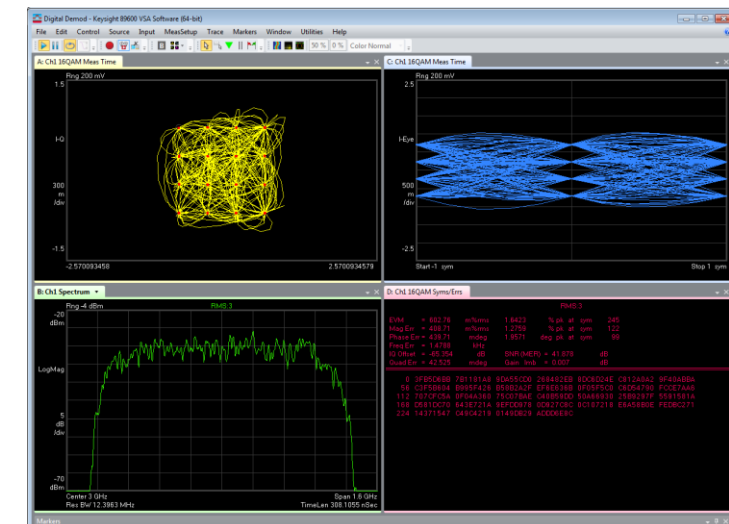


Advanced RF Measurements You Didn't Know Your Oscilloscope Could Make

Brad Frieden
Philip Gresock

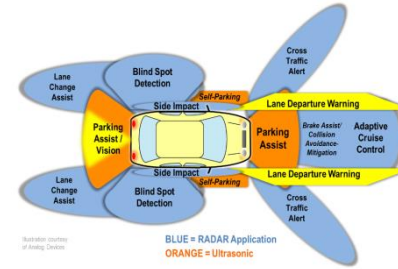
Agenda

- RF measurement challenges
- Oscilloscope platform overview
 - Typical “RF” characteristics
 - Bandwidth vs. frequency range
- Infiniium scope measurements
 - Radar “chirp”
 - Gated FFT
- Infiniium scopes plus 89600 VSA measurements
 - Radar “chirp”, MIMO cellular, Wideband Comms and more!

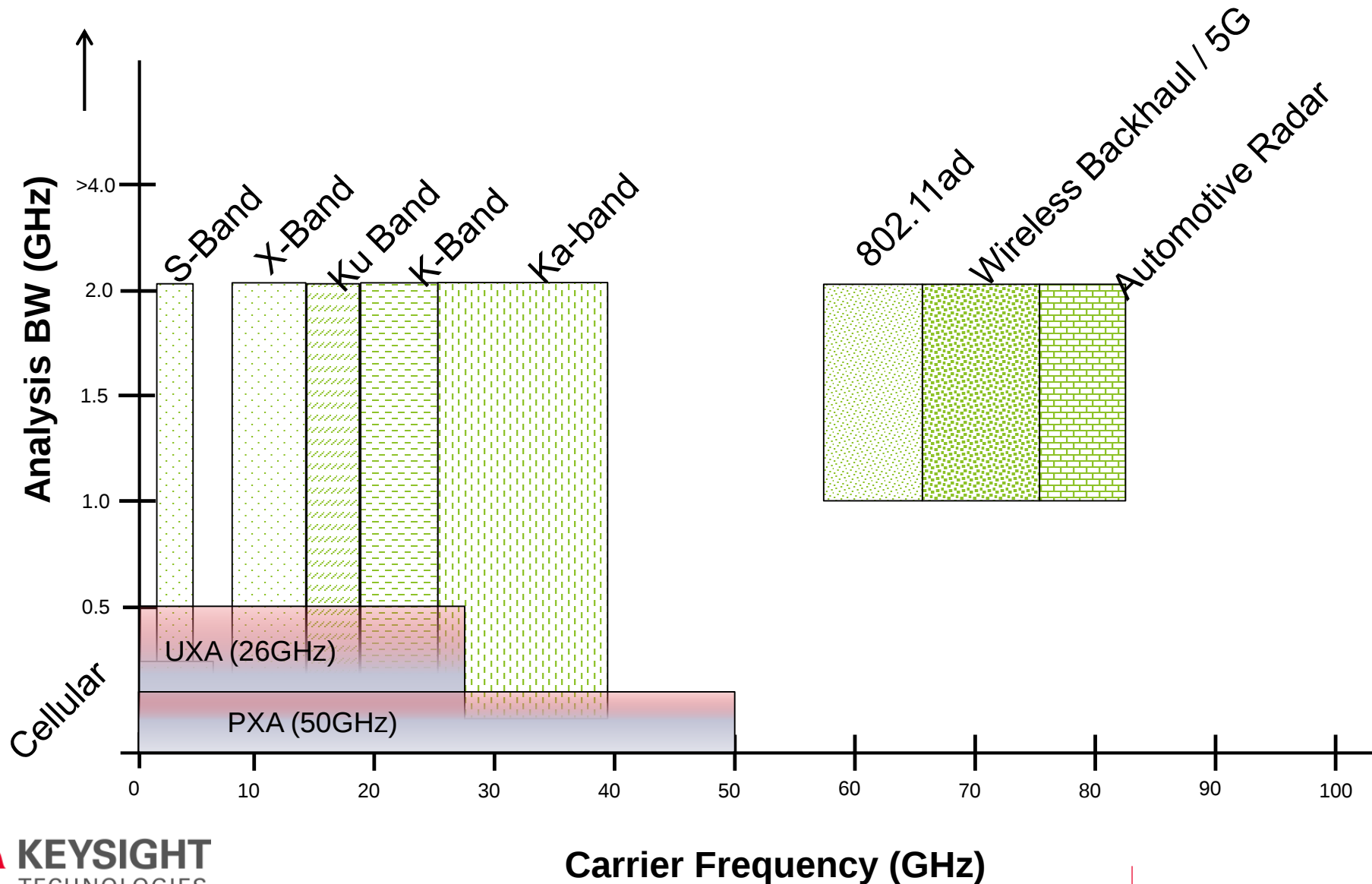


RF challenges for designers

- More RF designs now have modulation bandwidths wider than 510 MHz
- Seeing in radar/EW as well as communications systems
- Cannot use signal/spectrum analyzers for >510 MHz bandwidth signals
- Also seeing applications where have more than one signal (phased array antenna, MIMO)
- Designers needing good, wideband, multi-channel RF receivers for measurement front end

