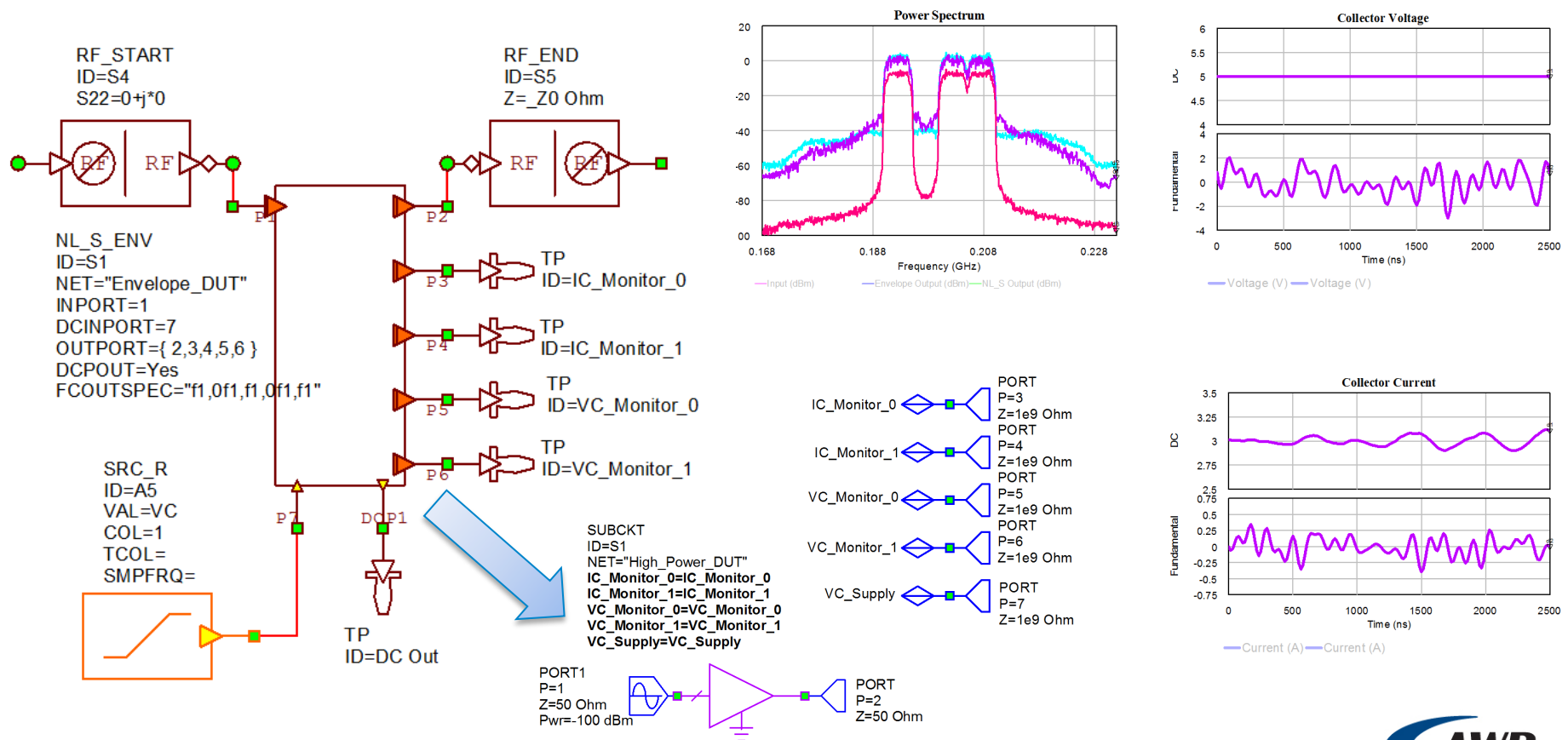
- LabVIEW VI's can be instantiated in system diagrams

- Signal Processing
- Modulated waveform creation and demodulation
- Comparing simulated and measured data
- Created behavioral models



# Circuit Envelope Simulation

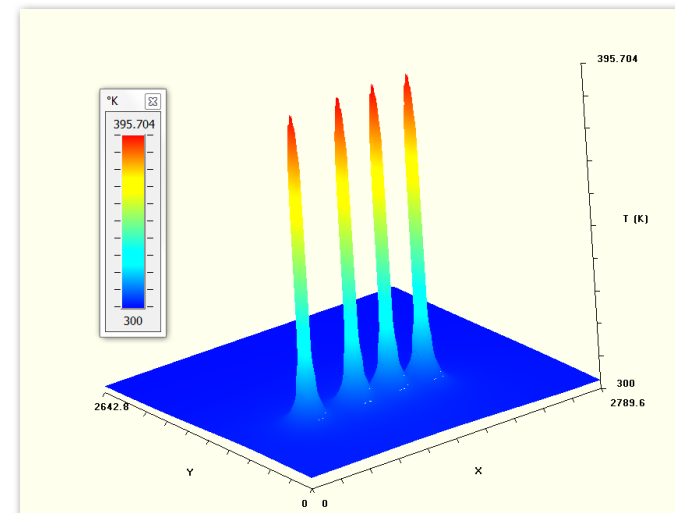
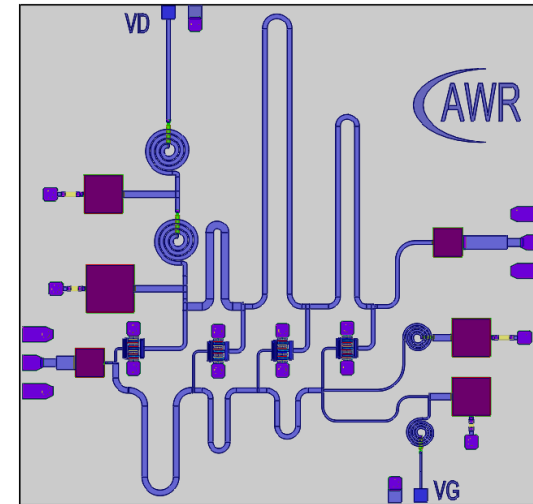
- Arbitrary circuit schematics in VSS for DPD / envelope tracking
- Monitor or control node current, node voltage, or PAE



# SYMMIC Thermal Simulator

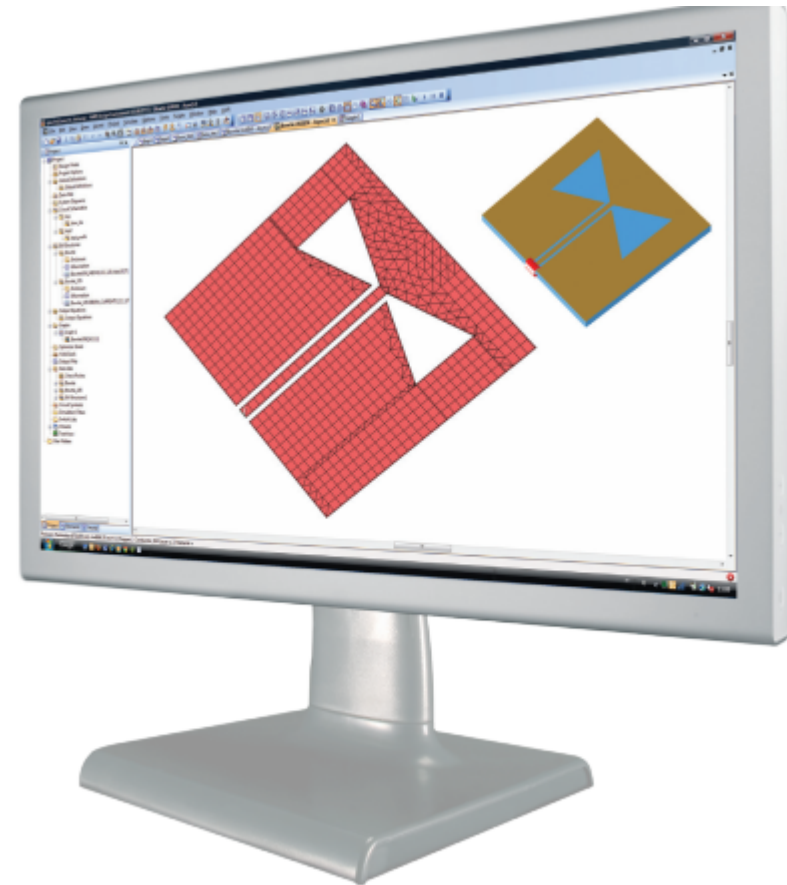
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- Design-state thermal analysis of MMIC PA's
- Thermal “stackups” defined by process simplifying setup for new circuits
- Generate thermal impedance networks for transient simulation



# Antenna Magus Interface

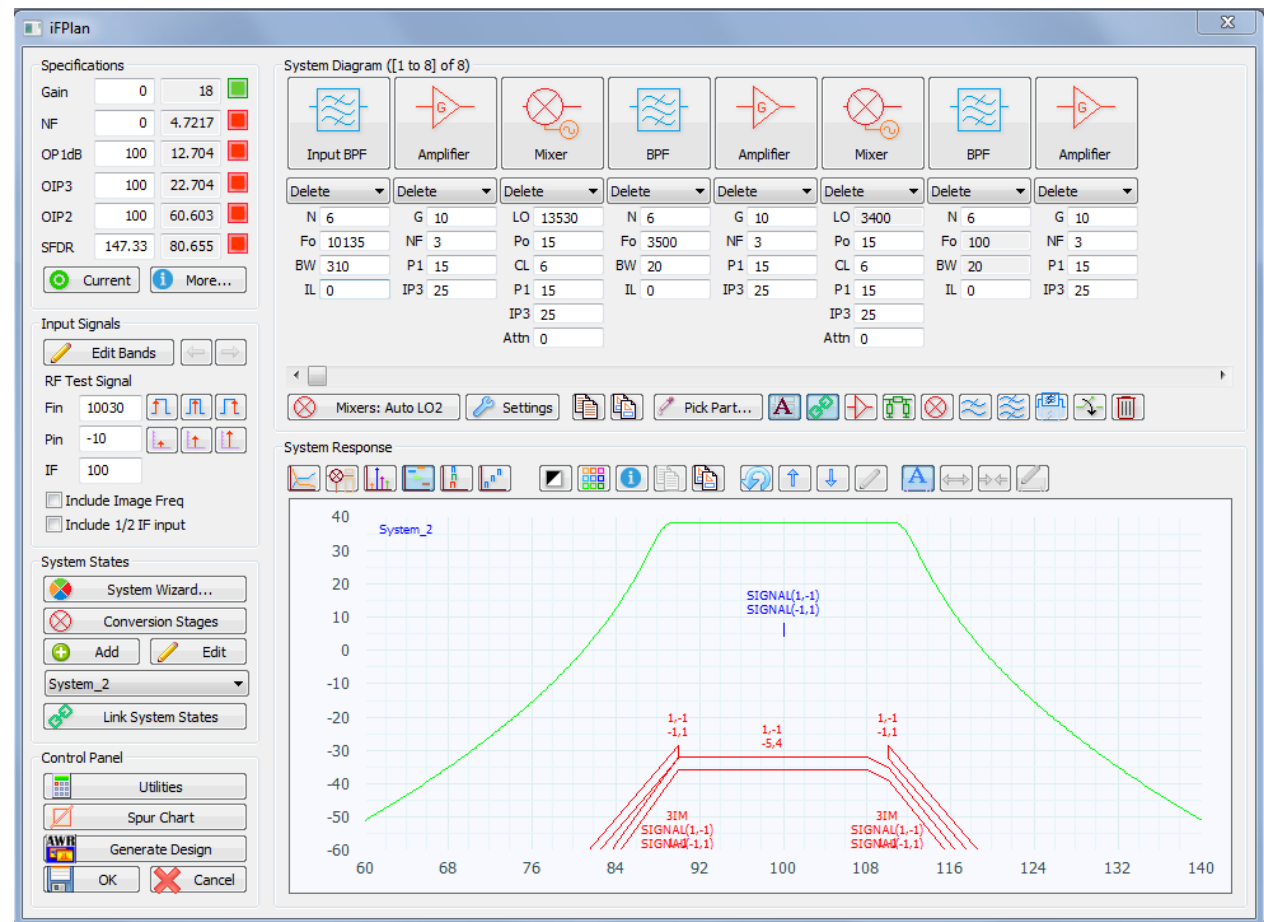
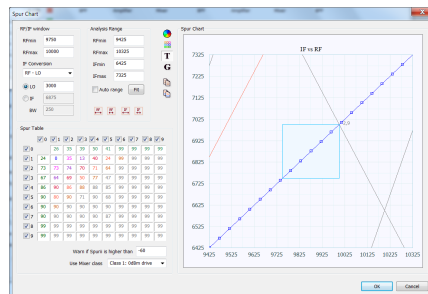
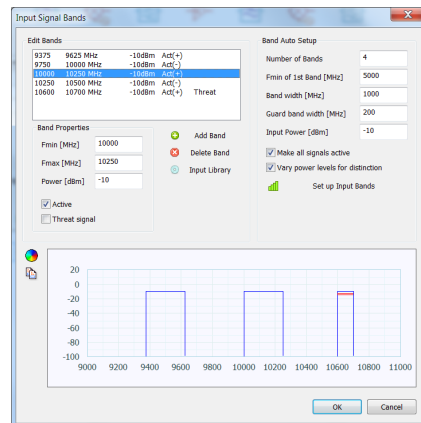
- Antenna evaluation, selection and synthesis
- Searchable database of antennas
- Synthesized planar antennas can be directly exported to MWO/AXIEM





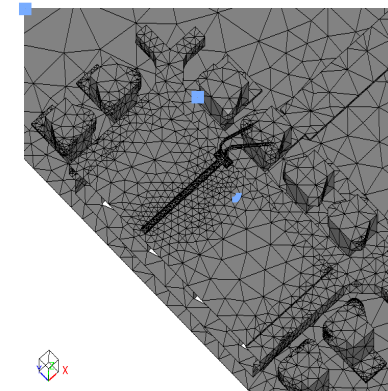
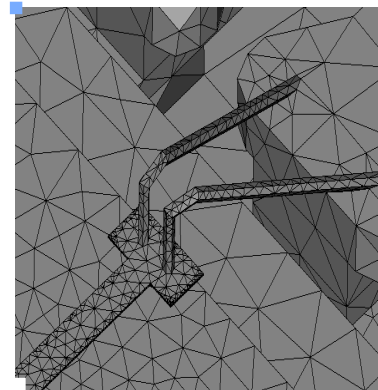
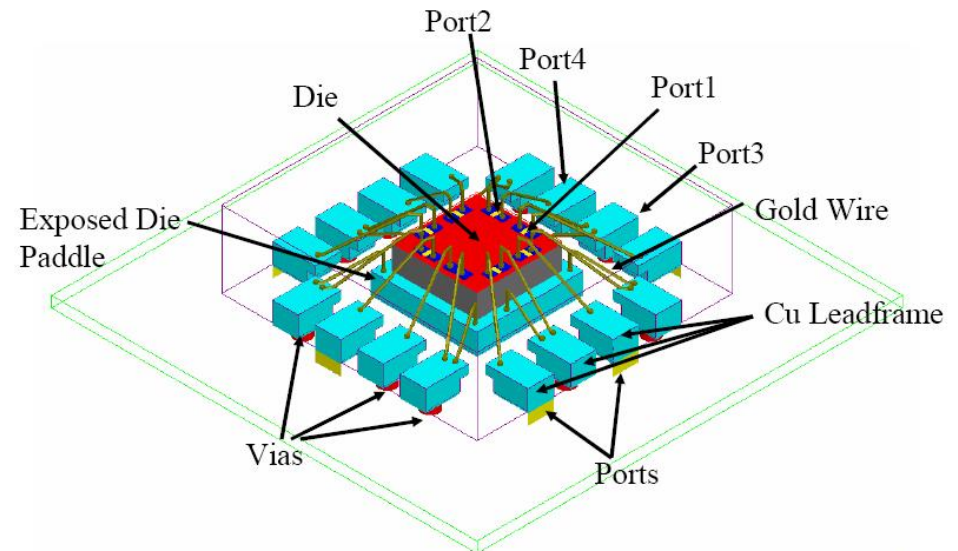
# Frequency Planner

- Select right system architecture



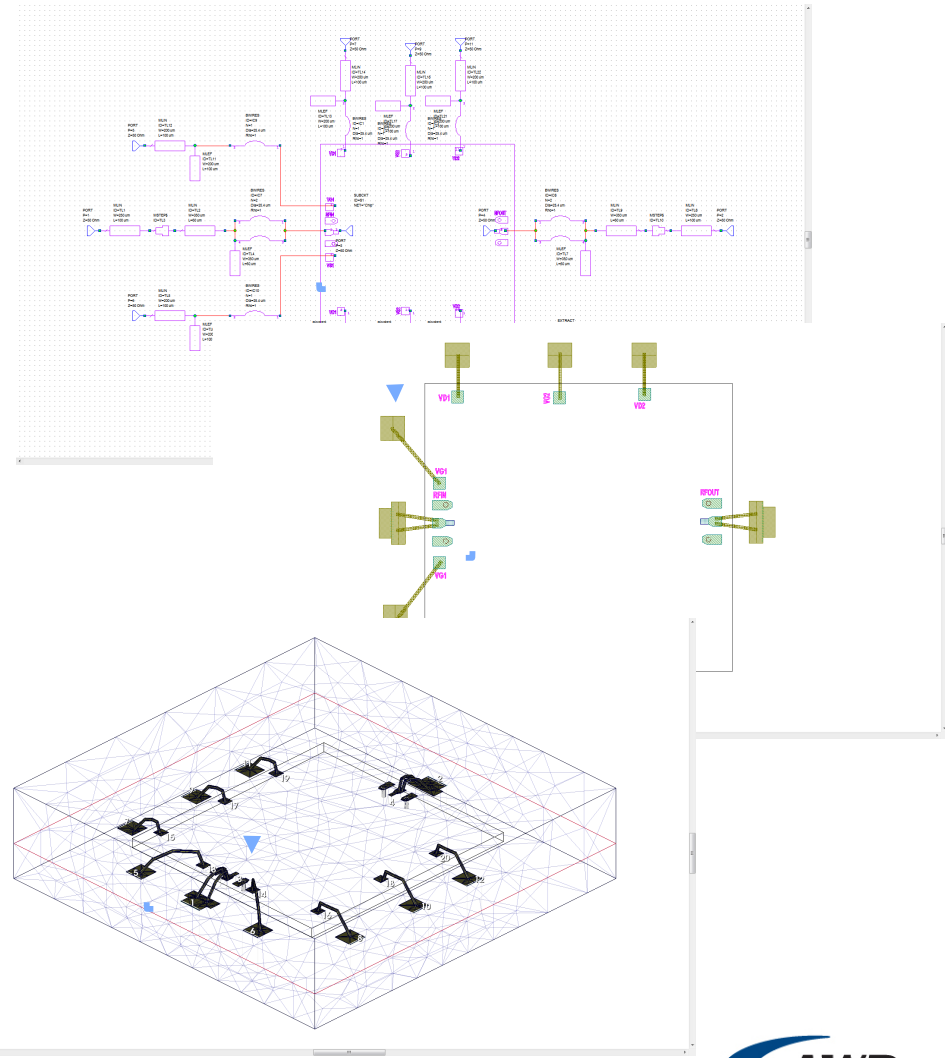
# Analyst 3D FEM Solver

- Finite Element, Open Boundary 3D Solver
- Over a Decade in Development in Collaboration with the Dept of Energy and DoD.
- Employed at Nearly all US National Labs and Accelerators as Well as Several Commercial Suppliers of X-Ray Equipment
- Highly Distributed, Very High Capacity
- Fully Integrated into AWR framework



