Agilent Technologies

Simulation & Design of Software-Defined Radios

November 28, 2007

presented by:

David Leiss and Greg Jue, Agilent Technologies

Agenda

SDRs: Overview, Challenges, and New Methodology

Evaluate an RF System with an FPGA based 16-QAM legacy Waveform

Evaluate System Performance with a new Commercial Off the Shelf (COTS) OFDMA Mobile WiMAX™ Waveform

Compare both Waveform's Susceptibility to RF Interference

FPGA Implementation and Test of an OFMDA Mobile WiMAX Waveform

"WiMAX" is a trademark of the WiMAX Forum

What Is a Software-Defined Radio?

Lots of definitions, but some key trends:

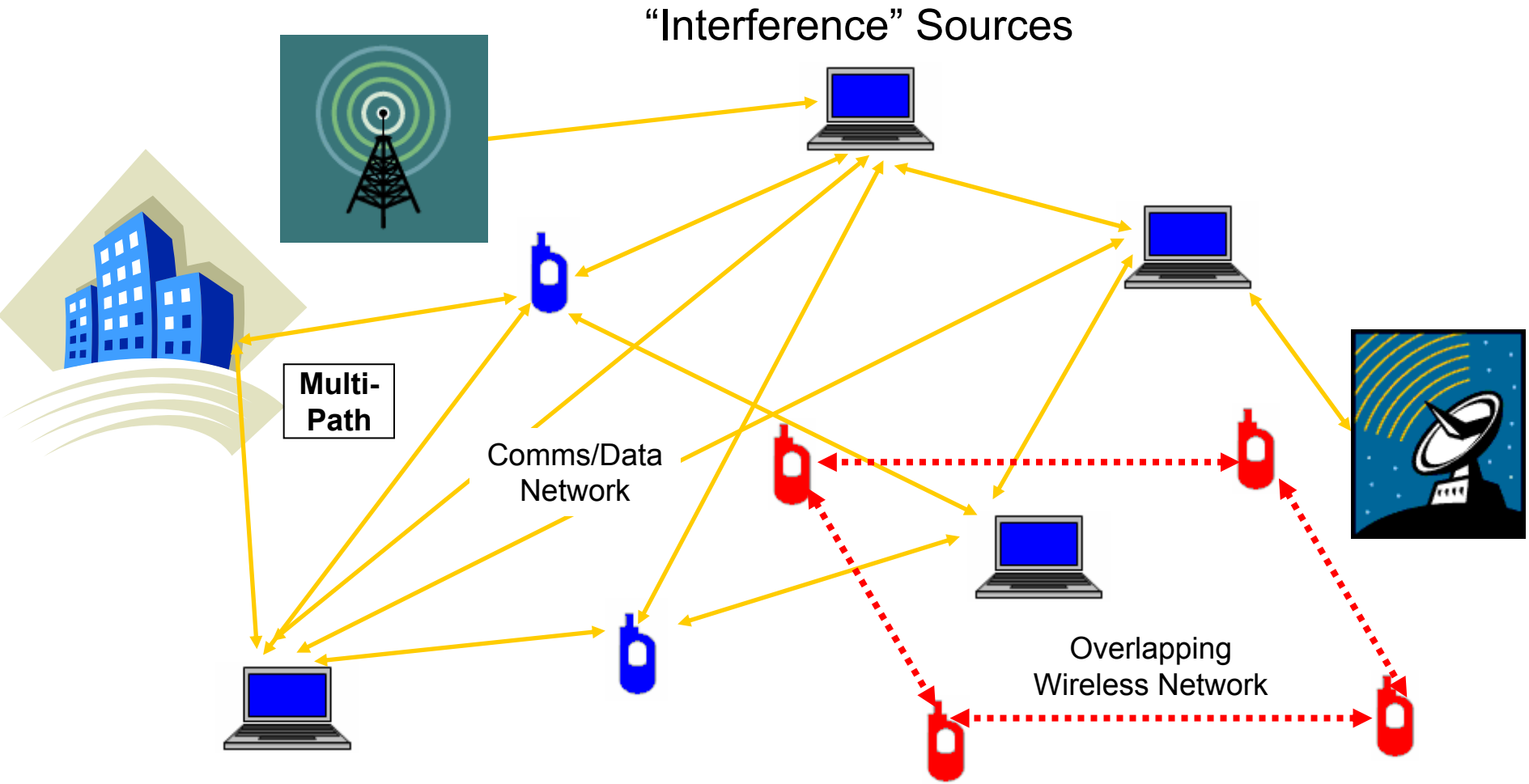
Radio where hardware is reconfigurable and will work with multiple software-defined waveforms

Baseband and digital IF may be implemented with FPGAs, ASICs, DSP

New communications waveforms can be quickly introduced into the system without requiring taking the hardware out of service for extended periods of time.

The Software Communications Architecture (SCA) enables programmable radios to load waveforms, run applications, and be networked into an integrated system.

Ad-Hoc Network Operations and Impairments



SDR Physical Layer Design & Test Challenges

Simulation is useful to evaluate waveform compatibility, but involves both baseband and RF. How can they be evaluated together?

How can new waveforms, such as COTS WiMAX OFDMA, be evaluated before implementing hardware?

How can new waveforms be evaluated with real-world field scenarios (e.g. interferers, jammers, etc..) *before* field deployment?

How can custom waveform interoperability be tested with off-the-shelf test solutions after hardware implementation?

New SDR Design and Test Methodology Helps Address these Challenges:

Capture and use baseband hardware waveforms* to design the SDR RF system. Evaluate baseband and RF together in simulation.

Leverage COTS reference waveforms* (such as WiMAX OFDMA) to evaluate RF system compatibility before implementing hardware

Evaluate real-world scenarios (such as RF interferers) in simulation before deploying hardware to the field

Test waveform* interoperability with off-the-shelf test solutions by leveraging simulation inside of test equipment

*Note: Waveforms shown in this presentation are physical layer IQ waveforms, not full SDR DSP implementations

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Solution:

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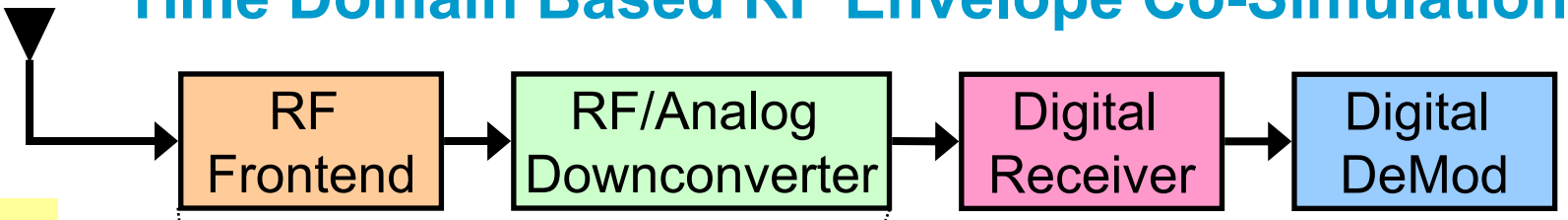
ADS Overview

Time Domain Based RF Envelope Co-Simulation



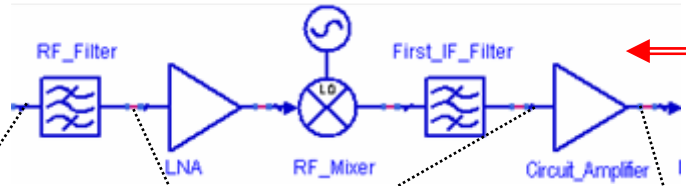
Simulation ▼ Level ▼

System

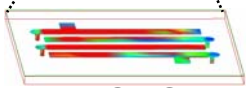
Circuit

Transistor

Behavioral RF/Analog Subsystem

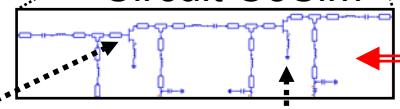


Typically Models Described by their Behavior, i.e. Gain, NF, TOI, Mixer Spurs, etc.



EM CoSim

Circuit CoSim



Component Level Models, Lumped and Distributed components, transistors, etc.

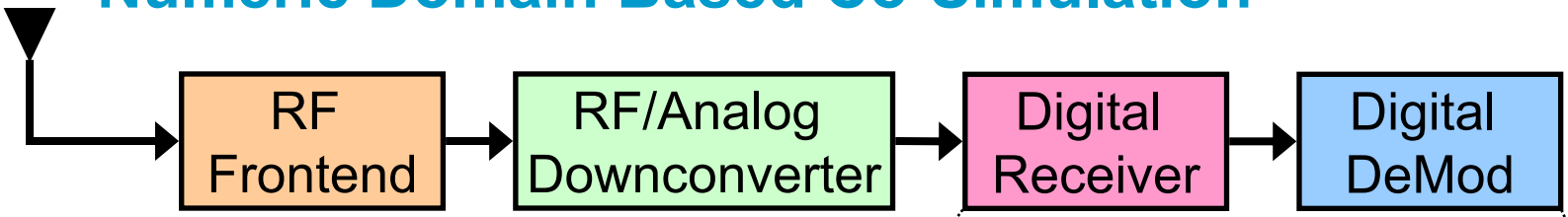
Network Analyzer & IC-CAP

Verilog - A

Measurement Based Models

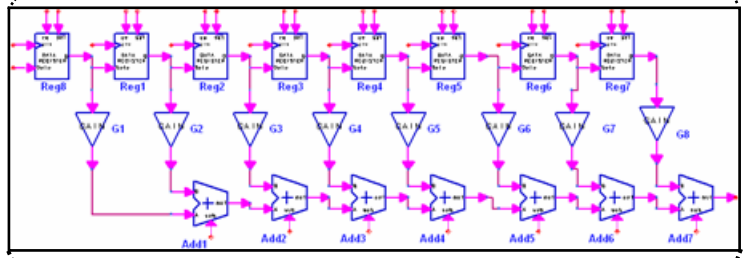
ADS Overview

Numeric Domain Based Co-Simulation



Numeric models, Floating Point, Fixed Point, Complex, Matrix, etc.