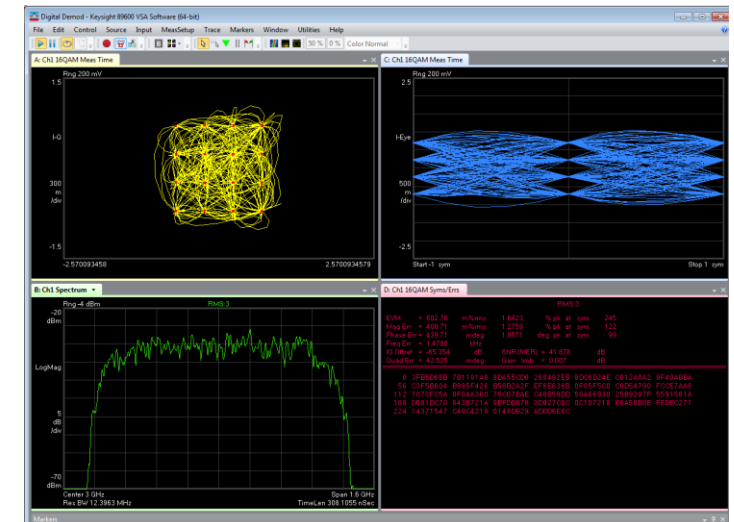


Wideband Applications that only Oscilloscopes Can Address



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Infiniium Oscilloscope Platform Overview