# Analyst Integration

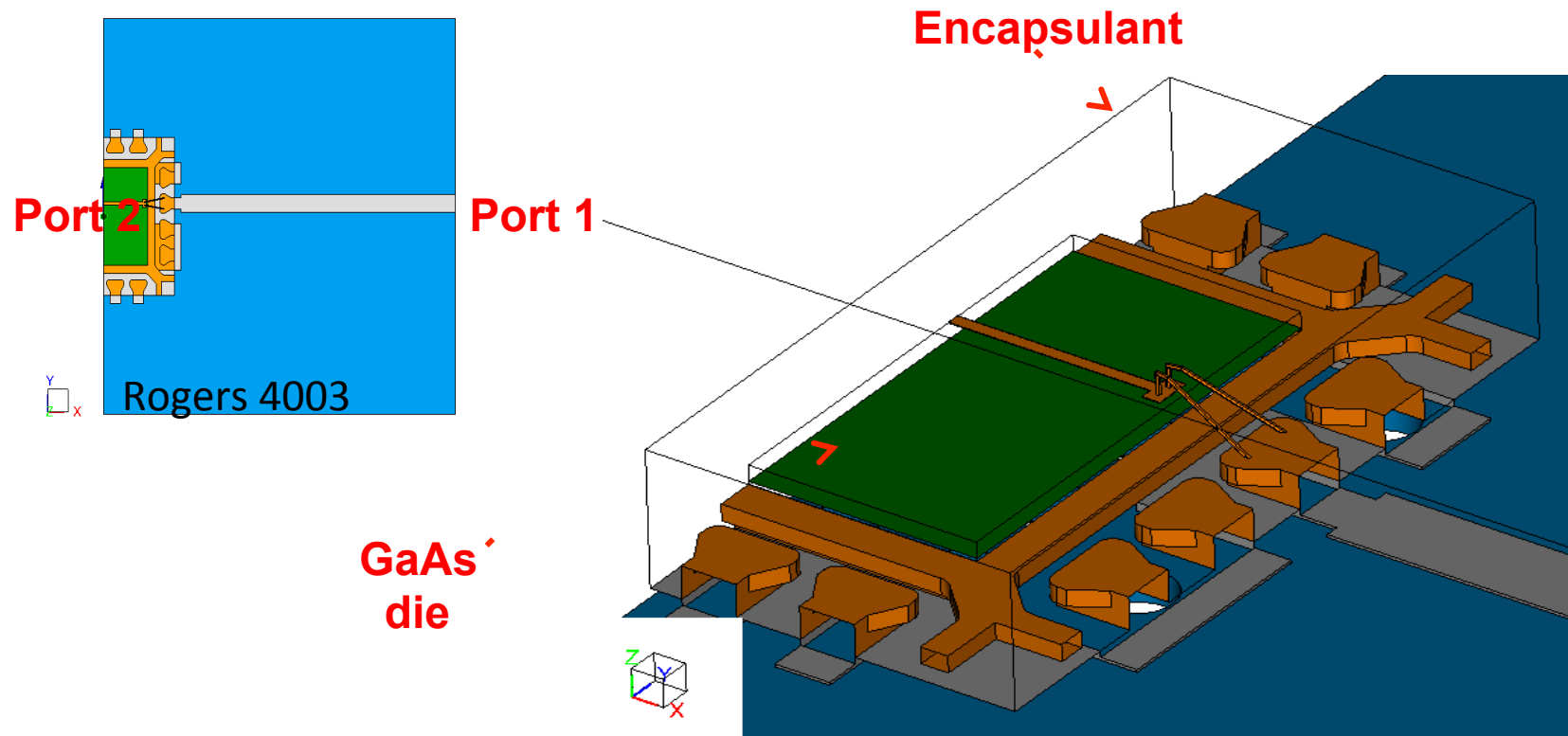
- Goal: Make 3D-EM Simulation Easier
- Analyst and AXIEM will both take advantage of the AWR Extract Flow.\*
- Same Schematic and Schematic-Layout in MWO as always
- 3D Pcells Setup Automatically



\*The extract flow for Analyst will be supported post AWR2012 release

# Analyst Integration Continued

- Supports extruded 2D shapes and 3D pcells today
- Support arbitrary 3D documents in future release







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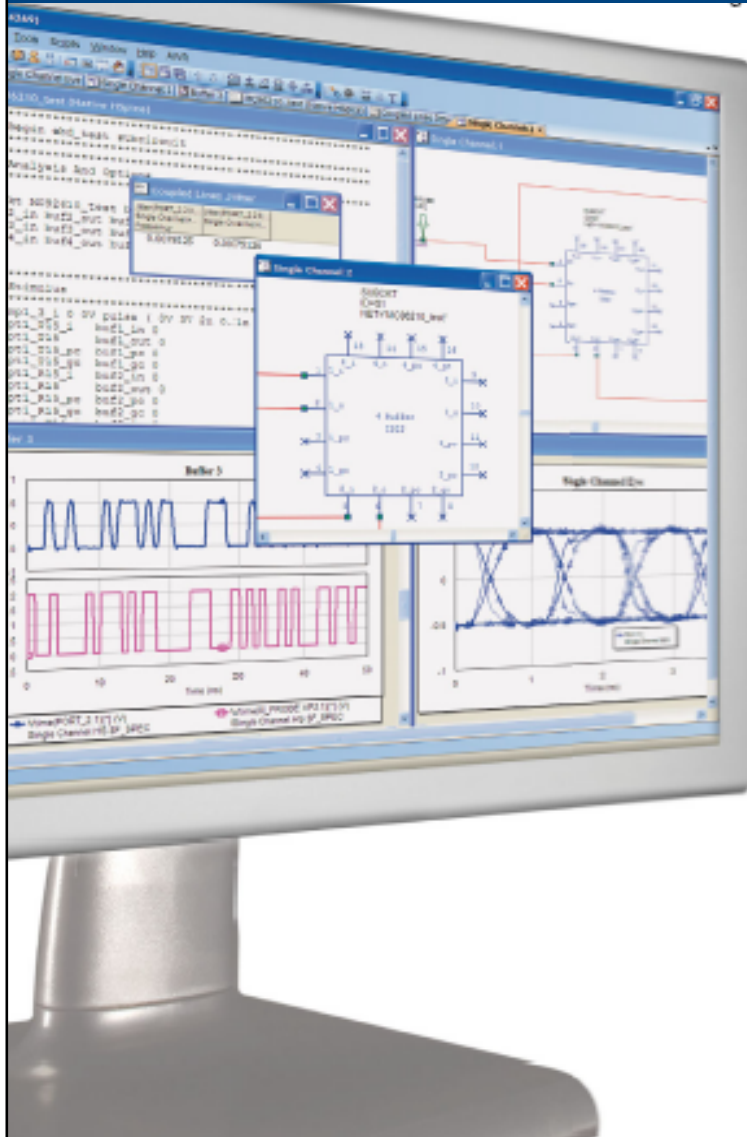


## Other V10 Improvements

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# Microwave Office: Highlights

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## Key New Features

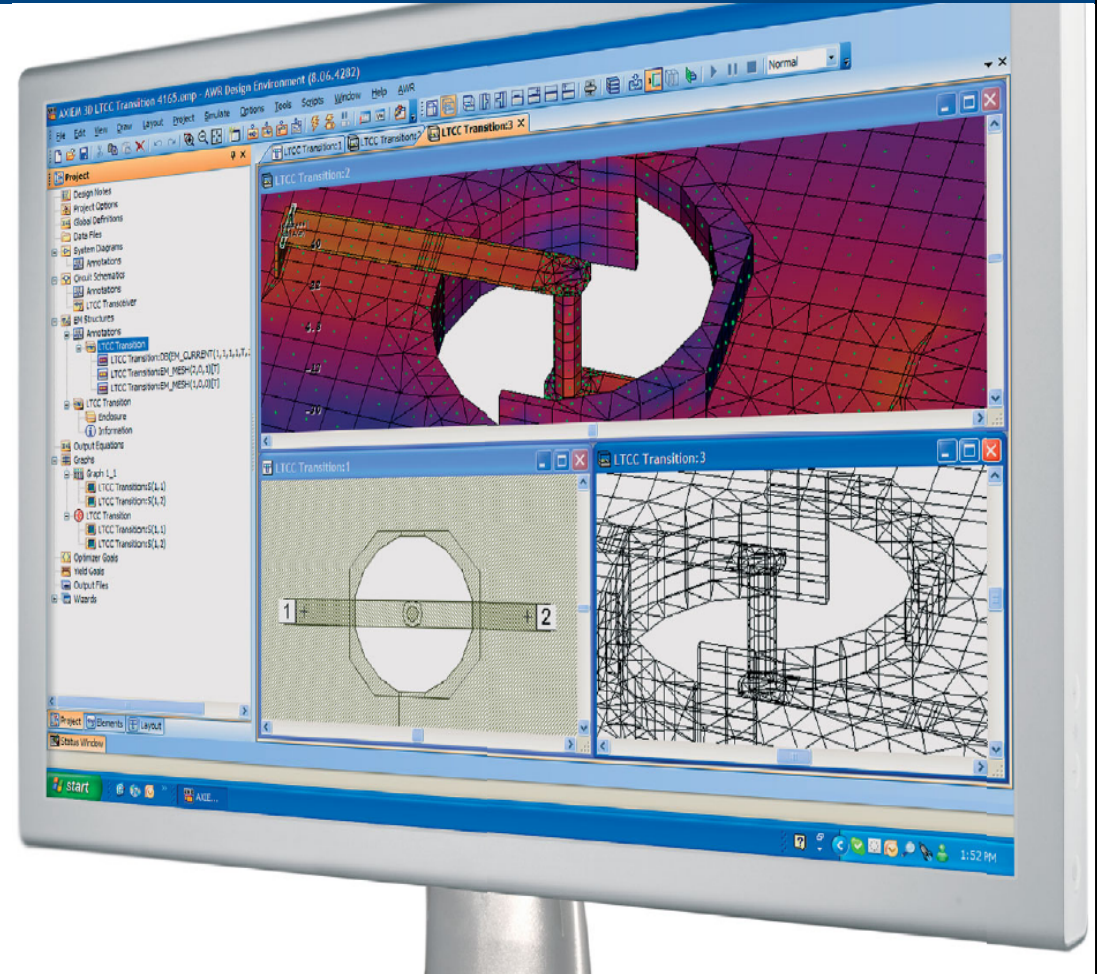
- Floating windows
- Project import
- Yield analysis and optimizers
- Layout setup wizard
- New example design kits
- RF aware short checker
- ADS Schematic Importer

# AXIEM: Highlights

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## Key New Features

- Asynchronous simulation
- Datasets
- Yield and optimization
- Improved de-embedding
- Rule-based shape modifiers
- User-defined X-models
- Frequency dependent materials
- New licensing model



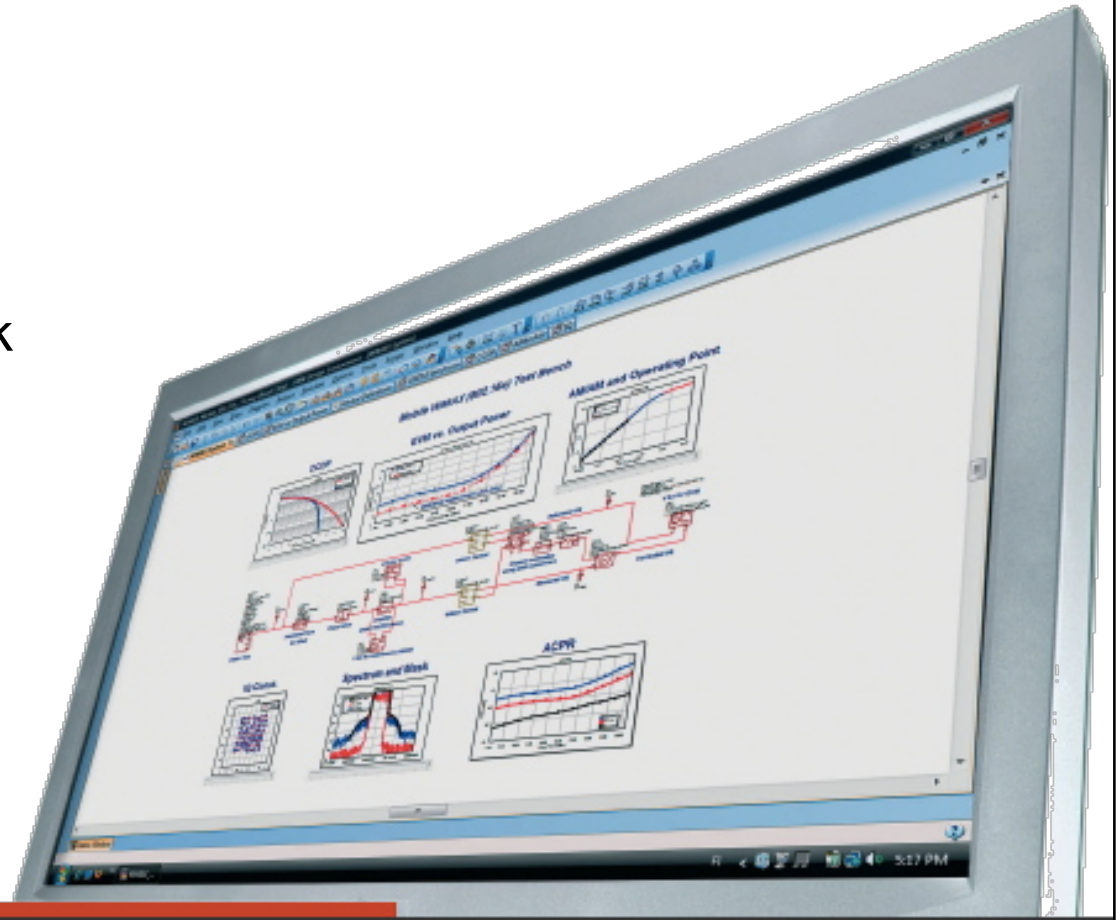


# Visual System Simulator: Highlights

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## Key New Features

- Radar library
- Envelope simulation
- RFB spreadsheet wizard
- Nonlinear co-simulation block  
passed parameters
- LabVIEW co-simulation







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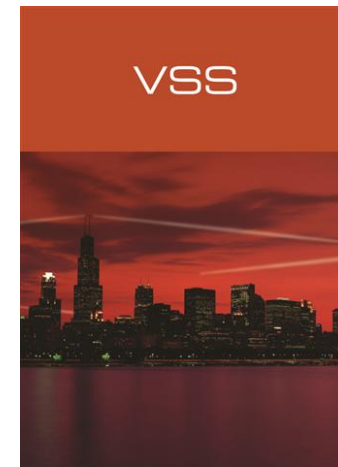
## Nonlinear Behavioural Modeling

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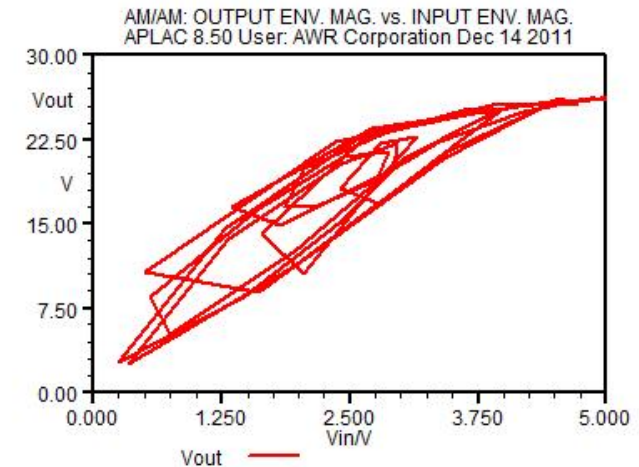
# Introduction

- Modeling domains
- Modeling effects
- Model types
- Simulator compatibility
- Other considerations
- Conclusions

- **Circuit Level**
  - Harmonic Balance, transient, and circuit envelope
  - Models formulated in time or frequency domain
  - Voltages, currents, power, etc.
  - Microwave Office
- **System Level**
  - Generally fixed time step, time domain (data flow)
  - One or more samples in, one or more samples out
  - EVM, ACPR, etc.
  - Visual System Simulator