Baseband Float, Fixed, Matrix, Cx

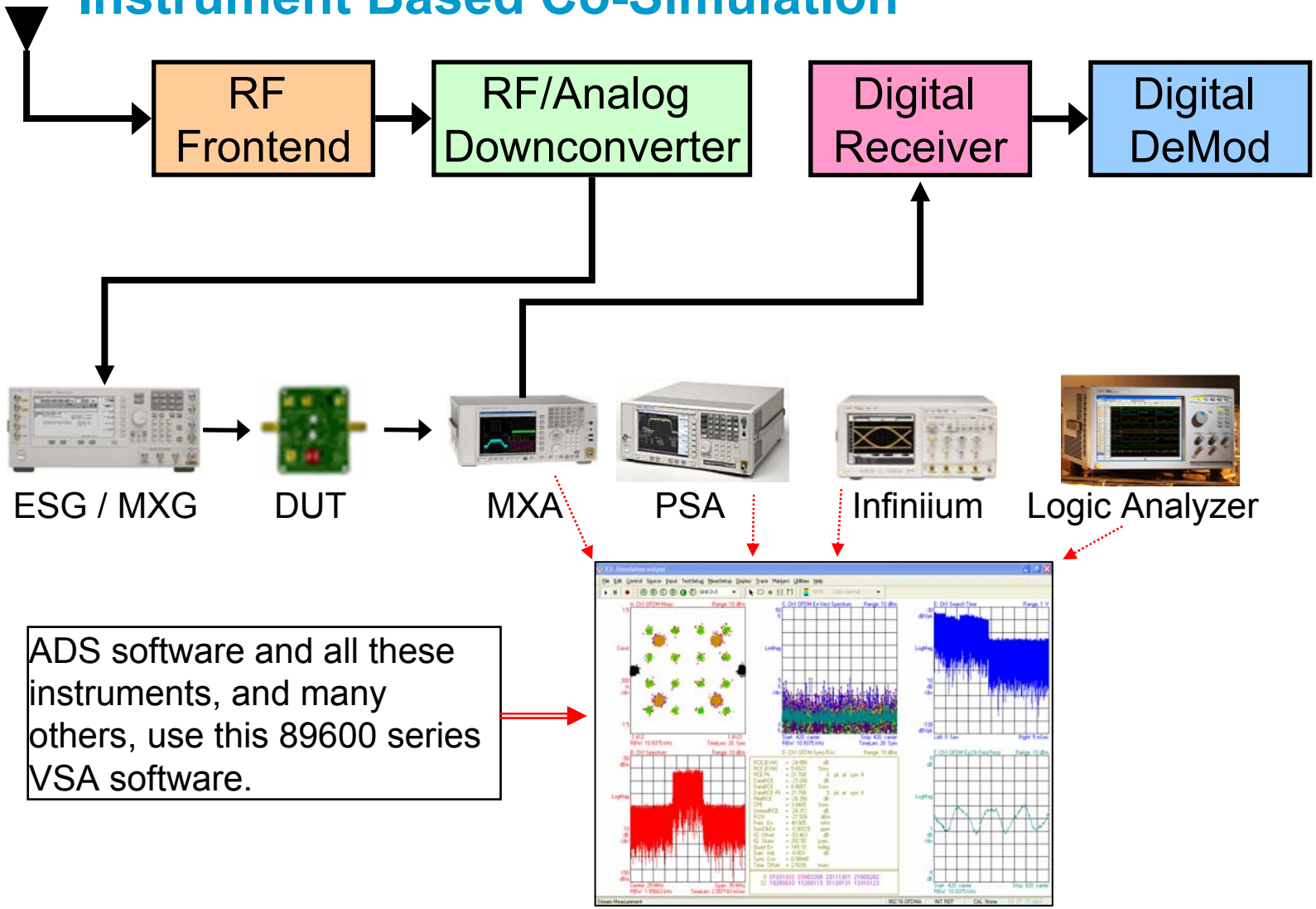


HDL / MATLAB® / C++

Co-simulate with MATLAB® HDL and C++

ADS Overview

Instrument Based Co-Simulation



ADS software and all these instruments, and many others, use this 89600 series VSA software.

Using ADS with FPGA Hardware

From ADS one can read and write directly to & from instruments:

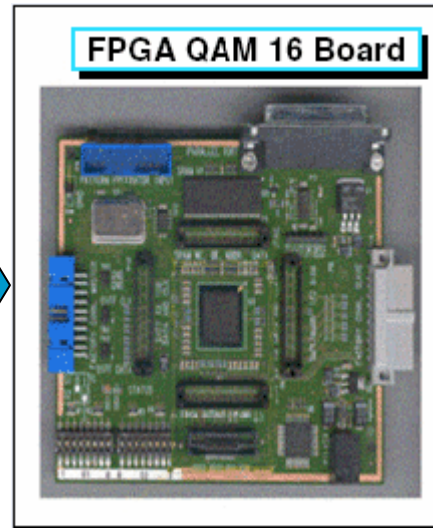
Download/ Write from ADS

ADS

CM_PatGen_169xx_Sink
C1

16900 Logic Analyzer with Pattern Generator Board

Download/Write Digital Stimulus from ADS to FPGA



Capture/Read Digital Output from FPGA into ADS

16900 Logic Analyzer

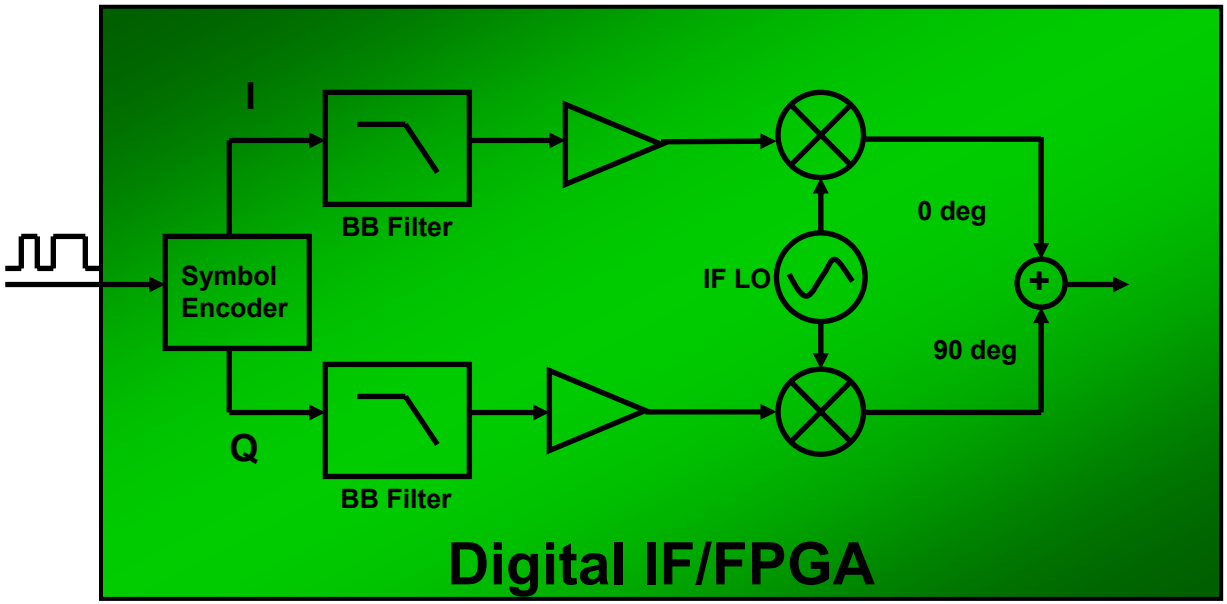
Capture/Read Into ADS

ADS

VSA

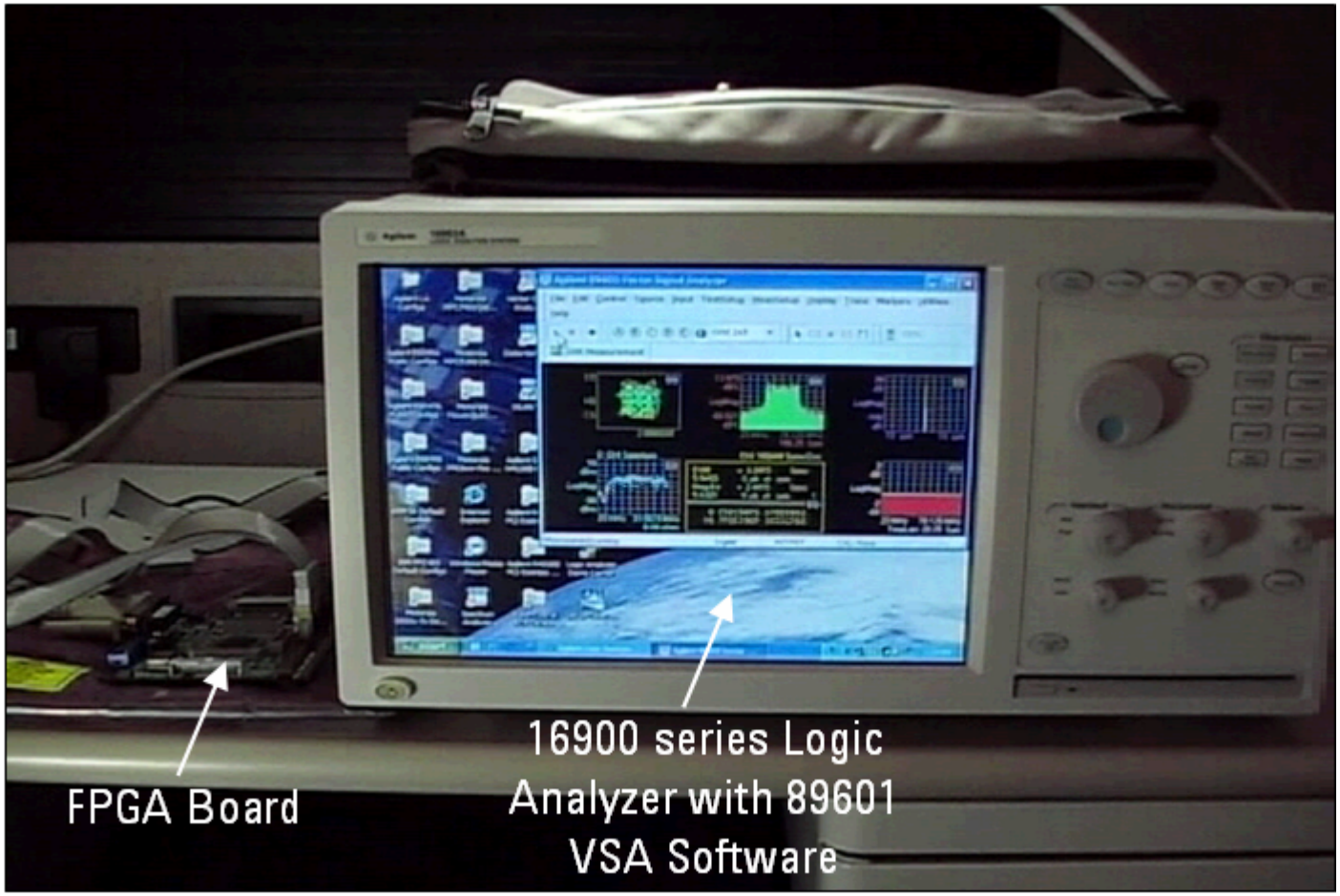
VSA_89600_Source
V1

FPGA QAM 16 Block Diagram

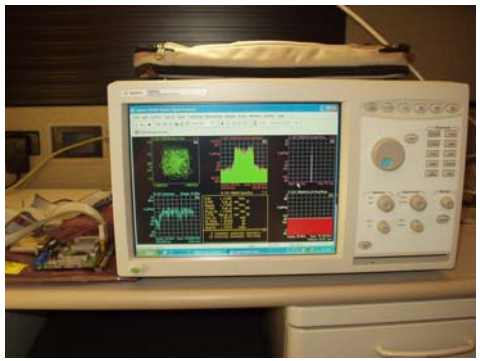


Capture and read FPGA waveform into ADS to design RF system

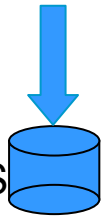
FPGA Test Setup



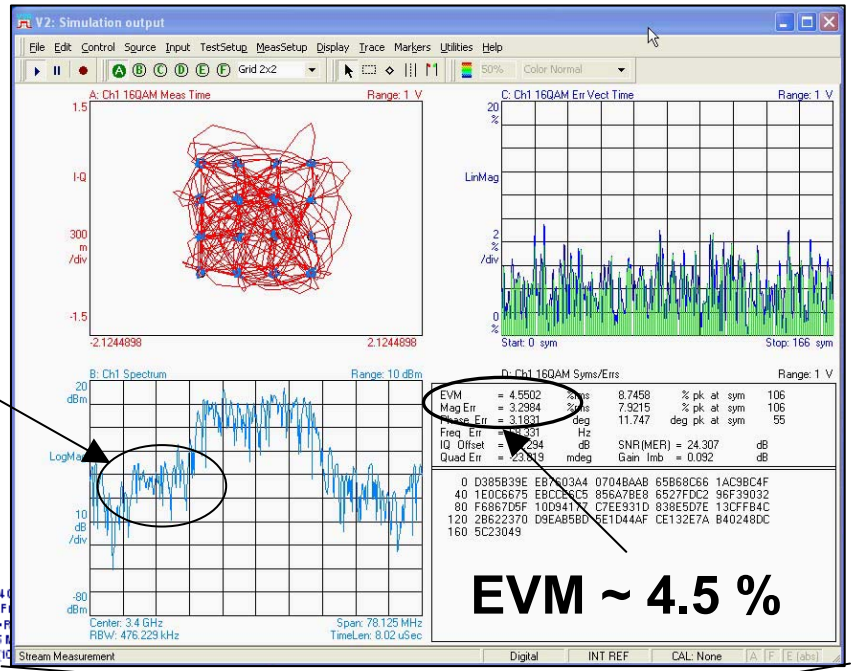
Capture FPGA Waveform and Design Transmitter