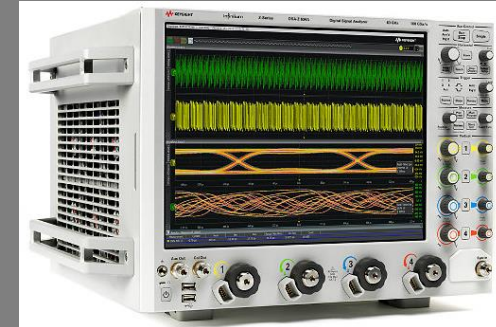
10 Bit ADC



S-Series



V-Series



Z-Series

500 MHz

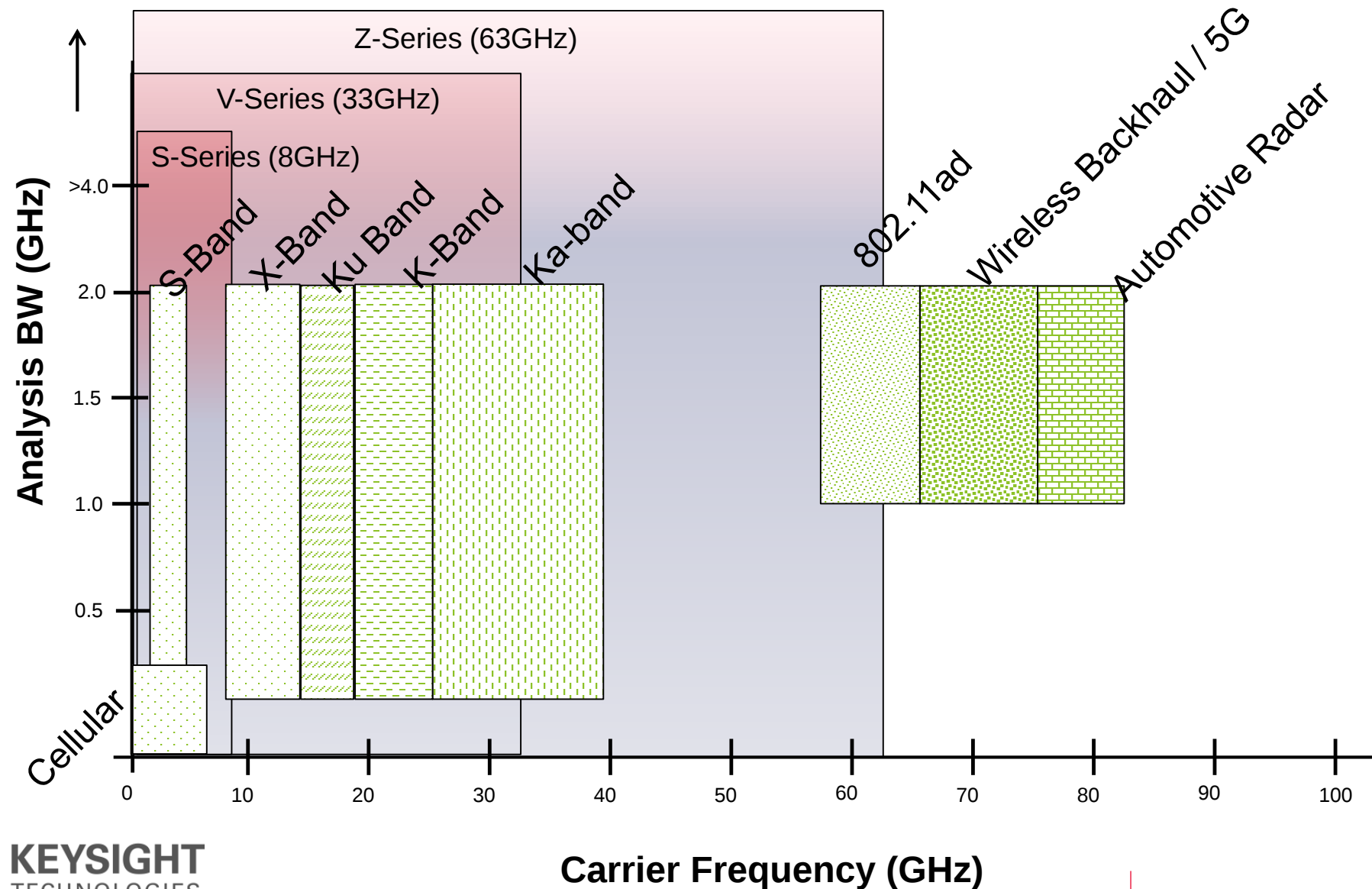
8 GHz

33 GHz

63 GHz

Bandwidth

Wideband Applications that only Oscilloscopes Can Address



Oscilloscope RF Performance

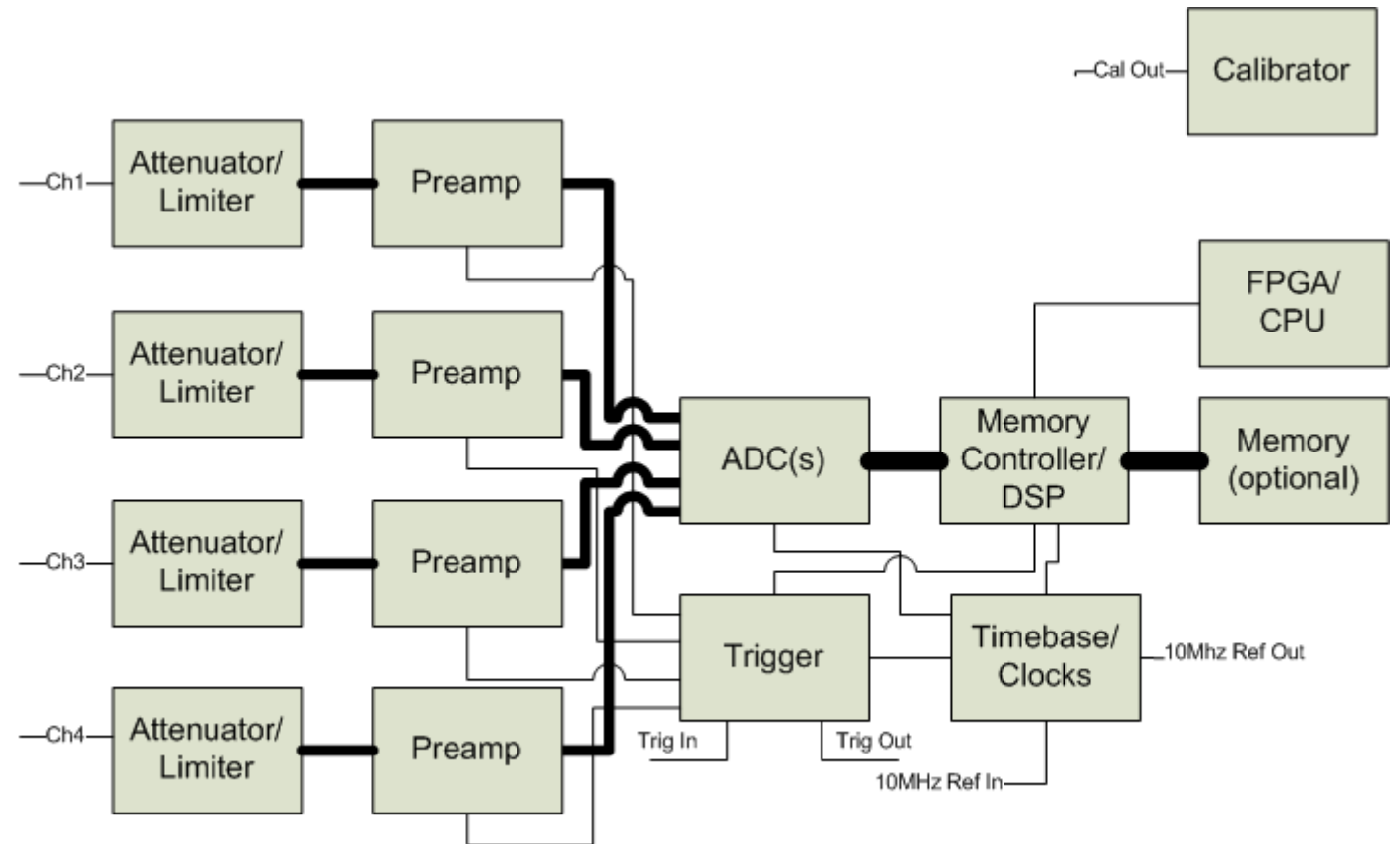
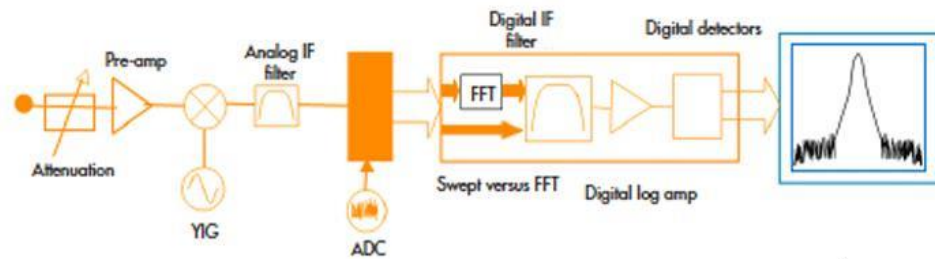
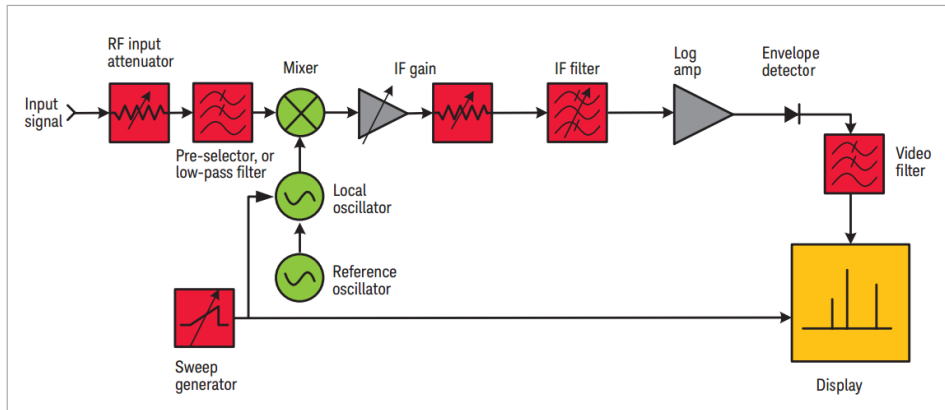
	S-Series Typical Values	V-Series Typical Values	Z-Series Typical Values
Noise Density / DANL*	-160 dBm/Hz	-159 dBm/Hz	-160 dBm/Hz
Signal to Noise Ratio / Dynamic Range	108 dB	111 dB	112 dB
Absolute amplitude accuracy	+/- 1 dB (0 to 7.5 GHz)	+/- 0.5 dB (0 to 30 GHz)	
Third Order Intercept	+21.5 dBm	+28 dBm	+26 dBm
Phase noise (@ 1 GHz)			
10 KHz offset	-121 dBc/Hz	-125 dBc/Hz	-122 dBm/Hz
100 KHz offset	-122 dBc/Hz	-131 dBc/Hz	-126 dBm/Hz
Spur Free Dynamic Range (SFDR)	-72 dBc	-67 dBc	-73 dBc