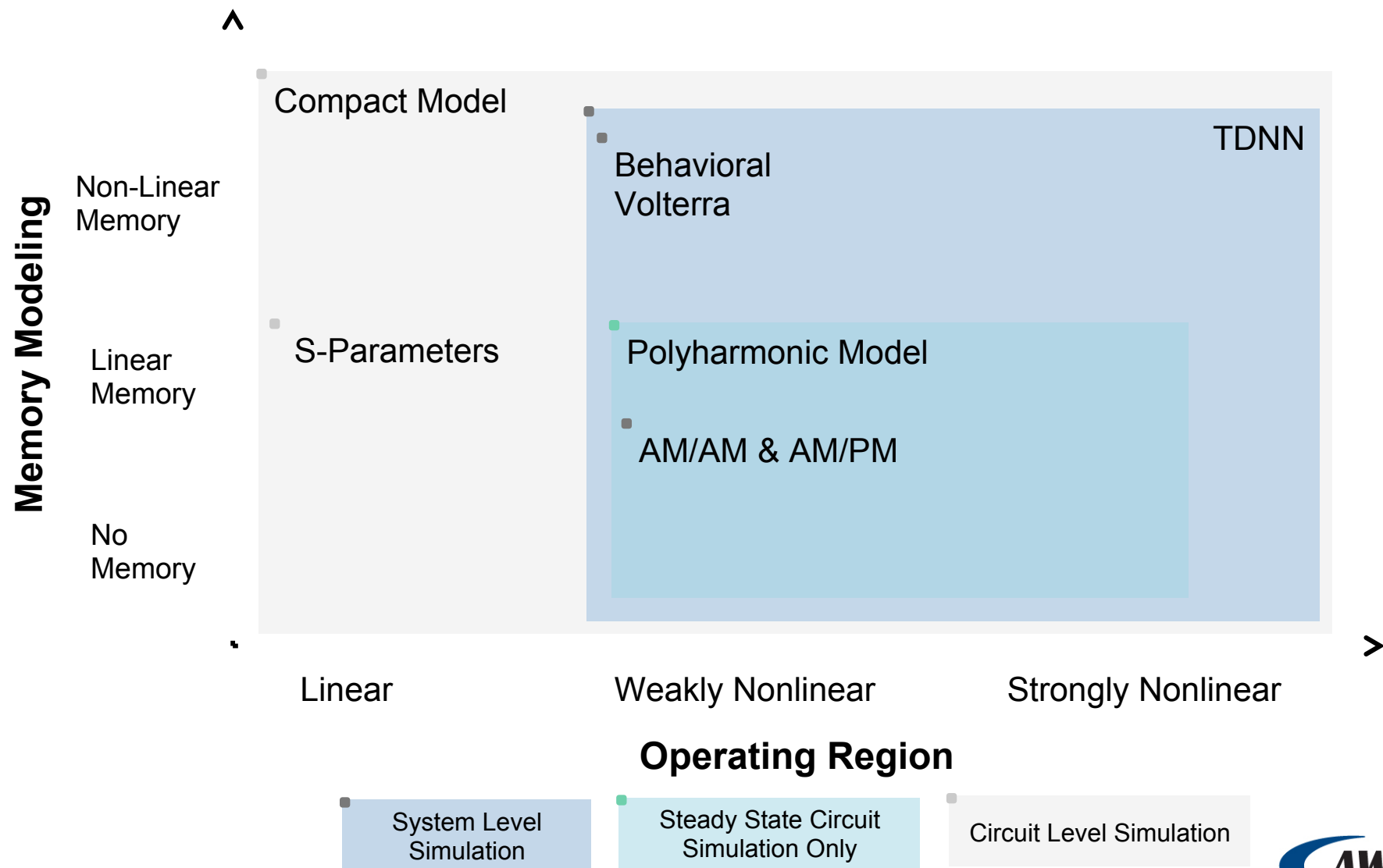
- Linear Memory
  - Frequency dependant behavior
  - Caused by linear capacitances and inductances



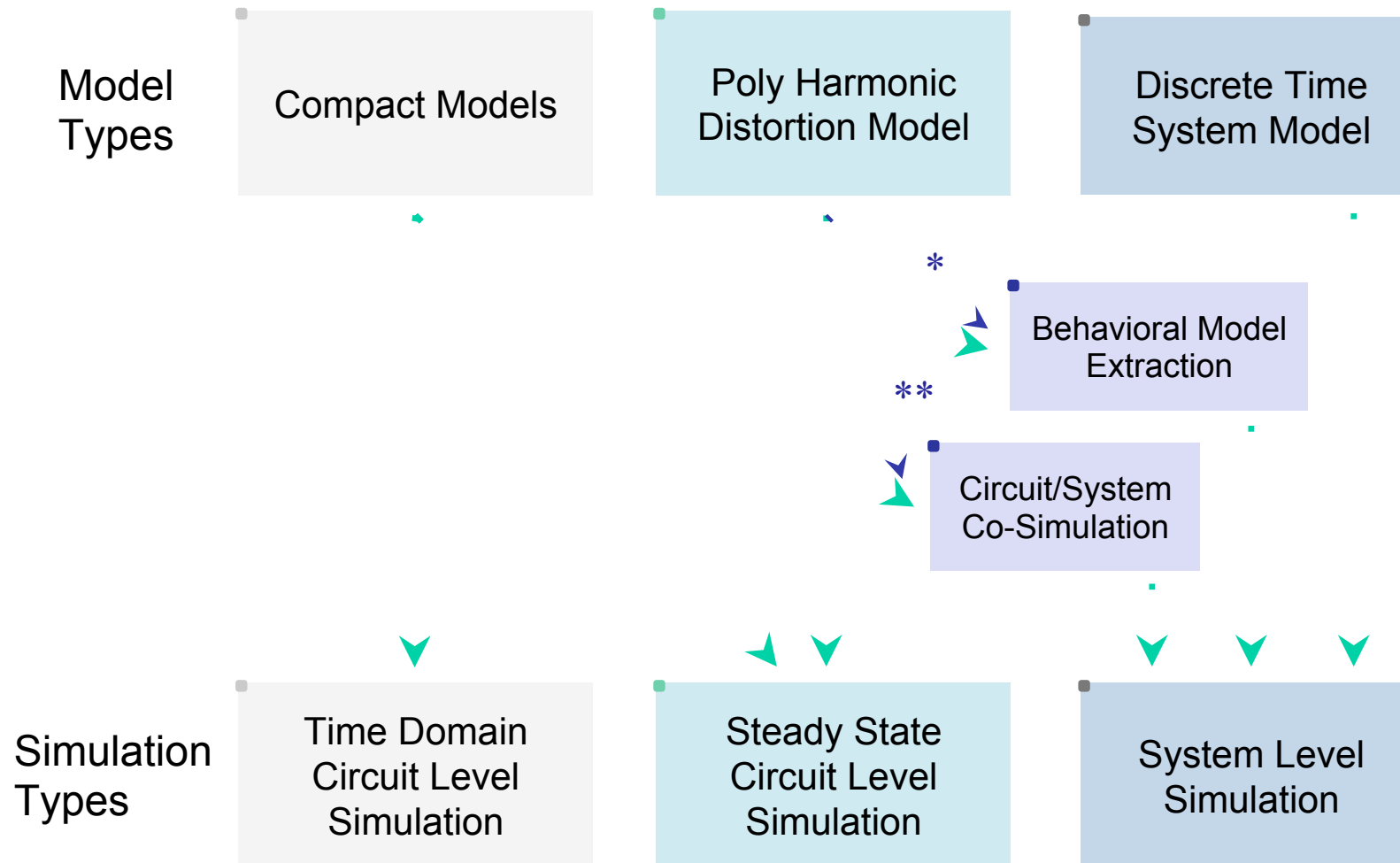
- Nonlinear Memory
  - Previous operating condition dependant behavior (e.g. Hysteresis)
  - Caused by interaction of low frequency mixing products with bias circuitry, self heating effects, trapping, etc.



# Model Types



# Simulator Compatibility

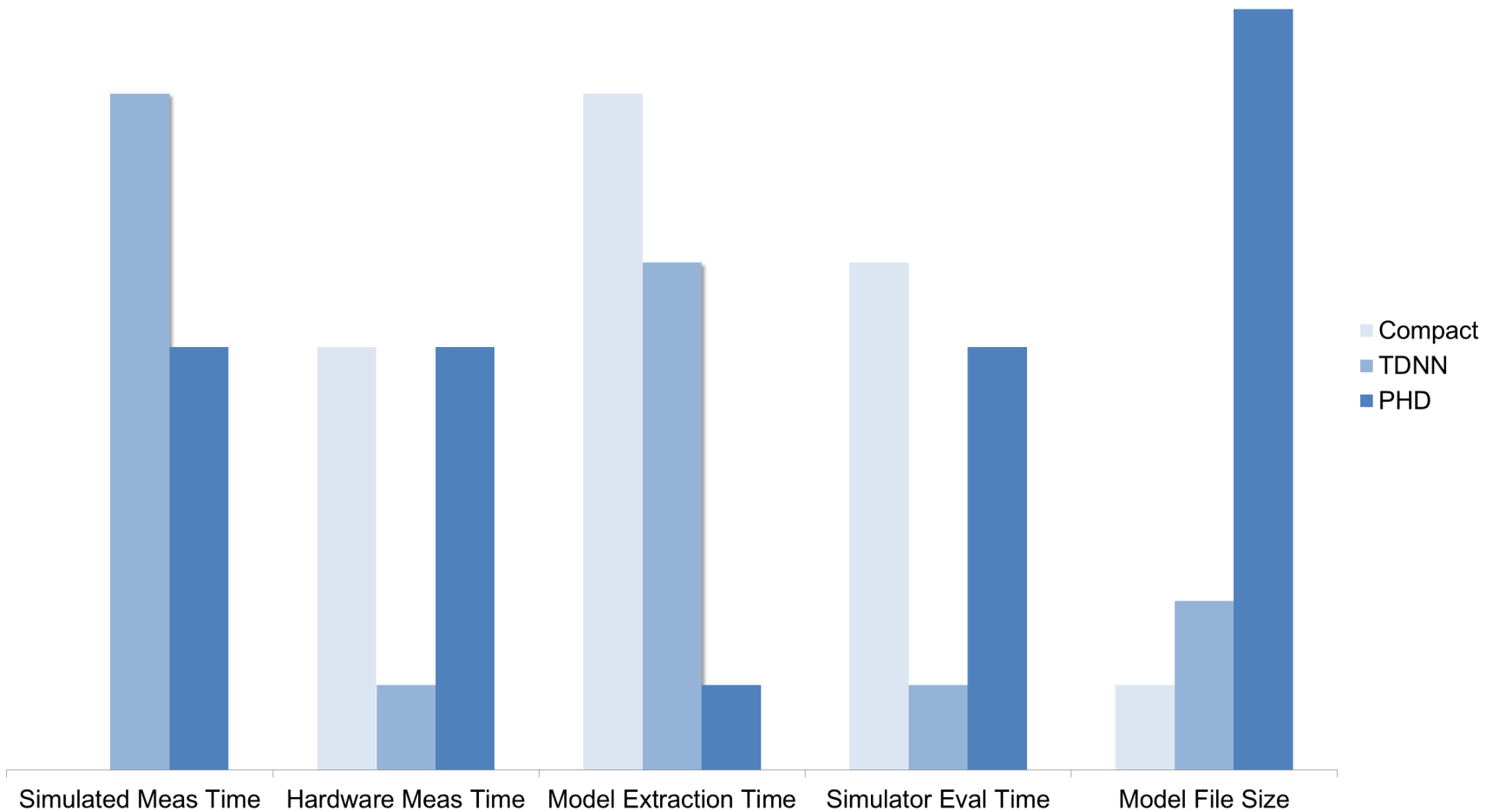


\* A system model can be extracted, but is equivalent to an AM/AM & AM/PM model

\*\* Currently, this path does not model linear or non-linear memory effects

- Measurement Time
  - Time to generate data needed to generate model
  - Can be simulated or hardware measurement based
- Model Extraction Time
  - Time to generate the model from measurement data
- Simulator Evaluation Time
  - How quickly model evaluates in intended simulators
- File Size
  - Generated model file size
  - Important for model distribution

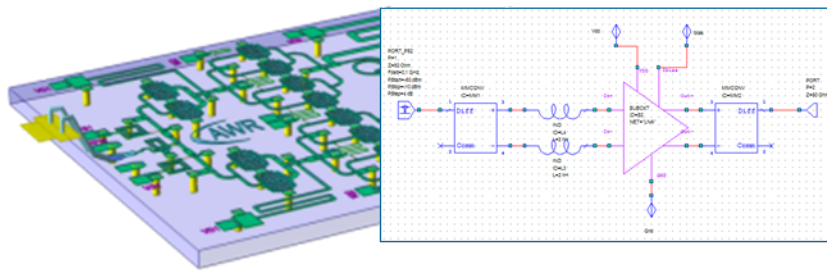
# Extraction and Distribution Details



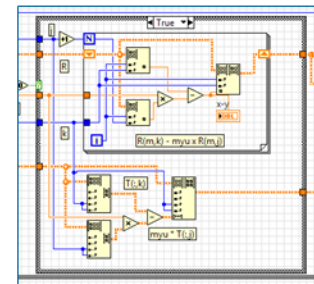


# Behavioral Modeling Conclusions

- Simulation tool support is important
- Polyharmonic distortion models in the real world
- System level modeling rapidly emerging



RF/Microwave Circuit Design  
Electromagnetic Simulation  
Link Budget Analysis



System simulation  
Real-time Control  
FPGA prototype



# Conclusions

- V10 Release
  - Circuit Envelope Simulation
  - 3D EM and Thermal Simulation
- Nonlinear Behavioral Modeling
  - Read and Write X-parameters
  - LabVIEW and TDNN

# Linking RF Design and Test

*Connecting RF Design Software to LabVIEW & Instruments*

David A. Hall

RF Product Marketing Manager



# Evolution of Instrumentation

Vacuum Tube



General  
Radio



1920

Transistor  
(Integrated Circuit)



Hewlett  
Packard



1965

Software



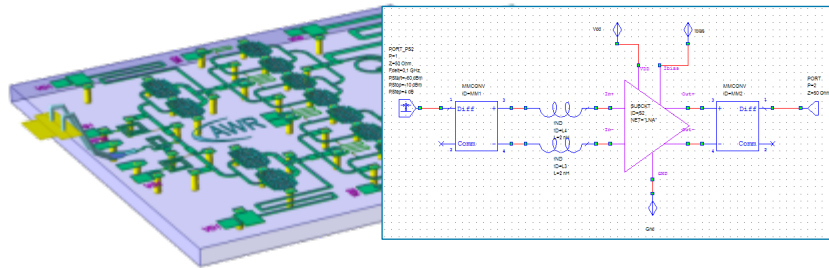
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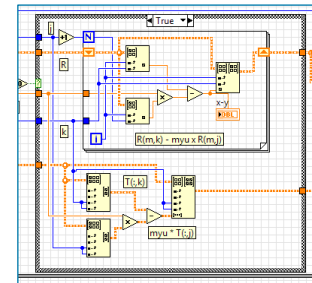
2010



# Future of RF System Design



RF/Microwave Circuit Design  
Electromagnetic Simulation  
Link Budget Analysis



System simulation  
Real-time Control  
FPGA prototype

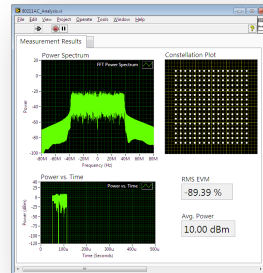


# National Instruments HW and SW

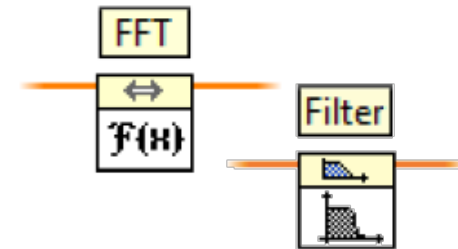
- NI LabVIEW Software
  - Graphical programming environment
  - Instrument control
  - Signal processing algorithms
  - Visualization and graphing
- NI PXI Hardware
  - PC-based instruments
  - RF signal generators and analysers



Instrument Control



Visualization & Display



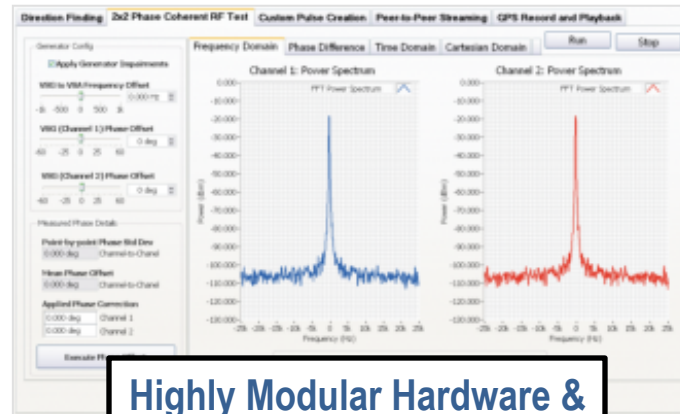
Signal Processing

# NI RF & Microwave Test Platform

## Optimized APIs

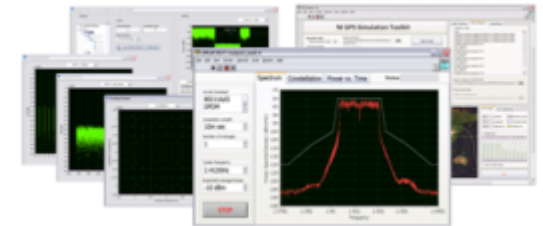


## Soft Front Panels

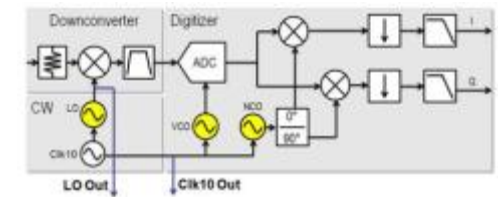


## Cellular, Wireless, and GPS Test Toolkits

(802.11 a/b/g/n , GSM/EDGE, WCDMA, LTE, WiMAX, GPS, etc.)