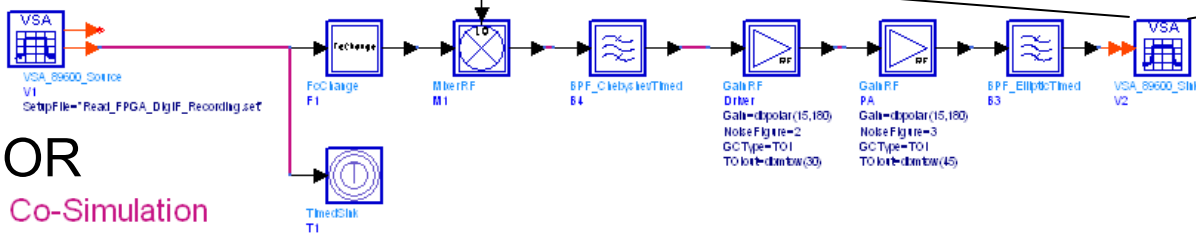
Transfer captured FPGA signal to ADS



3rd Order Spectral Regrowth



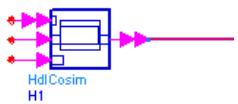
Read FPGA Signal into ADS



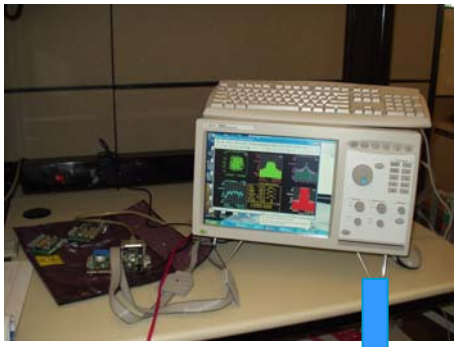
OR

ADS also has HDL Co-Simulation

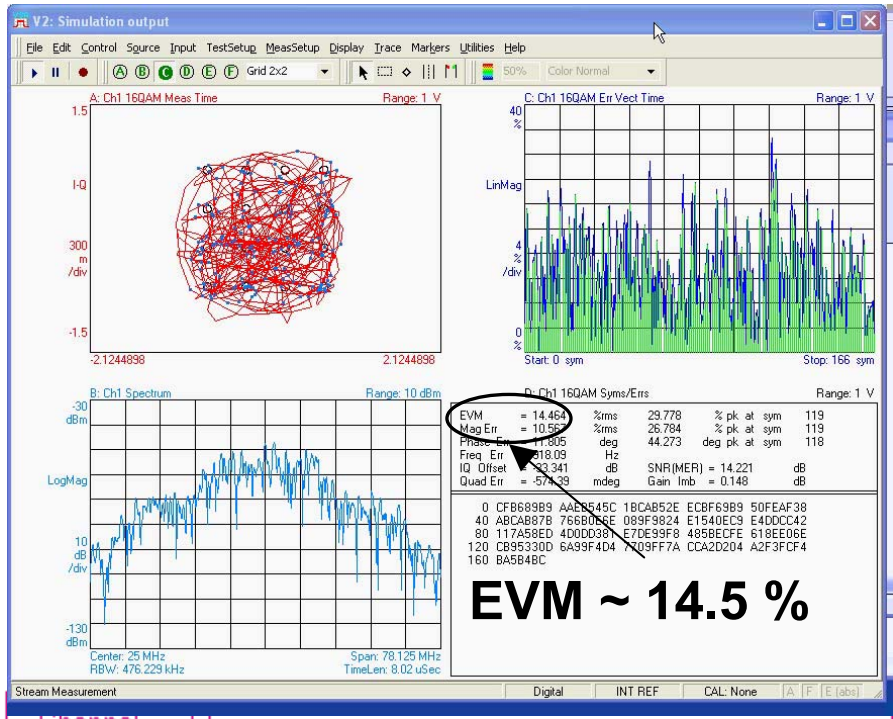
HDL co-simulate capabilities

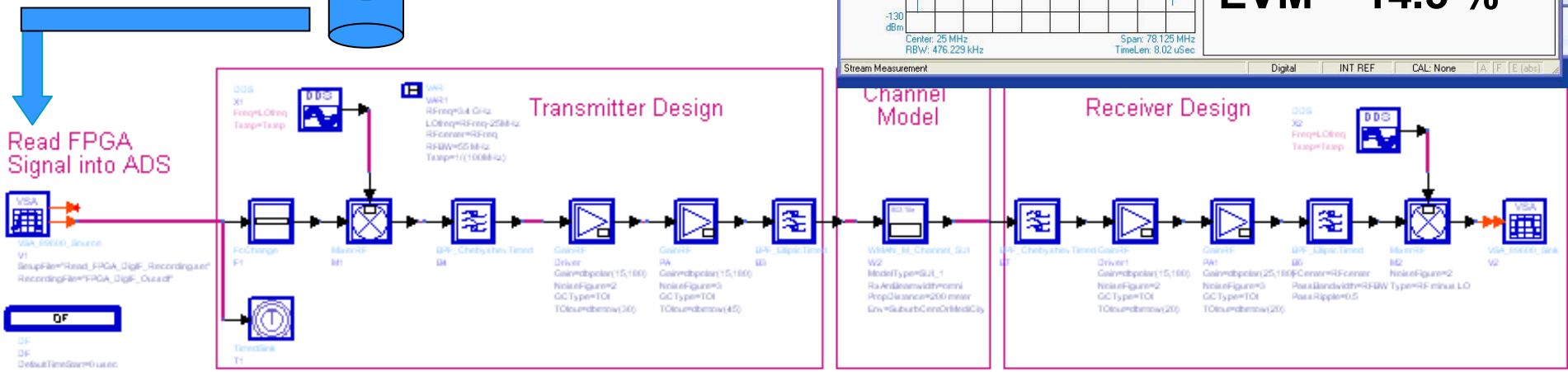


Add Channel Model and Design Receiver



Transfer captured FPGA signal into simulation





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Solution:

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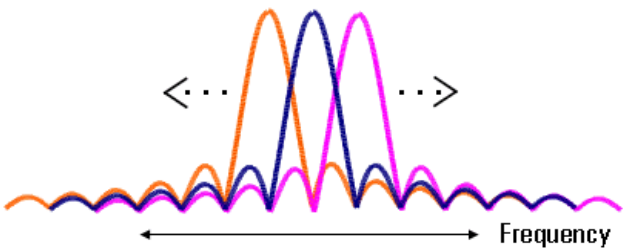
802.16e Mobile WiMAX OFDMA COTS



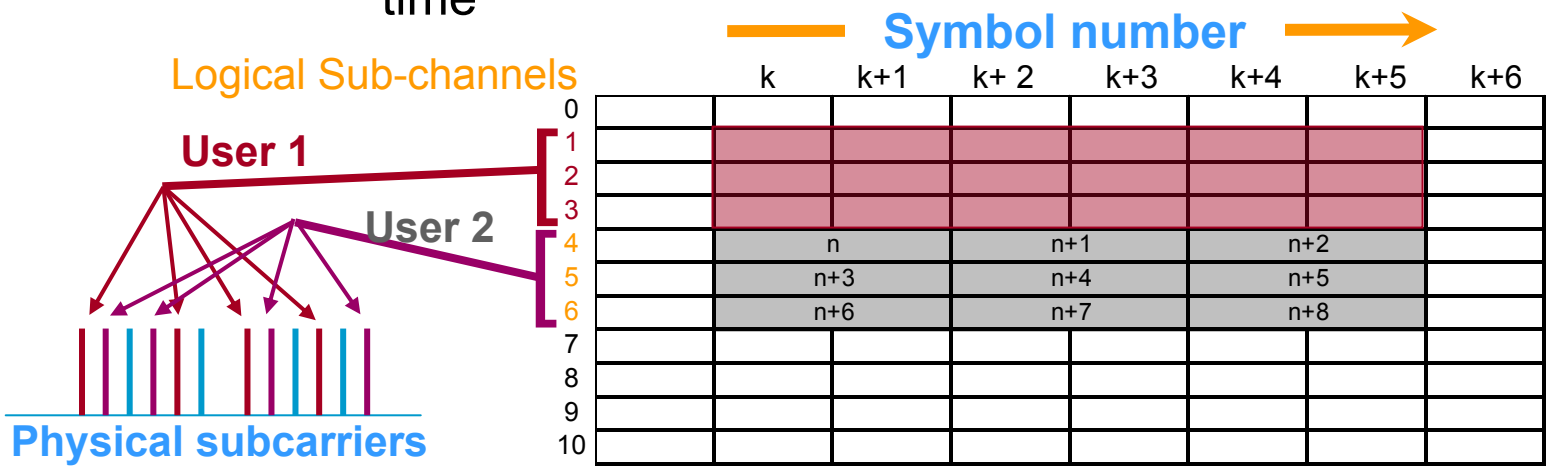
Nulls create orthogonality between subcarriers

OFDMA= Orthogonal Frequency Division Mult. Access

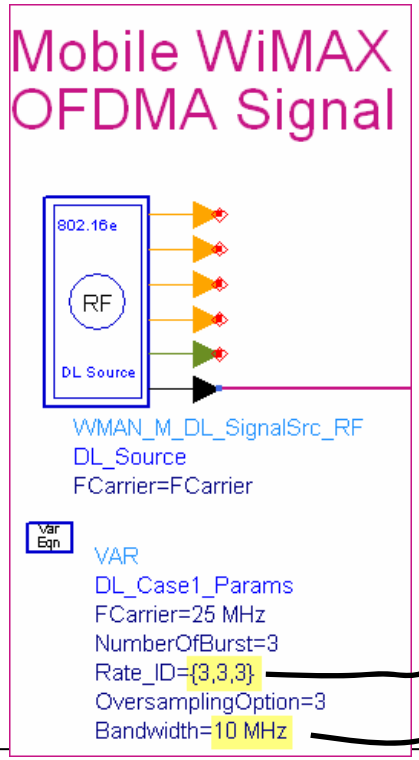
Data transmitted on multiple subcarriers for each symbol- variable FFT sizes (512,1024,..)

Less susceptible to narrowband interference and multipath

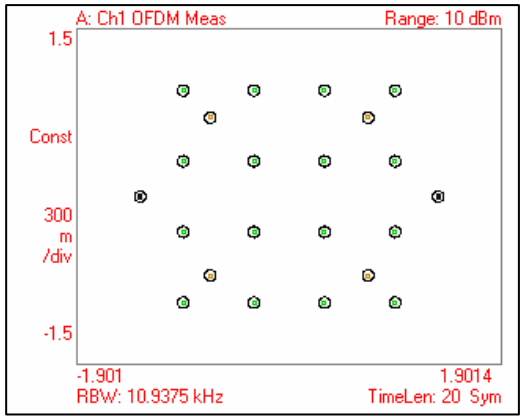
Parallel burst structure- multiple users ('Multiple Access') are assigned unique subcarrier mapping vs. time



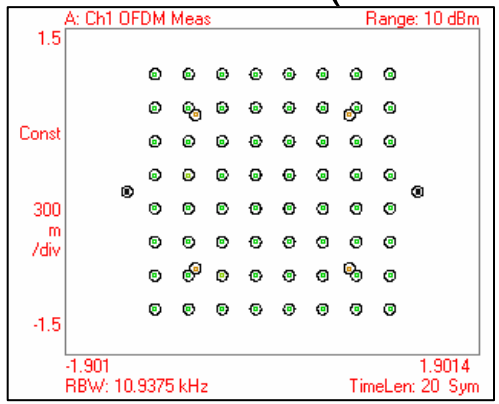
Customizing COTS Technologies for SDRs
Parameterized Signal Sources and Receivers



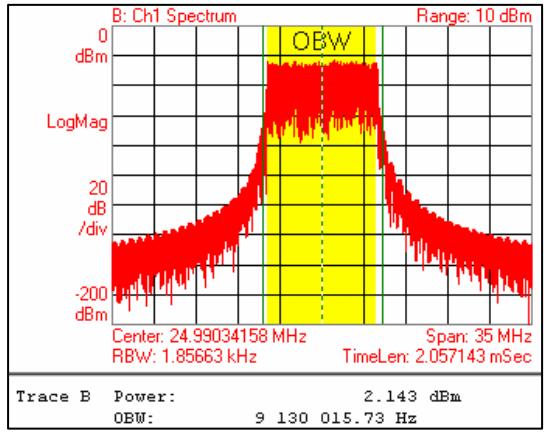
RateCode=3 (16 QAM)