Oscilloscope RF Performance

	S-Series Typical Values	V-Series Typical Values	Z-Series Typical Values	PXA	UXA
Noise Density / DANL*	-160 dBm/Hz	-159 dBm/Hz	-160 dBm/Hz	-171 dBm/Hz*	-171 dBm/Hz*
Signal to Noise Ratio / Dynamic Range	108 dB	111 dB	112 dB	119 dB	119 dB
Absolute amplitude accuracy	+/- 1 dB (0 to 7.5 GHz)	+/- 0.5 dB (0 to 30 GHz)		+/- 0.19 dB	+/- 0.16 dB
Third Order Intercept	+21.5 dBm	+28 dBm	+26 dBm	+22 dBm	+22 dBm
Phase noise (@ 1 GHz)					
10 KHz offset	-121 dBc/Hz	-125 dBc/Hz	-122 dBm/Hz	-132 dBm/Hz	-136 dBm/Hz
100 KHz offset	-122 dBc/Hz	-131 dBc/Hz	-126 dBm/Hz	-131 dBm/Hz	-142 dBc/Hz
Spur Free Dynamic Range (SFDR)	-72 dBc	-67 dBc	-73 dBc	-79 dBc	-79 dBc

Spectrum Analyzer vs Real-Time Oscilloscope

Block Diagrams



Getting Noise Density from Vrms Noise

Scope design driven by time domain constraints.

From S-Series Datasheet.

RMS noise floor (Vrms ac)

Vertical setting (Volts/div)	S-054A	S-104A	S-204A	S-254A	S-404A	S-604A	S-804A
1 mV/div	74 μ V	90 μ V	120 μ V	130 μ V	153 μ V	195 μ V	260 μ V
2 mV/div	74 μ V	90 μ V	120 μ V	130 μ V	153 μ V	195 μ V	260 μ V
5 mV/div	77 μ V	94 μ V	129 μ V	135 μ V	173 μ V	205 μ V	320 μ V
10 mV/div	87 μ V	110 μ V	163 μ V	172 μ V	220 μ V	256 μ V	390 μ V
20 mV/div	125 μ V	163 μ V	233 μ V	254 μ V	330 μ V	446 μ V	620 μ V
50 mV/div	372 μ V	456 μ V	610 μ V	650 μ V	768 μ V	1.3 mV	1.4 mV
100 mV/div	0.78 mV	0.96 mV	1.2 mV	1.3 mV	1.6 mV	2.3 mV	3.1 mV
200 mV/div	1.6 mV	2.0 mV	2.6 mV	2.8 mV	3.4 mV	4.9 mV	6.4 mV
500 mV/div	3.5 mV	4.2 mV	5.5 mV	6 mV	7.3 mV	10.0 mV	13.3 mV
1 V/div	5.1 mV	6.8 mV	9.2 mV	10.1 mV	12.5 mV	17.6 mV	24.1 mV

Translated (calculated) to RF-Speak!
(8GHz Model Only)

V/div	dBm Ref Level	dBm/Hz Noise
1mV/div	-28 dBm	-158 dBm/Hz
2mV/div	-28 dBm	-158 dBm/Hz
5mV/div	-24 dBm	-156 dBm/Hz
10mV/div	-18 dBm	-154 dBm/Hz
20mV/div	-12 dBm	-150 dBm/Hz
50mV/div	-4 dBm	-143 dBm/Hz
100mV/div	+2 dBm	-136 dBm/Hz
200mV/div	+6 dBm	-130 dBm/Hz
500mV/div	+16 dBm	-124 dBm/Hz
1V/div	+22 dBm	-118 dBm/Hz

50mV/div = 400mV full scale (Vpp) = -4dBm range.
4mV rms noise = -44dBm @ 8GHz = -143dBm/Hz

Getting Noise Density from Vrms Noise

Scope design driven by time domain constraints.

Translated (calculated) to RF-terms
(33 GHz Model Only)

From V-Series Datasheet.

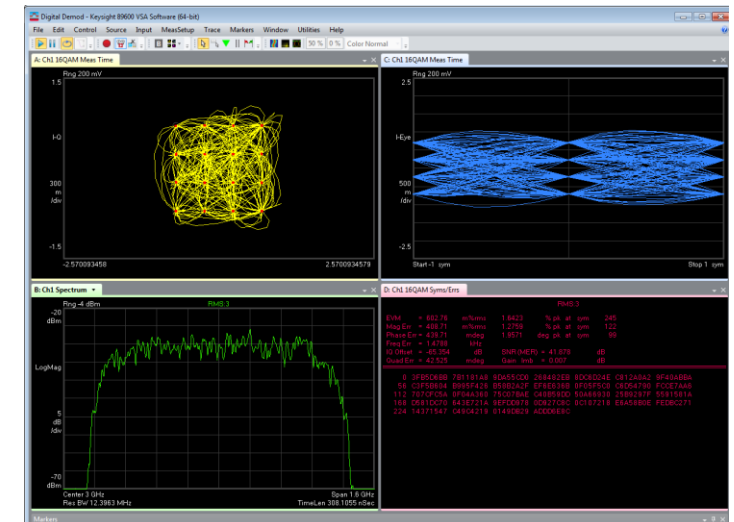
RMS noise floor (oscilloscope only)	V084A	V134A	V164A	V204A	V254A	V334A	dBm Ref Level	dBm/Hz Noise
Vertical setting (mVrms)	8 GHz	13 GHz	16 GHz	20 GHz	25 GHz	33 GHz		
5 mV/div	0.21 mV	0.27 mV	0.31 mV	0.37 mV	0.45 mV	0.58 mV	-24 dBm	-157 dBm/Hz
10 mV/div	0.23 mV	0.28 mV	0.36 mV	0.42 mV	0.49 mV	0.60 mV	-18 dBm	-157 dBm/Hz
20 mV/div	0.46 mV	0.57 mV	0.65 mV	0.74 mV	0.83 mV	1.04 mV	-12 dBm	-152 dBm/Hz
50 mV/div	1.04 mV	1.09 mV	1.32 mV	1.54 mV	1.73 mV	2.09 mV	-4 dBm	-146 dBm/Hz
100 mV/div	1.92 mV	2.30 mV	2.63 mV	3.02 mV	3.39 mV	3.98 mV	+2 dBm	-140 dBm/Hz
200 mV/div	4.39 mV	5.52 mV	6.14 mV	6.92 mV	8.16 mV	9.88 mV	+6 dBm	-132 dBm/Hz
500mV/div	10.07 mV	12.42 mV	13.68 mV	15.05 mV	17.08 mV	20.25 mV	+16 dBm	-126 dBm/Hz
1 V/div	18.47 mV	21.36 mV	26.12 mV	30.15 mV	34.36 mV	39.35 mV	+22 dBm	-120 dBm/Hz

