Flexible Digital Modulation Testing for Satellite Regenerative Payloads

Presented by: Greg Jue and John Hansen
Agilent Technologies, Inc.

Anticipate Accelerate Achieve

Agenda

- **Digital Regenerative Payloads**
- **Modulation Techniques and EVM Overview**
- **Creating and Analyzing Wideband Signals**
- **BER Overview and Example**
- **Summary**

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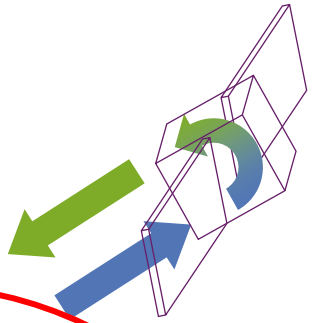
Regenerative Payloads



Digitally Regenerative & Switched

Conventional Hardware

Digital Signal Processing

ADC

Demodulator

FEC

DSP

DAC

Modulator

Encode

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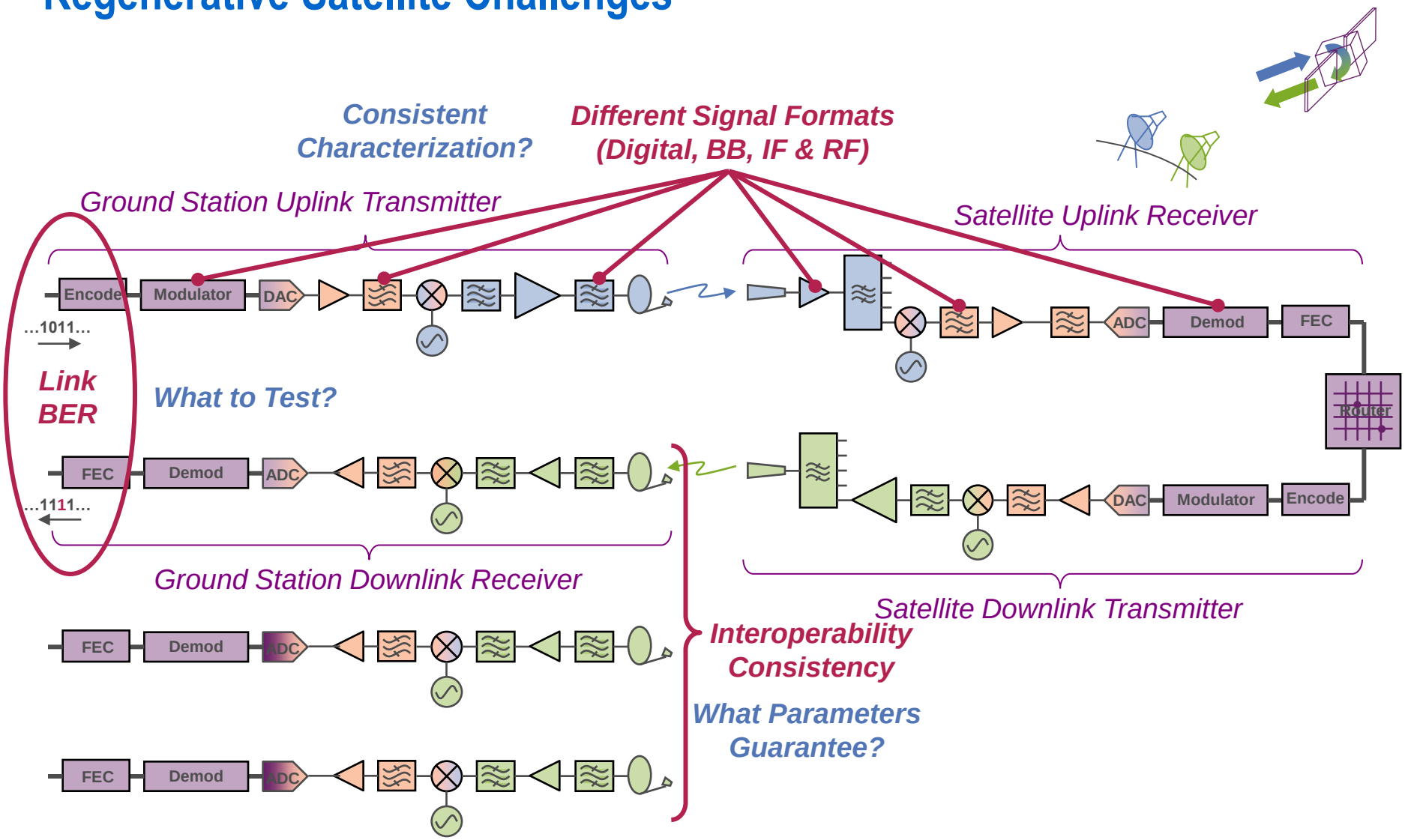
Regenerative Satellite Challenges



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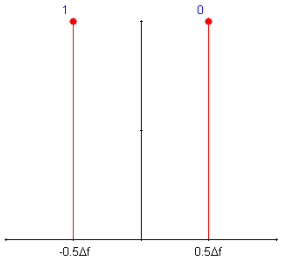
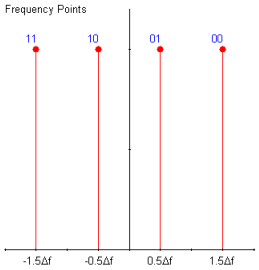
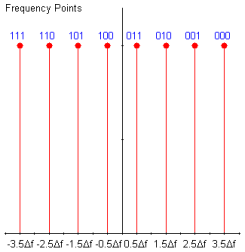
Digital Modulation Choices

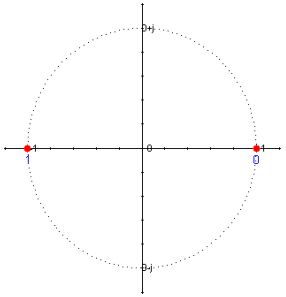
2, 4, 8-FSK



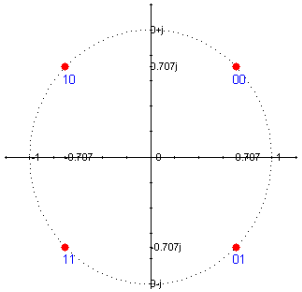




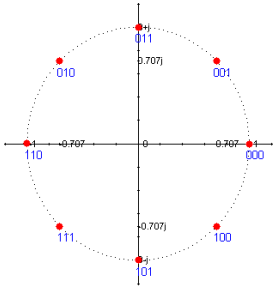
BPSK



QPSK



8PSK



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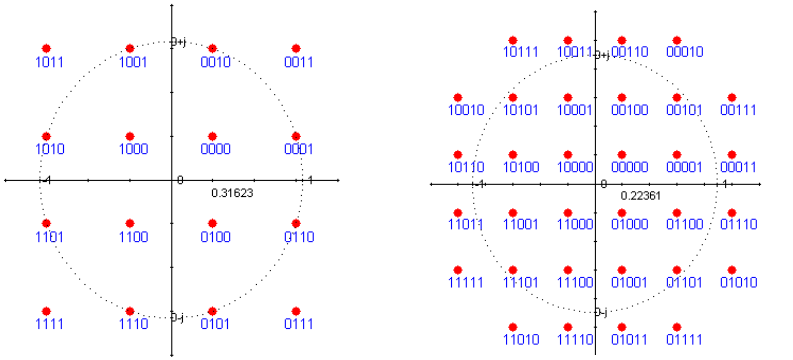
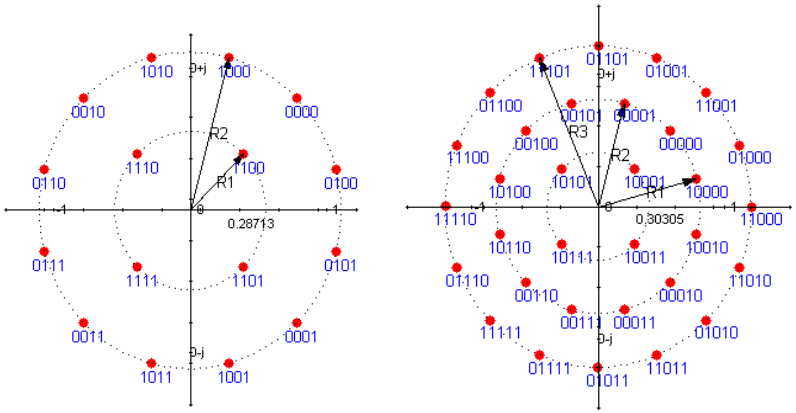
Higher Order Digital Modulation Choices

16, 32- QAM



16, 32- APSK



What is APSK?:

- Used in DVB-S2 (8PSK, 16APSK, 32APSK)
- Compression has less effect on spacing, relative to QAM
- Lower PAPR than QAM
- May lend itself to pre-distortion by varying ring spacing

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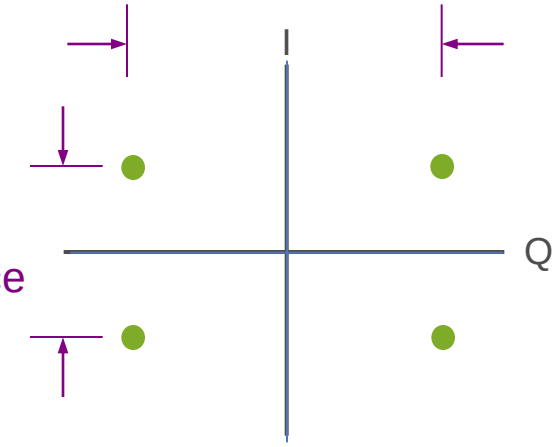
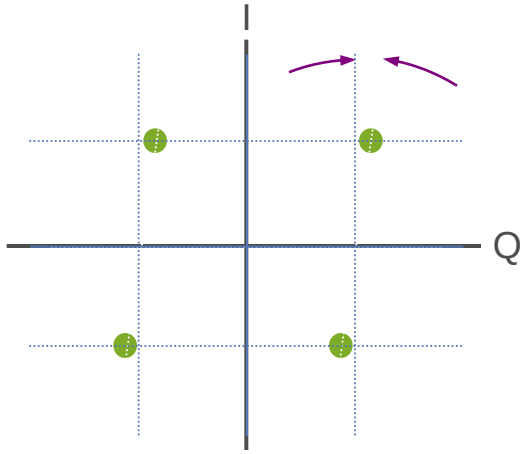
Basic Constellation Measurements

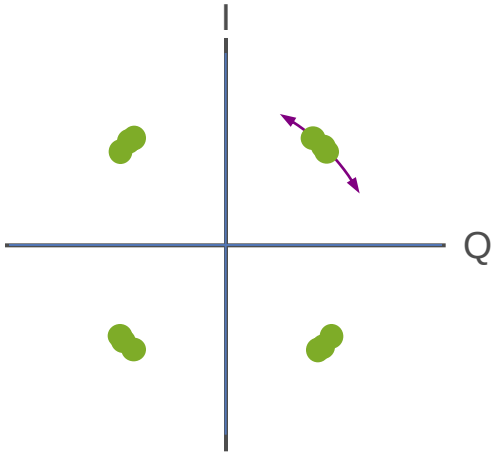
Gain Imbalance



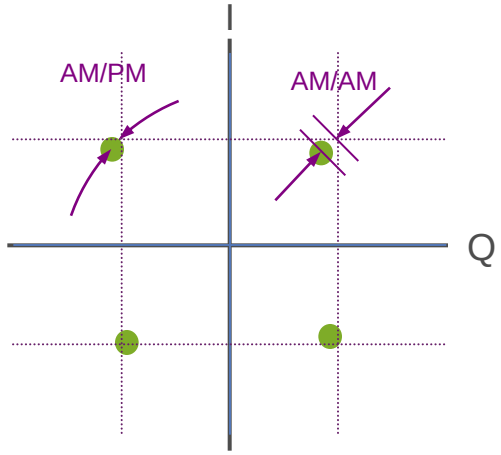
Skew



Phase Noise



AM/AM
AM/PM



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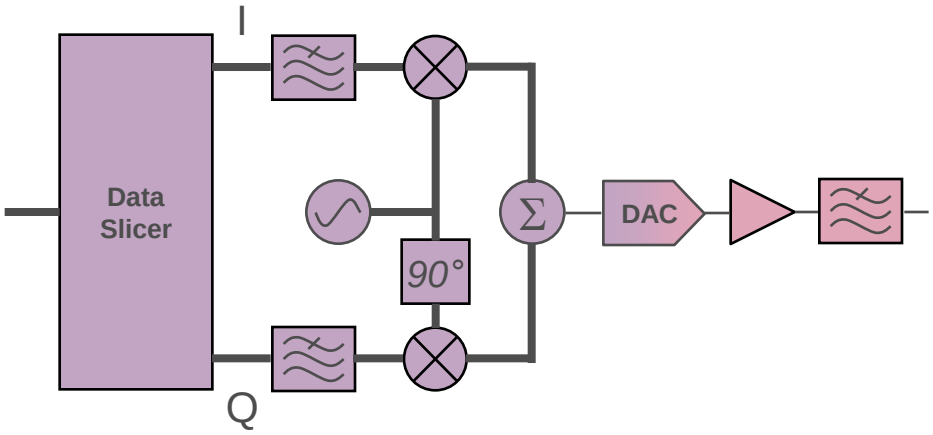
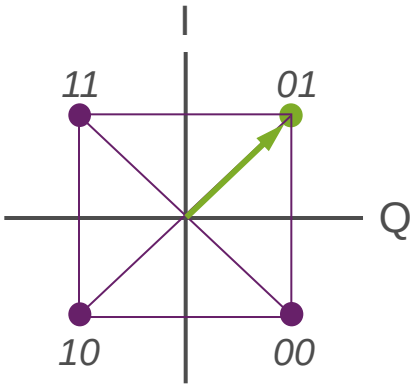
Filter α Effects

Modulator Filtering

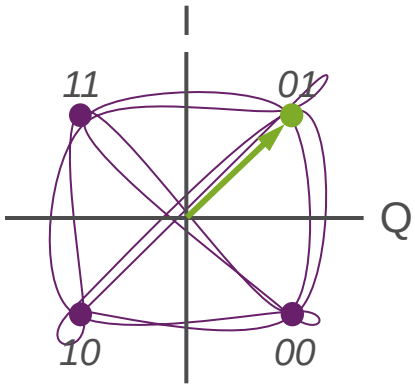


QPSK

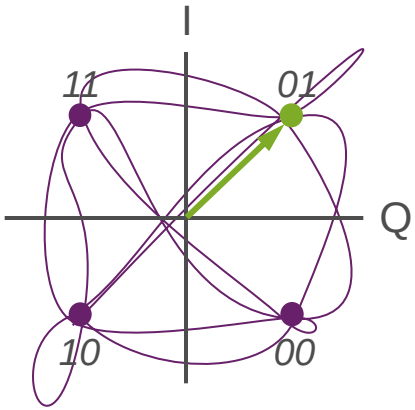
α = 1.0



α = 0.5



α = 0.1



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Error Vector Magnitude

What is the EVM Metric?