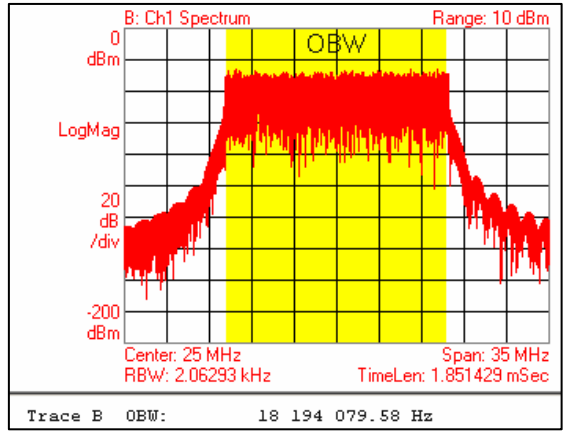
RateCode=4 (64 QAM)



Bandwidth=10 MHz



Bandwidth=20 MHz

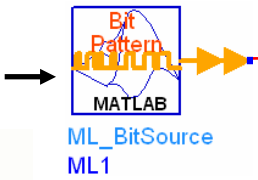


Sources and Receivers have parameters which can be modified

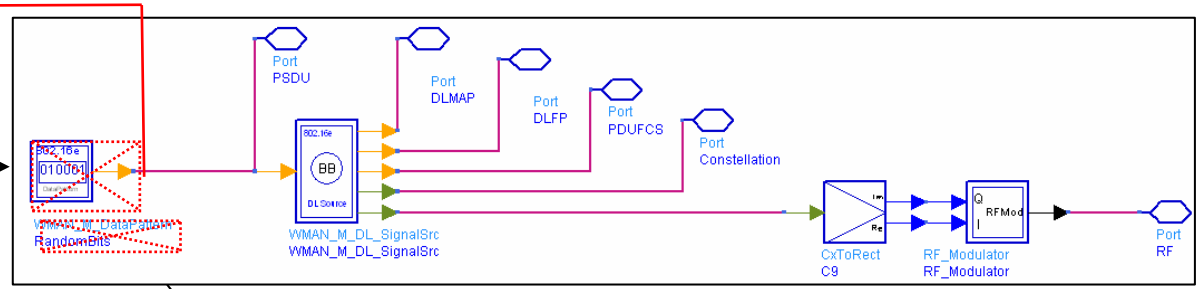
Customizing COTS Technologies for SDRs

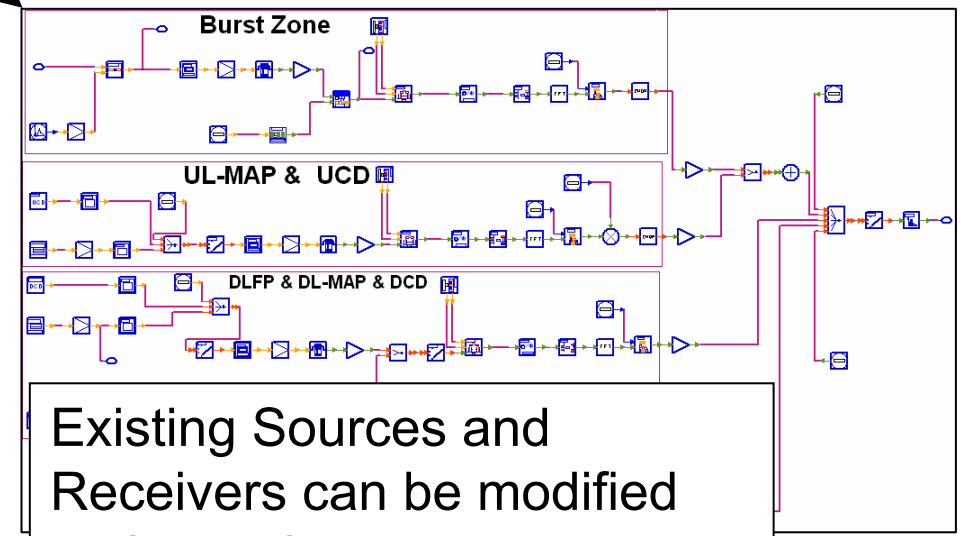
Flexible Parameterized Signal Sources and Receivers

Example: Replace ADS Bit Source with a customized MATLAB® source



WMAN_M_DL_SignalSrc_RF
DL_Source
FCarrier=FCarrier
Power=SignalPower
Bandwidth=Bandwidth
OversamplingOption=OversamplingOption
FFTSize=FFTSize
CyclicPrefix=CyclicPrefix
FrameMode=TDD
DL_Ratio=0.6177143
FrameDuration=FrameDuration
DLMAP_Enable=YES
ULMAP_Enable=YES
PreambleIndex=PreambleIndex
FrameNumber=FrameNumber
DL_PermBase=DL_PermBase
PRBS_ID=PRBS_ID



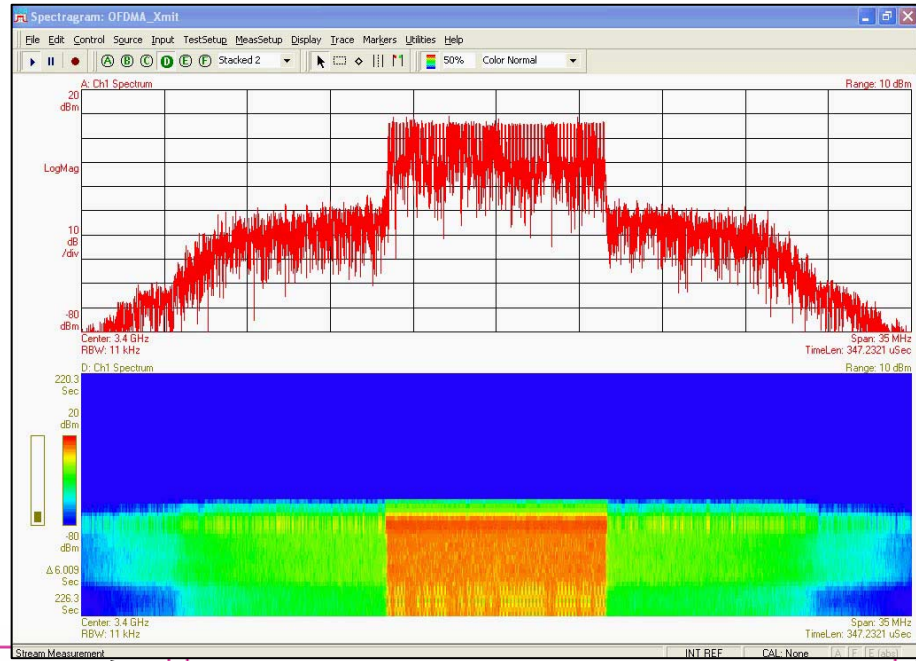


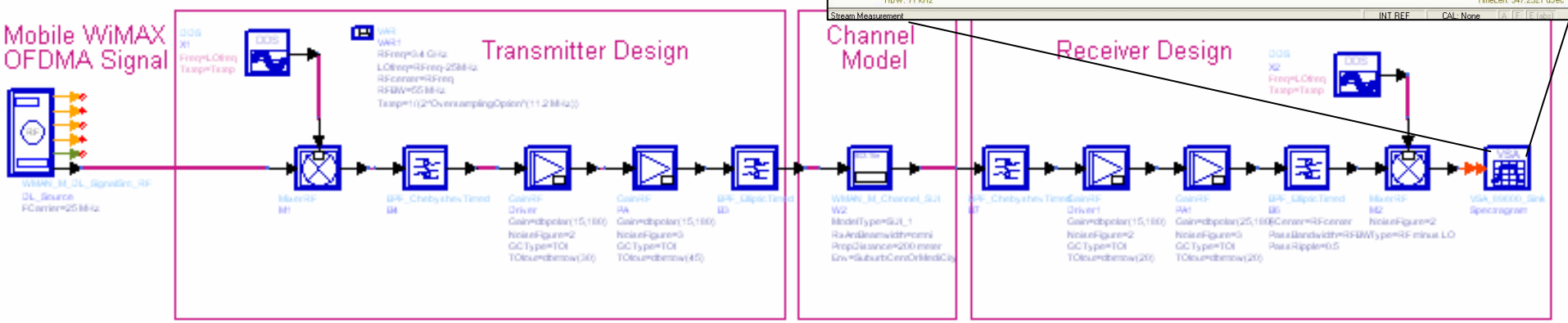
Sources and Receivers have parameters which can be easily modified

Existing Sources and Receivers can be modified and saved to create custom systems

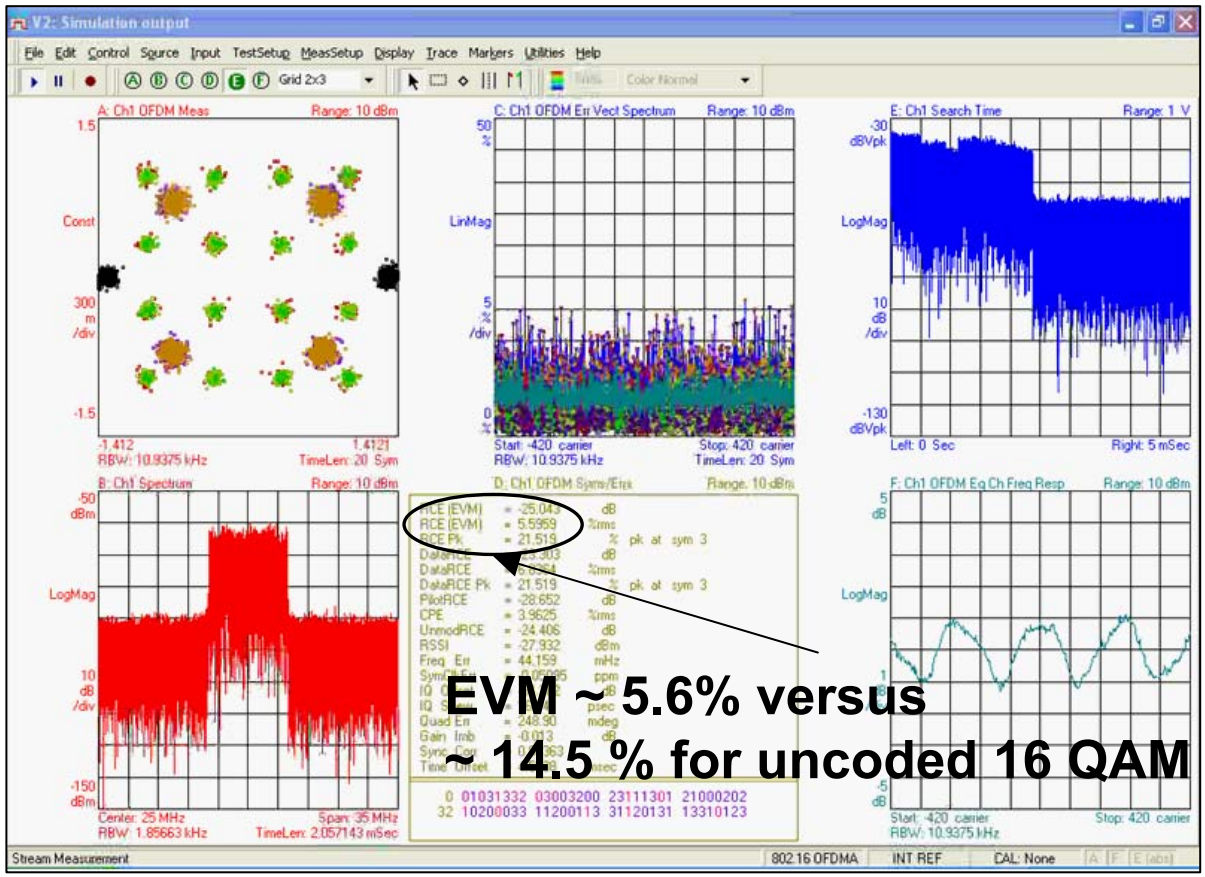
Evaluate Performance with WiMAX COTS Waveform

As you watch the demonstration think about potential performance issues with the system and what could be done very early in the design process to fix them.