## Reference Architectures



**Multicore Processing**



**RF Signal Generators & Analyzers**



**FPGA I/O and Coprocessing**



**RF Vector Network Analyzer**

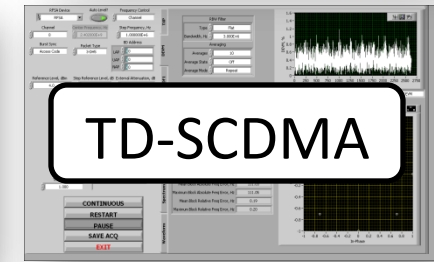
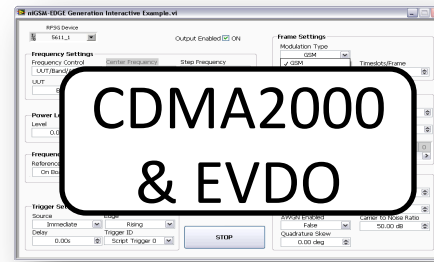
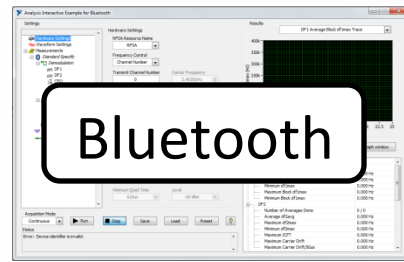
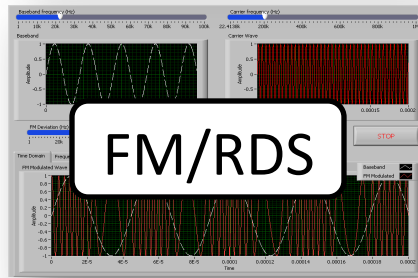
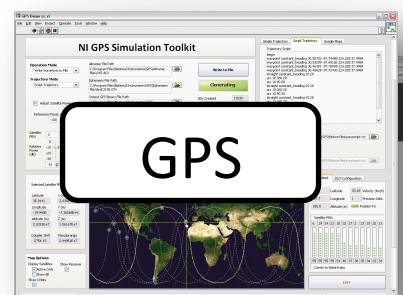
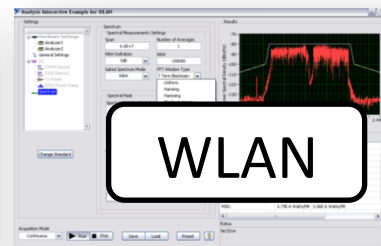
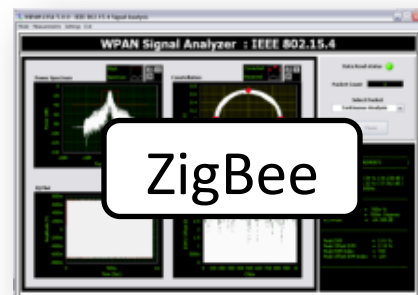
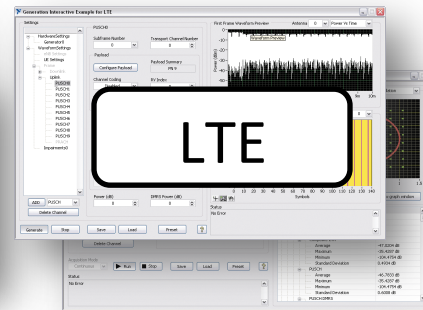
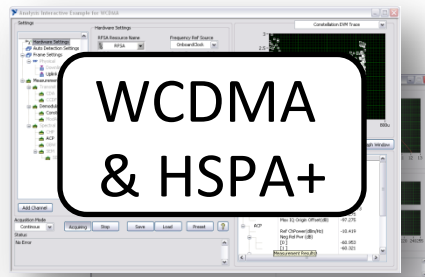


**Switching, Amplifiers, Attenuators**



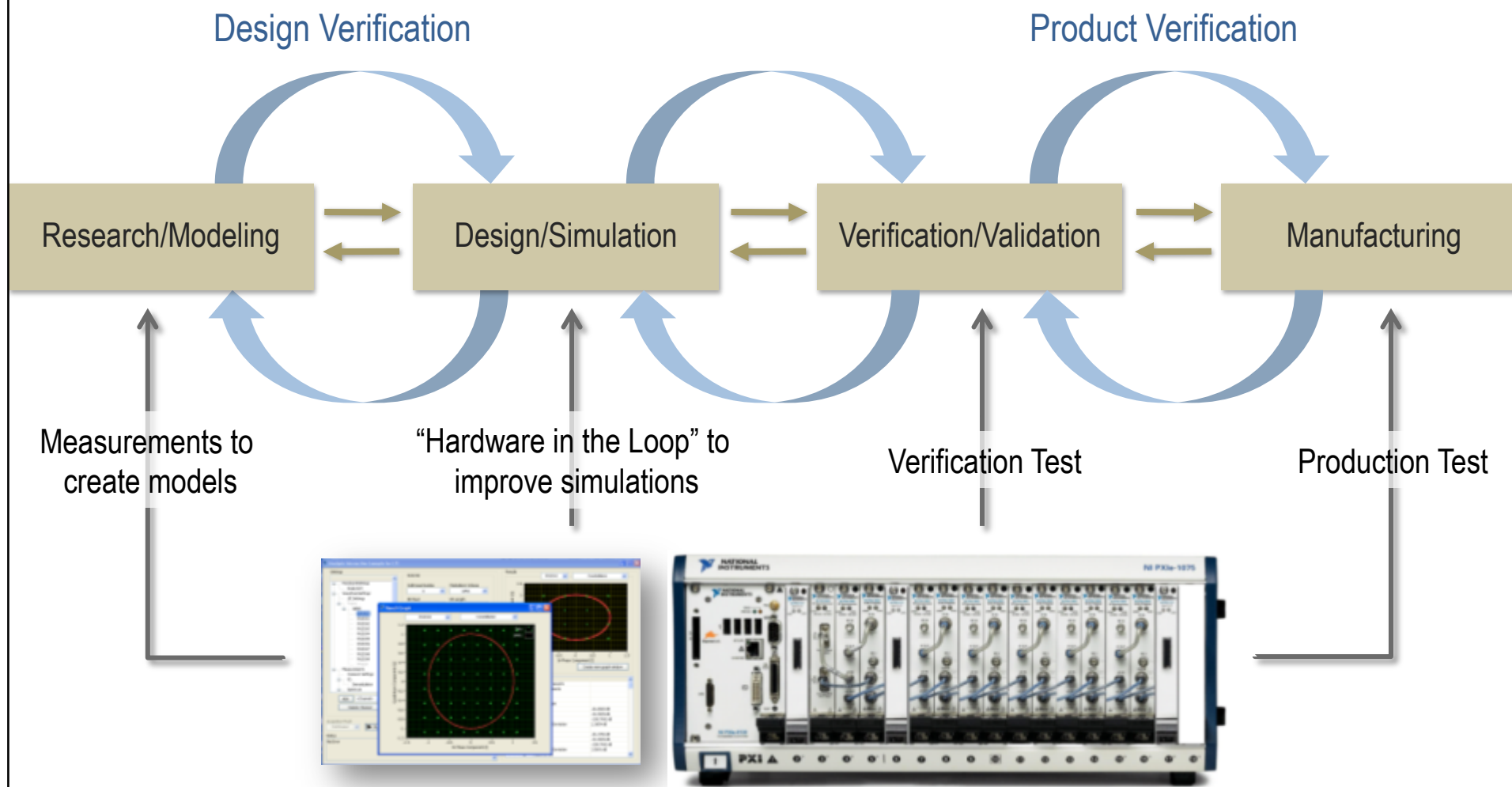
**Power Meters**

# NI Platform for Software-Defined RF Test

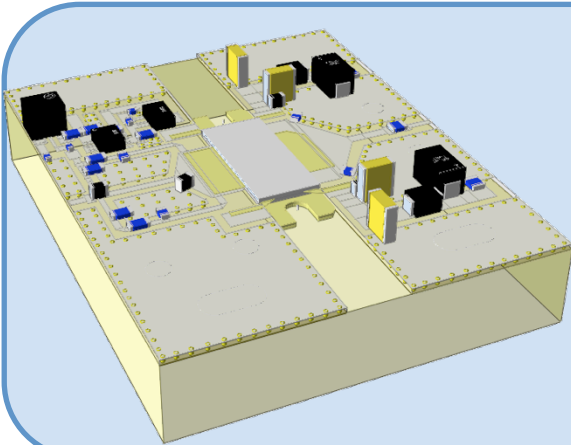




# Linking Design and Test

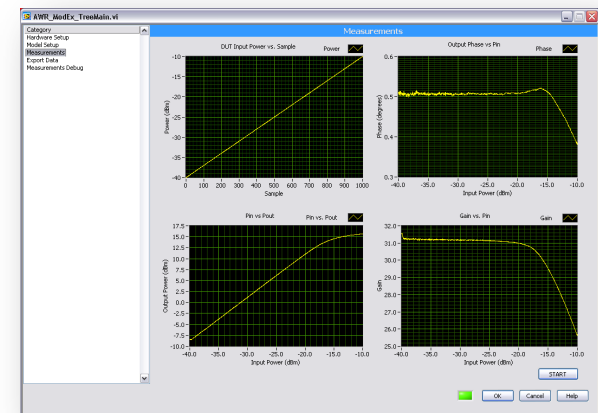


# Linking Design and Test: Agenda



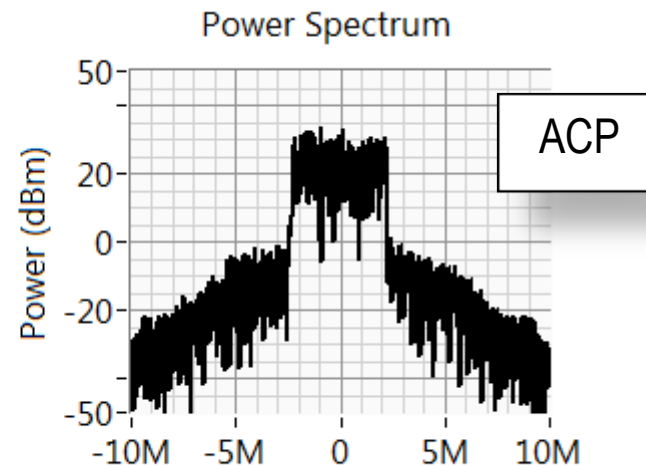
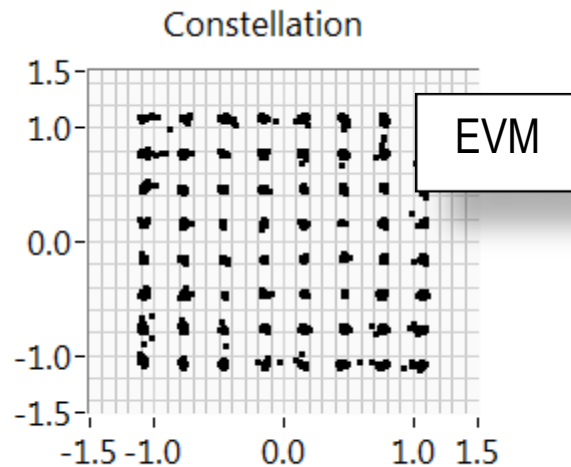
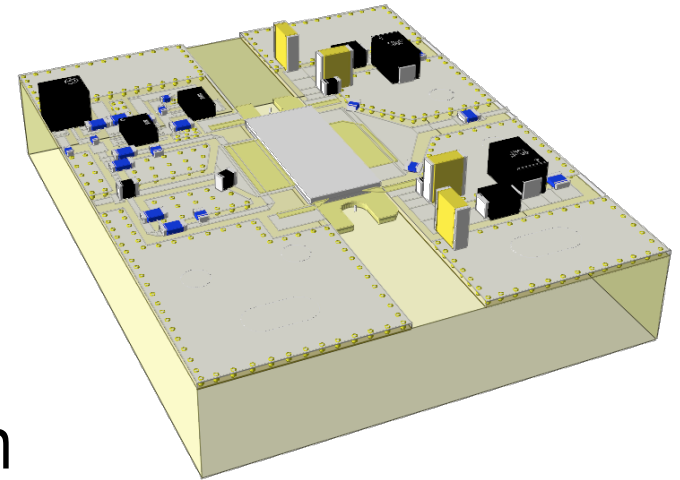
Correlating simulation with measurements  
Using LabVIEW signal processing in VSS

Extracting device models with instrumentation



# LTE Base Station PA in VSS

- Infineon amplifier characteristics
  - Designed in Microwave Office
  - Up to 250W output power
  - LTE Measurements: EVM and ACP
- Can be tested through HIL simulation