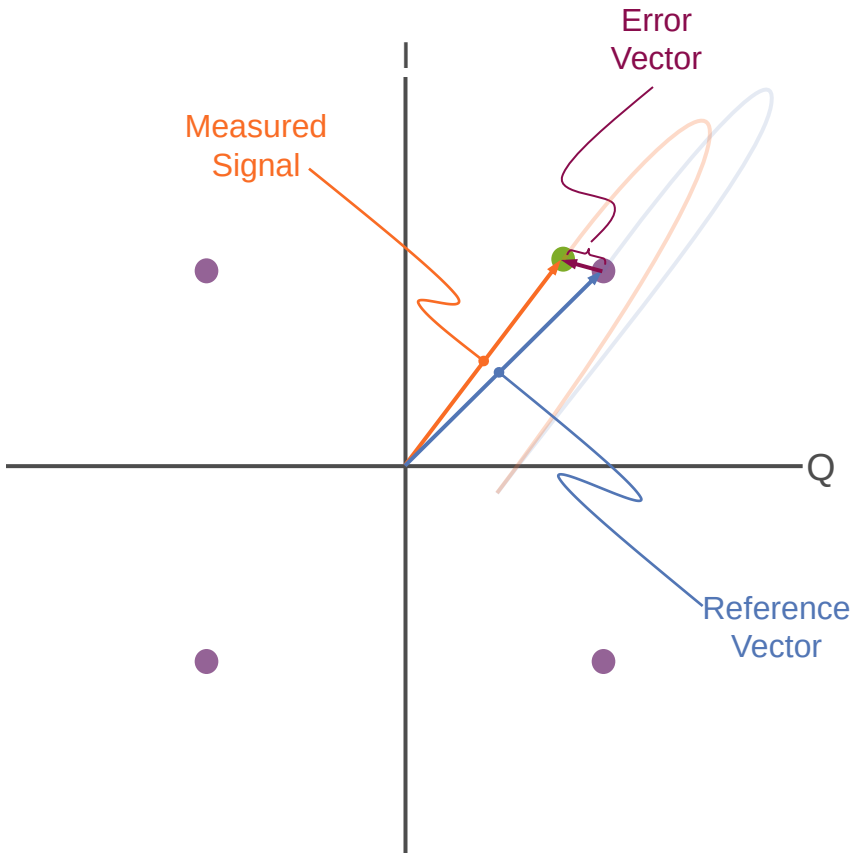
Reference Signal

Measurement Signal

Vector Difference

Compares Ref. to Actual

Quantizes Degradation



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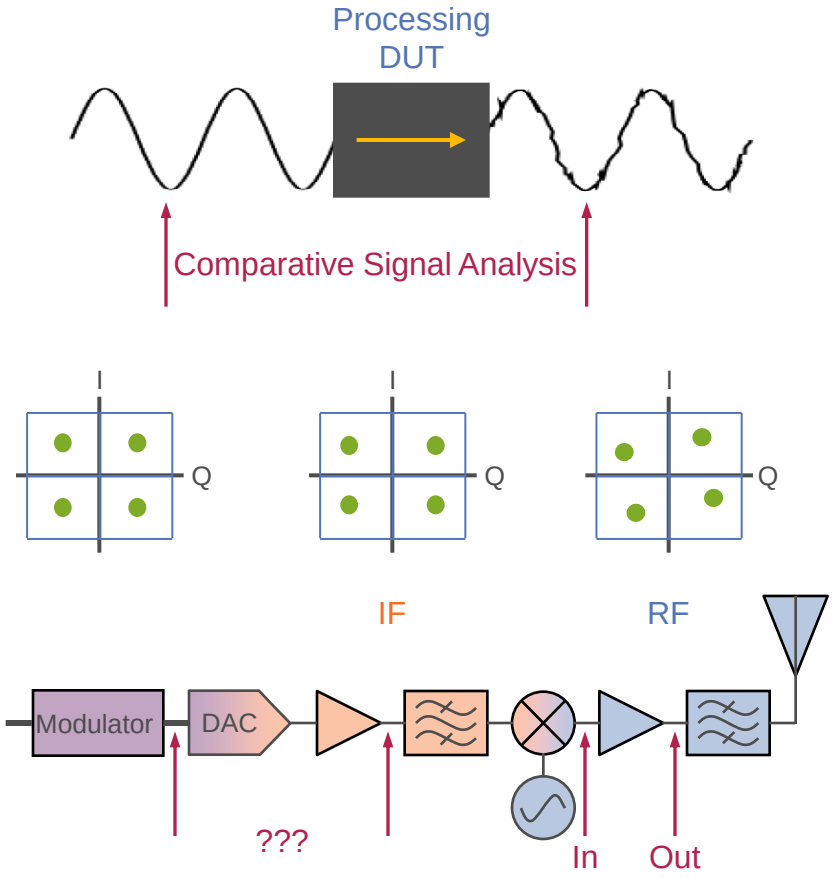
Diagnosing Digital Modulation Issues



Comparative Analysis

Measure EVM In & Out

Difference is Impairment

Requires Consistent Tools

Need Cross Format Tools

Need Software Tools…

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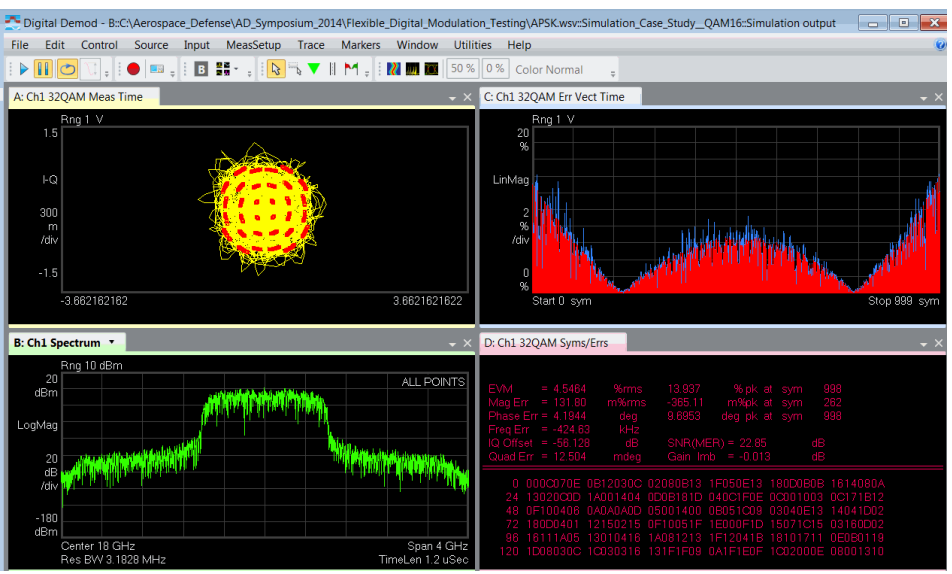
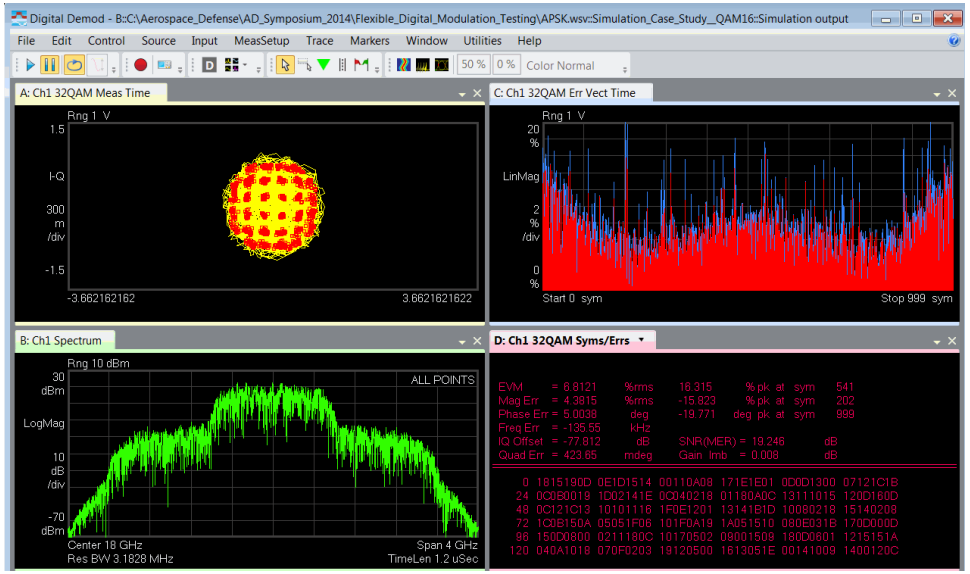
Diagnosing Digital Modulation Issues



Phase Noise



Gain Compression and Phase Noise

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Mixed Signal Implementation Test Challenges

Different Signal Formats…

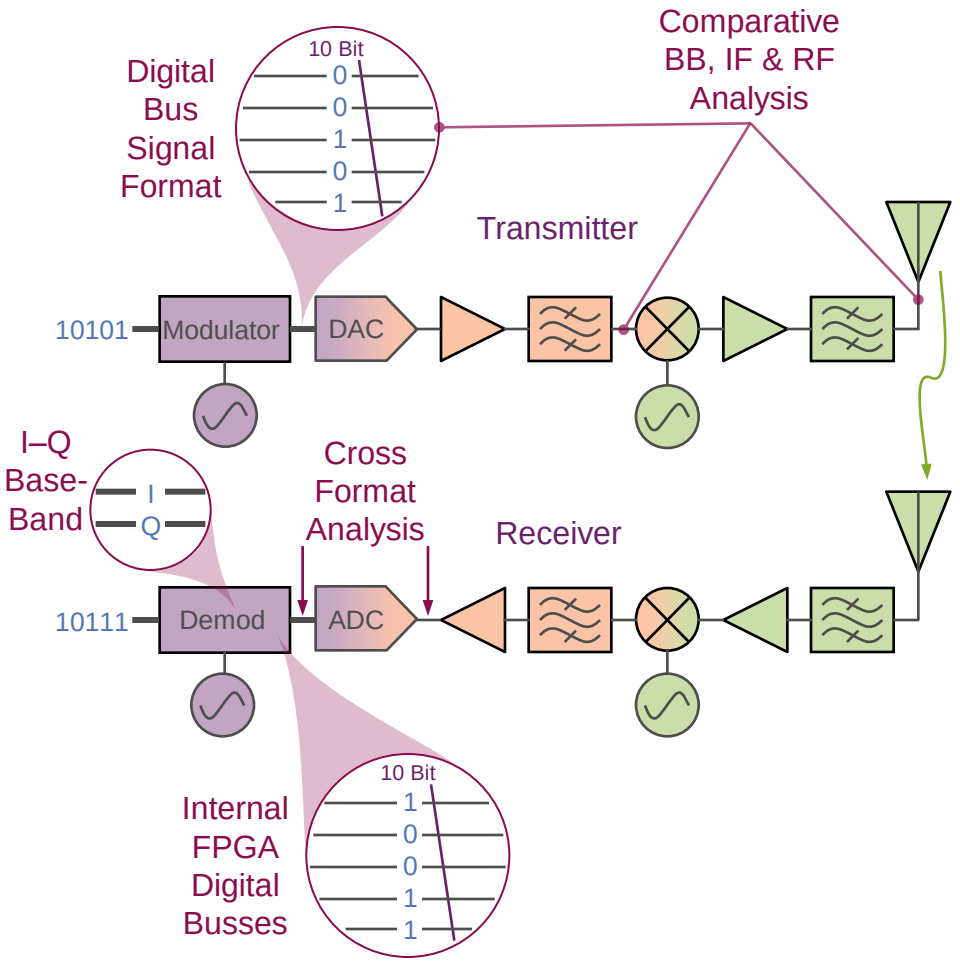
Analog vs. Digital Words

Cross Domain Analysis…

Probing Challenges…

Internal FPGA Signals

New Development Processes



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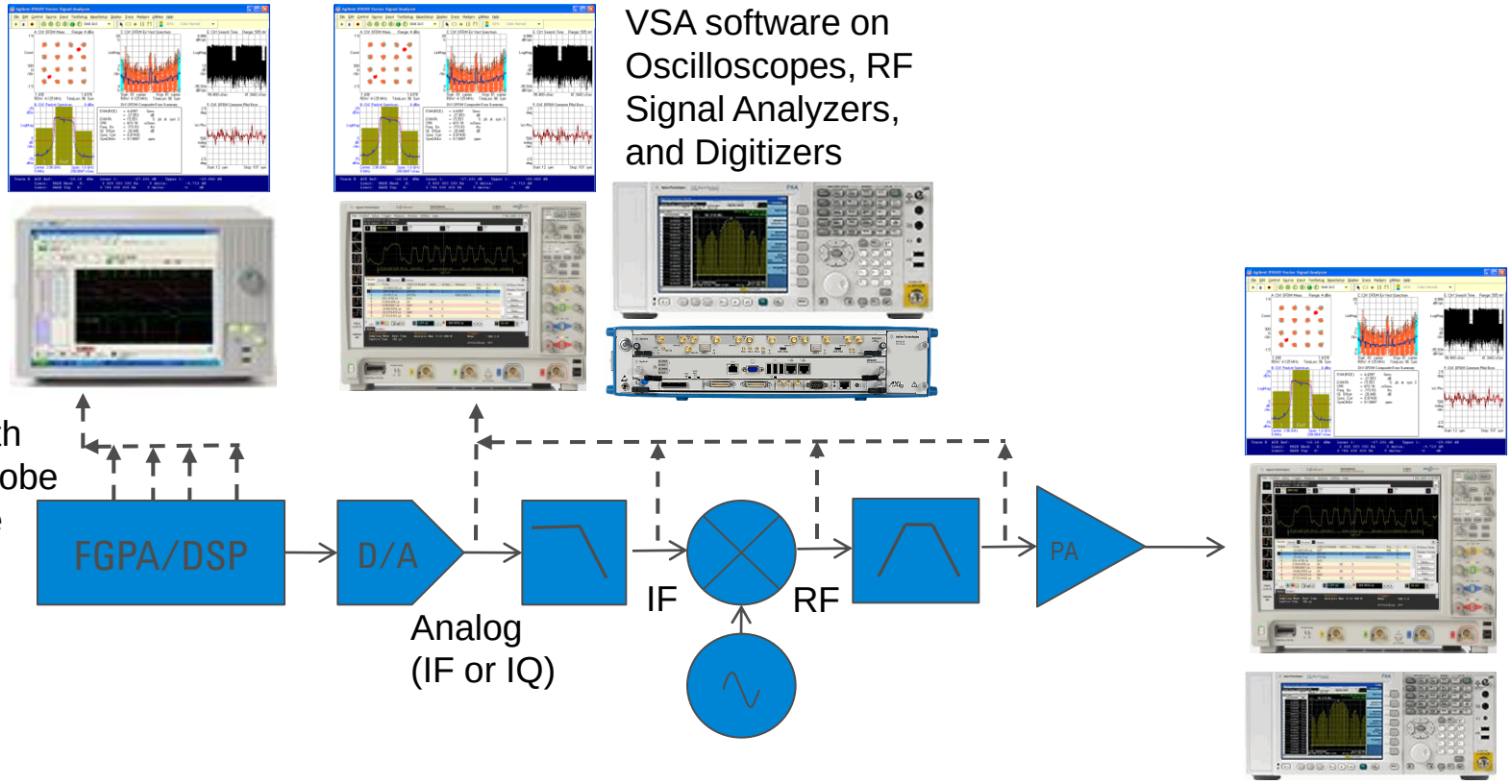
Use Same VSA Software Along a Mixed Signal Tx Chain with Different Instruments