System Simulation Results with WiMAX OFDMA COTS Waveform



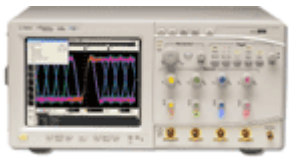
Other COTS Wireless Libraries in ADS

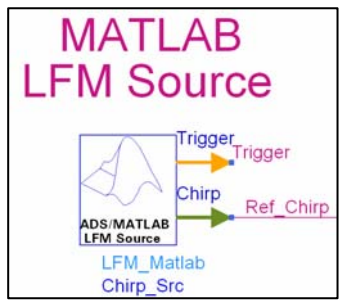
http://eesof.tm.agilent.com/products/wireless_libraries.html

CDMA	EDGE	Fixed WiMAX
GSM	WLAN	Mobile WiMAX
DTV	CDMA2000 1XEV	802.11n
3GPP WCDMA	TDSDMA	WiMedia
CDMA2000	HSPA	3GPP LTE

Other possible sources of signals and measurements:

- The ADS MATLAB® Co-Simulation Elements:
- Agilent Instruments:





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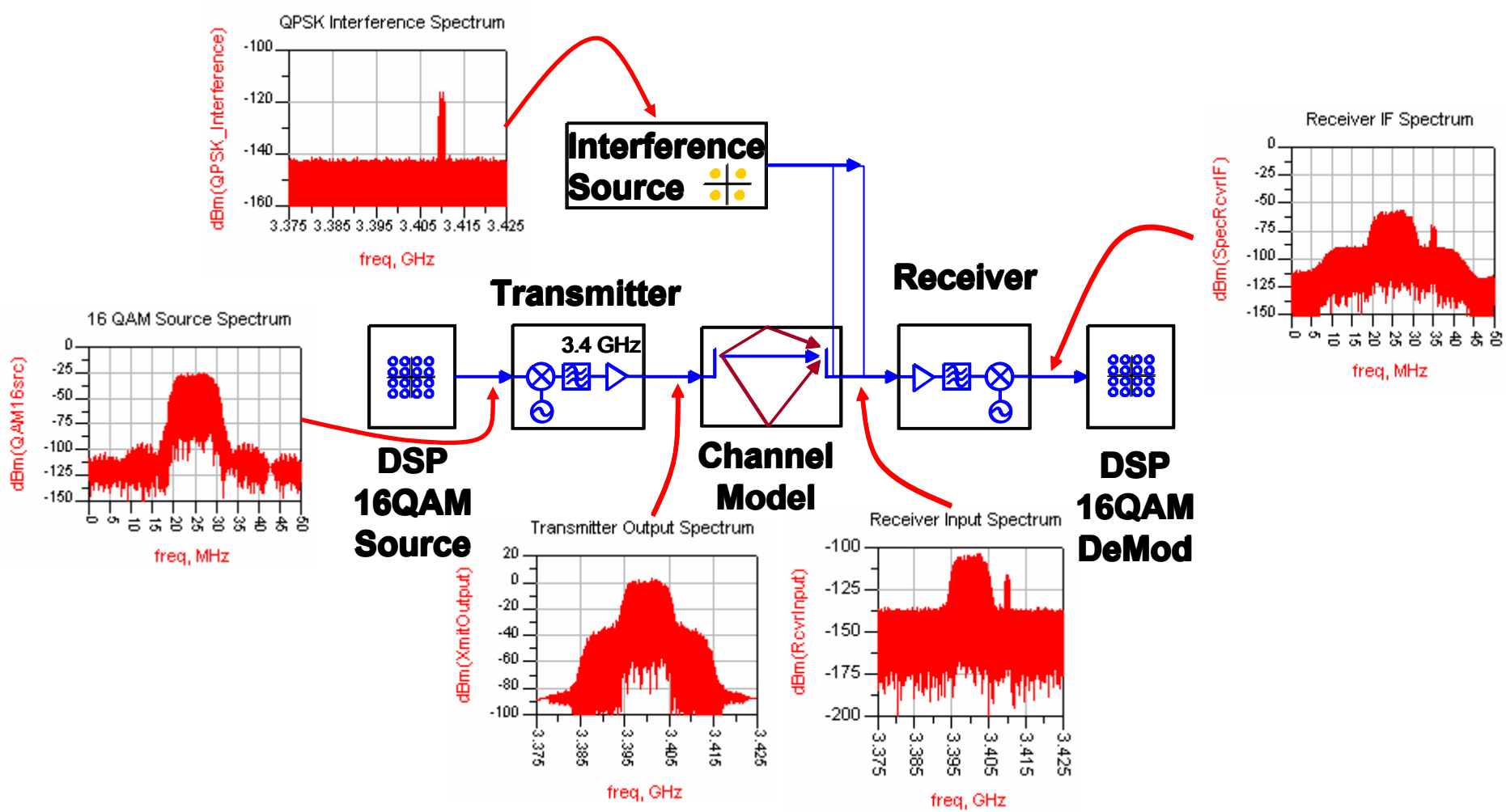
Solution:

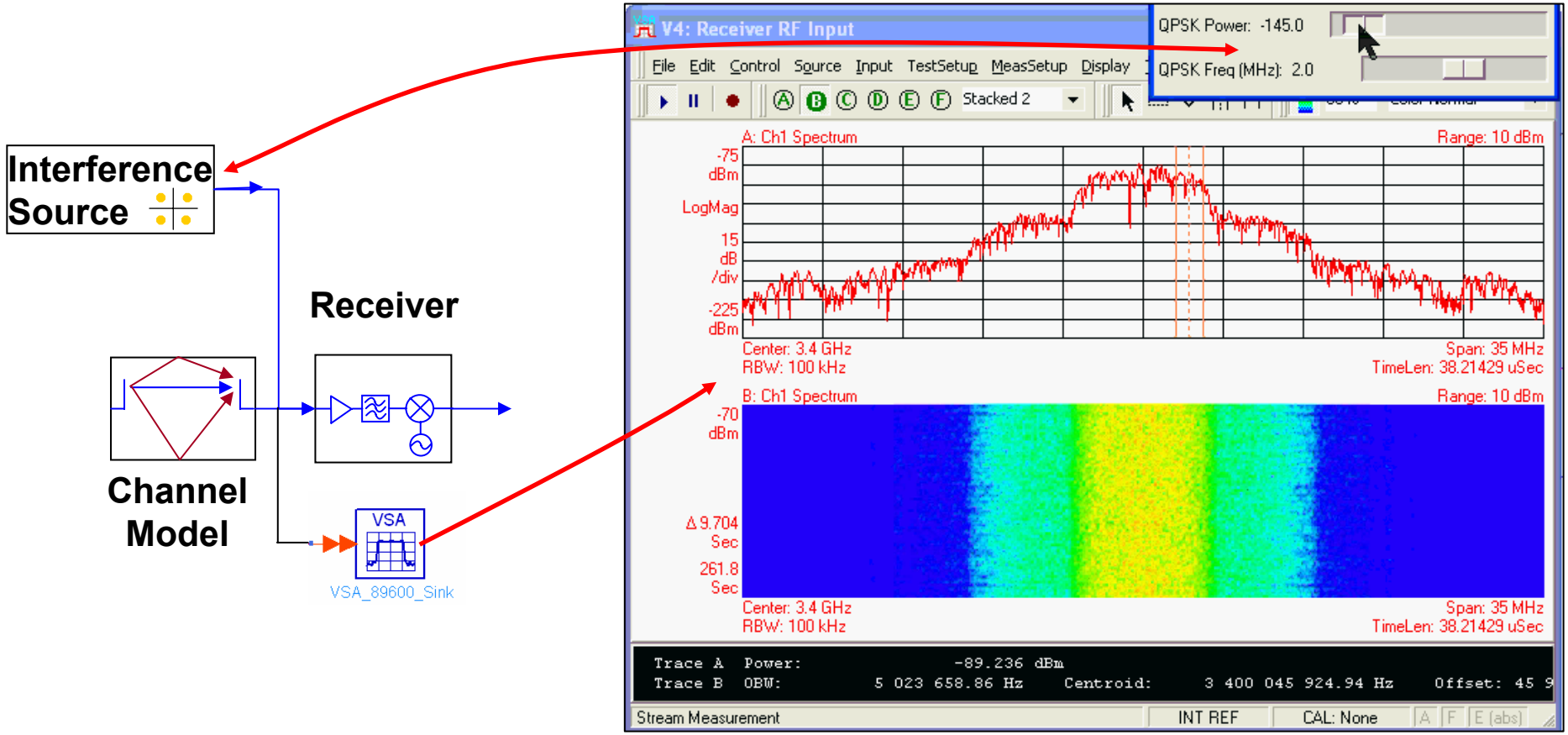
Evaluate real-world scenarios (such as RF interferers) in simulation before deploying hardware to the field

Evaluate Effects of Interferers on QAM16 System

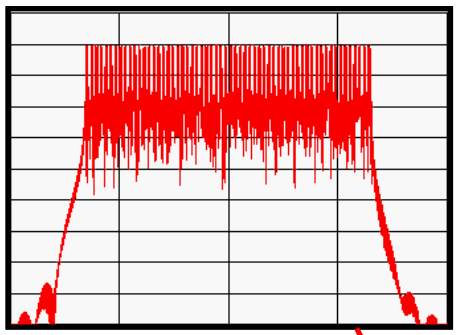


Effects of Interferers on QAM16

Swept QPSK Interference Frequency and Power using VSA Software



Next: Evaluate Effects of Interferers on OFDMA System



OFDMA Src
BW=10 MHz
Fctr=25 MHz
Pwr≈ 0 dBm

DSP OFDMA Source

Transmitter

3.4 GHz

~30 dBm

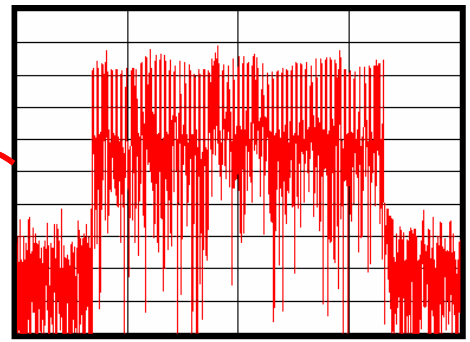
Interference
Type=QPSK
Fc=3385 to 3415 MHz
Pwr= -150 to -70 dBm

Interference Source

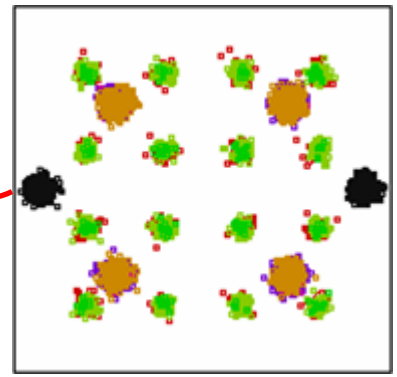
Channel Model

Path Model
Length=200M
Loss≈103 dB
Suburban Env.