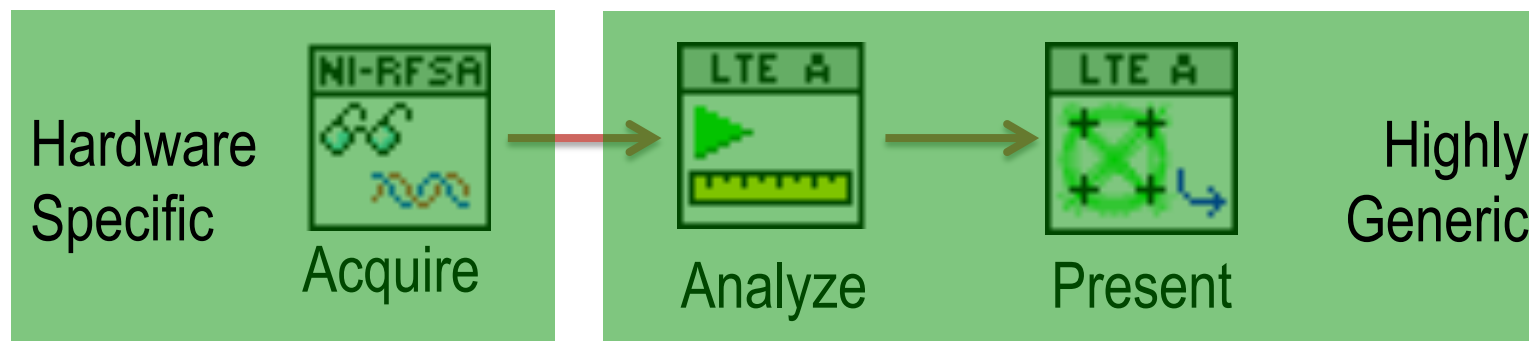


# How PXI RF Signal Analyzer's Work

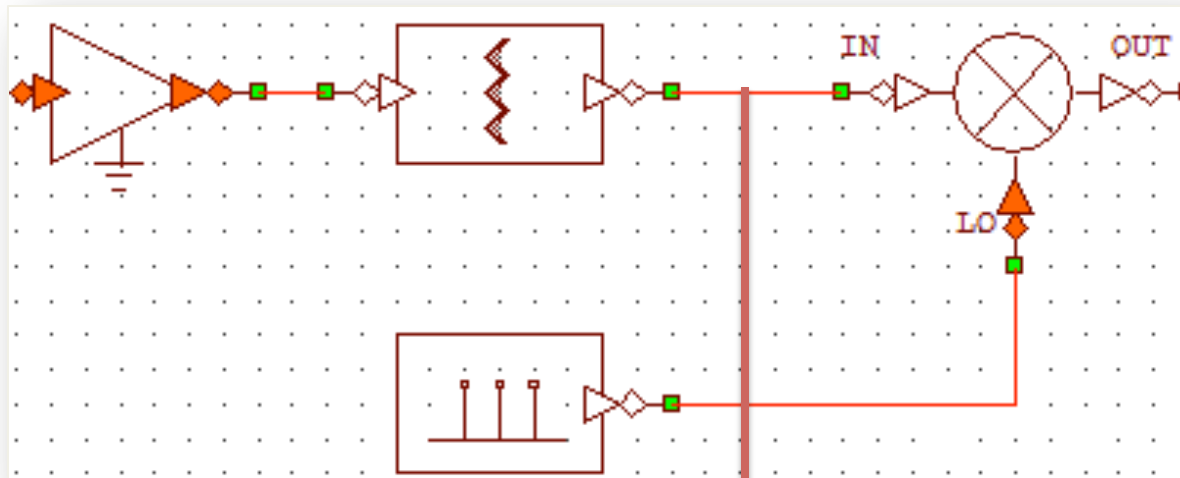


Hardware View

Software View



# Connecting LabVIEW to AWR VSS



VSS Time Domain  
Simulation

Design Software

Test Software

Using LabVIEW LTE  
Analysis Algorithms



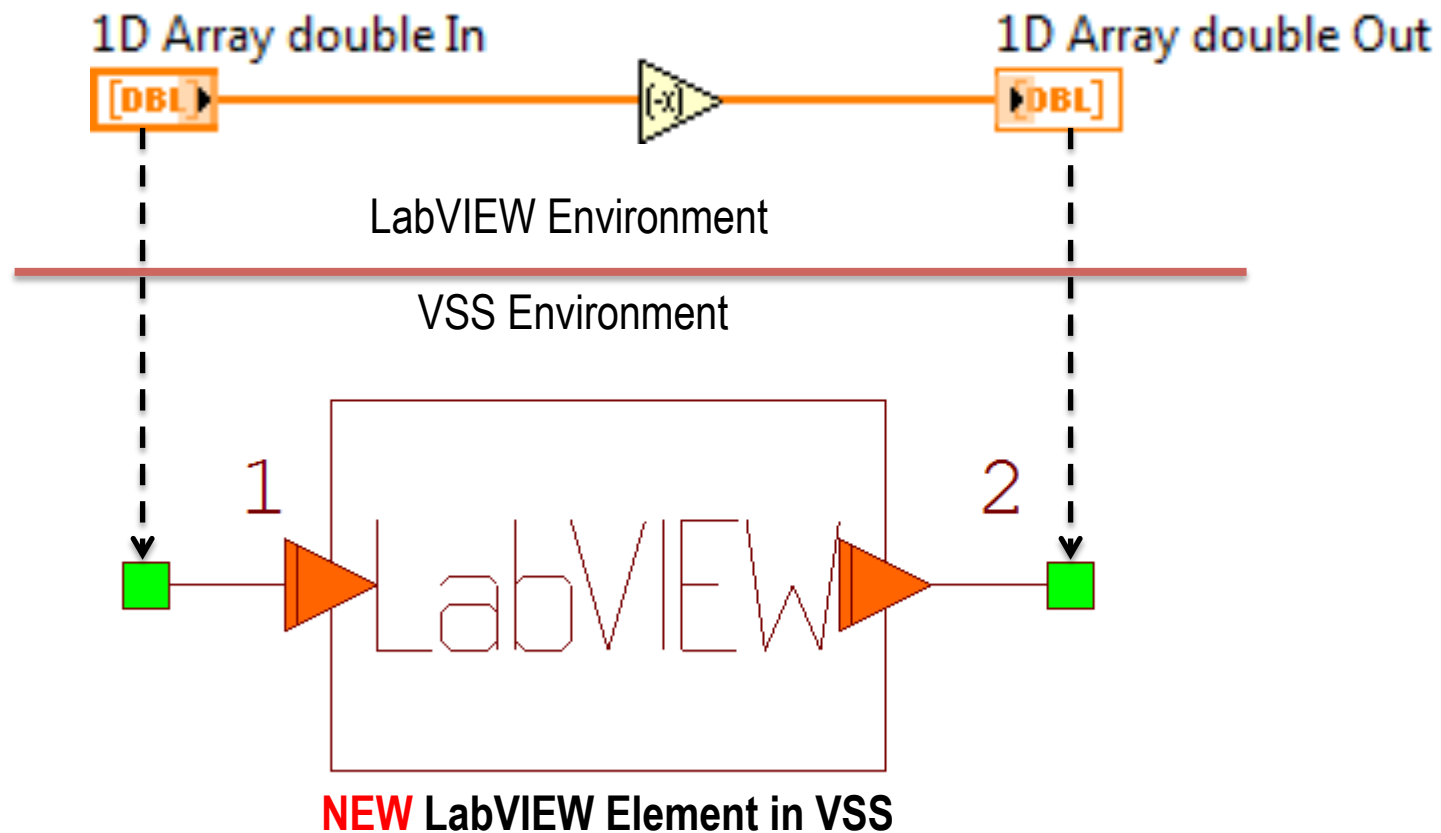
Analyze



Present

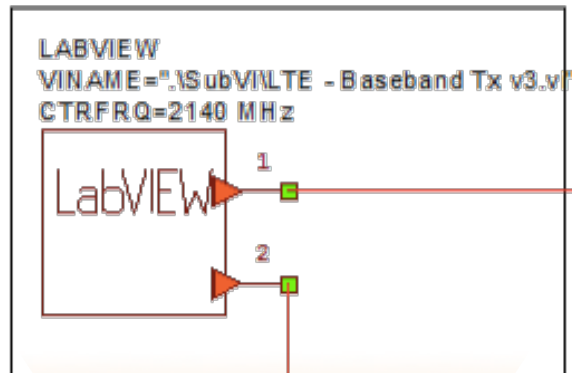


# Connecting LabVIEW and VSS diagrams

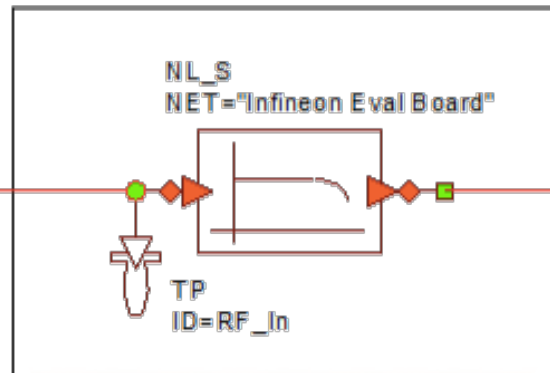


# Testing a VSS Model with LabVIEW

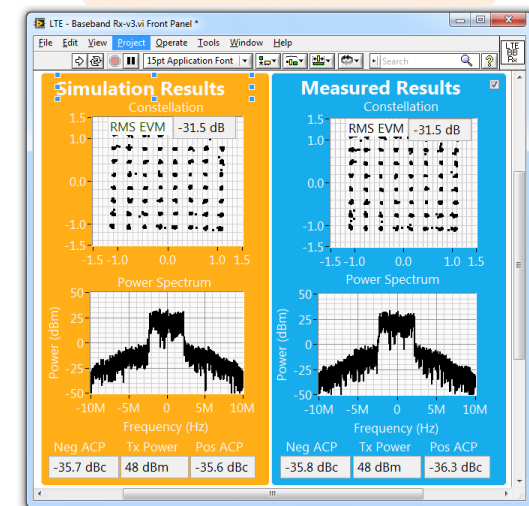
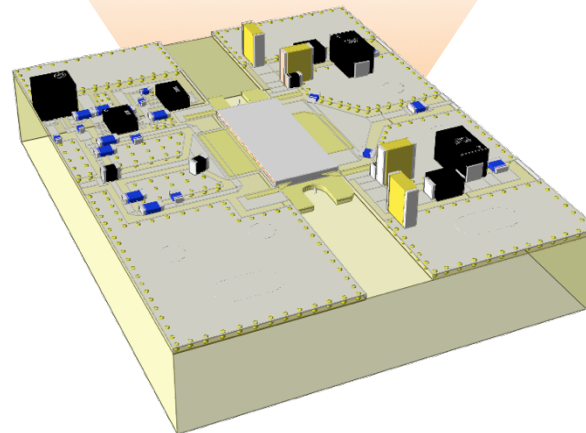
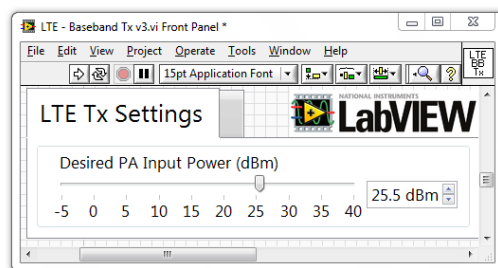
## LTE Baseband Generation



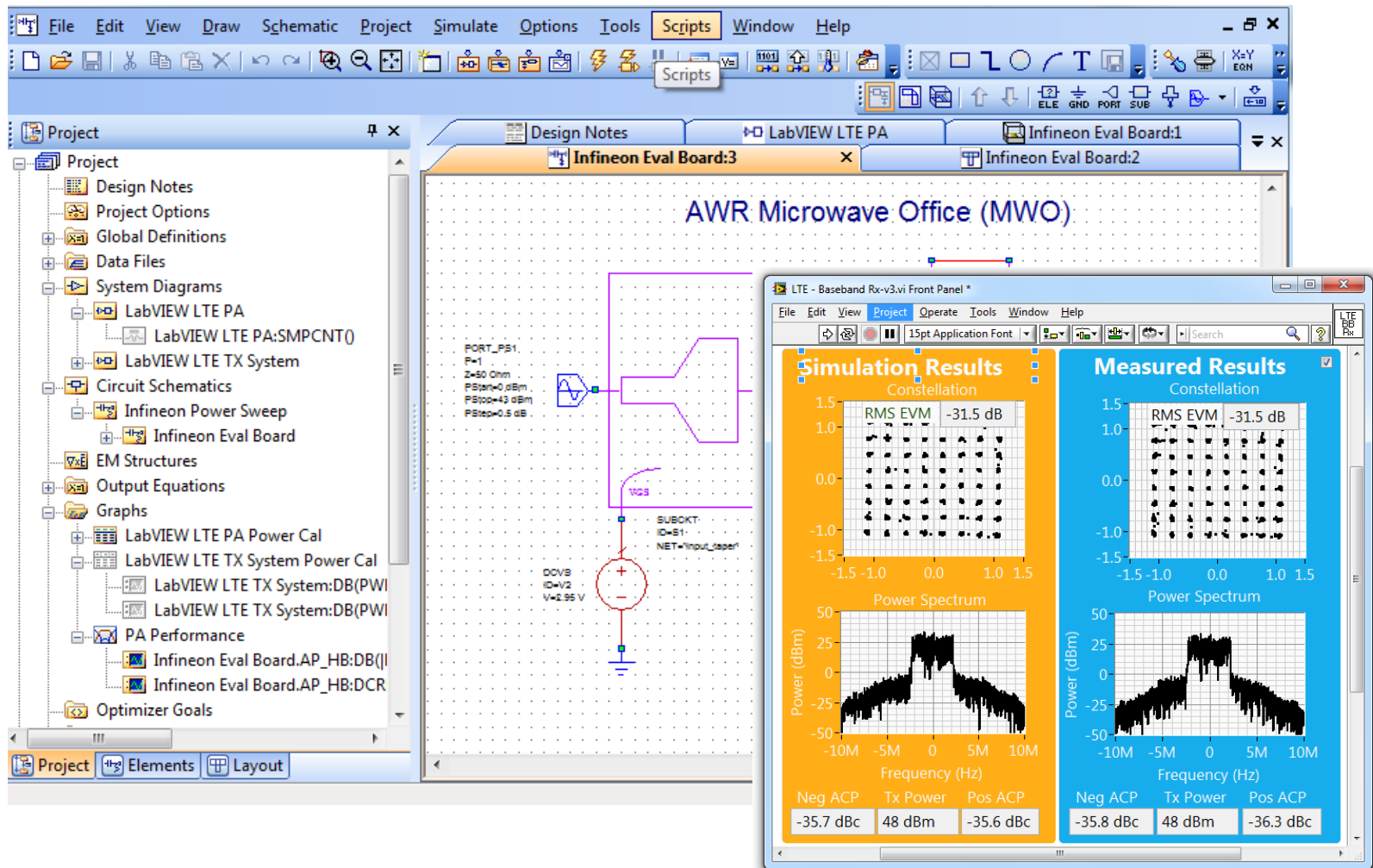
## Infinion PA Behavioral Model



## LTE Baseband Analysis



# LTE PA Measurement Demo

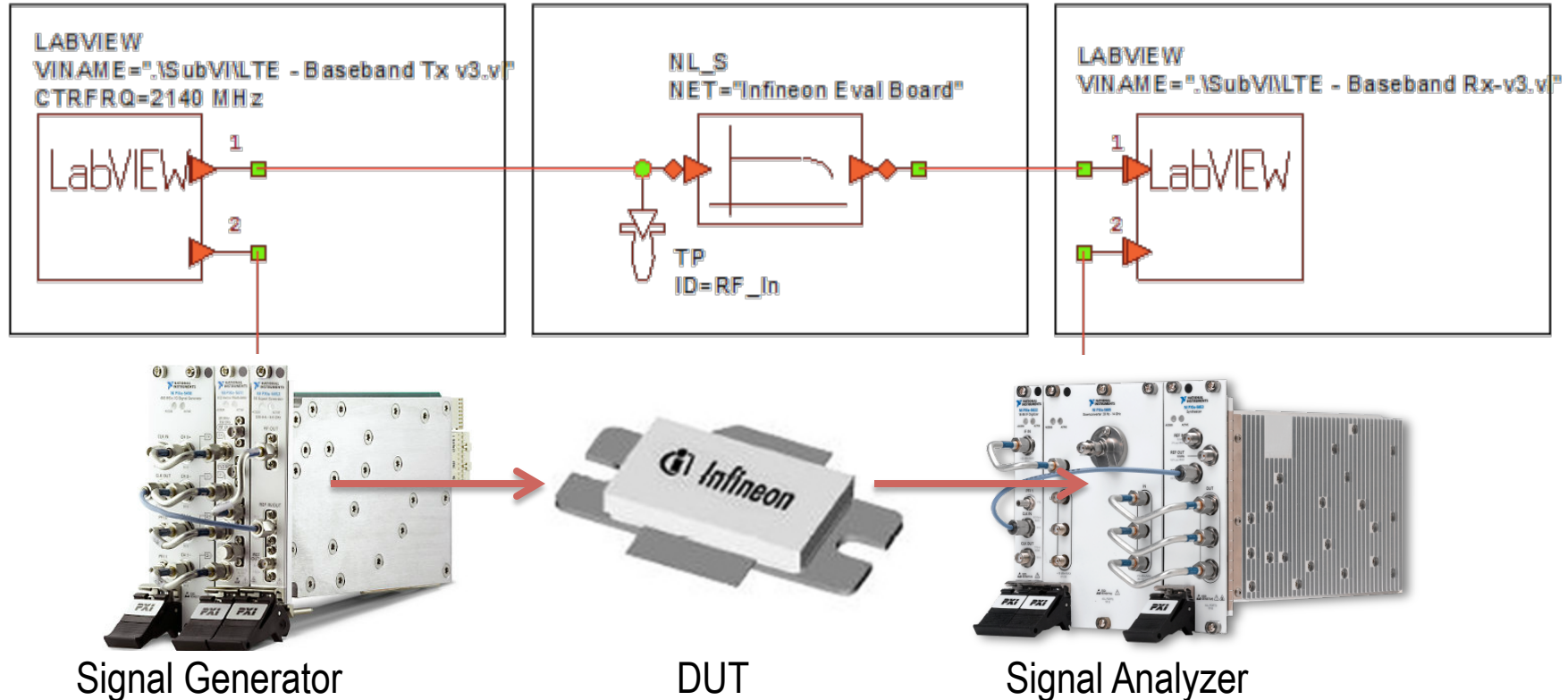


# Hardware in the Loop

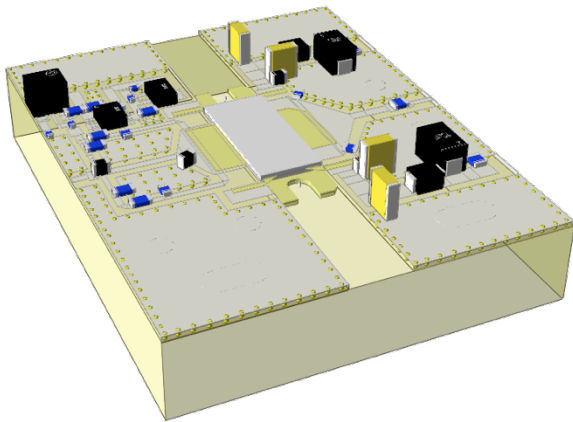
LTE Baseband Generation

Infineon PA Behavioral Model

LTE Baseband Analysis

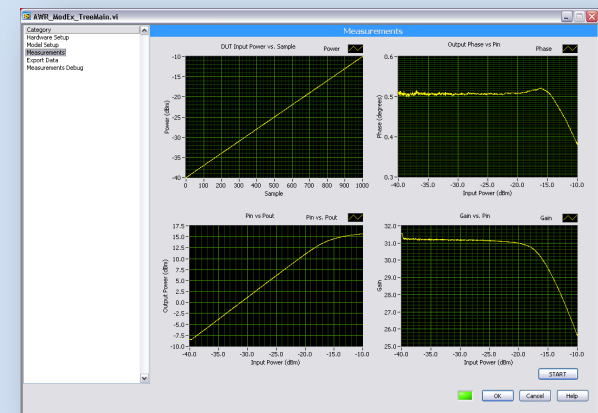


# Linking Design and Test: Agenda



Correlating simulation with measurements  
Using LabVIEW signal processing in VSS

Extracting device models with instrumentation





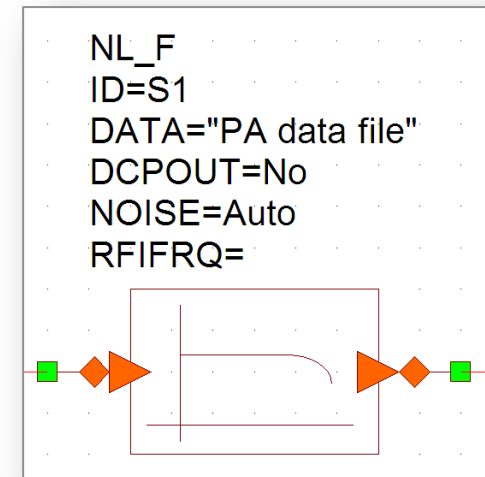
# What is Model Extraction...