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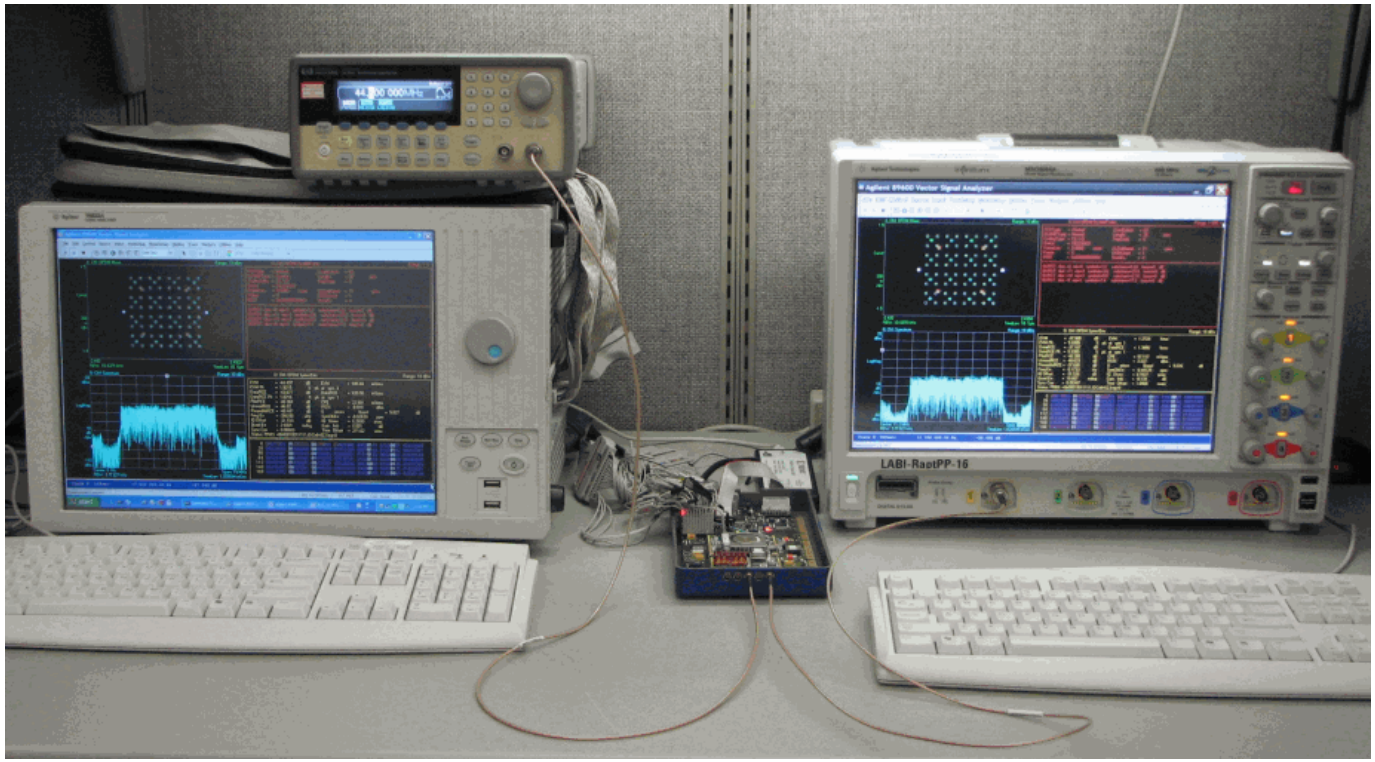
Probing Across the DAC Boundary Using VSA Software with a Logic Analyzer (Digital) and Oscilloscope (Analog IF)



Logic analyzer on left probing digital signals on 21 FPGA pins via flying leads --- fed to VSA

Digital oscilloscope on right probing DAC analog output IF --- fed to VSA

FPGA Dynamic Probe accesses three points along the signal path

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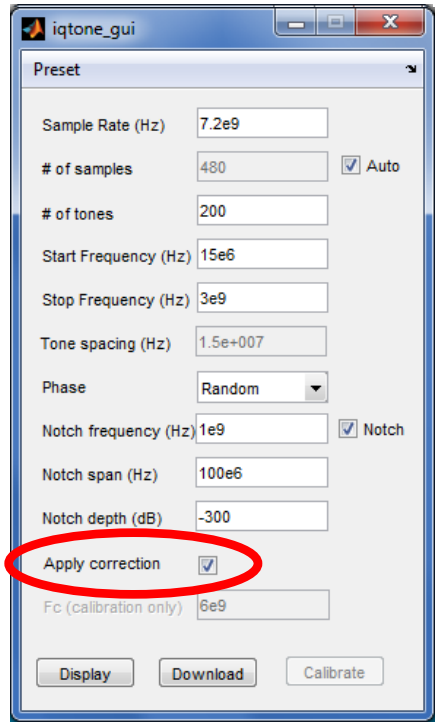
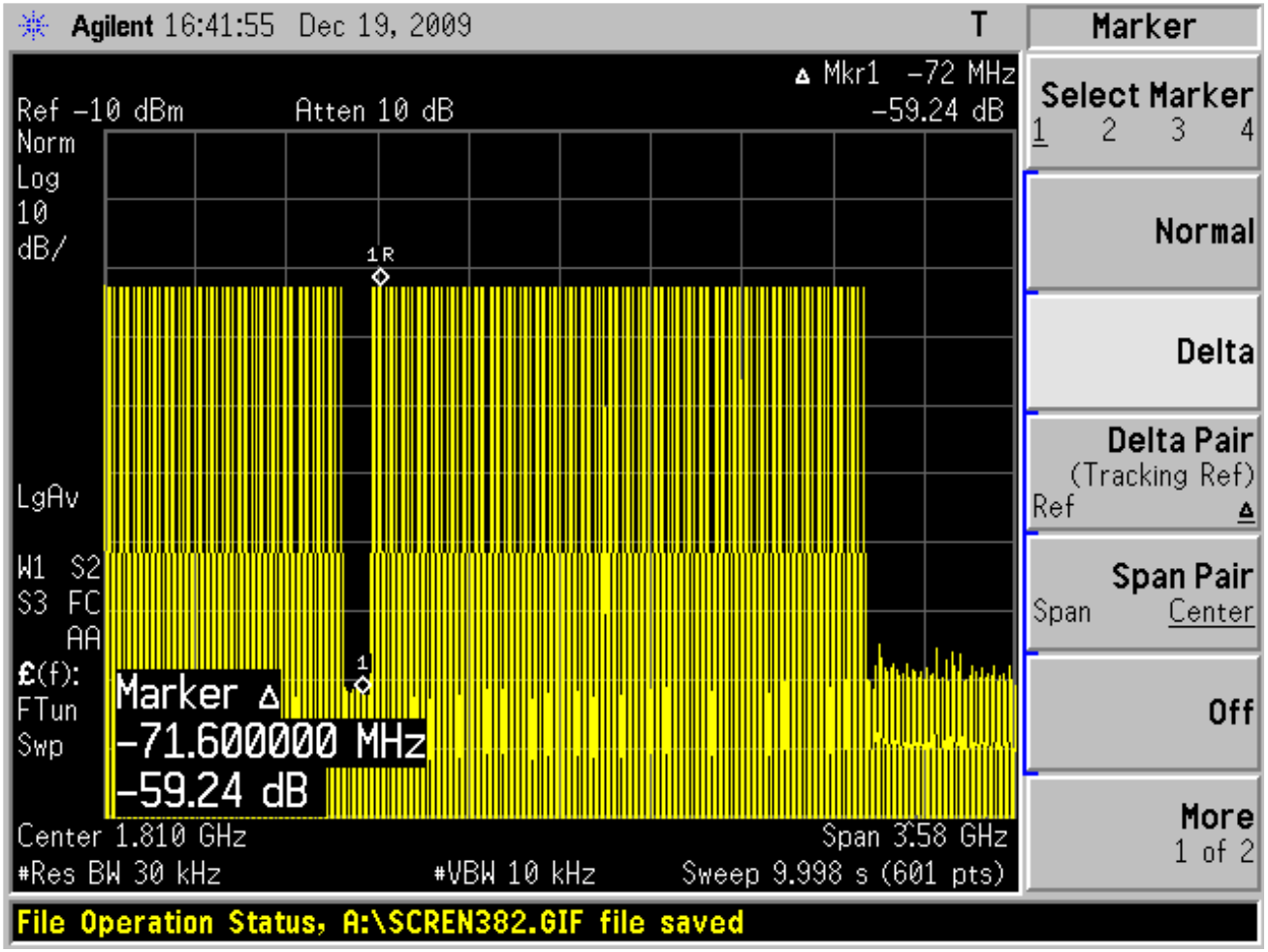
High-Precision AWG Example: Multi-Tone Signal

Multi-tone signal with 200 tones, 3 GHz bandwidth

Fs = 7.2 GHz





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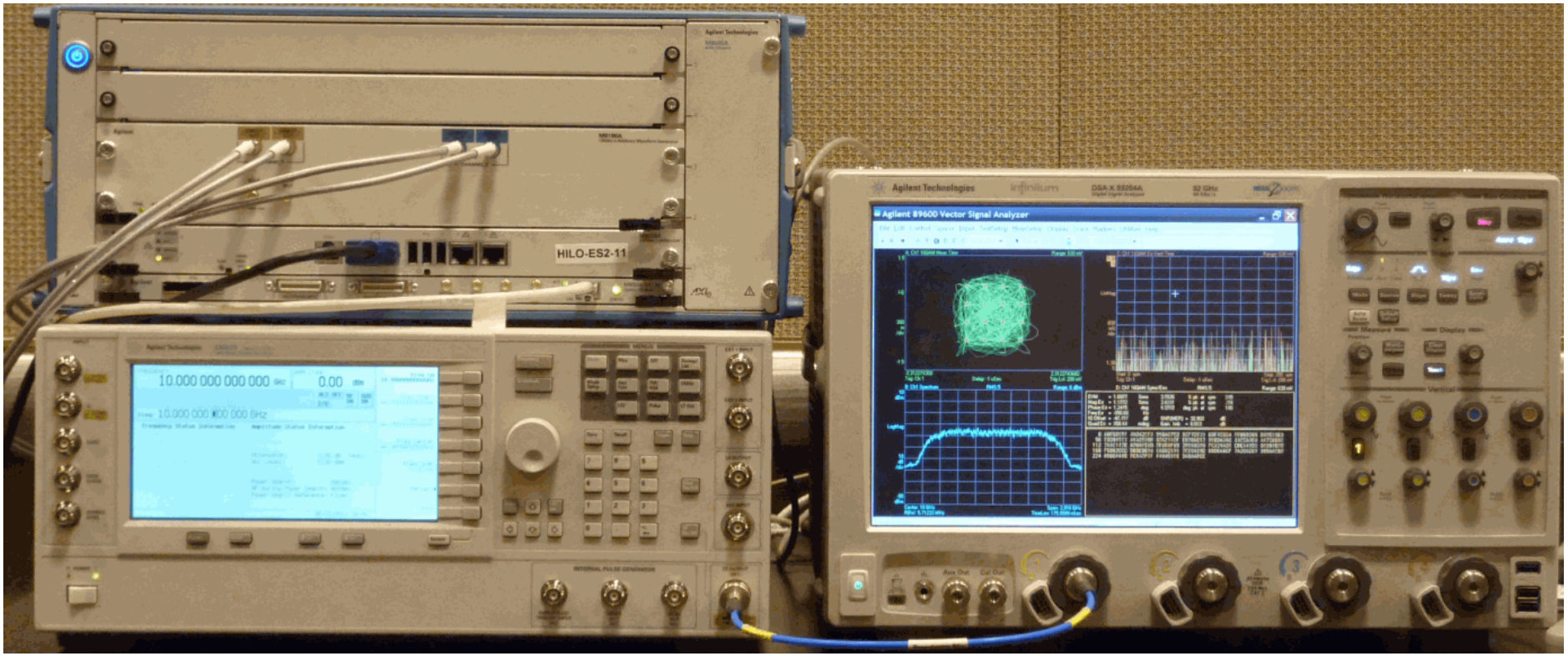
Picture of Wideband VSA Test Setup: Wideband 16 QAM Example with Analog IQ Modulation using Vector Signal Generator



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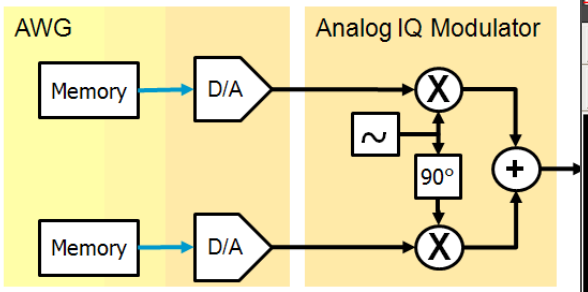
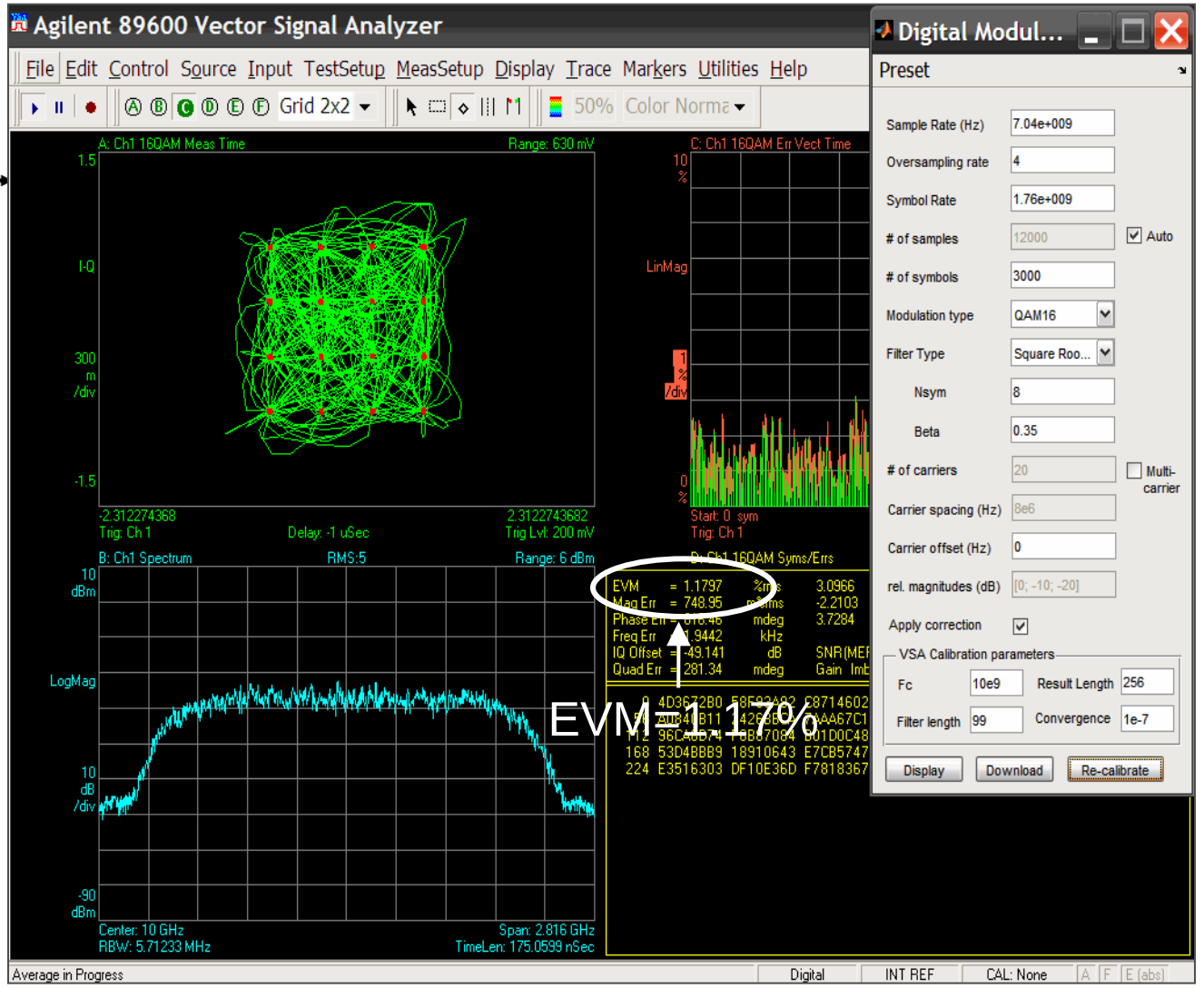
High-Precision AWG Example: Analog IQ Modulation, Fc=10GHz