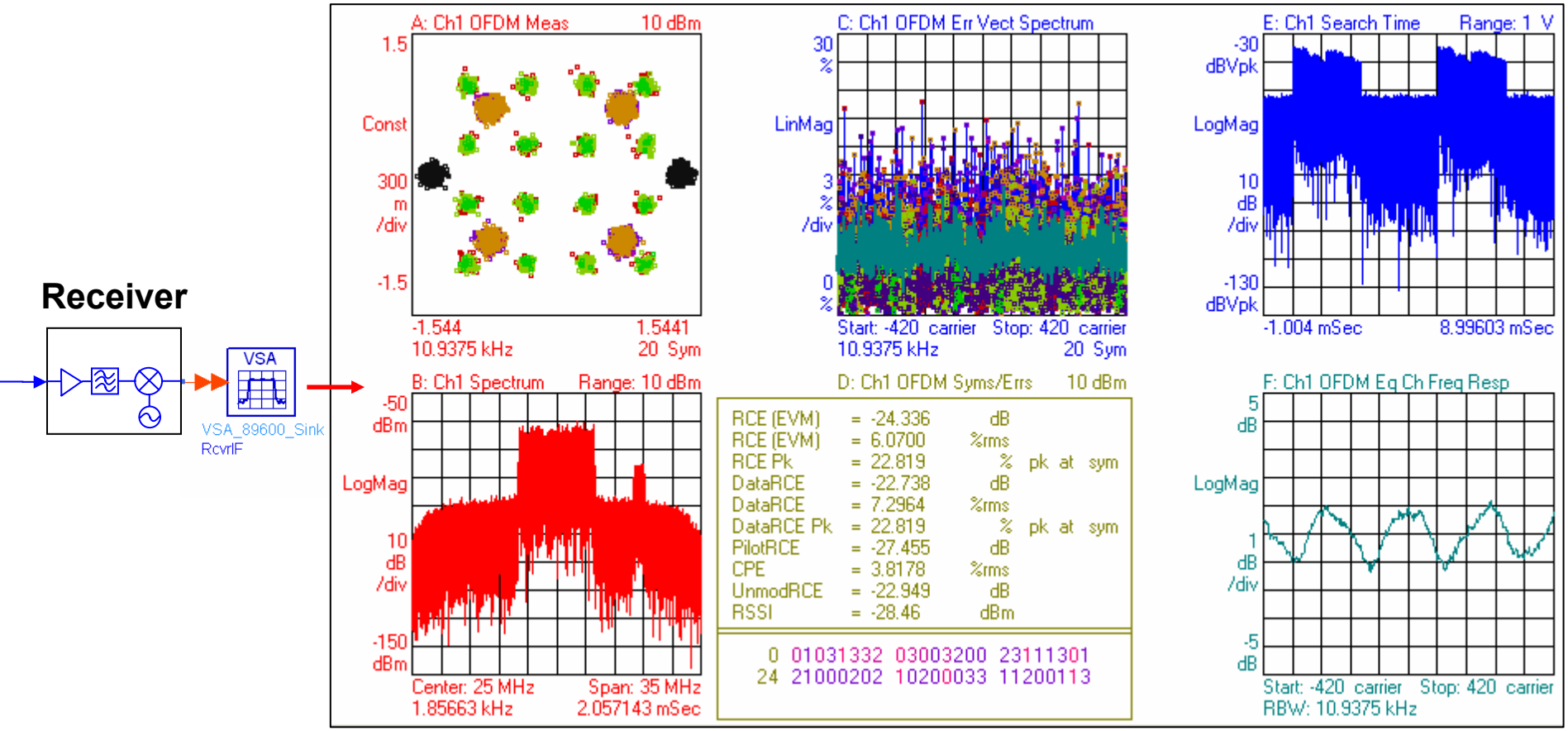
Receiver



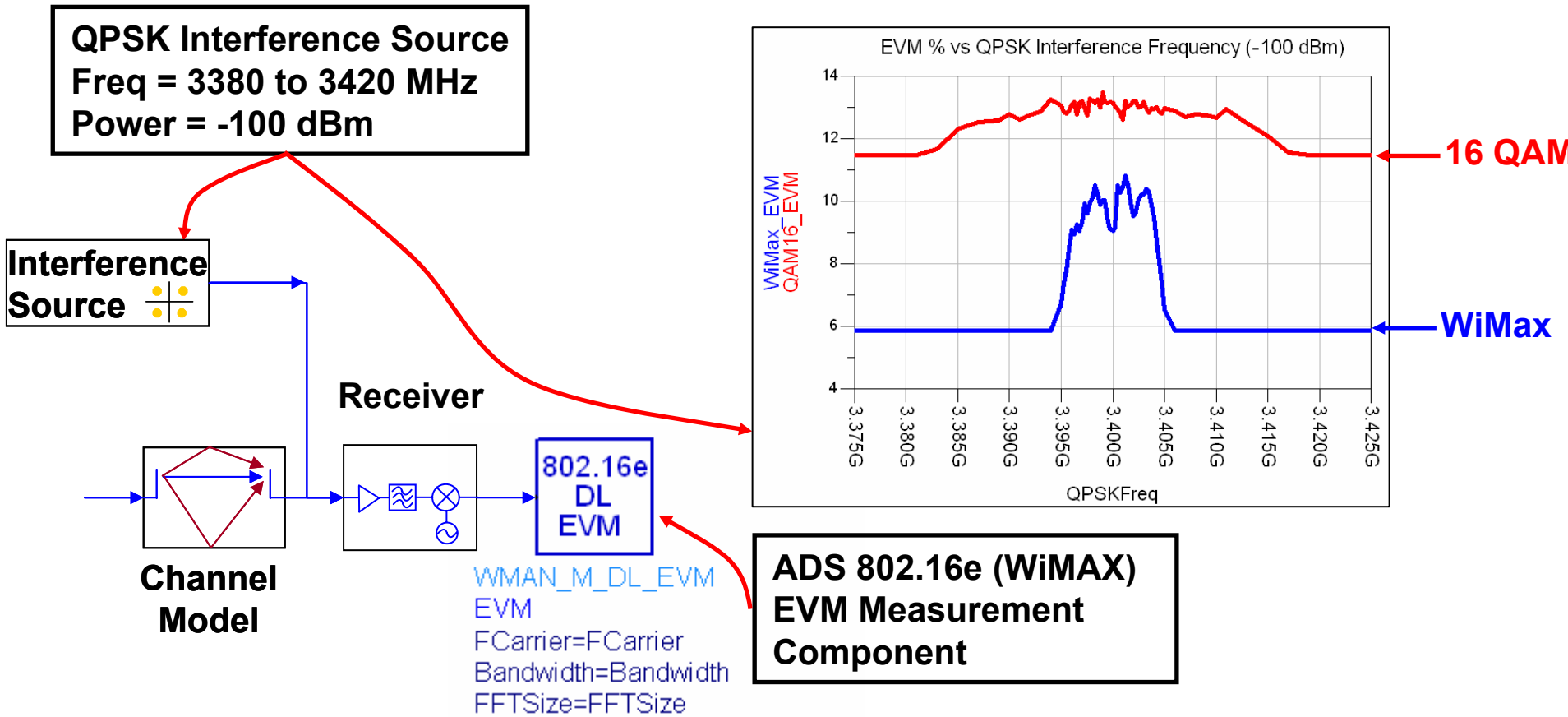
DSP OFDMA DeMod



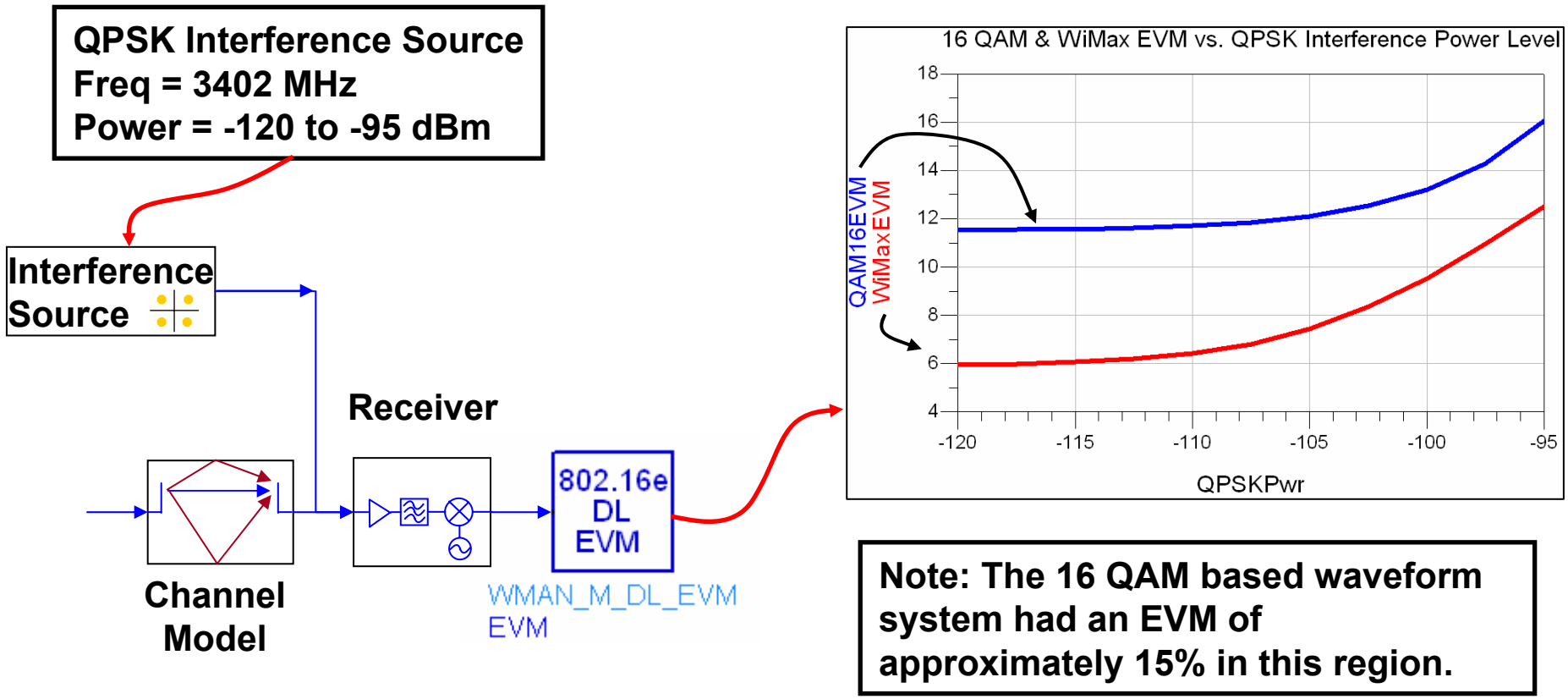
Effects of Interferers on WiMAX OFDMA



Effects of Interferers on WiMAX OFDMA Interference Frequency Sweep



Effects of Interferers on WiMAX OFDMA Interference Power Level Sweep



Note: The 16 QAM based waveform system had an EVM of approximately 15% in this region.

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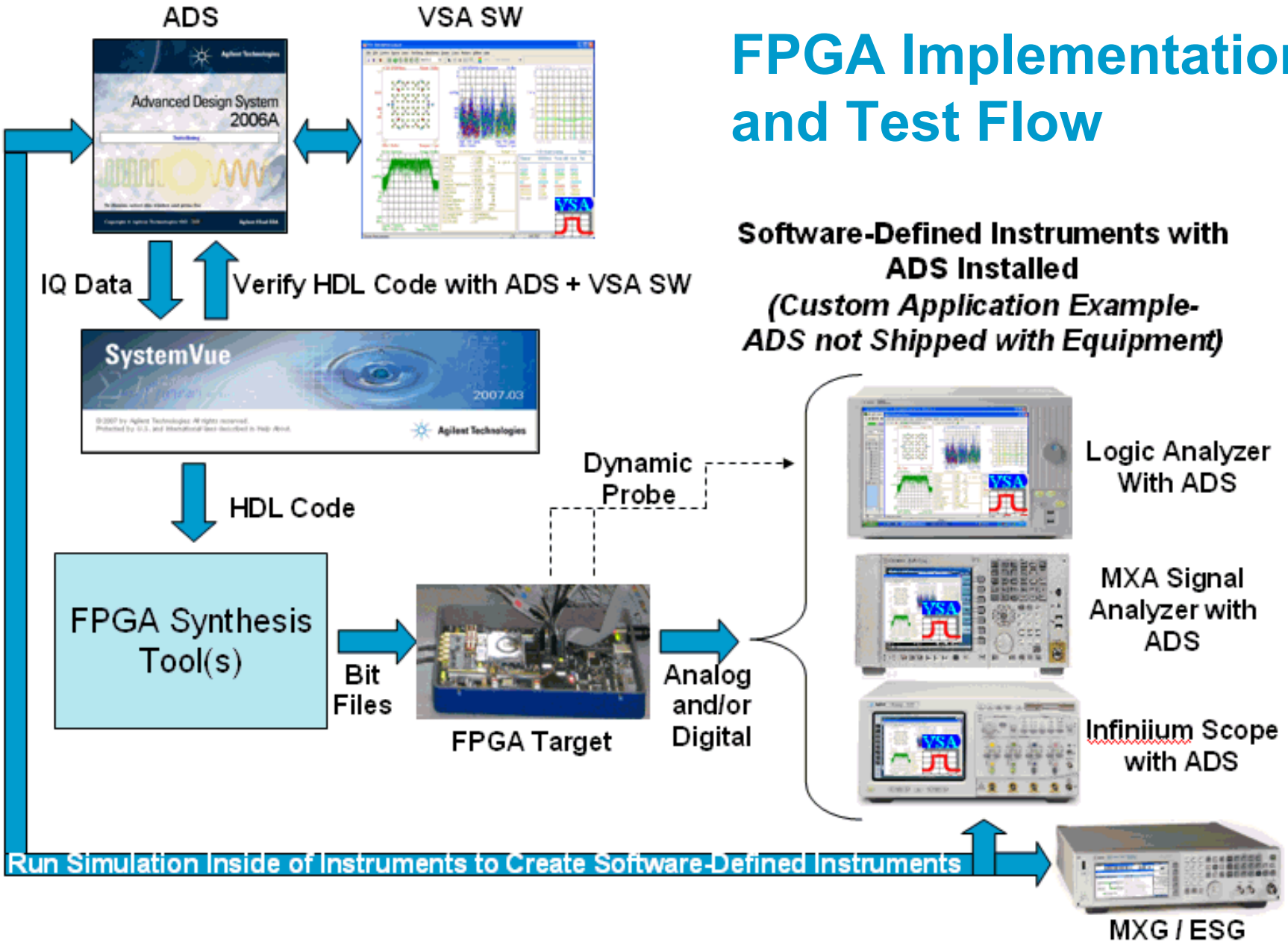
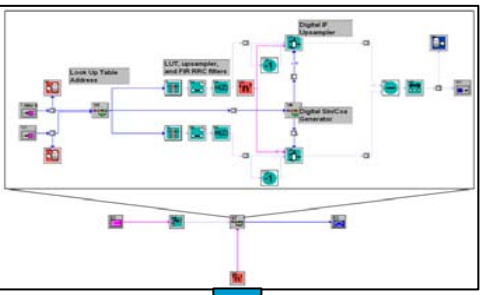
FPGA Implementation and Test Flow