## ...and Why Use it?

- Model extraction is the idea of using **measured** data in conjunction with mathematical models to simulate circuit performance in a simulation environment
- Imagine...
  - You buy an RF amplifier from [www.mini-circuits.com](http://www.mini-circuits.com)
  - The spec sheet...
    - Tells you...P1DB, IP3, and 3<sup>rd</sup> harmonic
    - But doesn't tell you...AM-AM, or AM-PM
    - ...And doesn't give you a model to plug into VSS

# System Modeling in VSS

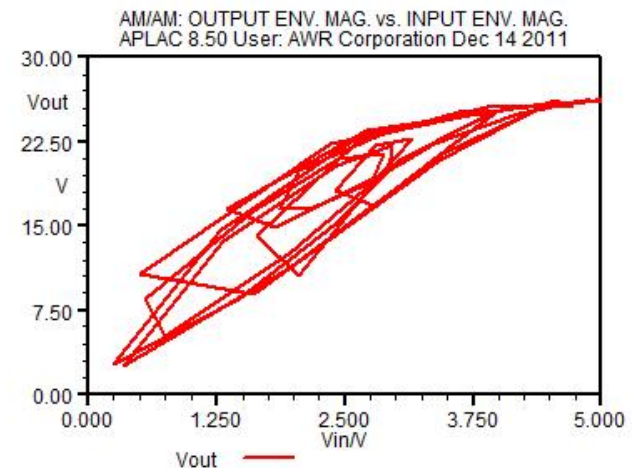
- NL\_F
  - Constructed with CW signals
  - Derived from measurements such as
    - AM-AM
    - AM-PM
    - Harmonics
    - DC noise level
    - $S_{11}$  and  $S_{22}$
- Time-delay Neural Networks
  - Constructed with modulated signals
  - Capture memory affects



# Modeling Effects

## ■ Linear Memory

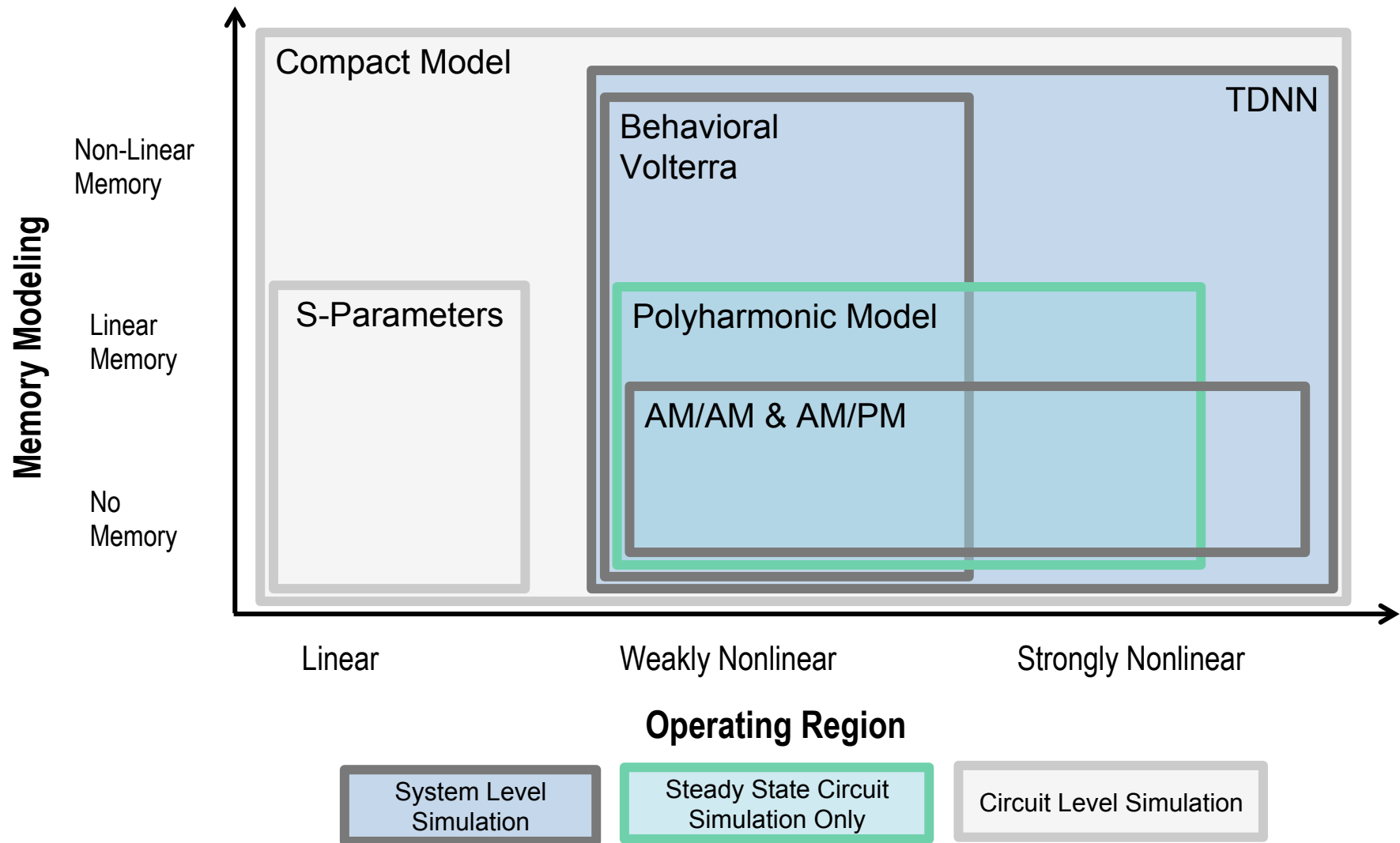
- Frequency dependant behavior
- Caused by linear capacitances and inductances



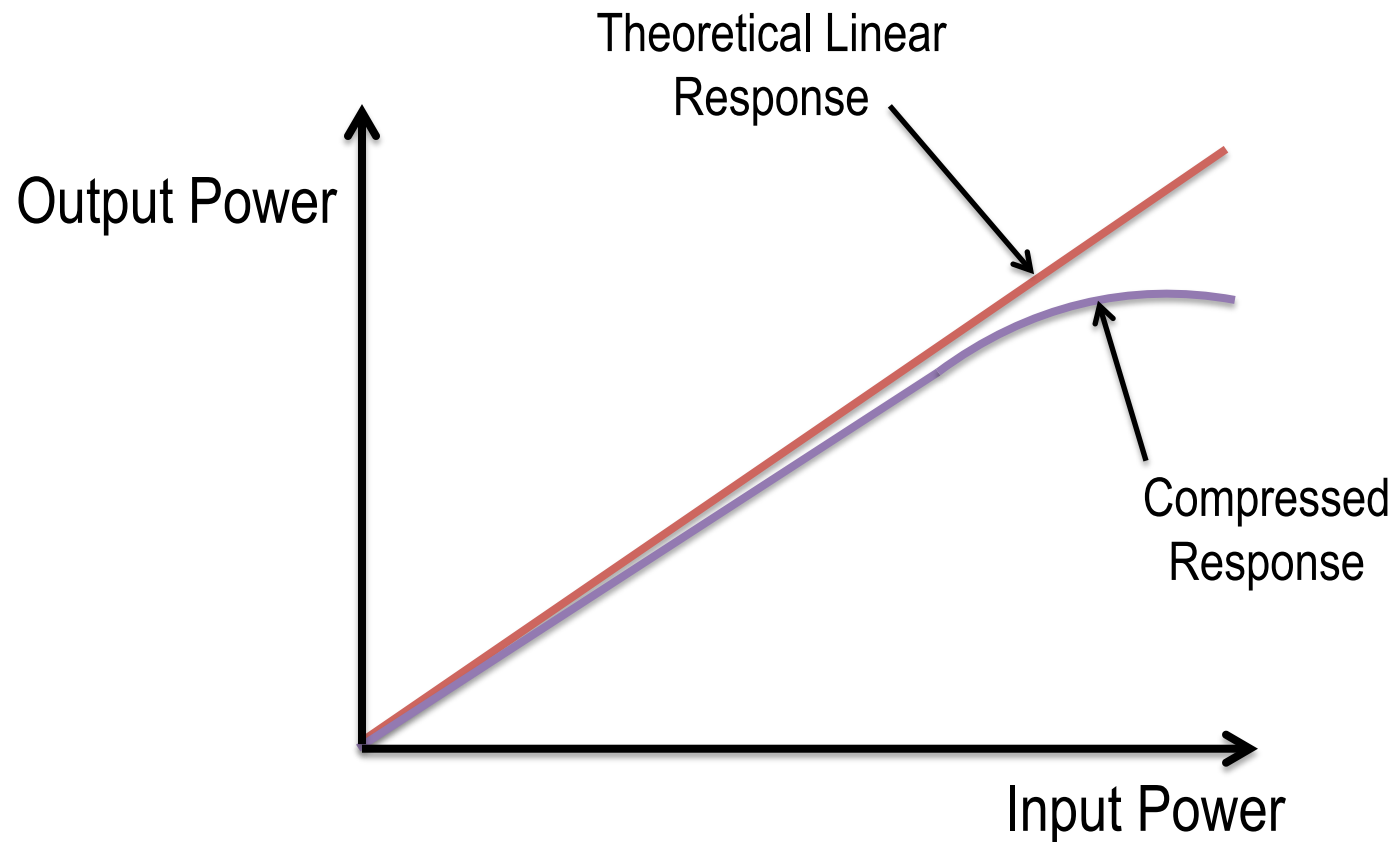
## ■ Nonlinear Memory

- Previous operating condition dependant behavior (e.g. Hysteresis)
- Caused by interaction of low frequency mixing products with bias circuitry, self heating effects, trapping, etc.

# Model Types

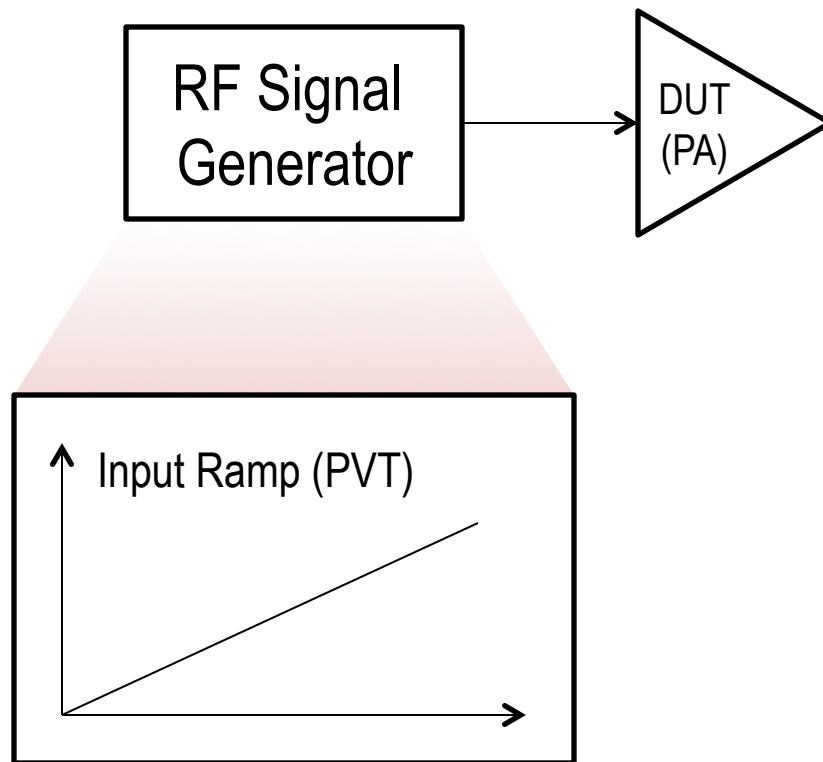


# AM-AM Through a Power Amplifier



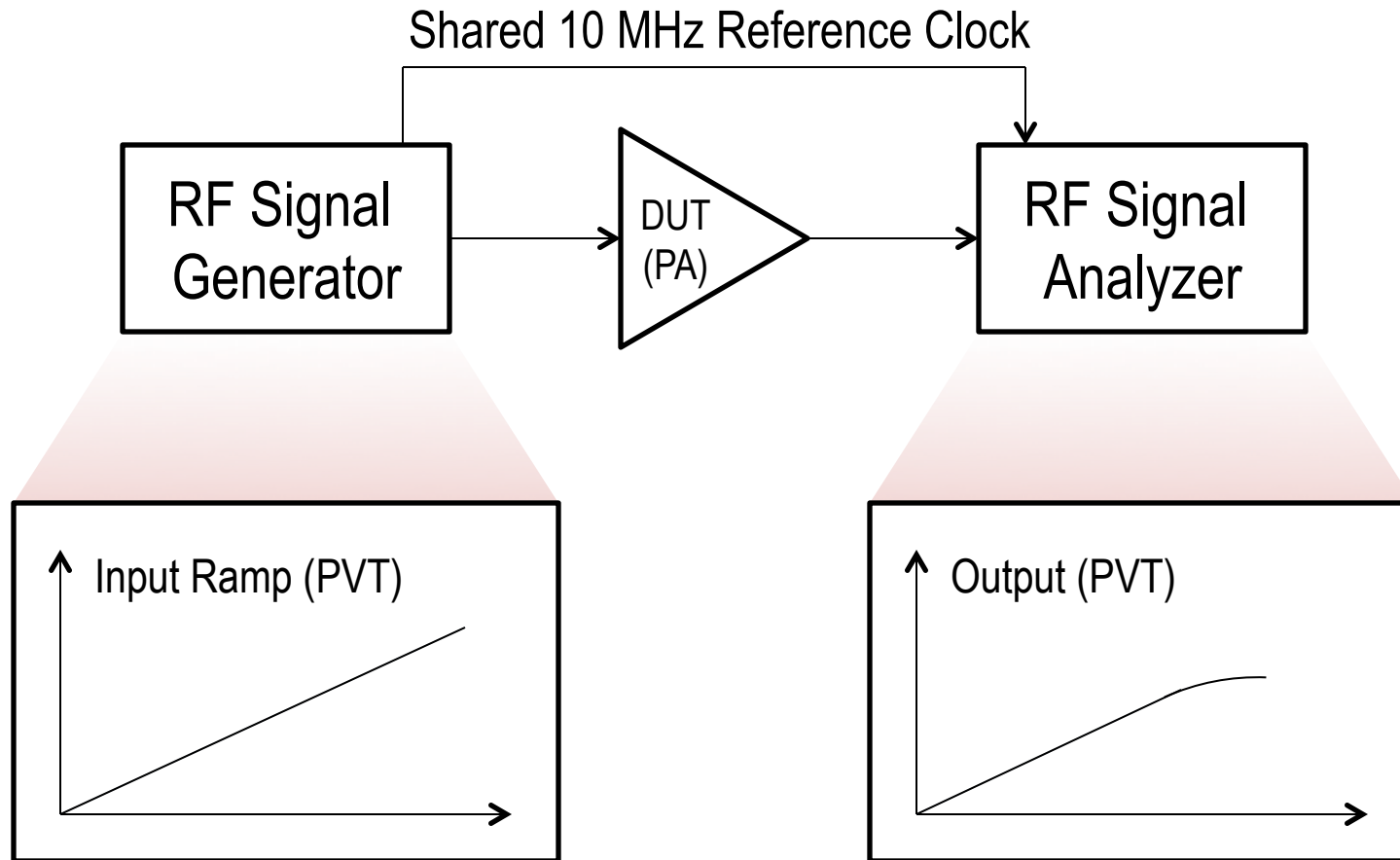


# Measuring AM-AM and AM-PM



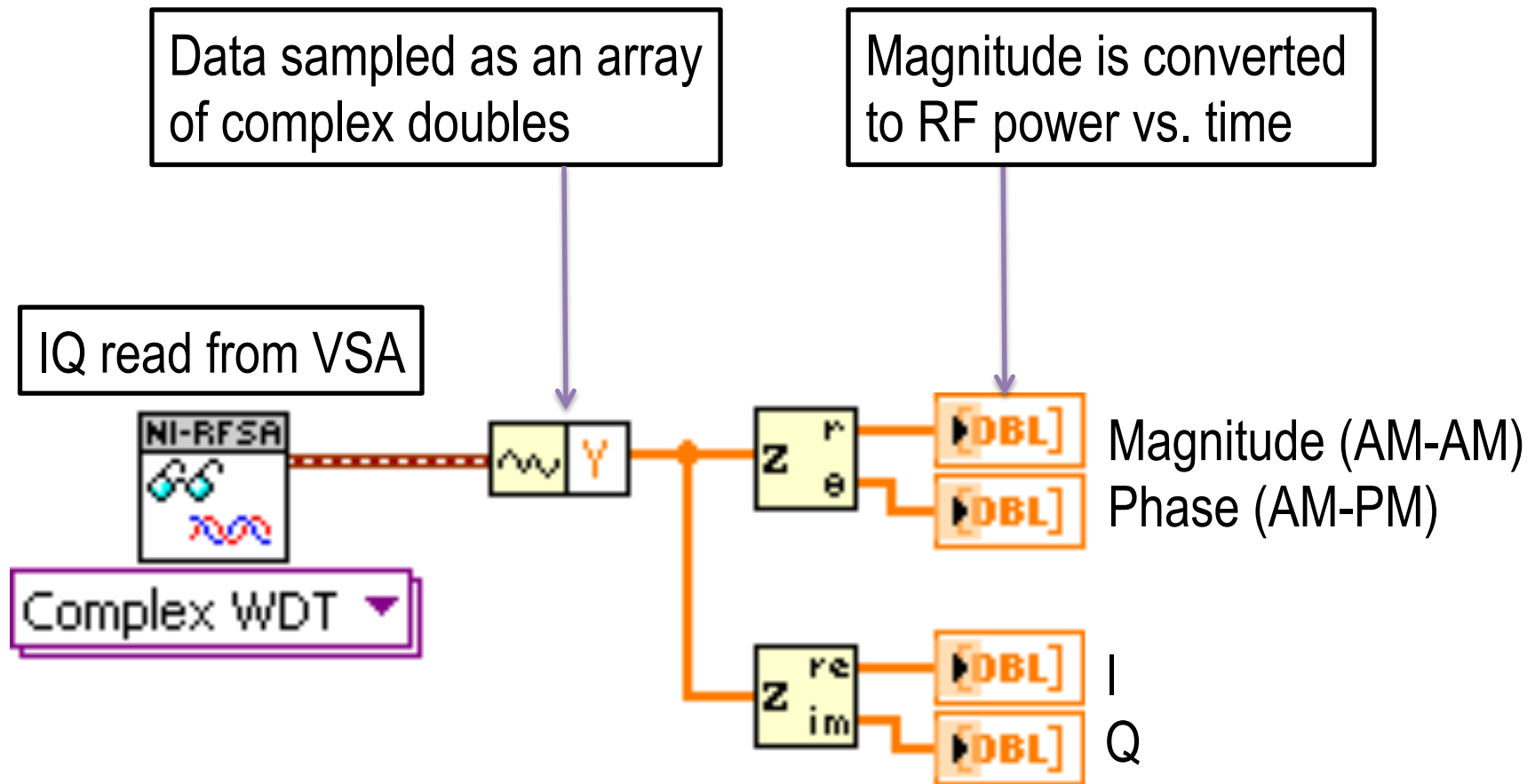
- Signal stimulus
  - IQ waveform is a “ramped CW” signal
  - Linear phase vs. time
- Required measurements
  - Power vs. time
  - Phase vs. time