Wideband digital modulation: QAM16, 1.76G Sym/s

Fs = 7.2 GHz with amplitude correction



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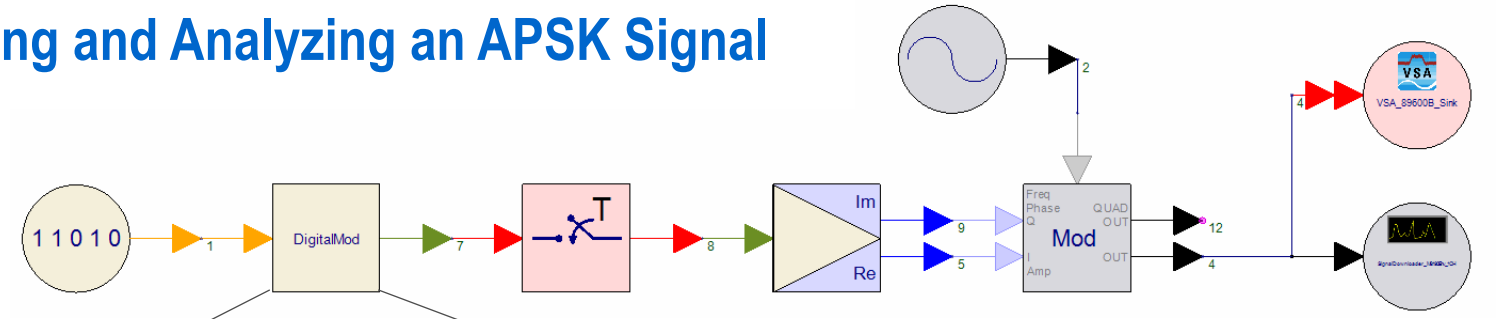
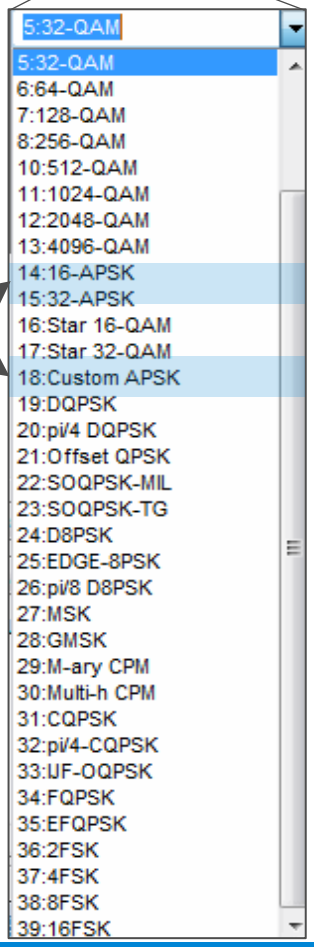
Creating and Analyzing an APSK Signal





Select 16, 32, or Custom APSK

M8190A AWG

I Q

Vector PSG

X, Ku-Band

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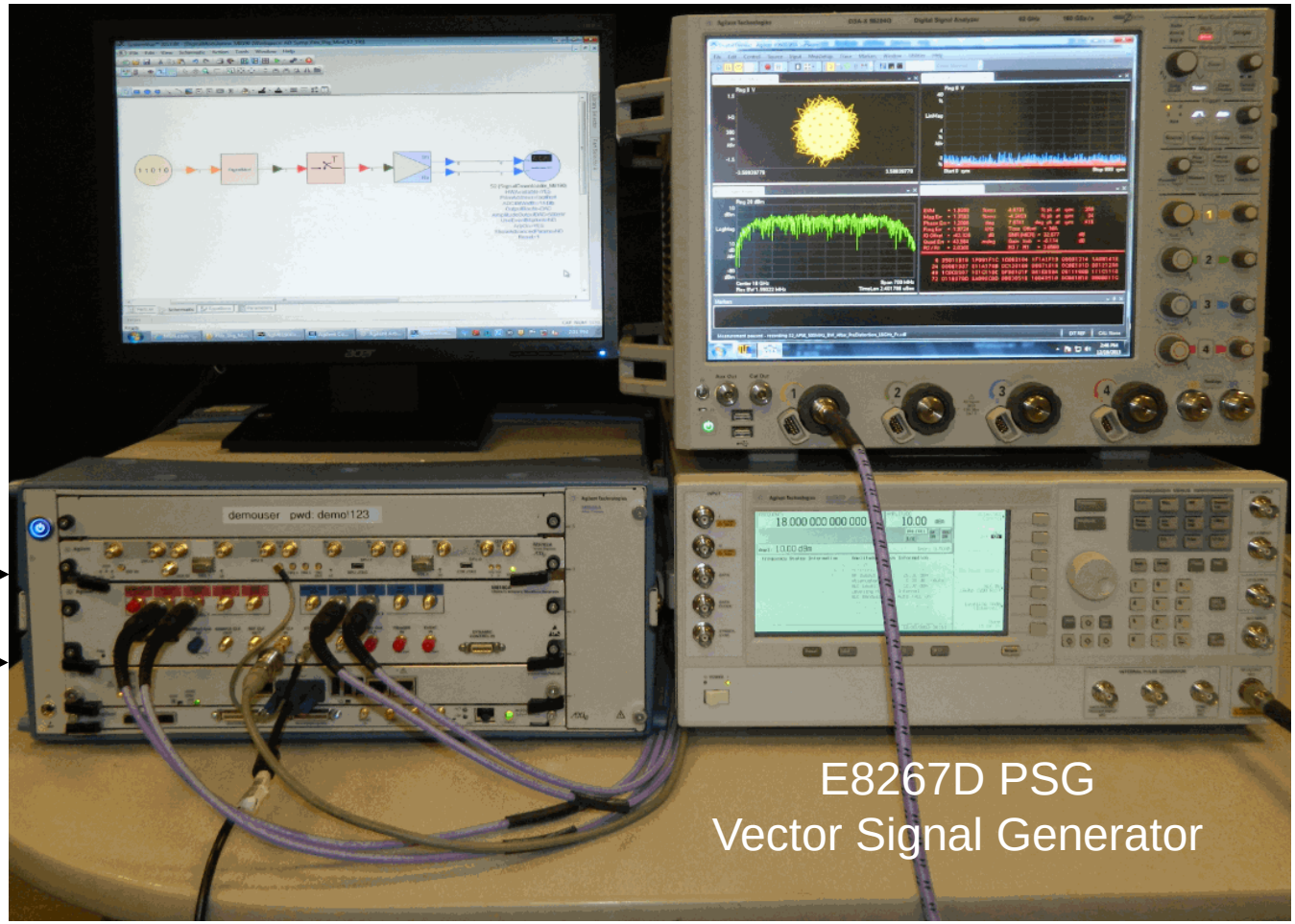
Test Setup to Generate and Analyze Wideband 32 APSK Signals

62 GHz Infiniium Oscilloscope
with 89600 VSA Software



M8190A AWG

SystemVue
Installed on Controller

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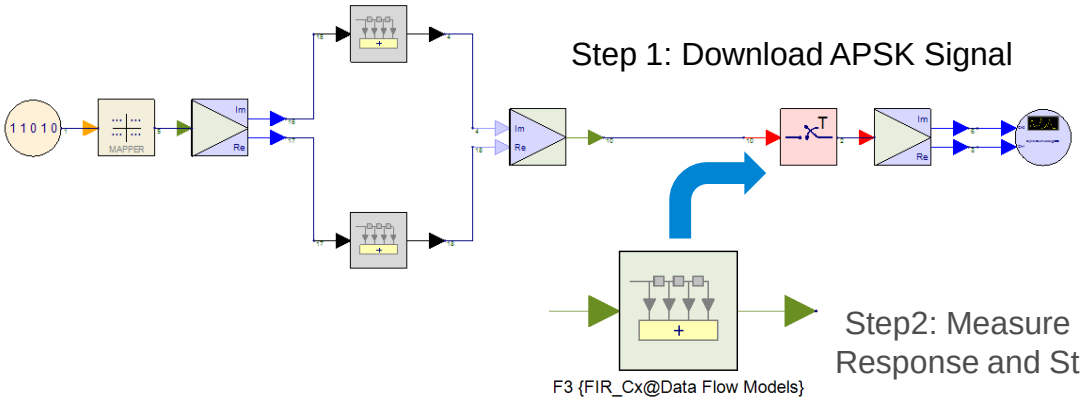
Apply IQ Waveform Corrections Using VSA Complex EQ Response



Step 1: Download APSK Signal

M8190A AWG

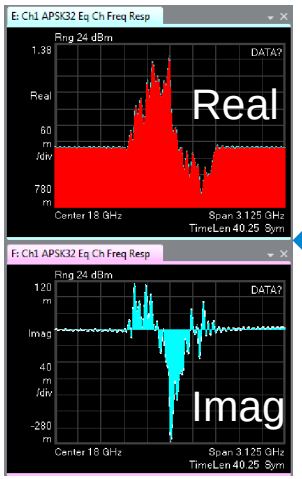
I Q

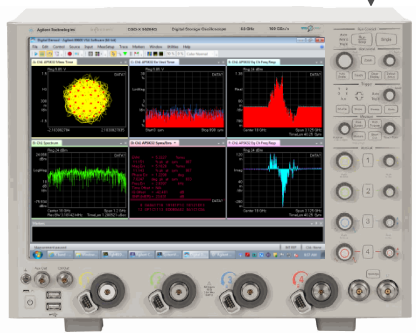
Step2: Measure Equalizer Response and Store to File

Vector PSG

Step 3: Re-Download APSK Signal With Complex FIR Correction Tap Coefficients

Complex Tap Coeffs





62 GHz Oscilloscope

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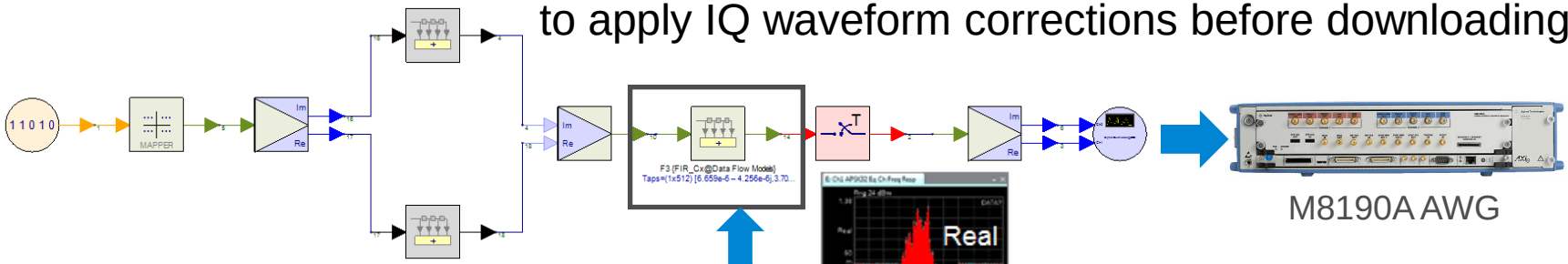
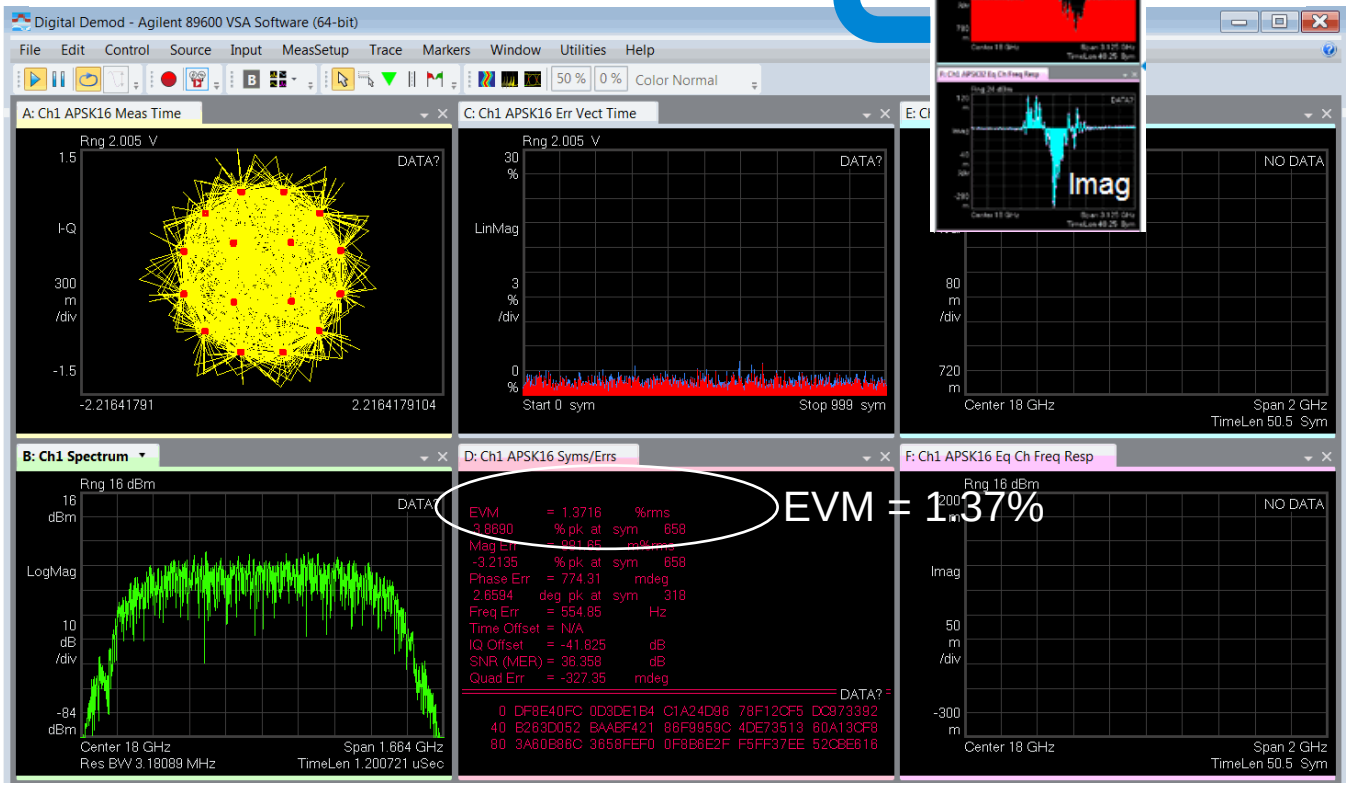
16 APSK Measurement Results After Apply IQ Corrections

Apply EQ real and imag frequency response
to apply IQ waveform corrections before downloading