50mV/div = 400mV full scale (Vpp) = -4dBm range.

2.09 mV rms noise = -40.6 dBm - 10log(33e9) = -146 dBm/Hz

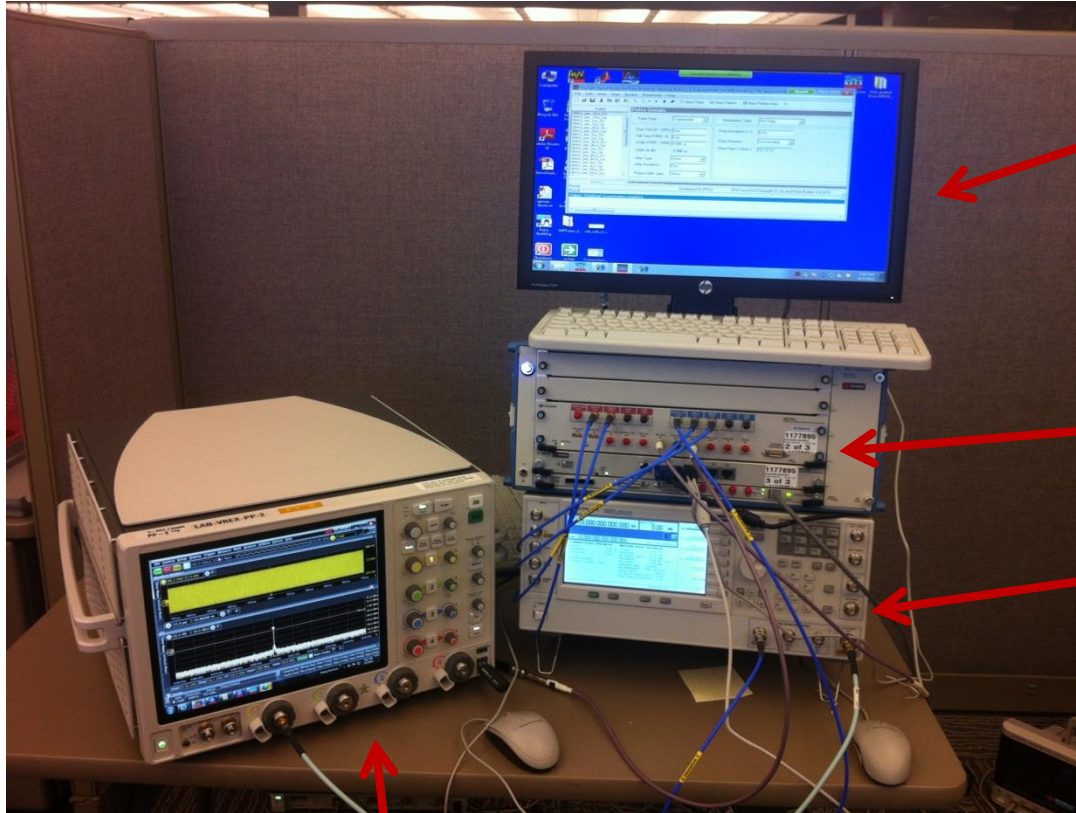
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Insert Infiniium FFT & LTE spectrum
analysis video
Gated FFT & LTE

Measurement setup for wideband pulse measurements



V-Series 33 GHz
bandwidth oscilloscope

M8190A arbitrary
waveform generator
(AWG)

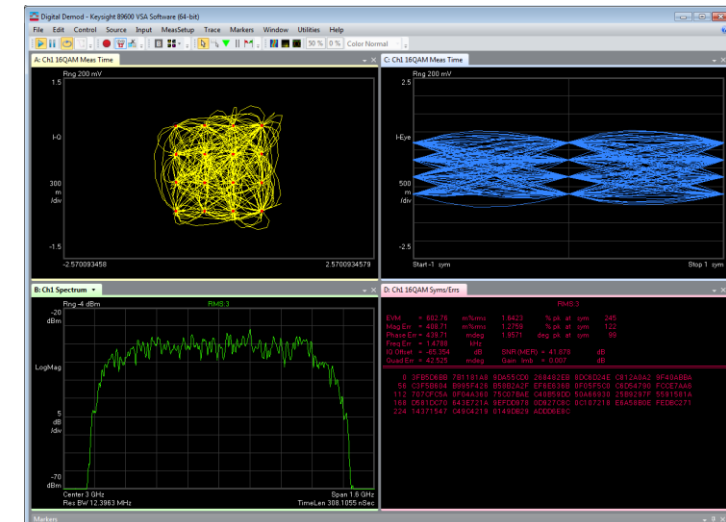
AWG Driving wideband
I/Q inputs of E8267D
PSG vector signal
source