# Measuring AM-AM and AM-PM

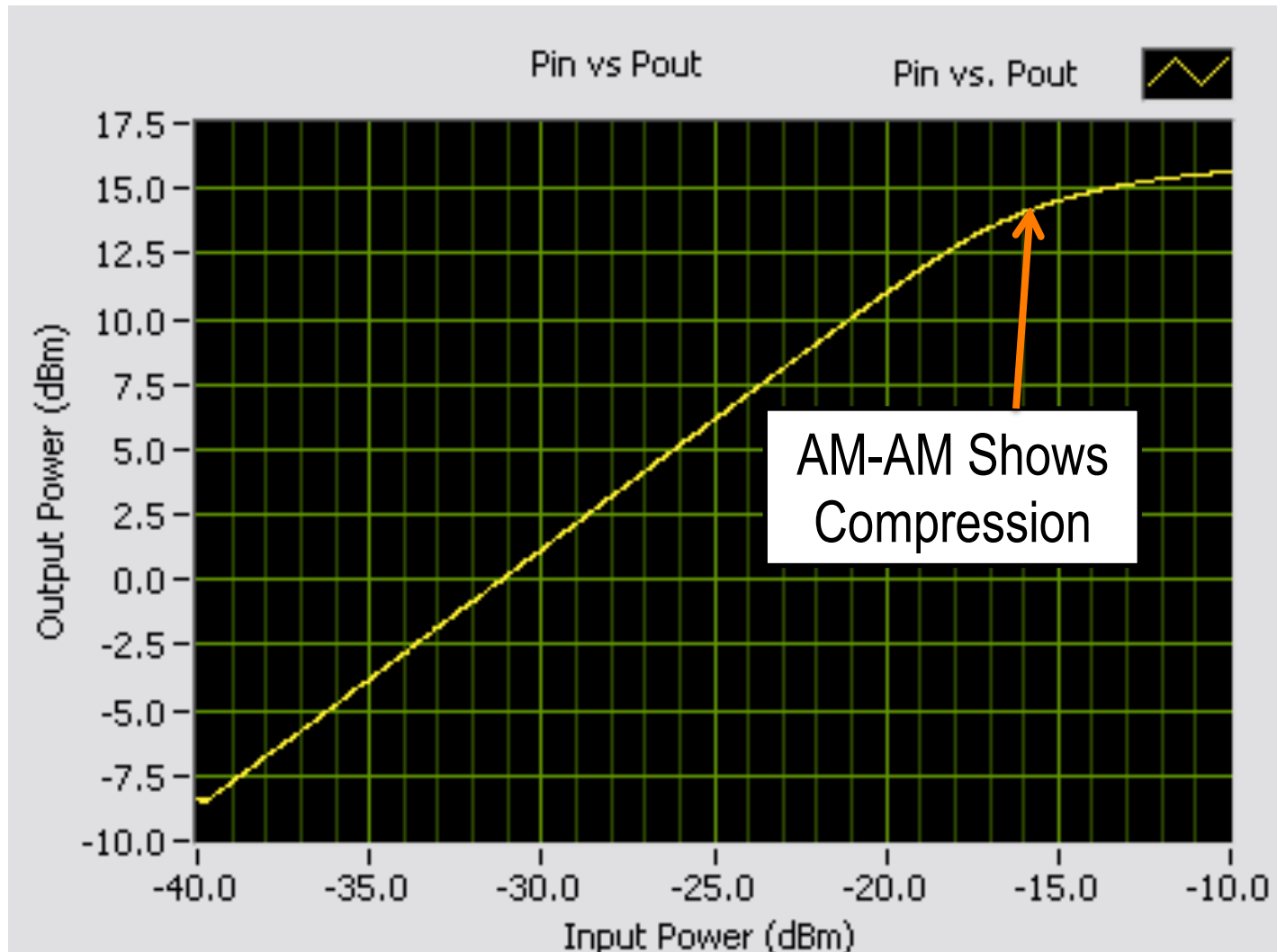


*Note: 10 MHz Reference preserves phase between VSG and VSA*

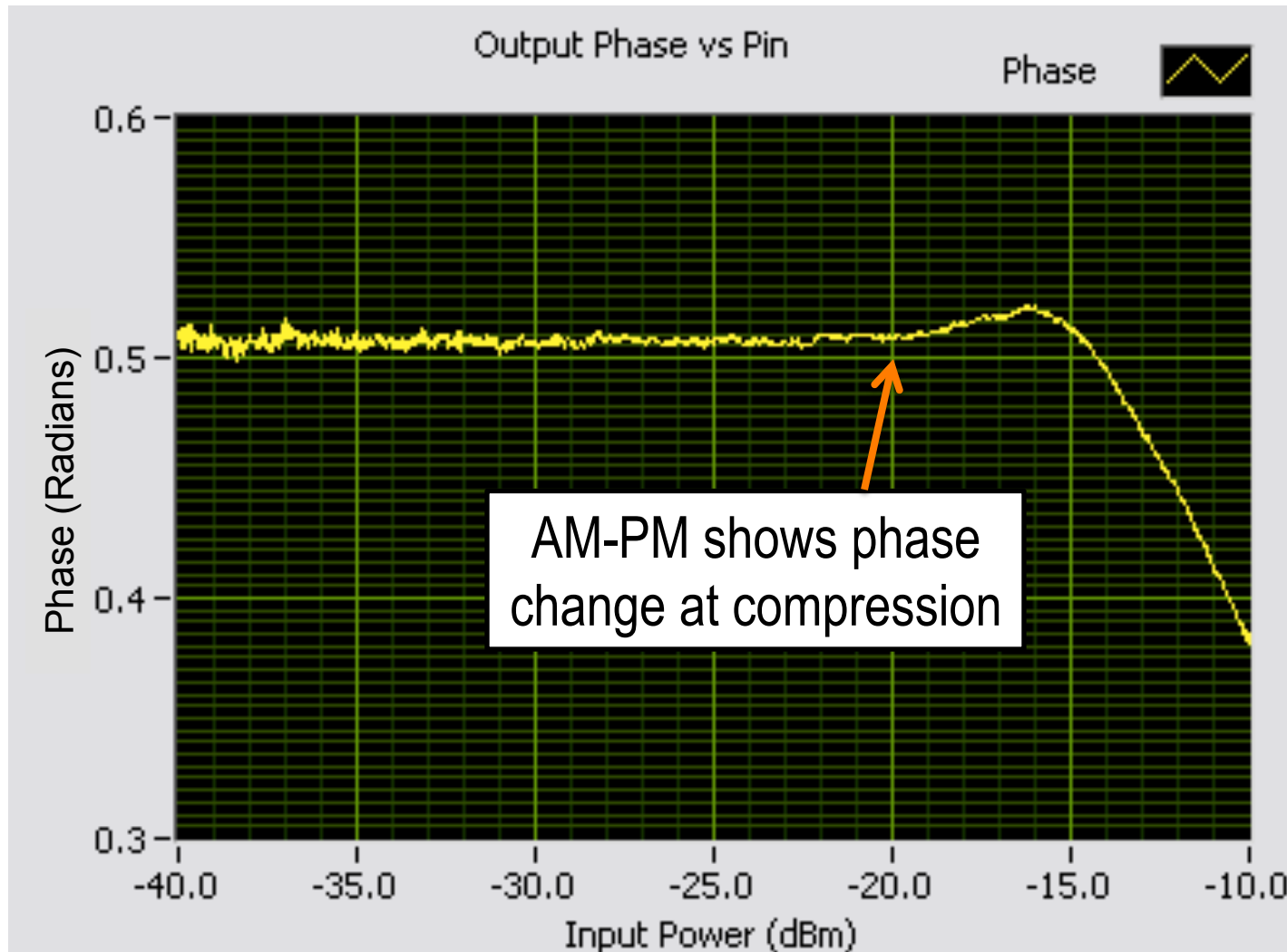
# Looking at the IQ in LabVIEW



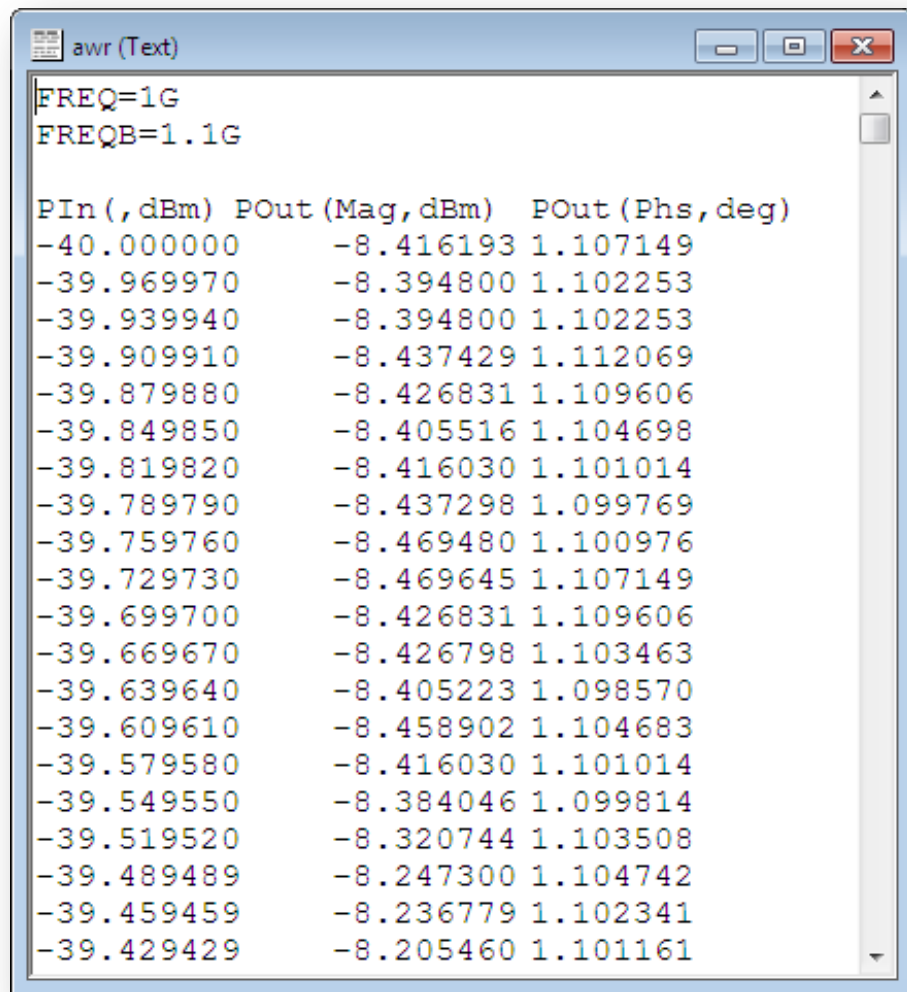
# AM-AM Measurement



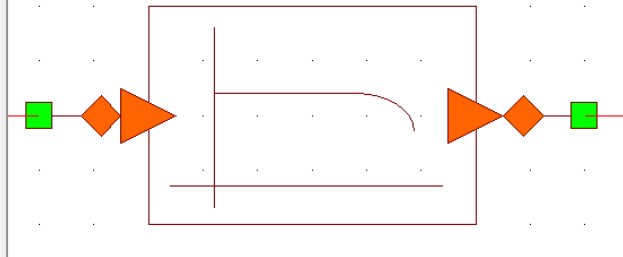
# AM-PM Measurement



# Using Models in VSS

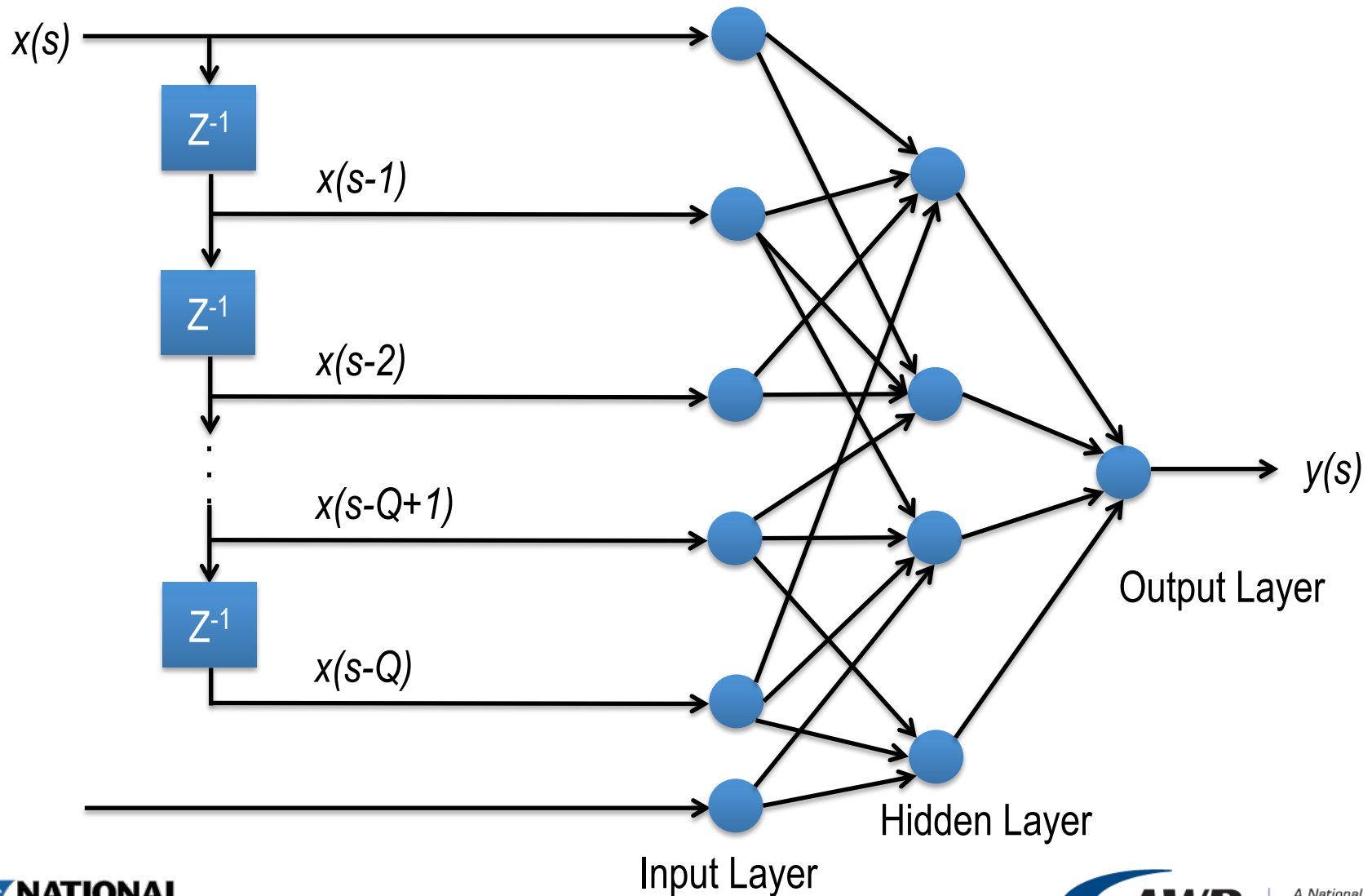


NL\_F  
ID=S1  
DATA="PA data file"  
DCPOUT=No  
NOISE=Auto  
RFIFRQ=





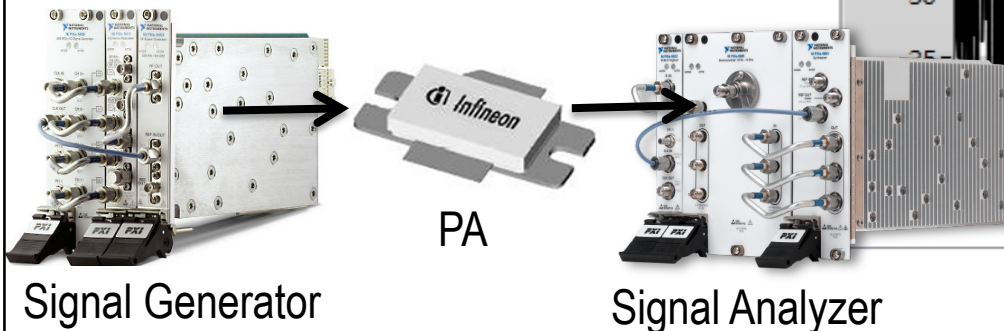
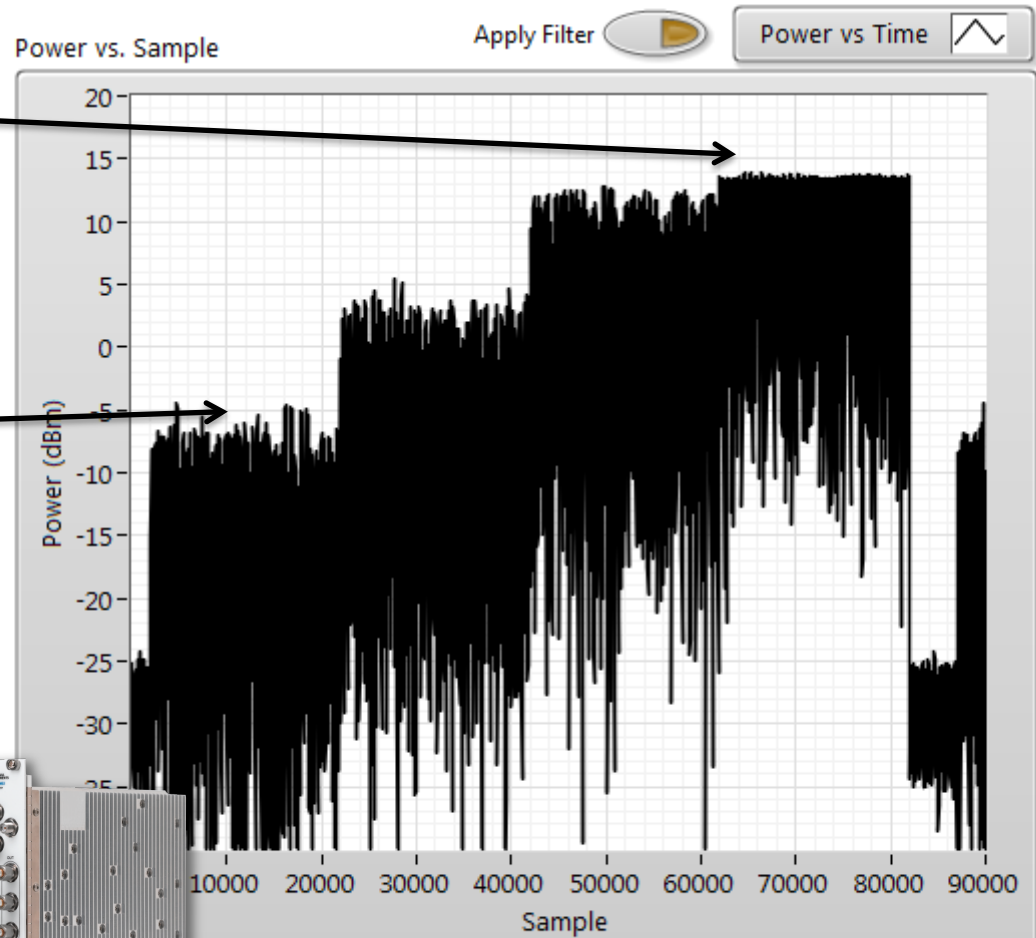
# Time-Delay Neural Networks (TDNN)