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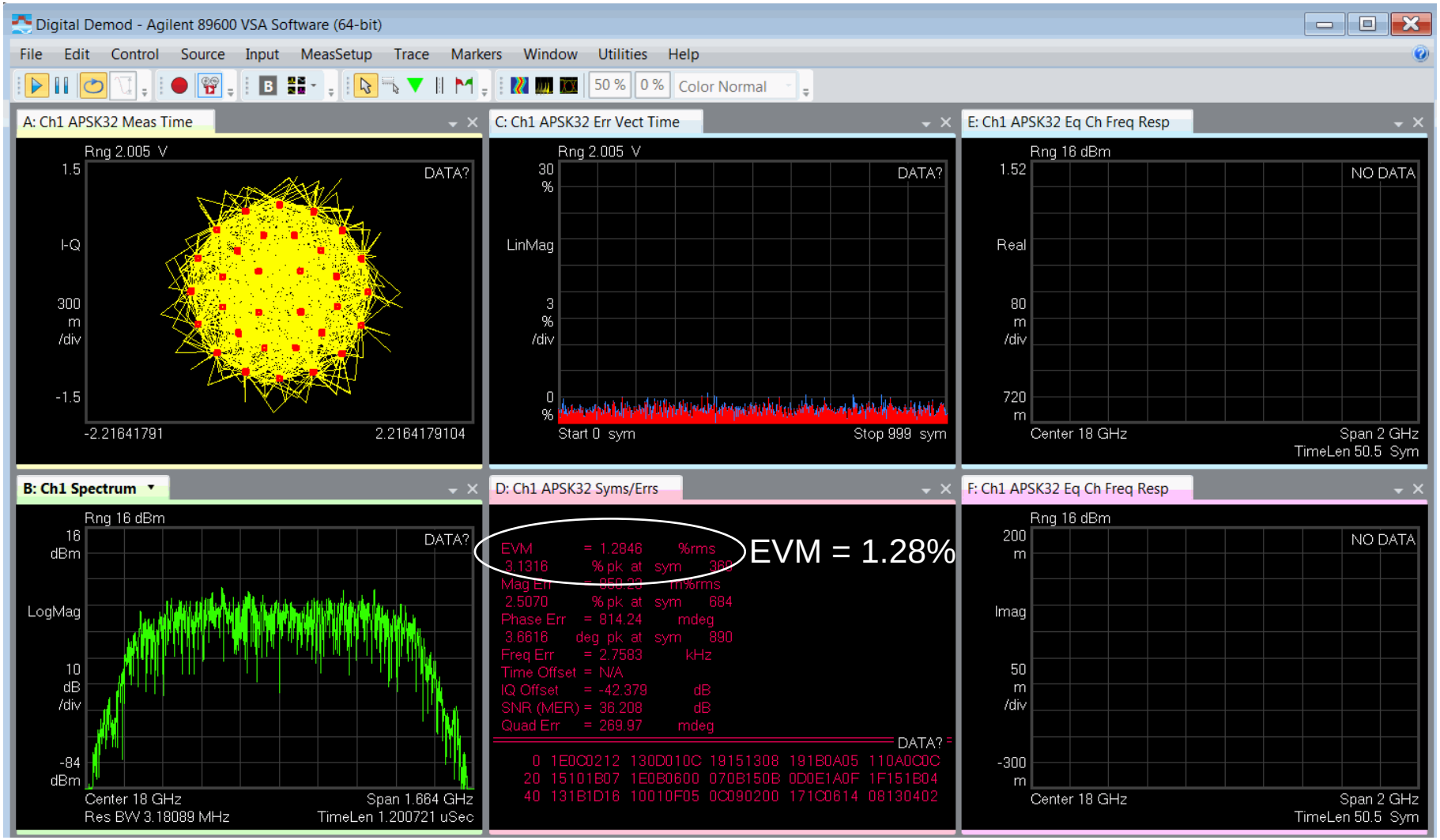
32 APSK Measurement Results After Applying Corrections



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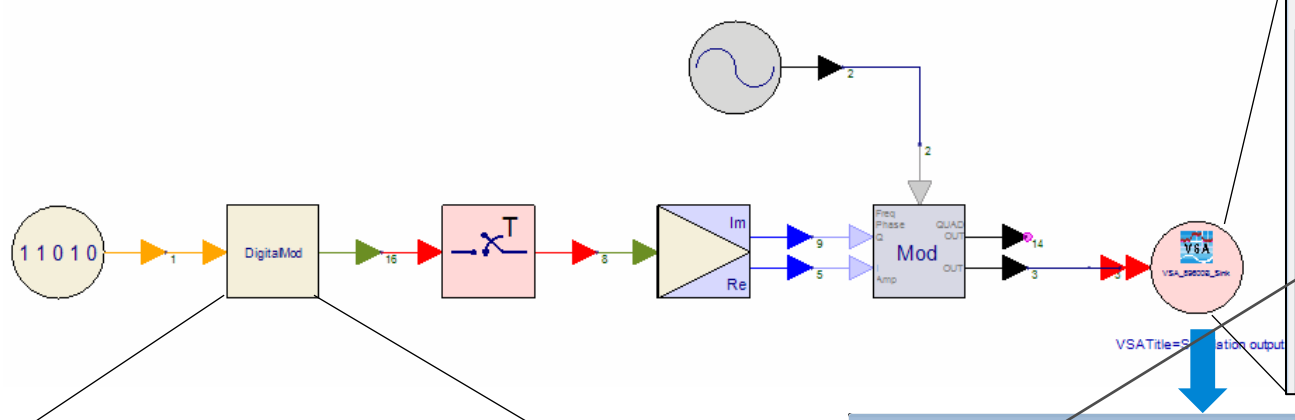
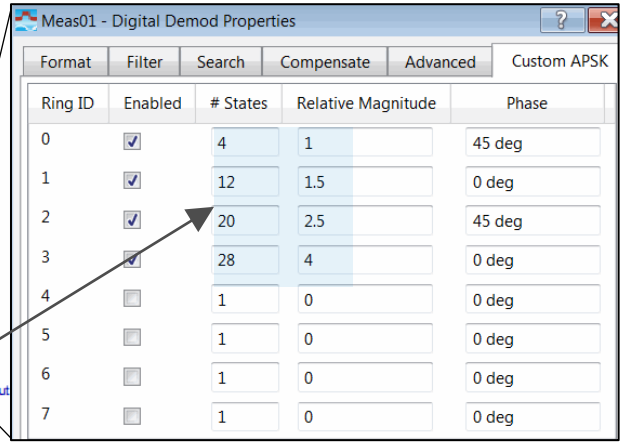
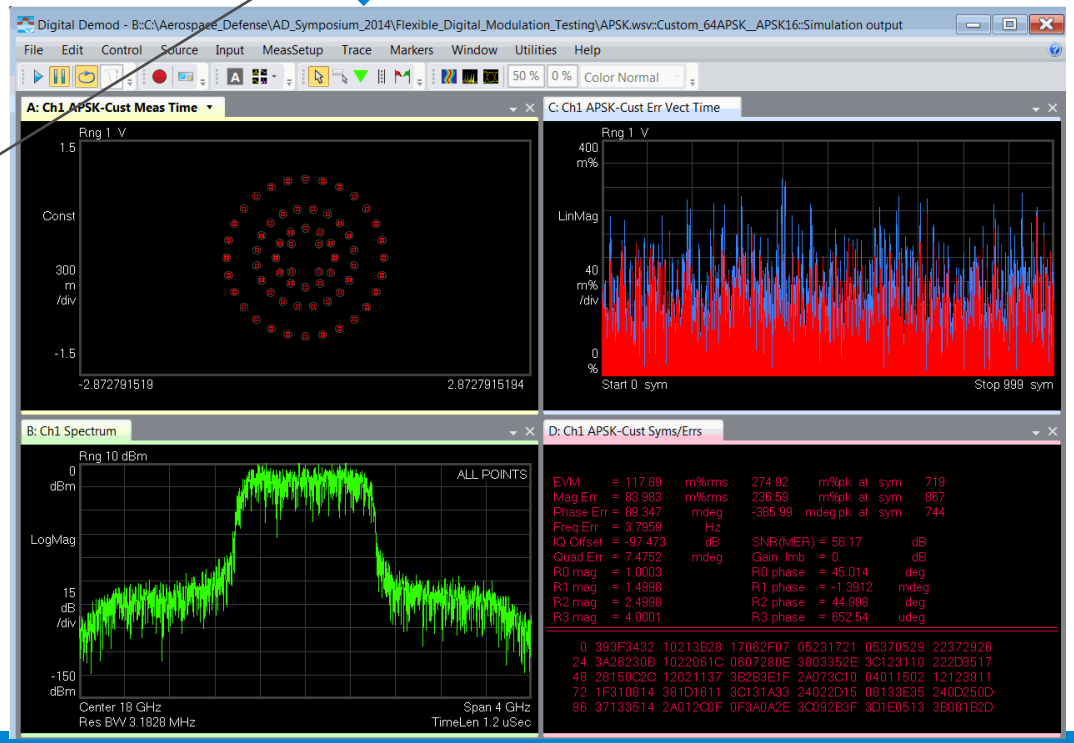
Customizing APSK- 64 APSK Example





Name	Value
ModType	18:Custom APSK
RingStates	[4;12;20;28]
RingMagnitudes	[1;1.5;2.5;4]
RingInitialPhases	[45; 0;45;0]
DefaultState	DefaultState
OversampleRatio	OversamplingRatio
PulseShapingFiter	PulseShapingFilter
FilterLengthOption	FilterLengthOption
Length	LengthInTaps
Alpha	0.25
BitOrder	BitOrder
WorkMode	WorkMode



Custom Ring States, Magnitudes, and Phases

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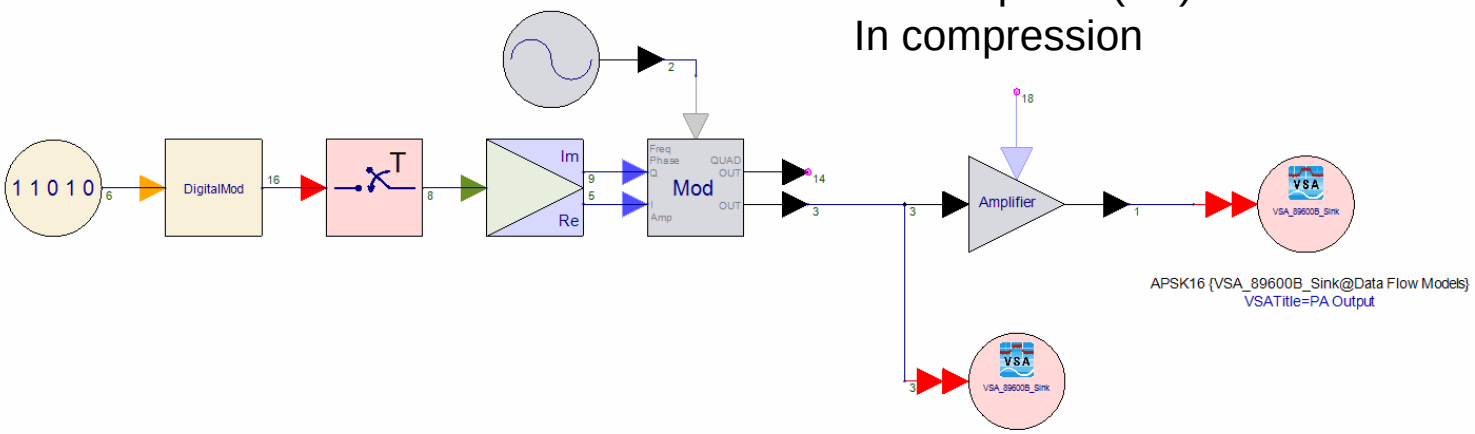
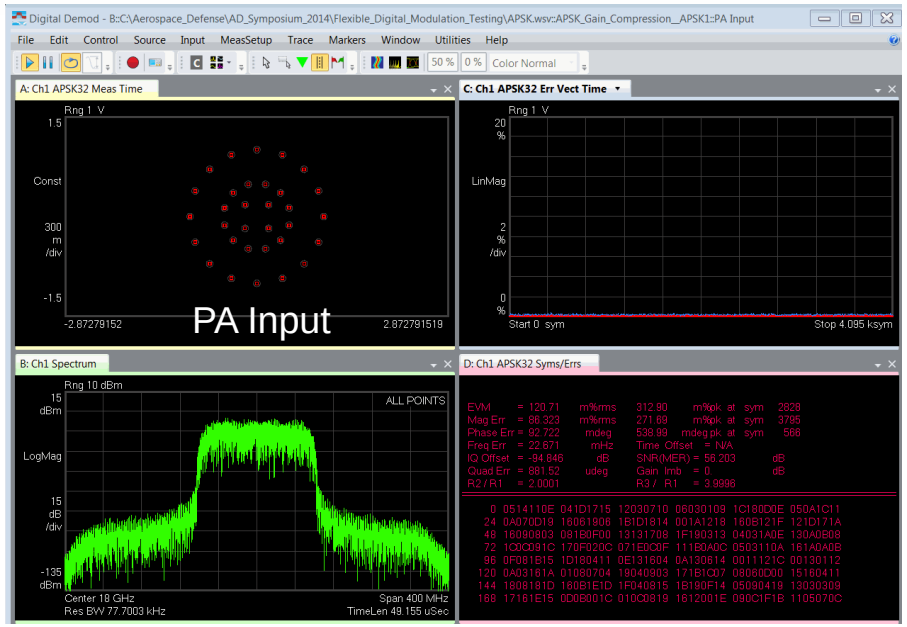
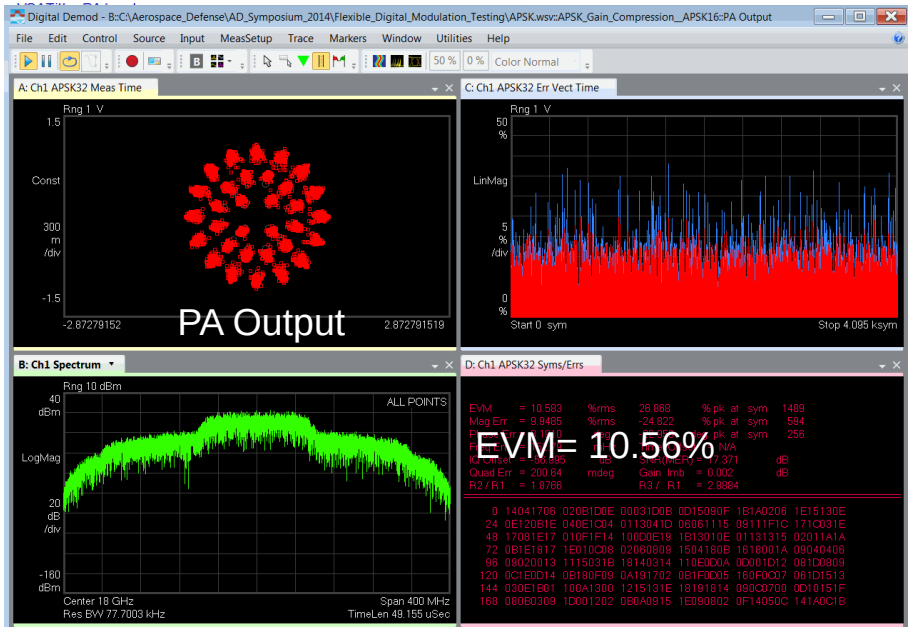
APSK - Adjust Ring Ratios to Compensate for PA Gain Compression