PSG driving scope

Insert pulsed RF Infiniium only

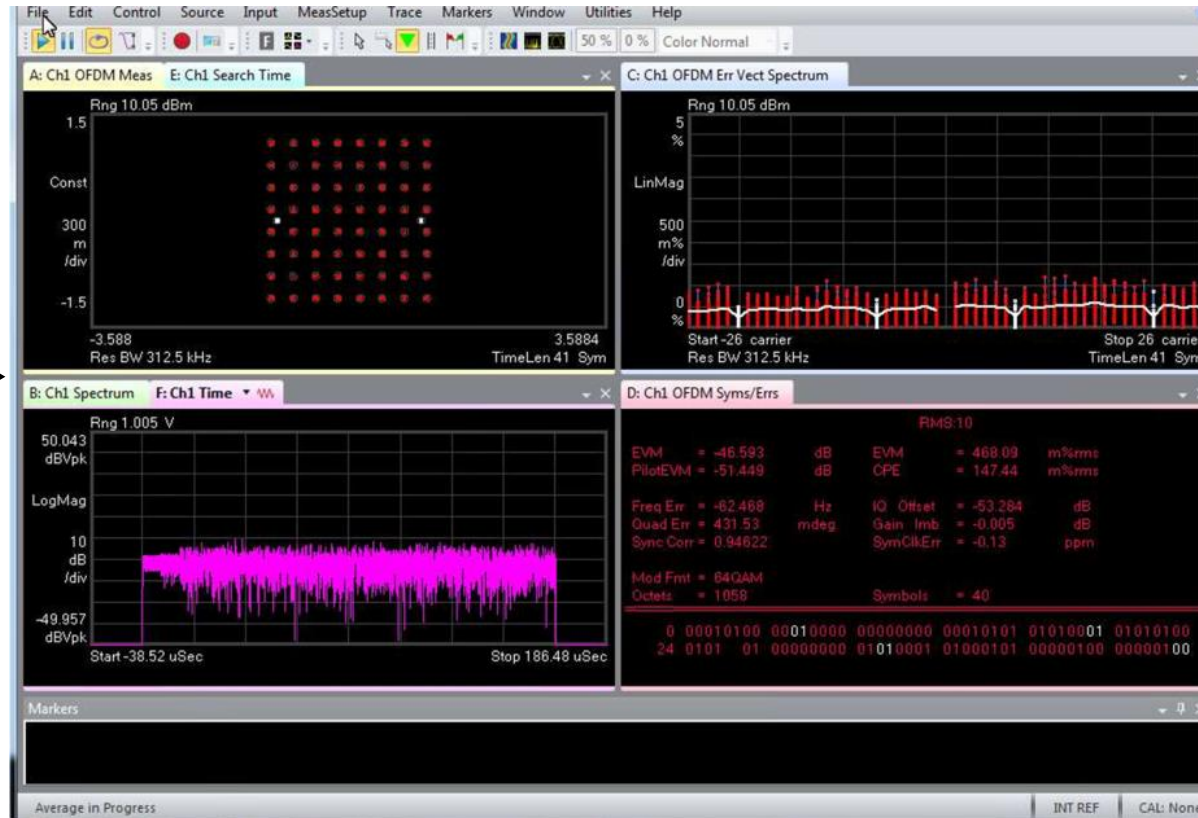
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Additional Analysis