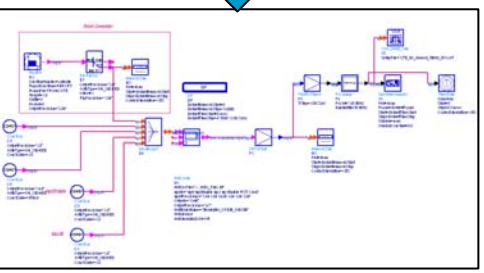


ADS HDL Co-Simulation of SystemVue HDL

Agilent SystemVue

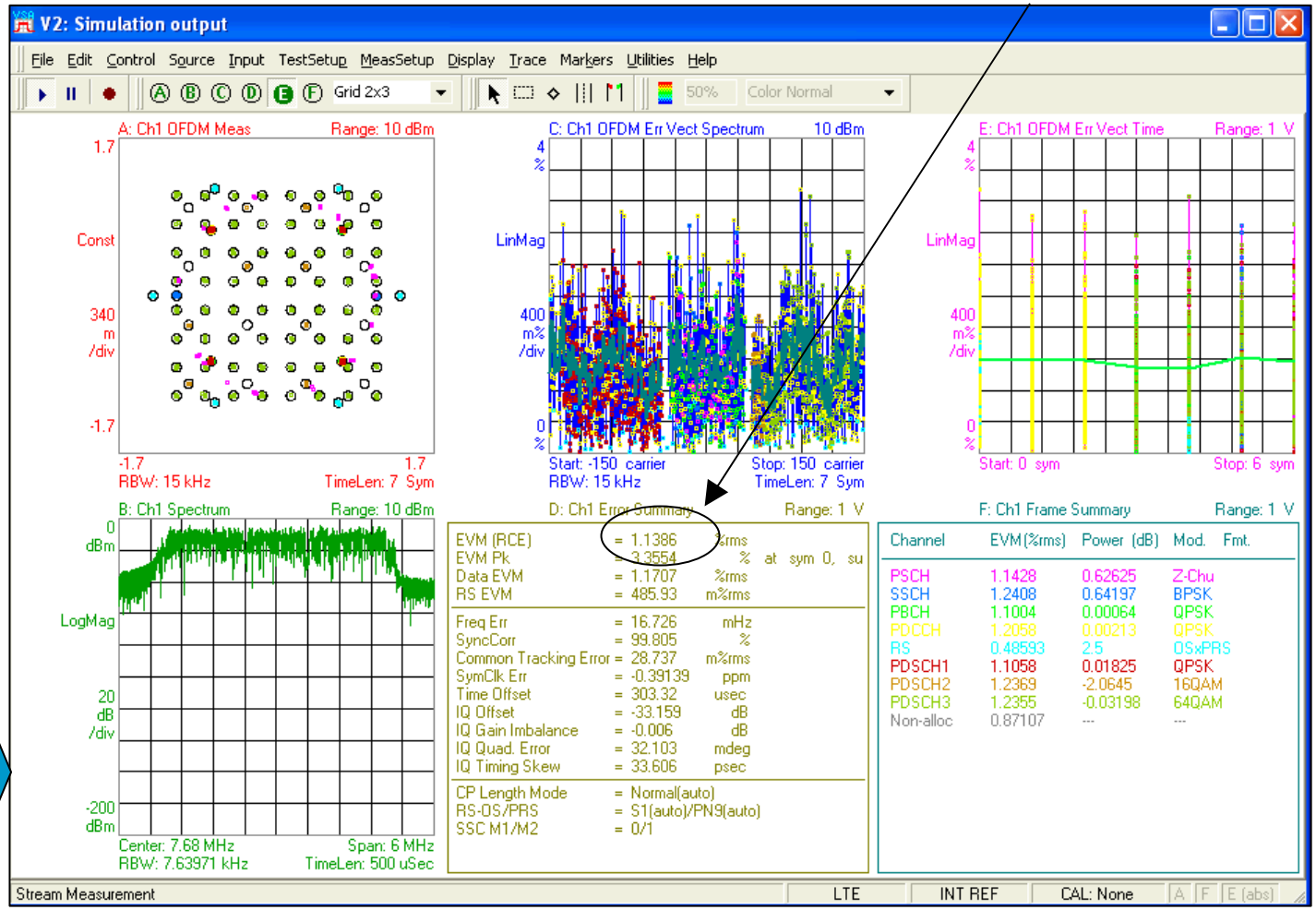


Generate HDL with HDS3



Co-Simulate with HDL in ADS and VSA SW

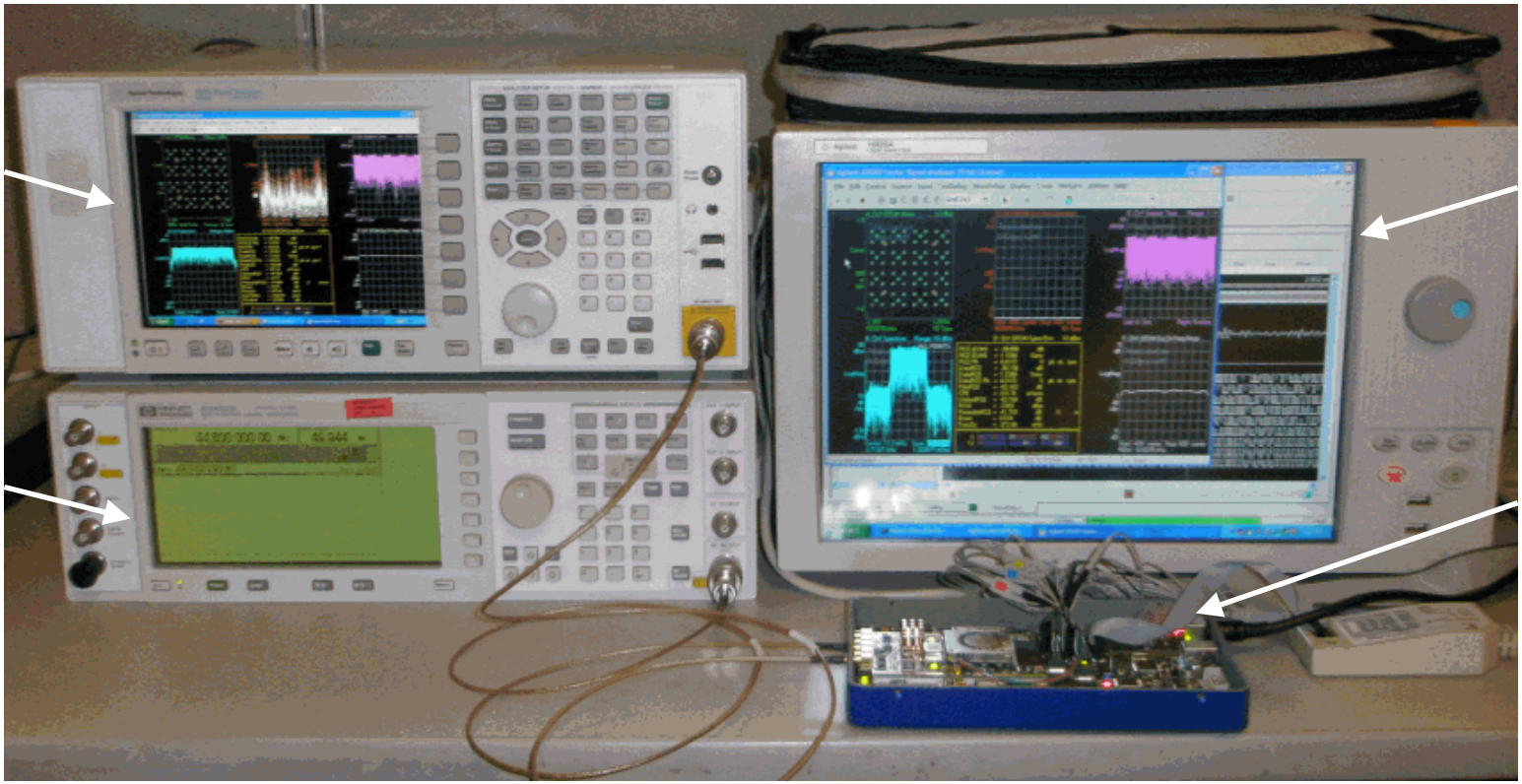
ADS HDL Co-Simulation Results : EVM ~ 1.1%



FPGA Implementation Test Setup

MXA Signal Analyzer with VSA SW and ADS

ESG to Clock FPGA Board



16900 Logic Analyzer with VSA SW and ADS

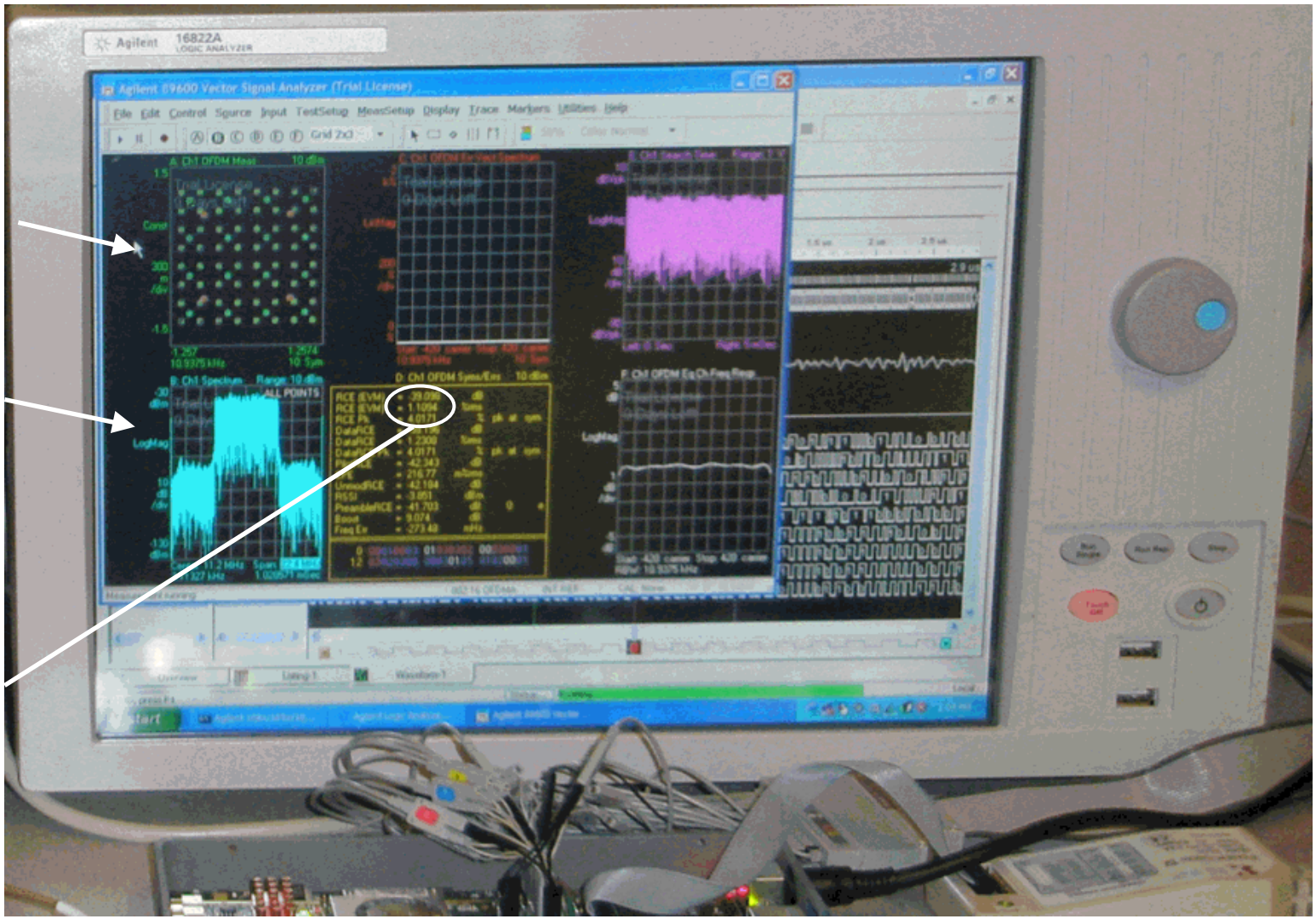
FPGA Board (DUT)