Power Amplifier (PA)
In compression







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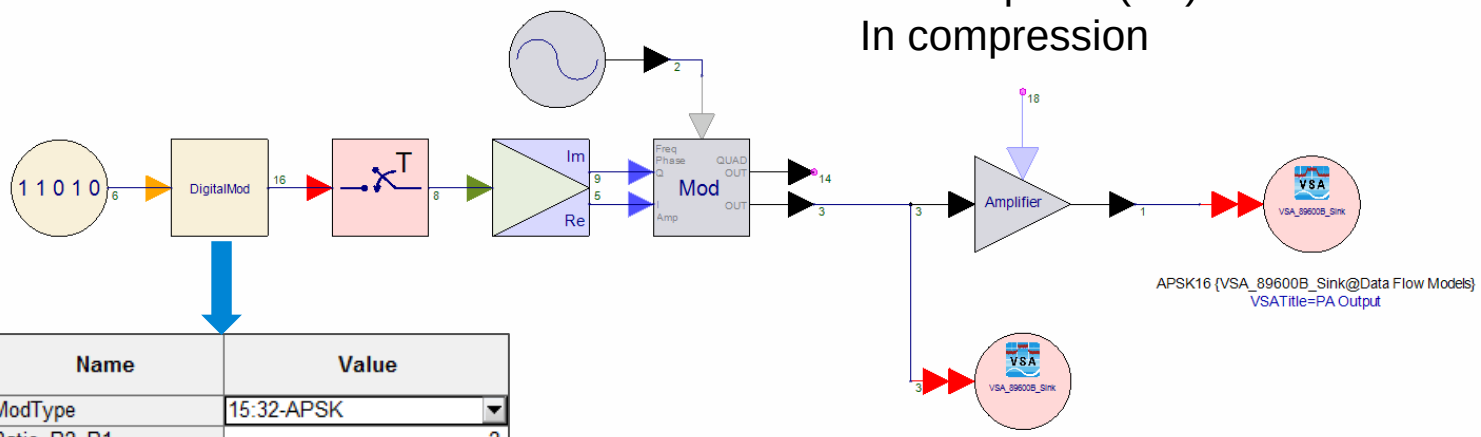
APSK - Adjust Ring Ratios to Compensate for PA Gain Compression

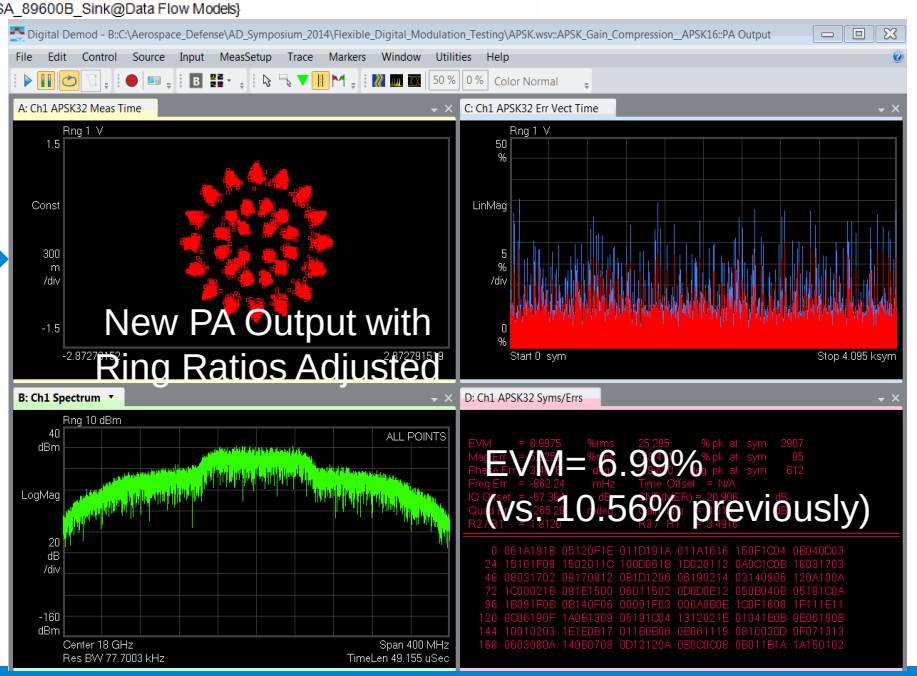
Power Amplifier (PA)
In compression



Name	Value
ModType	15:32-APSK
Ratio_R2_R1	2
Ratio_R3_R1	4

Name	Value
ModType	15:32-APSK
Ratio_R2_R1	2
Ratio_R3_R1	5

Changed outer R3/R1 ring ratio from 4 to 5



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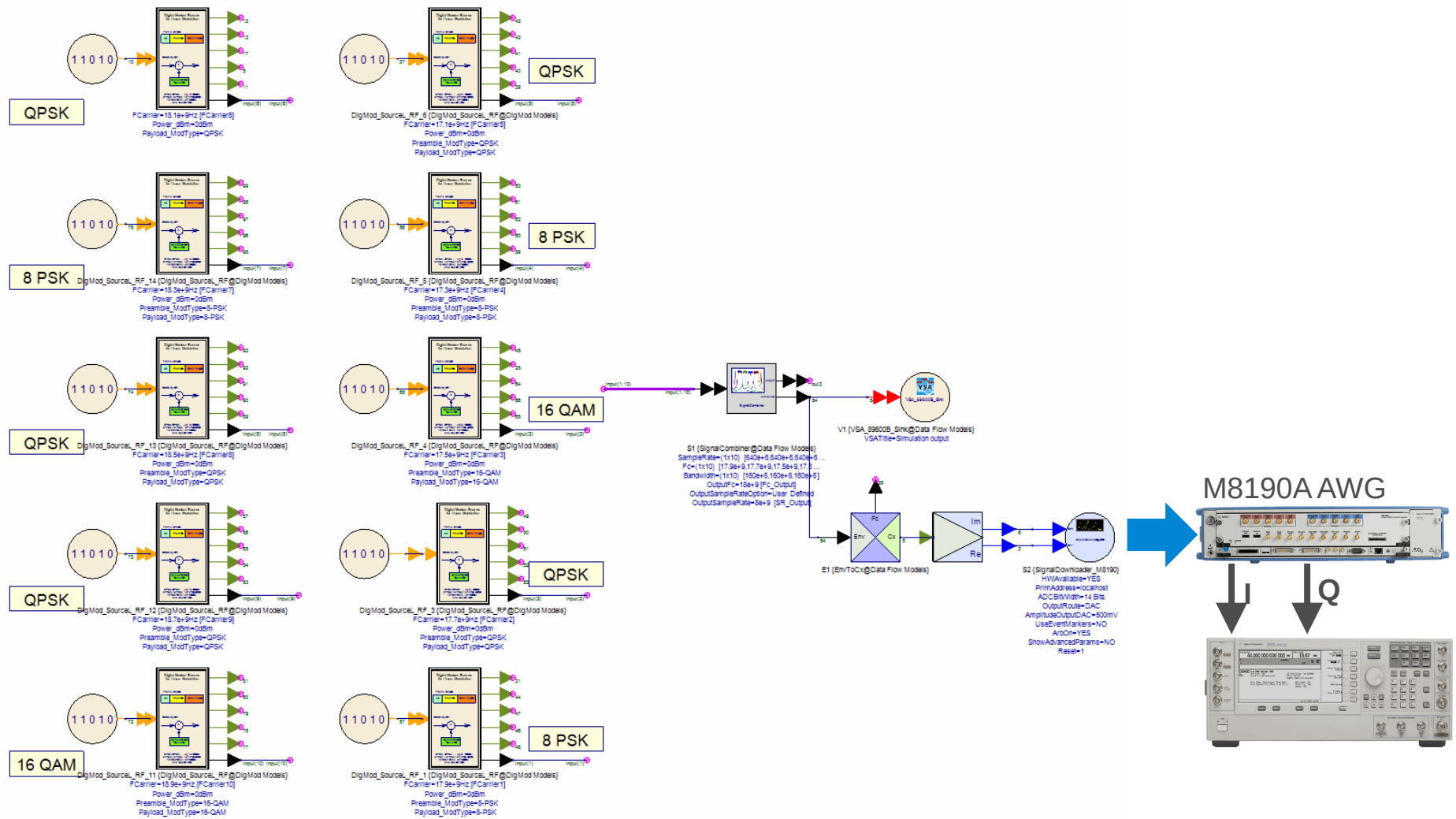
Generating Multiple Independent Modulated Signals Spanning 2 GHz



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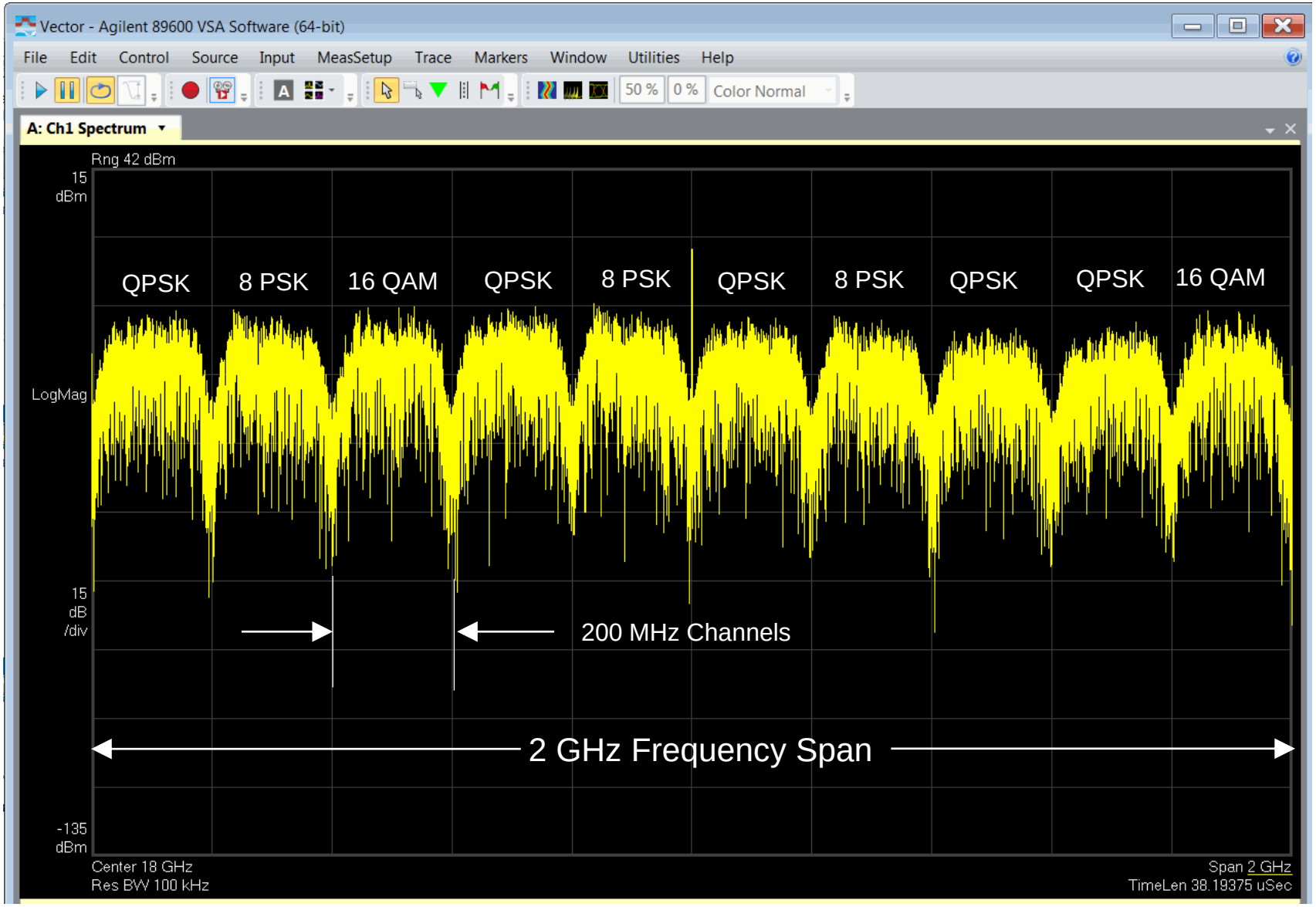
Generating Multiple Independent Modulated Signals Spanning 2 GHz



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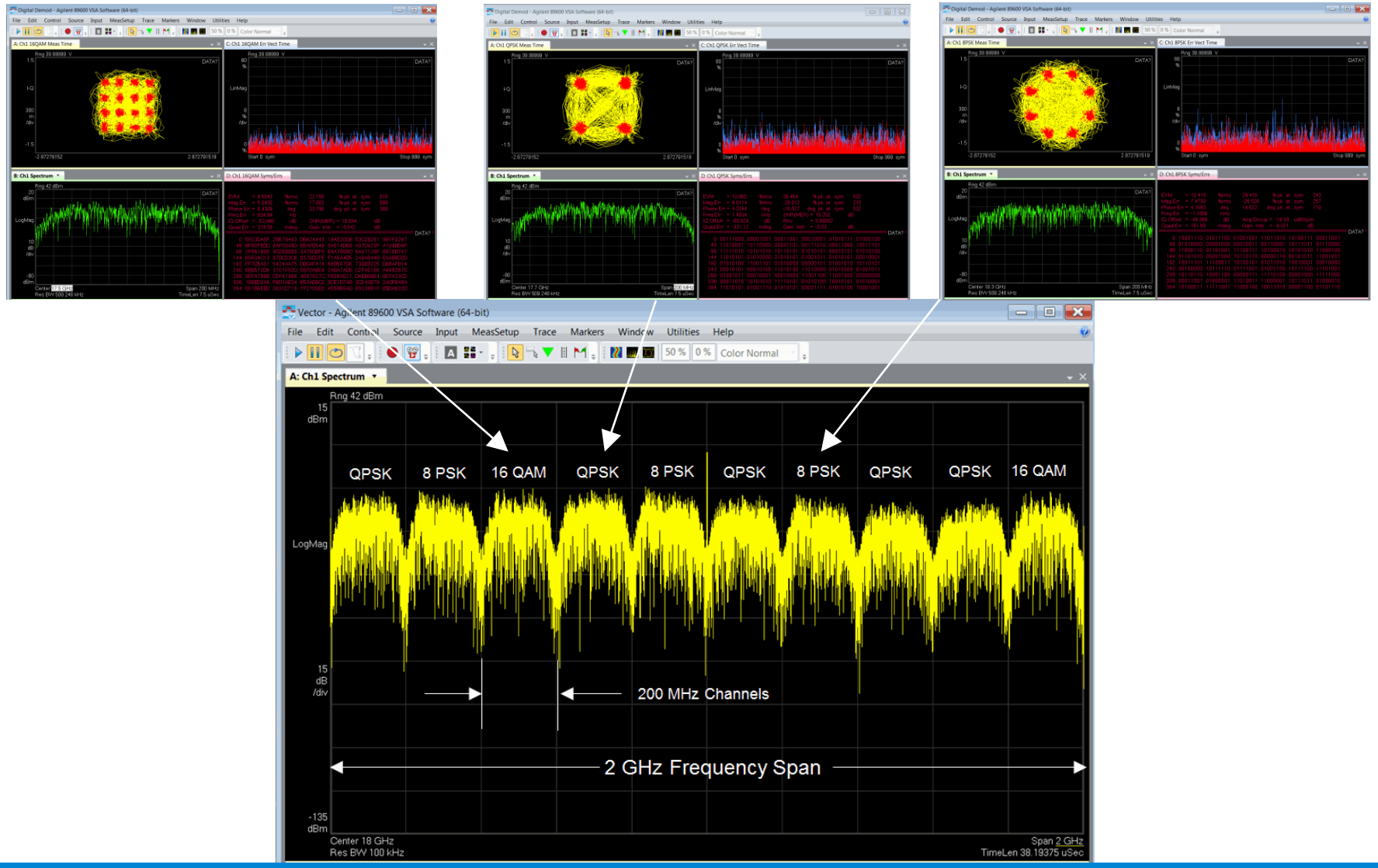
Analyzing the Multiple Independent Test Signals