VSA (Vector Signal Analysis) App can run on the scope, or on a PC



Spectrum Analysis

- Channel power
- PSD
- ACP
- OBW

Demodulation Analysis

- Constellation diagrams
- EVM

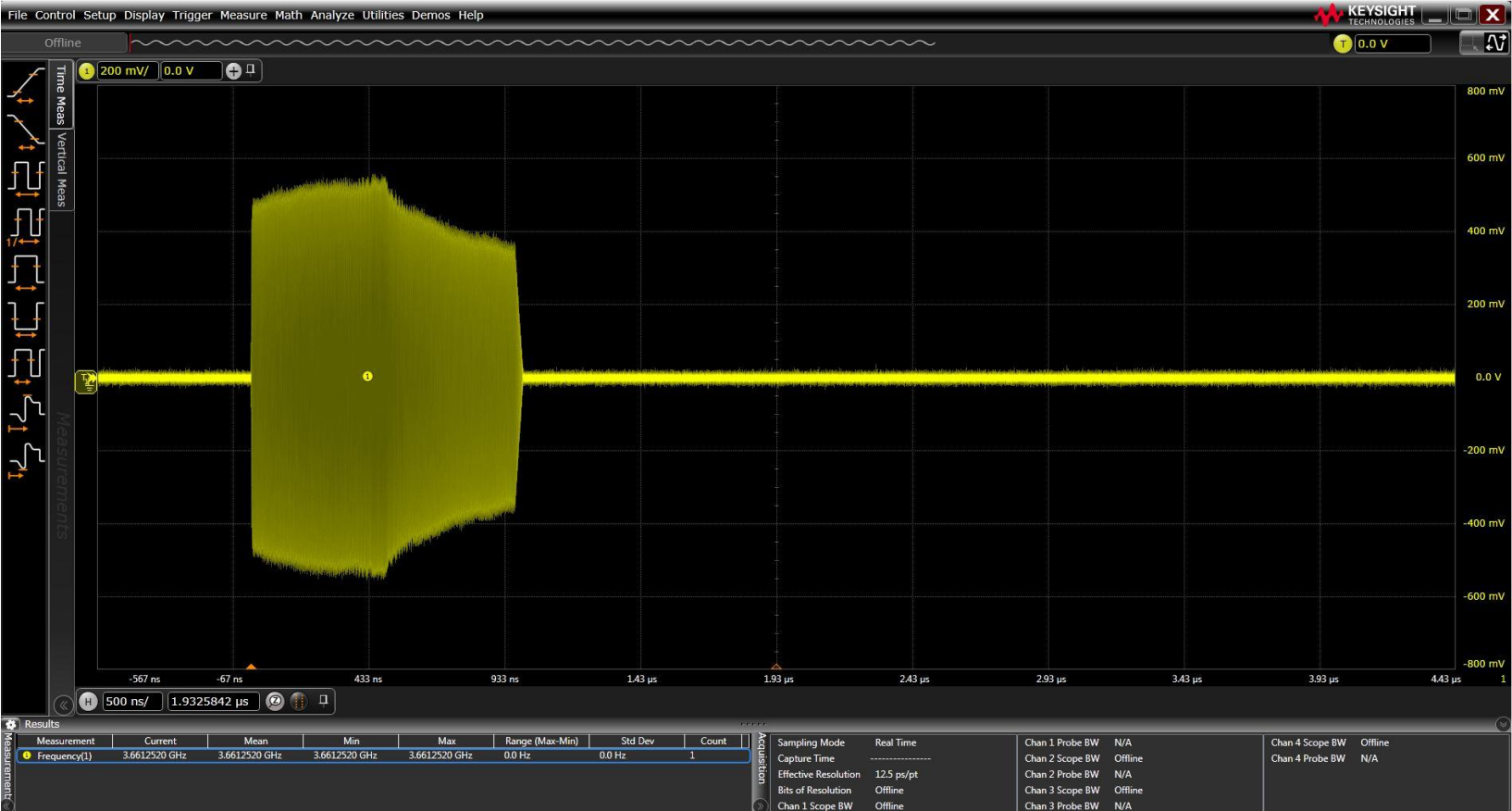
Advanced Pulse Analysis

- P2P frequency, phase, amplitude
- FMCW

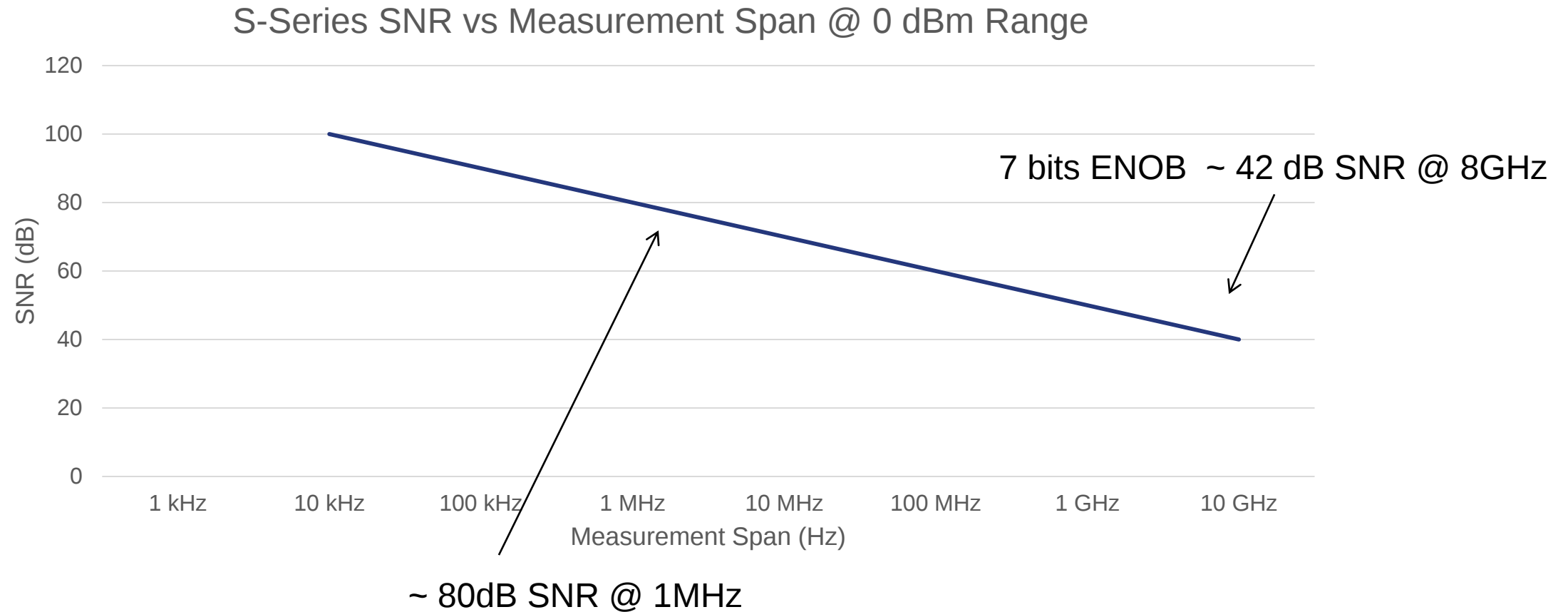
Insert pulsed VSA video

Insert pulsed BHQ video

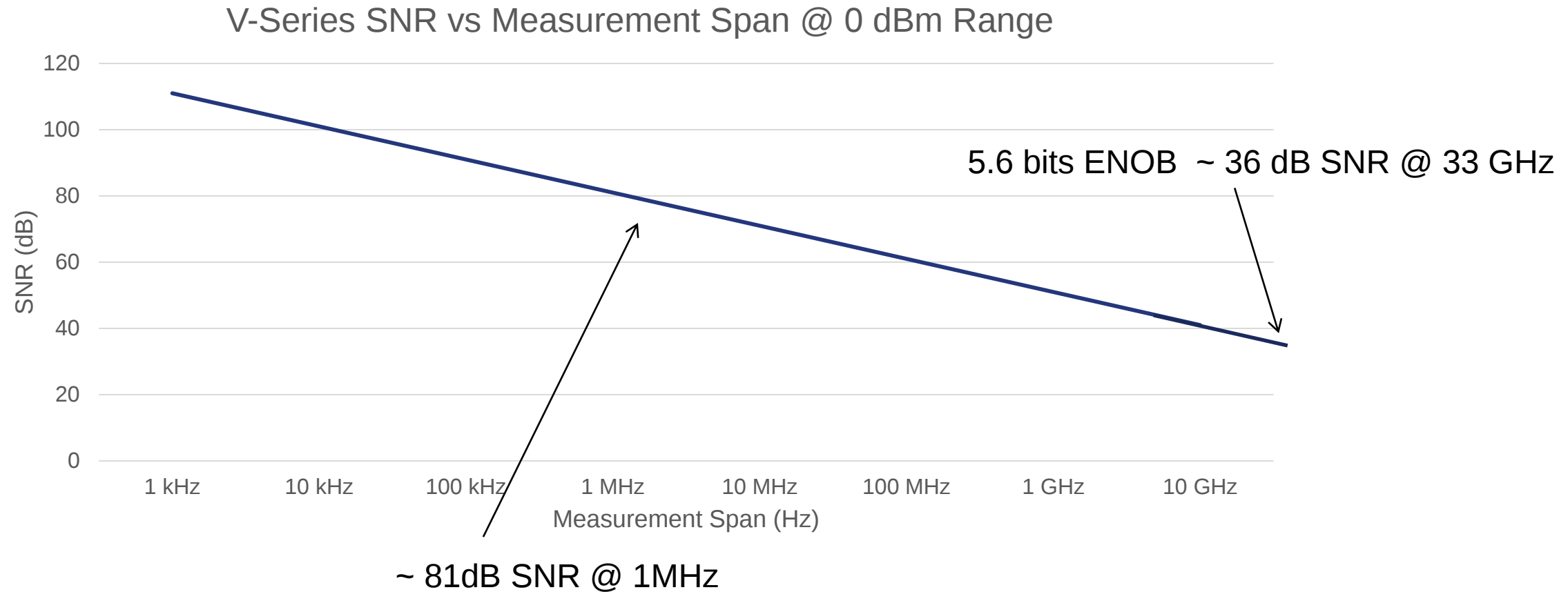
Can't see 50 dB down pulse next to large pulse