Close-Up of Mobile WiMAX Measurement

OFDMA Constellation

Spectrum

Measured EVM ~1.1% (versus ~1.1% simulated)



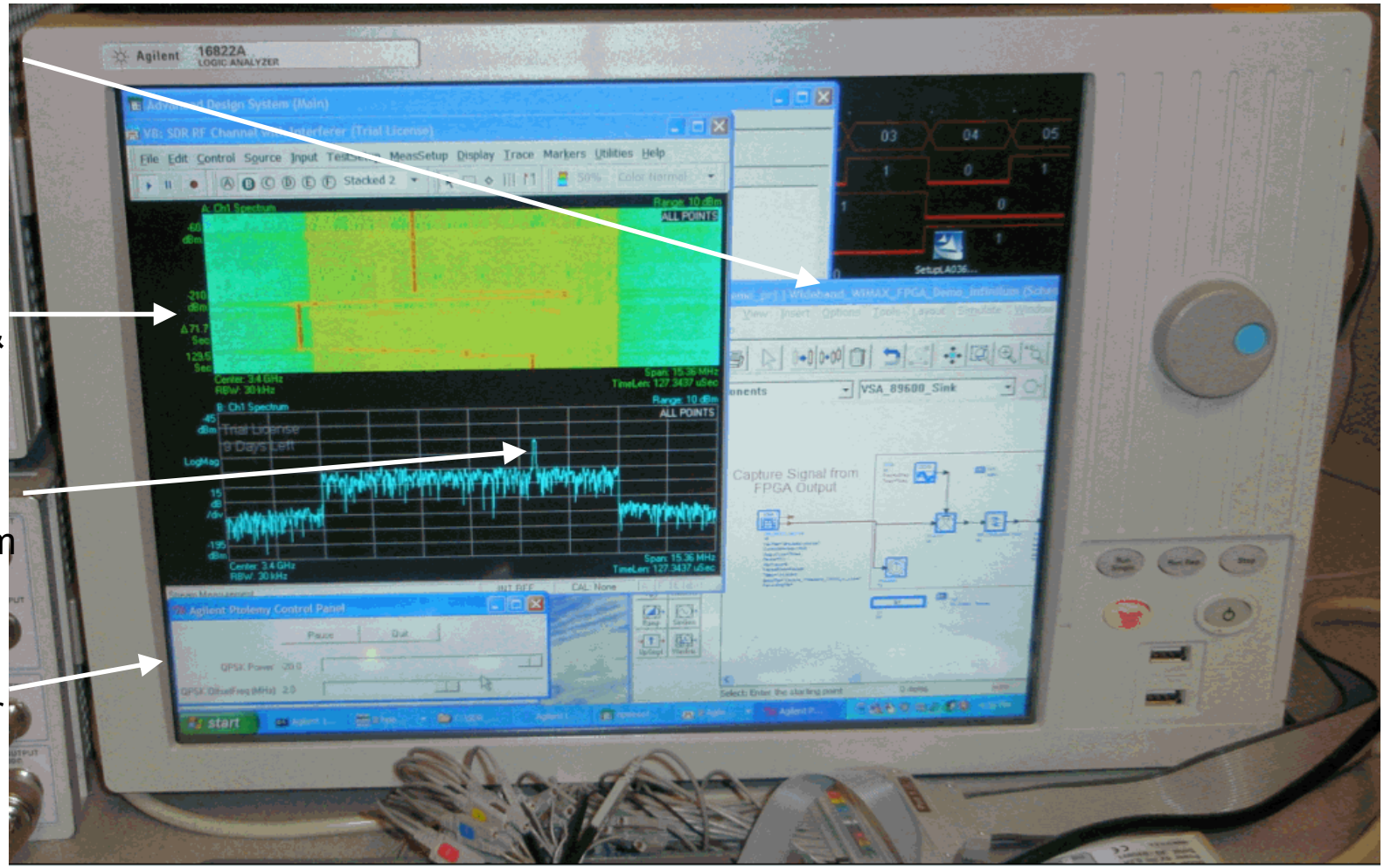
Software-Defined Instruments with ADS

ADS Adds Simulated RF Interferer to FPGA Signal

Spectrogram Showing Interferer Freq. & Intensity vs. Time

Interferer in WiMAX Spectrum

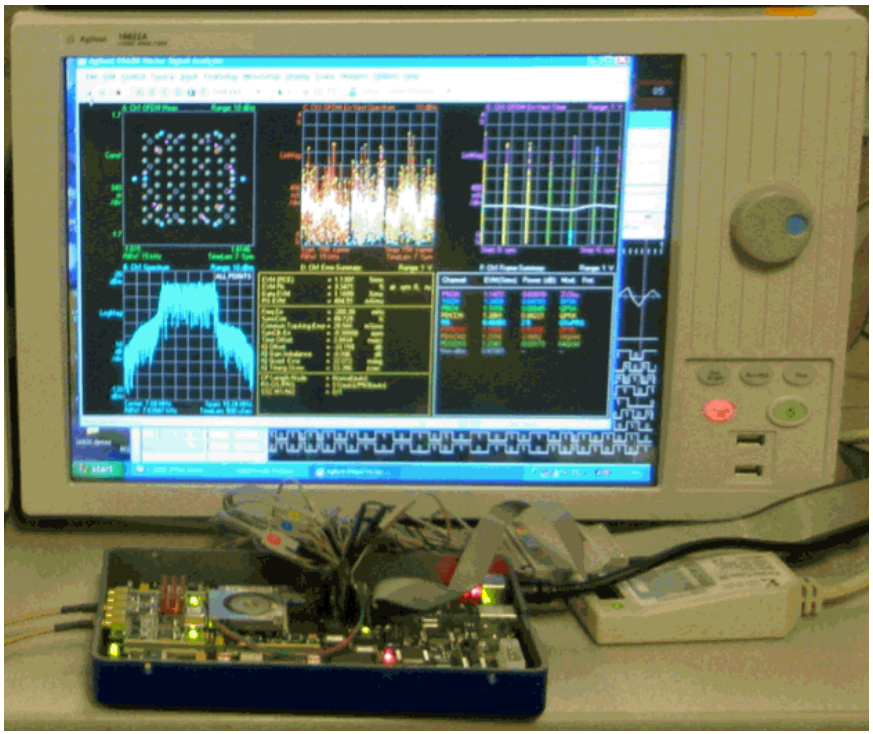
ADS Slider to Control Interferer Freq. Offset and Power



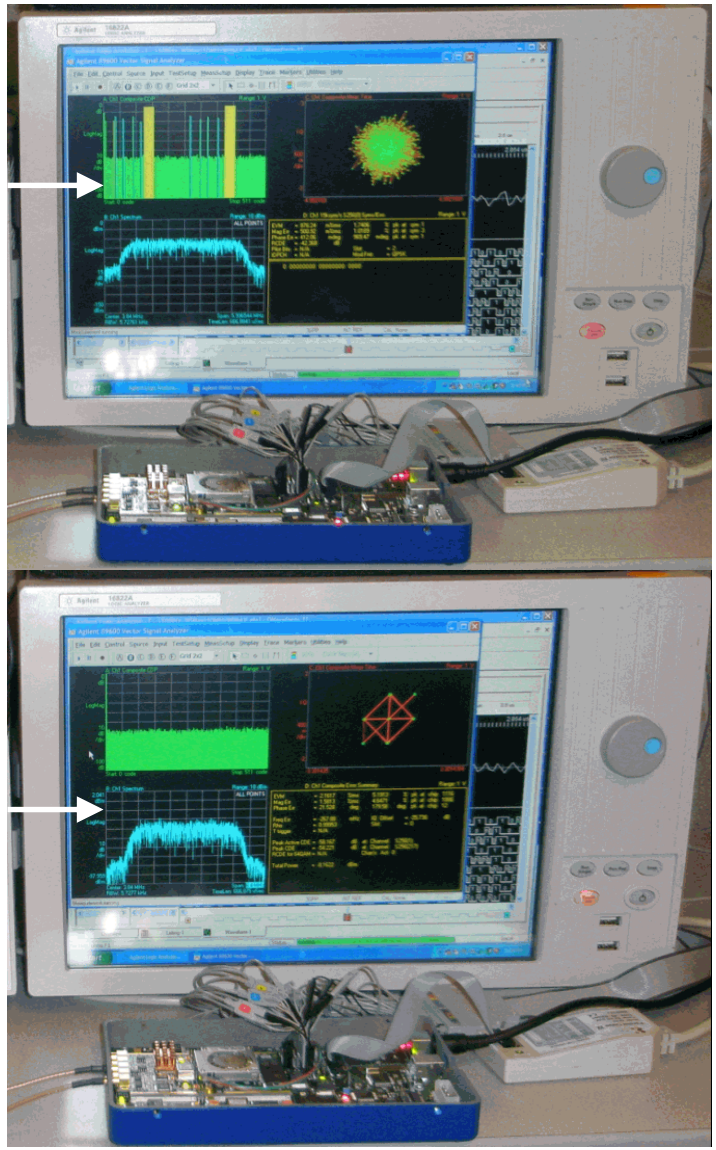
Other Waveforms Implemented

HSPA TestModel5
(Wideband Code Domain
Spread Spectrum)

3GPP LTE Downlink (OFDMA)



3GPP
WCDMA



Summary

Capturing baseband hardware waveforms to design the SDR RF system was shown. Baseband and RF were evaluated together in simulation.

A COTS WiMAX OFDMA reference waveform was used to evaluate RF system compatibility before the hardware implementation

An RF interferer scenario was evaluated in simulation before implementing and deploying hardware

The FPGA hardware implementation was testing using Software-Defined Instruments, leveraging simulation inside of off-the-shelf test equipment

Additional References

Web Links:

Agilent EEsof EDA Home Page:
http://eesof.tm.agilent.com/

EEsof SDR Applications:
http://eesof.tm.agilent.com/applications/sdr.html

EEsof Aerospace Defense Applications:
http://eesof.tm.agilent.com/applications/aerospace-b.html

EEsof Connected Solutions:
http://eesof.tm.agilent.com/products/connected_solutions_main.html

Application Notes:

Software Defined Radio Measurement Solutions:
http://cp.literature.agilent.com/litweb/pdf/5989-6931EN.pdf

Connected Simulation and Test Solutions Using ADS:
http://literature.agilent.com/litweb/pdf/5988-6044EN.pdf

RF/IF-to-Digital Connected Solutions BER Using ADS:
http://literature.agilent.com/litweb/pdf/5989-0024EN.pdf

Thank You !