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- Modulation Techniques and EVM Overview
- Creating and Analyzing Wideband Signals
- BER Overview and Example
- Summary

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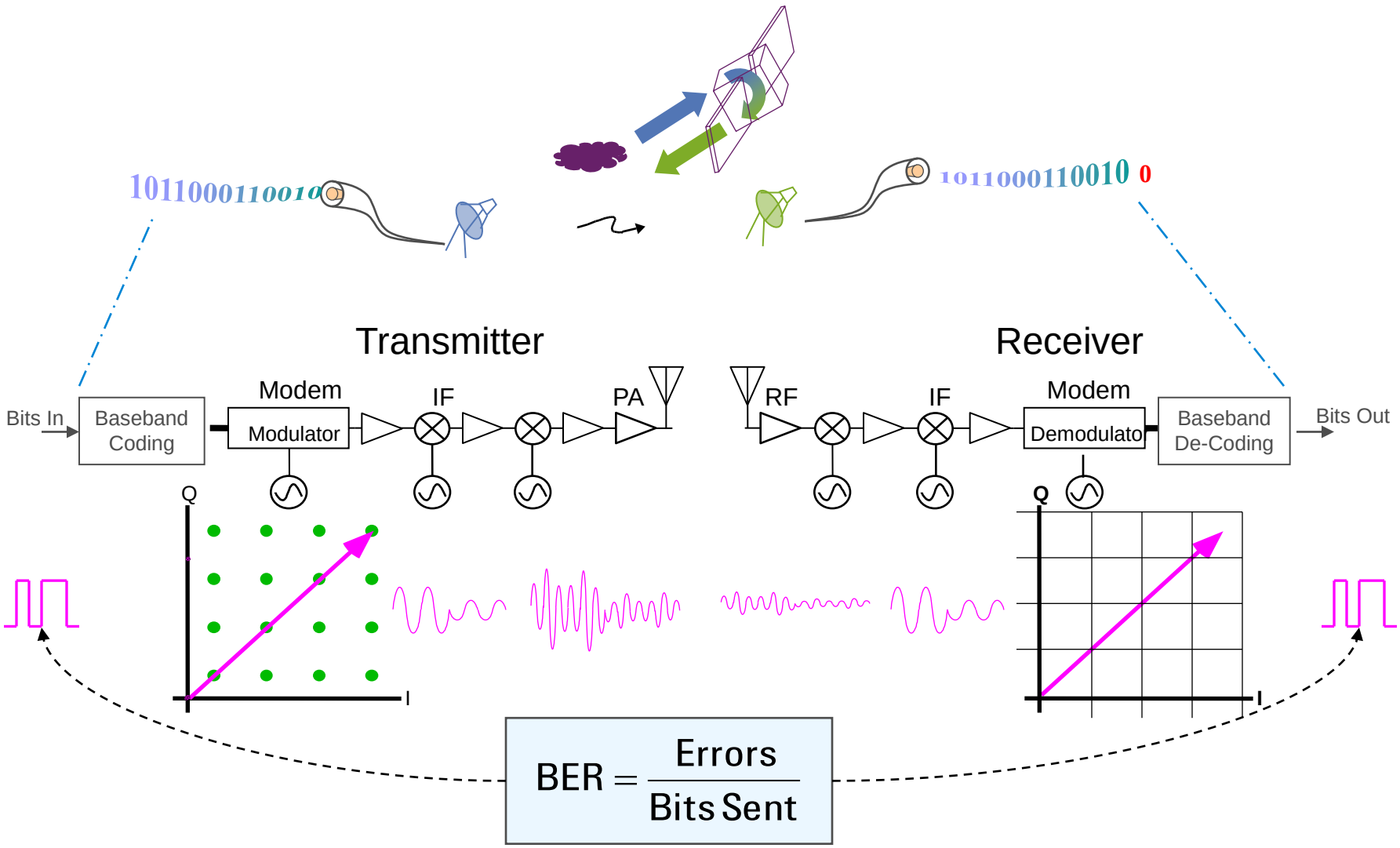
What is BER?



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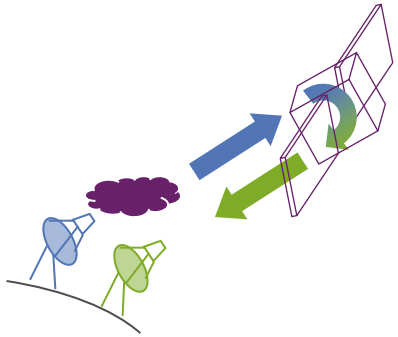
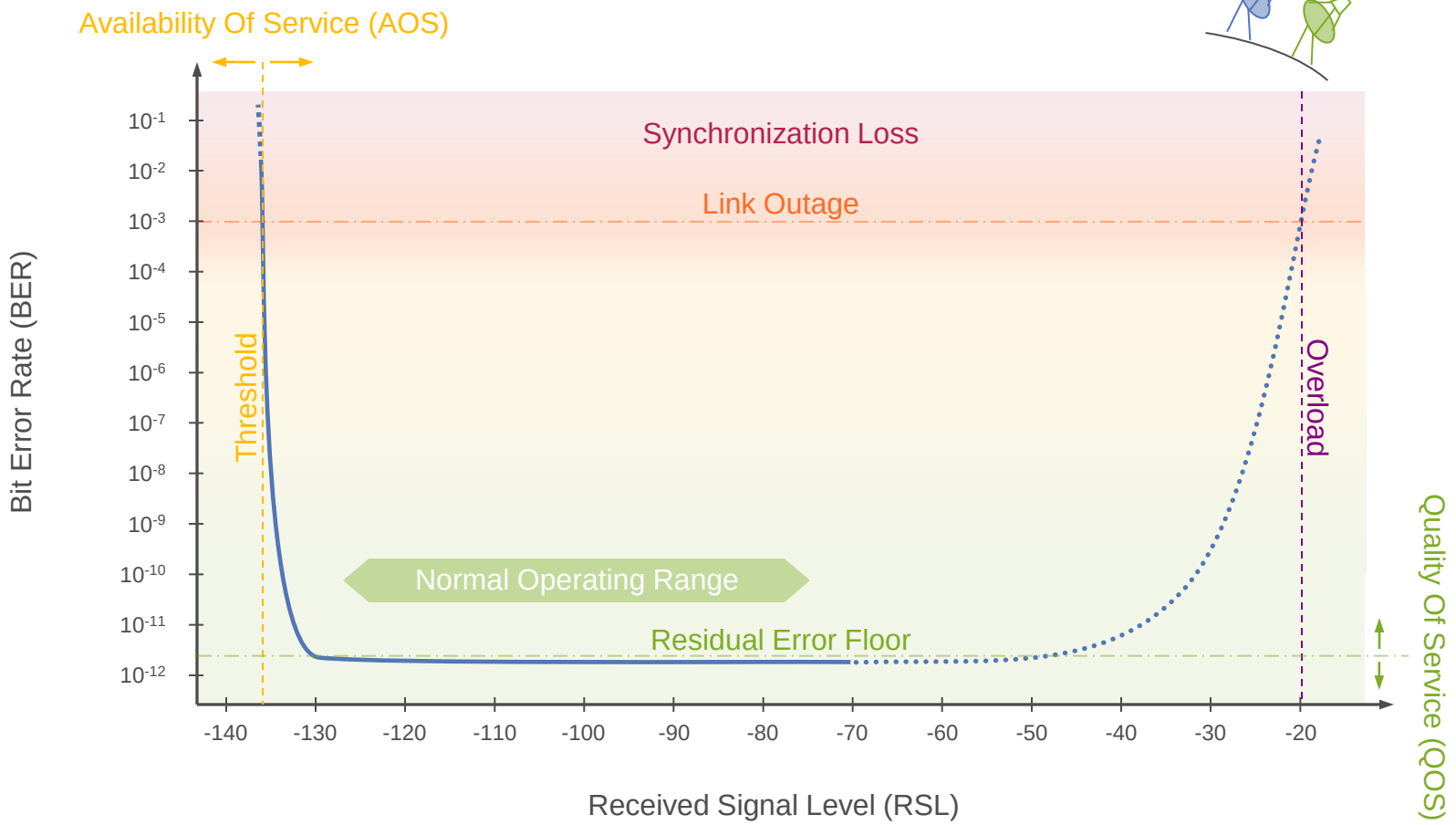
The BER Bath Tub Curve Properties





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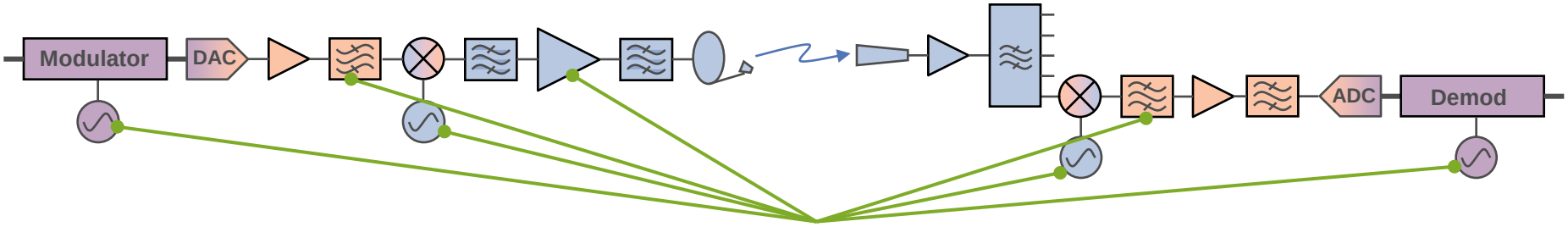
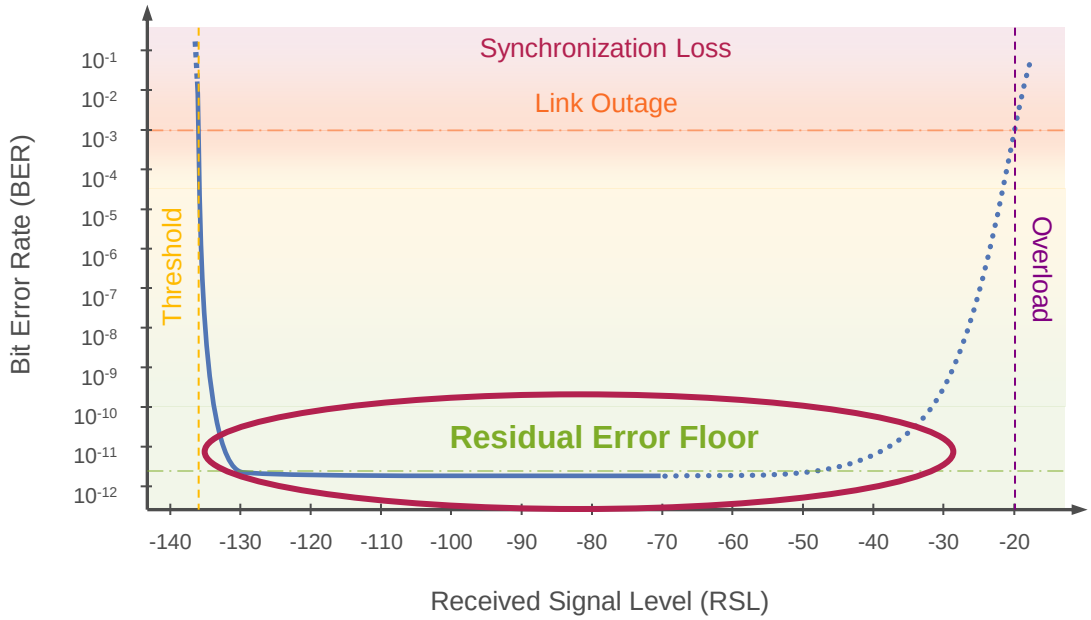
The Residual Error Floor Contributors