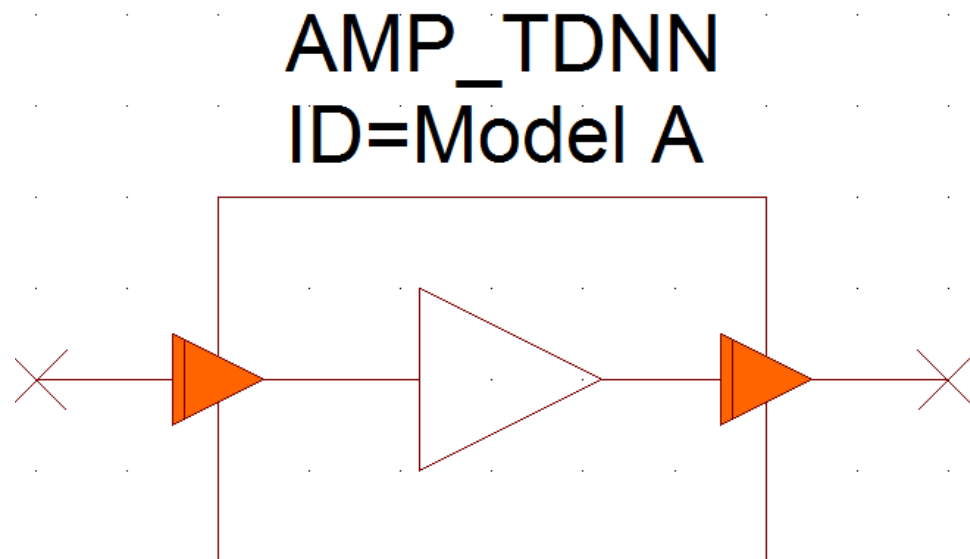
# Acquiring Data for a TDNN Model

PA saturation observed at higher power levels

A “Stepped” WCDMA waveform produces wide ranges of signal power



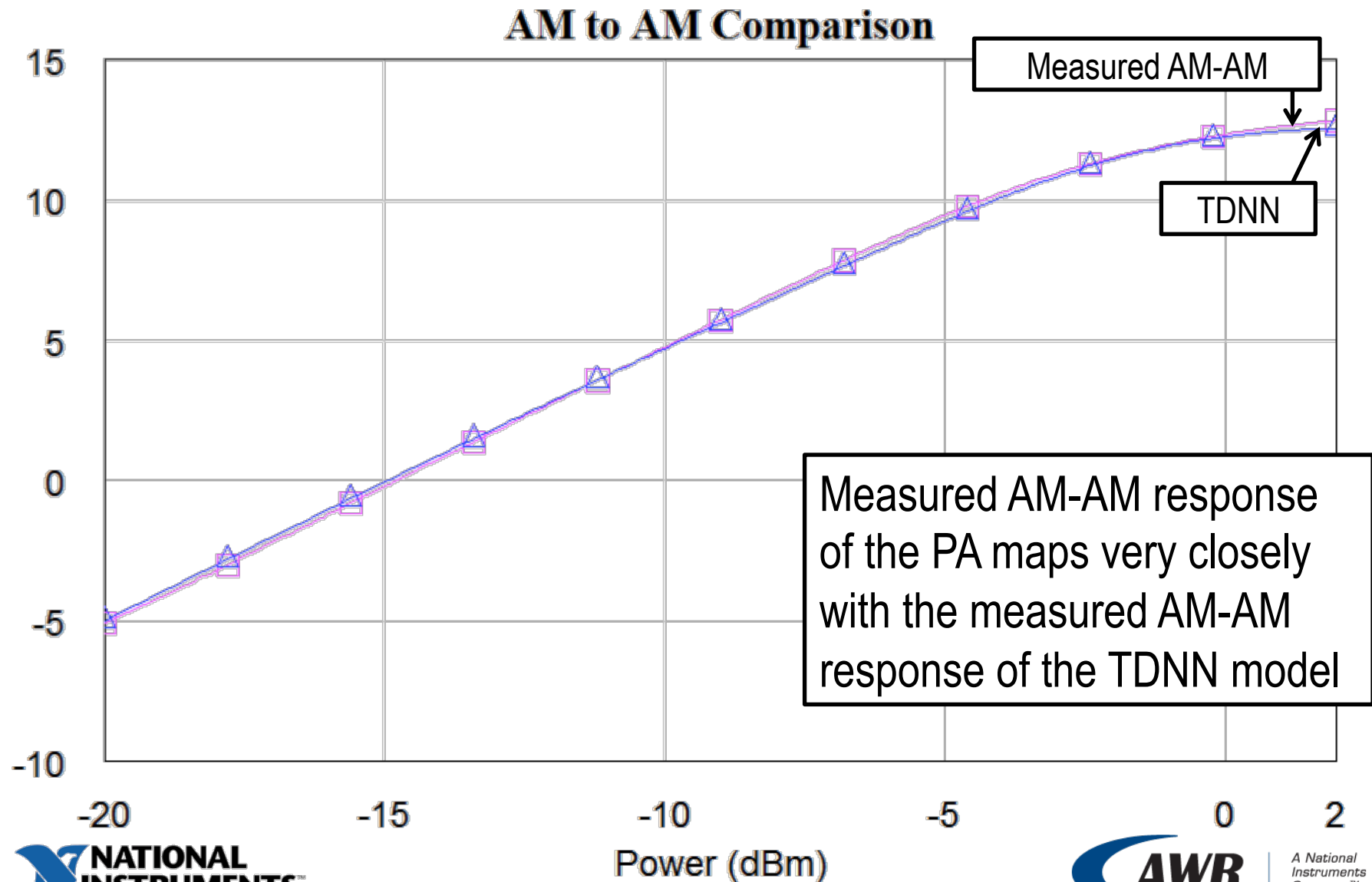
# Building a TDNN Model in VSS



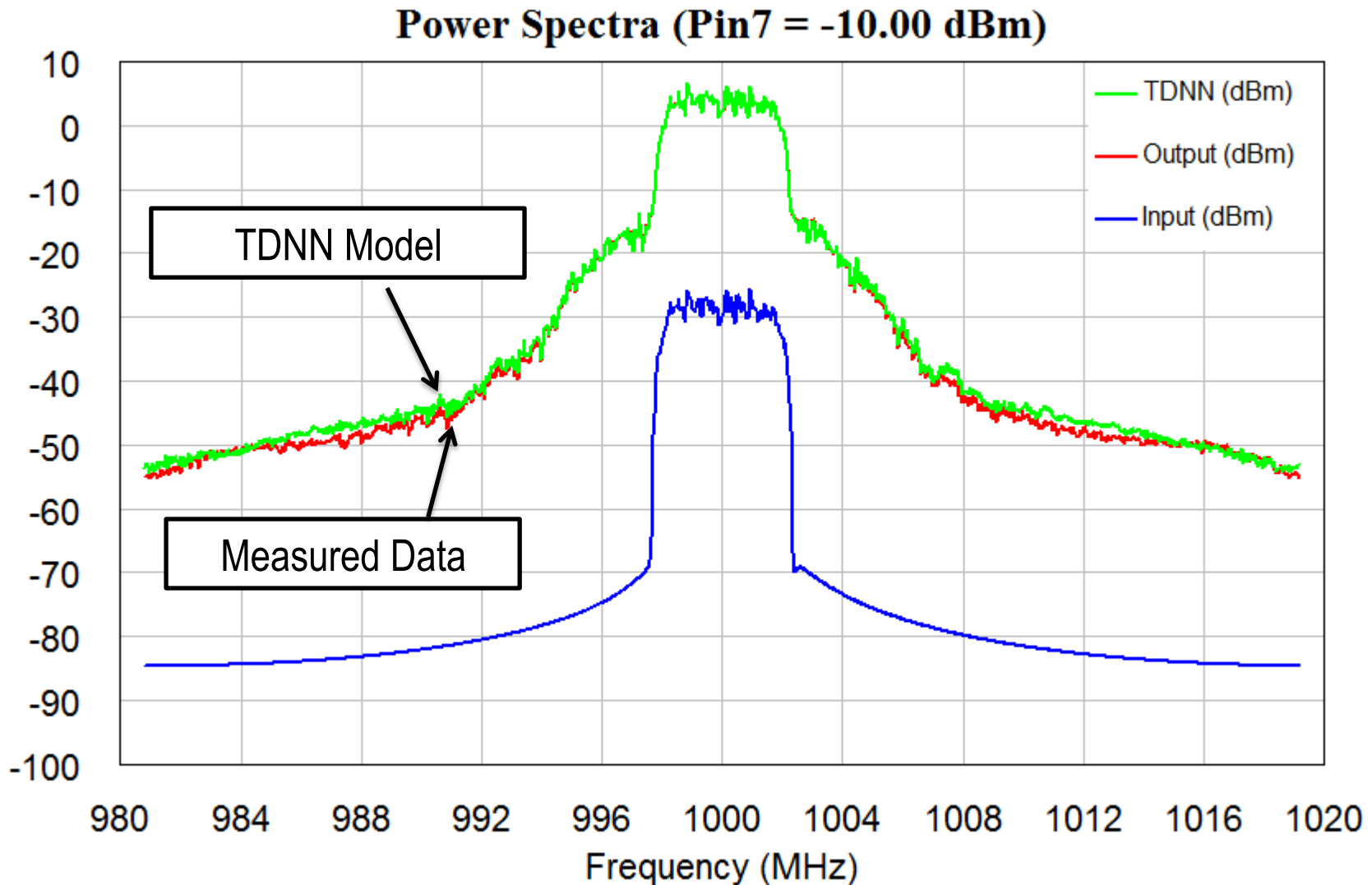
# Validating TDNN Model Accuracy

- AM-AM Measurements
  - In theory, the measured AM-AM response of the amplifier should match the AM-AM response of the TDNN model
- Spectrum profile
  - In theory, the measured spectrum of the amplifier should match the spectrum generated with a TDNN model
- Modulation quality
  - In theory, non-linear characteristics of the TDNN model should match the measured behavior. EVM results should be similar.

# AM-AM of NL\_F and TDNN



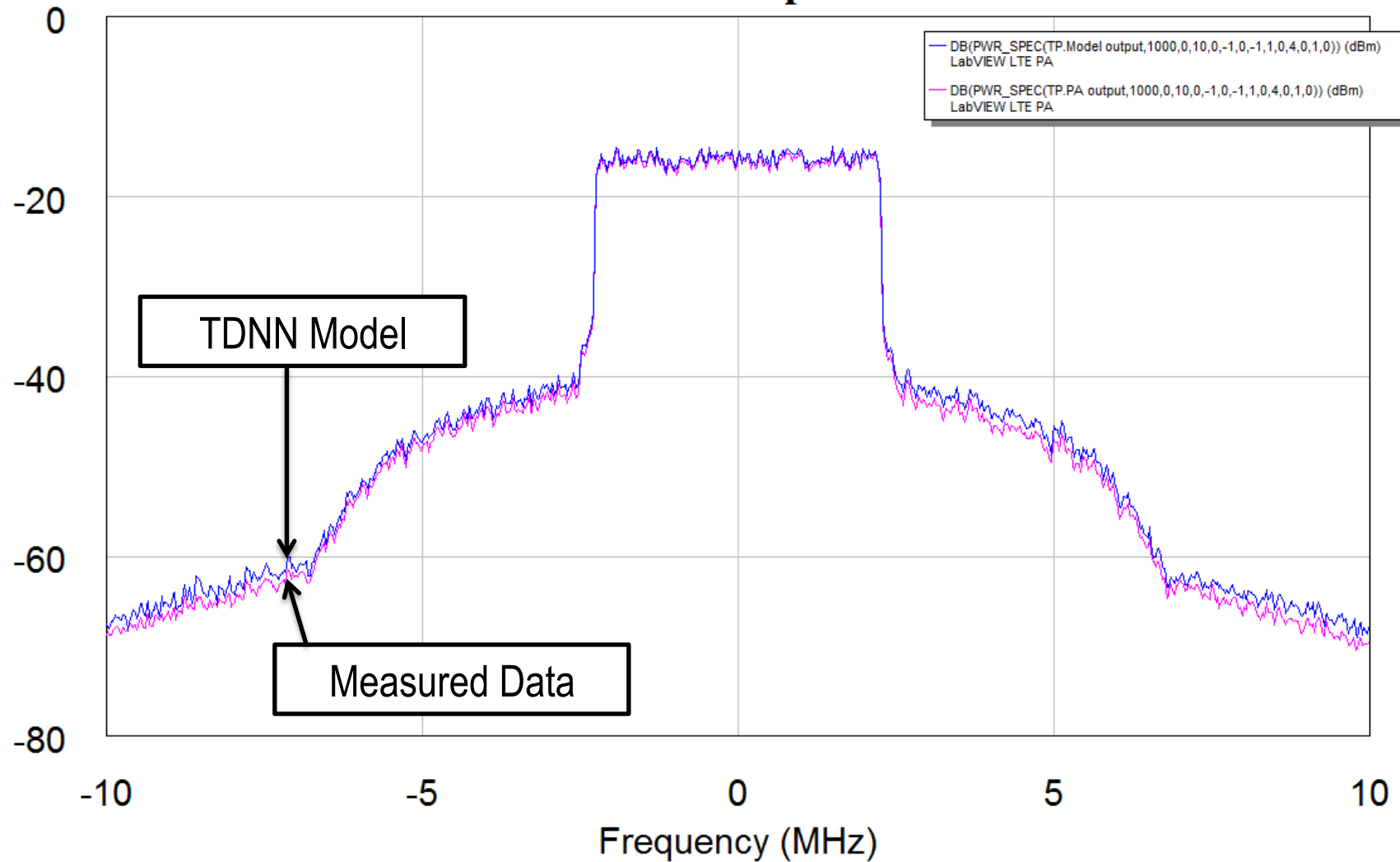
# Spectrum Profile - WCDMA



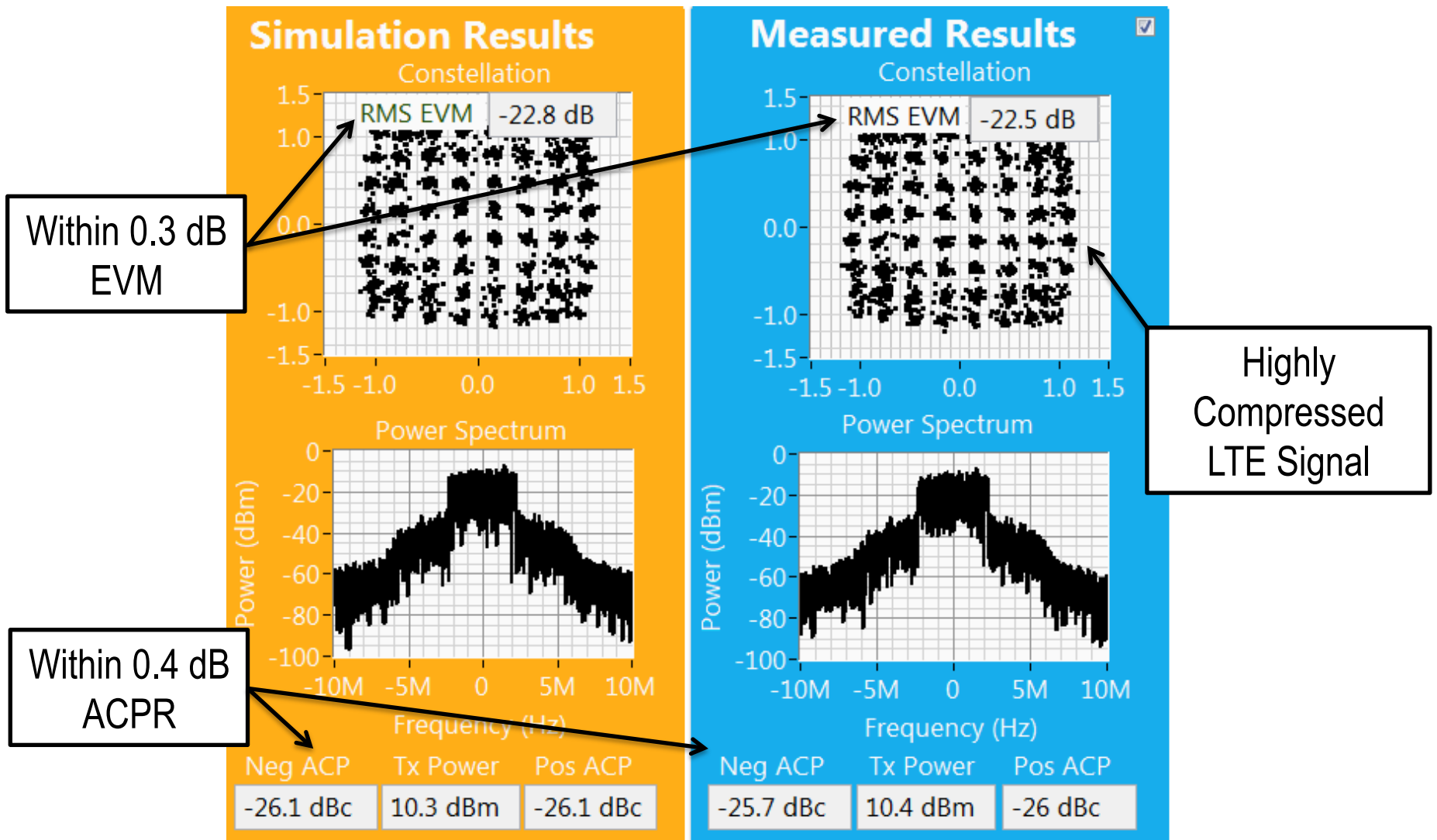


# Spectrum Profile - LTE

## LTE Power Spectrum



# EVM & ACP Comparison (LTE)



# Parting thoughts

- New LabVIEW + AWR connectivity enables use of instrumentation to improve simulation
- Example applications include
  - Correlating measurement with simulation
  - Hardware in the loop
  - Model extraction