Residual Error Floor



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Bit Errors & Symbol Errors

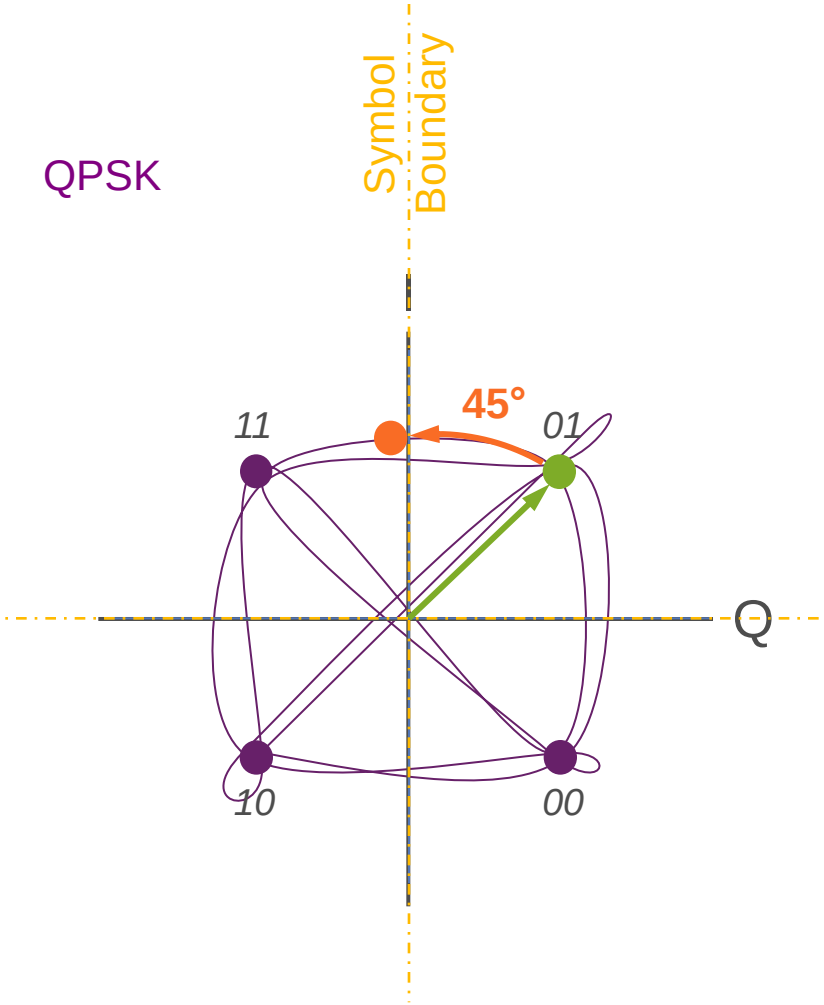
At Sample Time…

Phasor in Wrong Quadrant

Creates a Symbol Error

Symbol Map to Bits

Symbol Error ≤ Bit Errors



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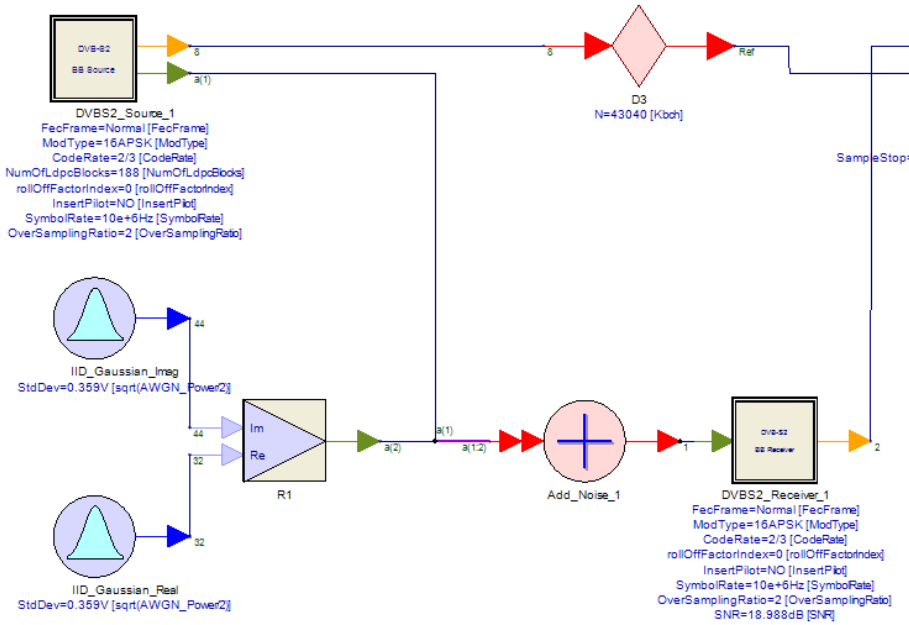
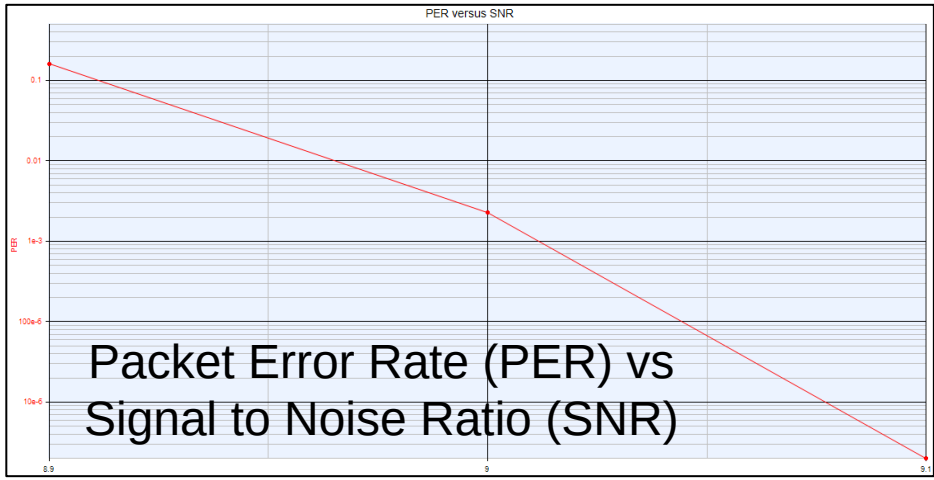
BER Simulation- DVB-S2 Example

DVB-S2 Source



BER Sink



AWGN

DVB-S2 Receiver

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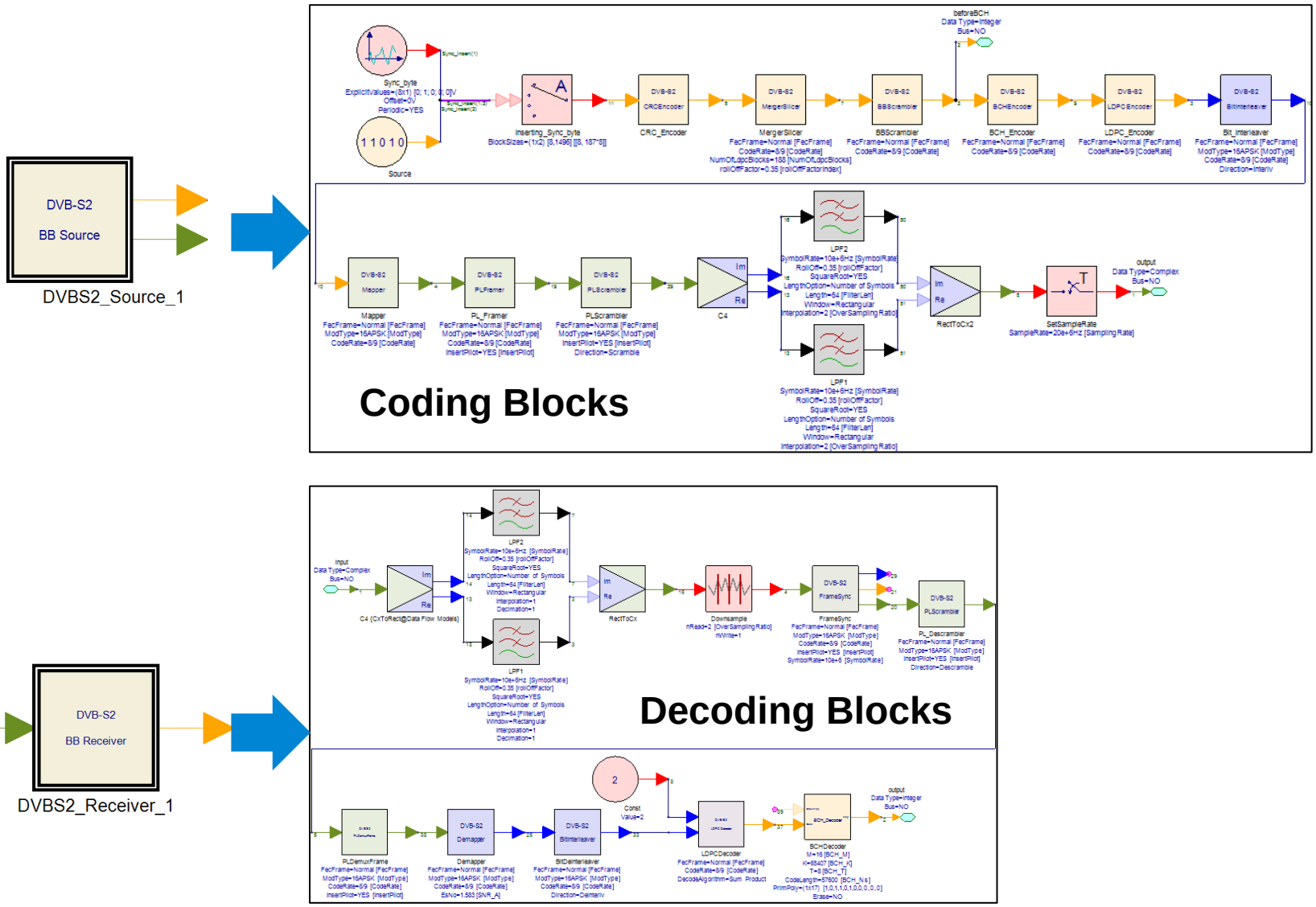
Coded BER Simulation- Push into DVB-S2 Source and Receiver



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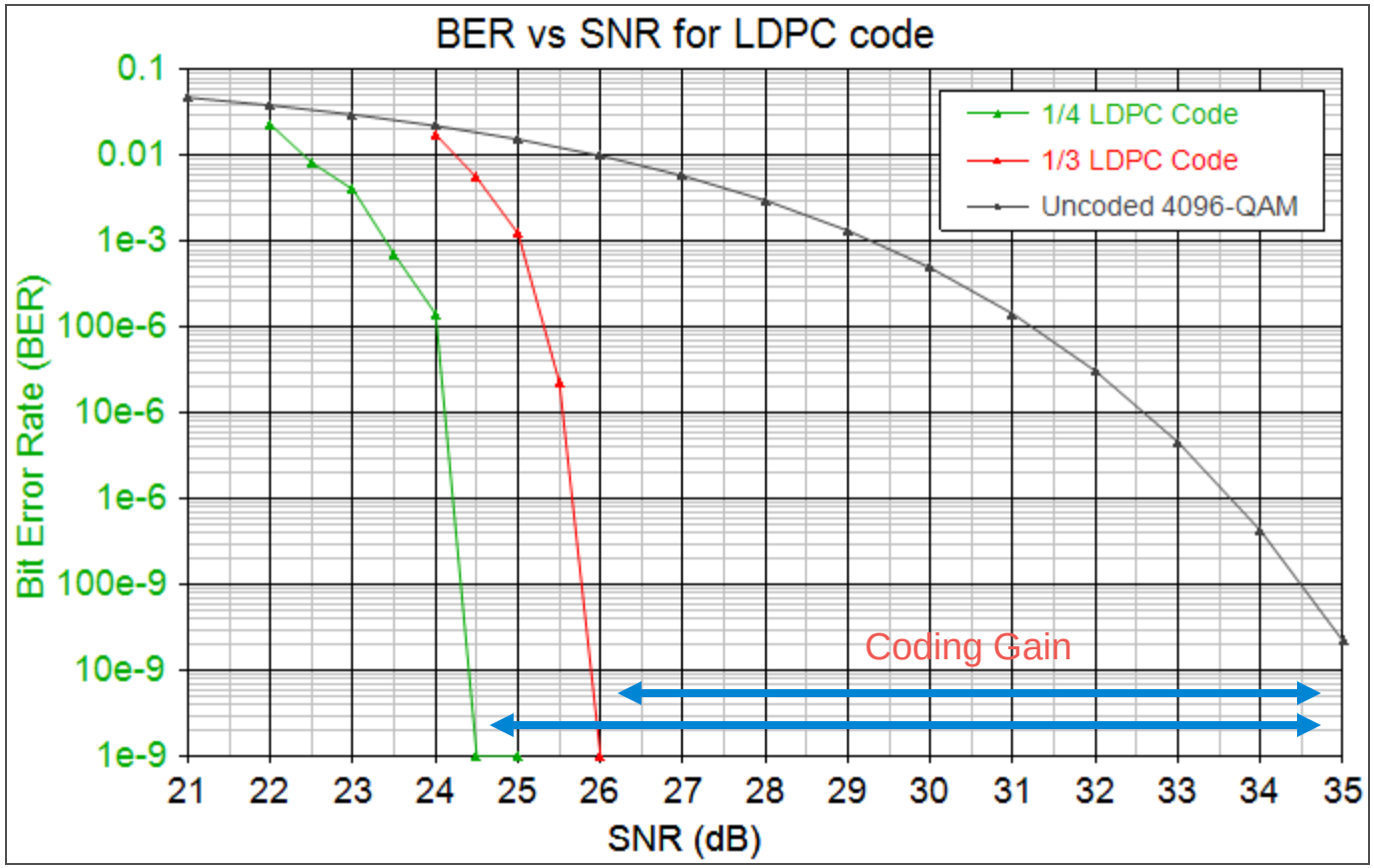
Coding Gain- Simulated BER vs. Eb/No with Custom LDPC Codes



Optimum receiver with FEC sub-system (BCH and LDPC Coding)

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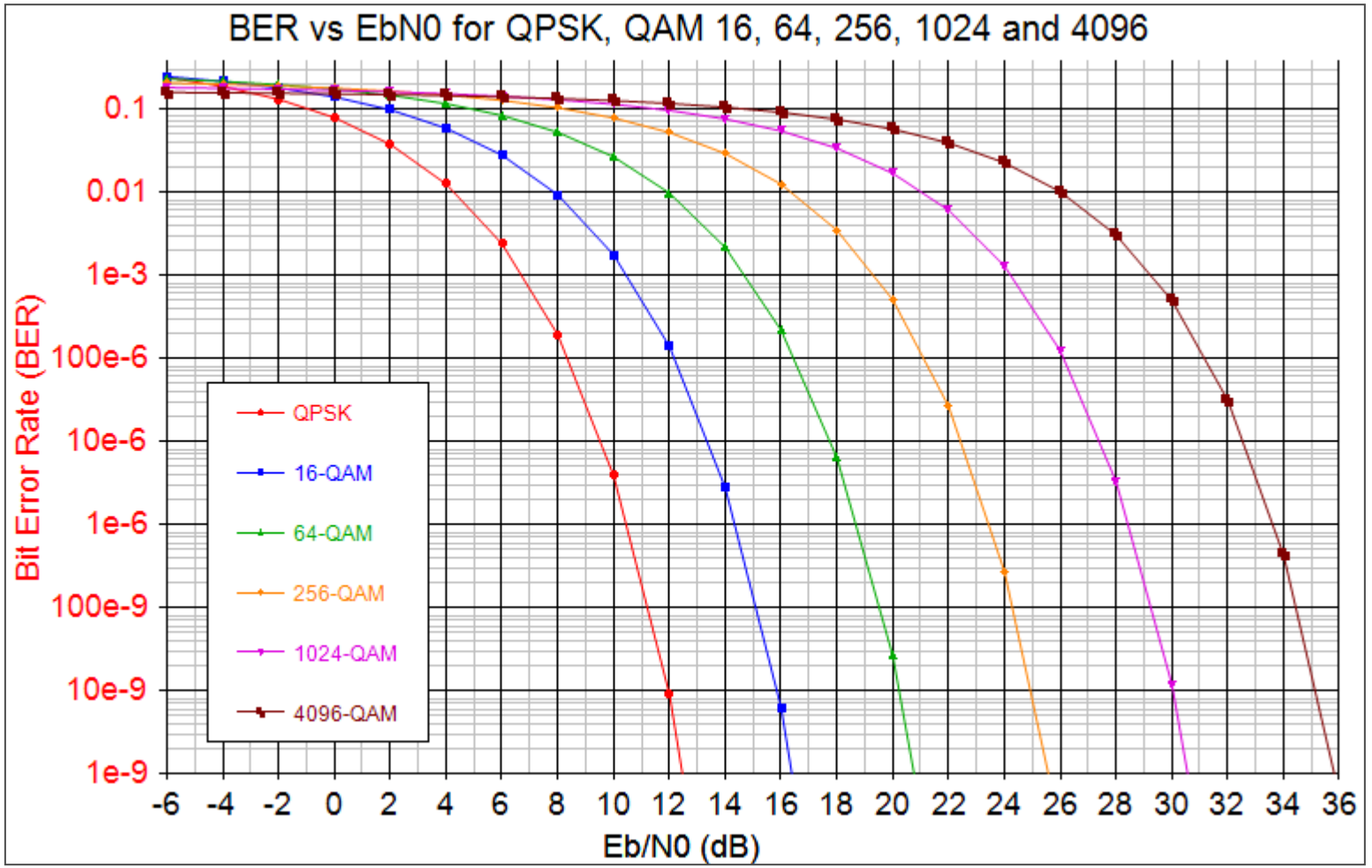
Additional BER Simulation Results- Theoretical BER vs Eb/No in AWG Channel



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Summary

- Digital regenerative designs can require more complex simulation, signal generation, and signal analysis relative to bent-pipe approaches
- Combining design simulation with precision AWGs enables flexibility
- VSA software with test equipment (logic analyzers, oscilloscopes, RF signal analyzers) enable transmitter EVM performance to be evaluated along the mixed-signal RF transmitter chain
- BER simulation enables design impairments to be evaluated earlier in the design cycle

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Thank You !

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