Optimize SNR by Reducing Measurement Span in VSA



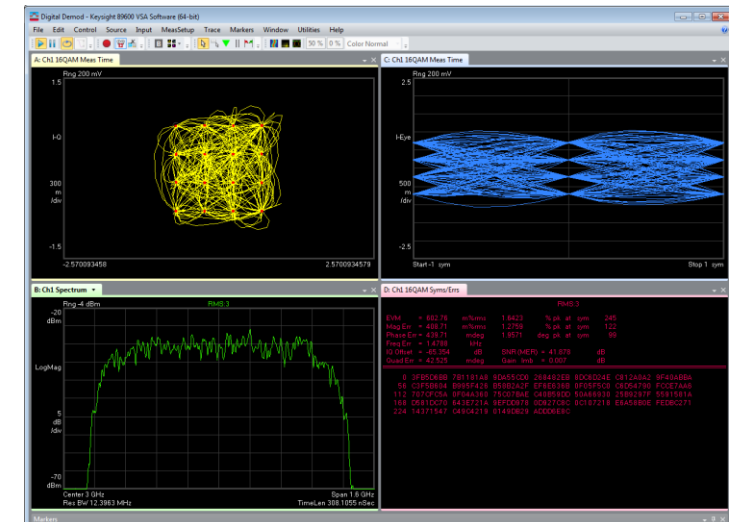
Optimize SNR by Reducing Measurement Span in VSA



Insert pulse SNR video directly on
Infiniium

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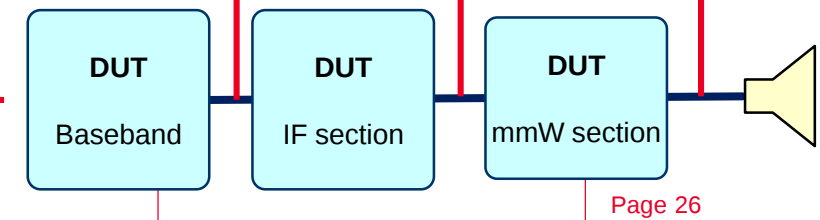
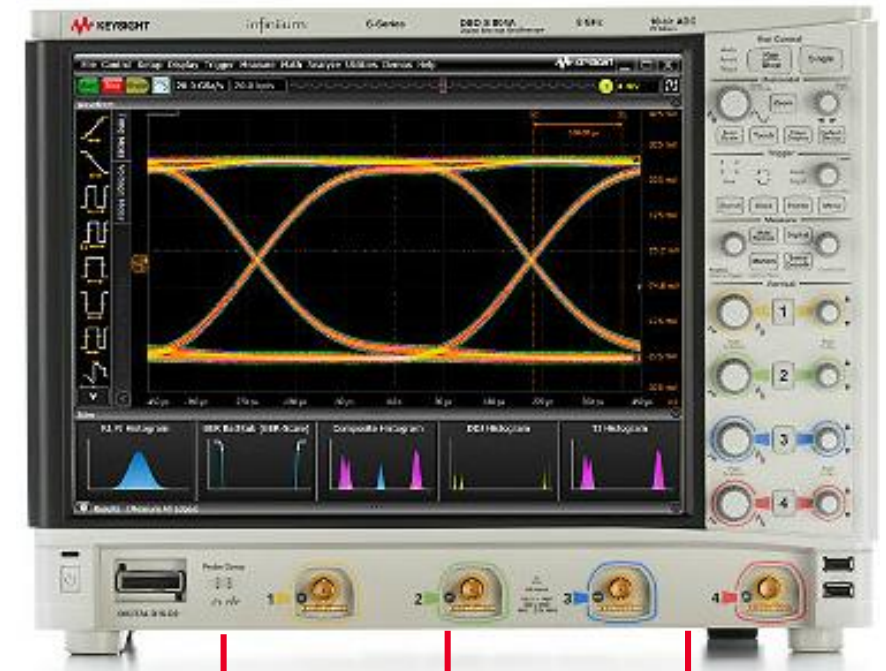
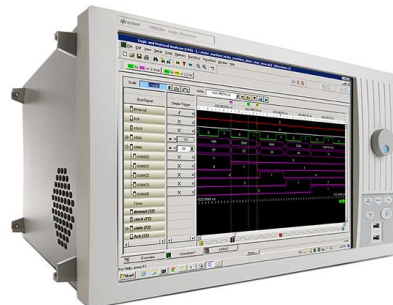


Wideband Communications Testing

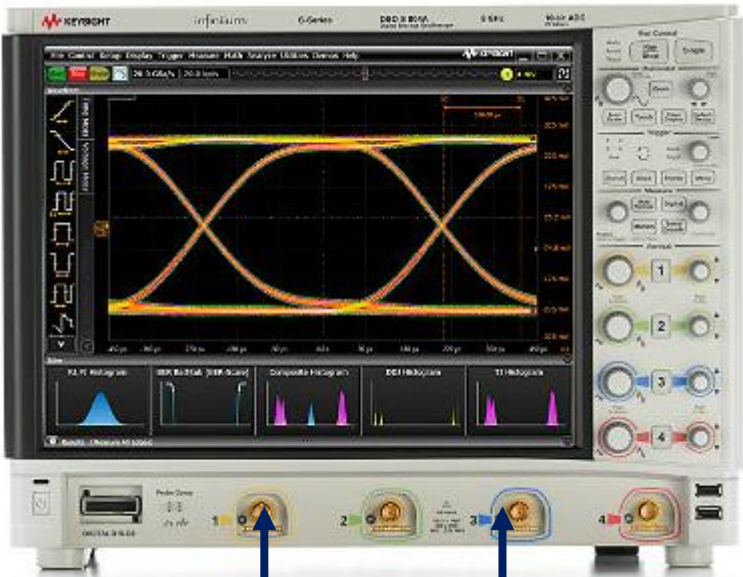
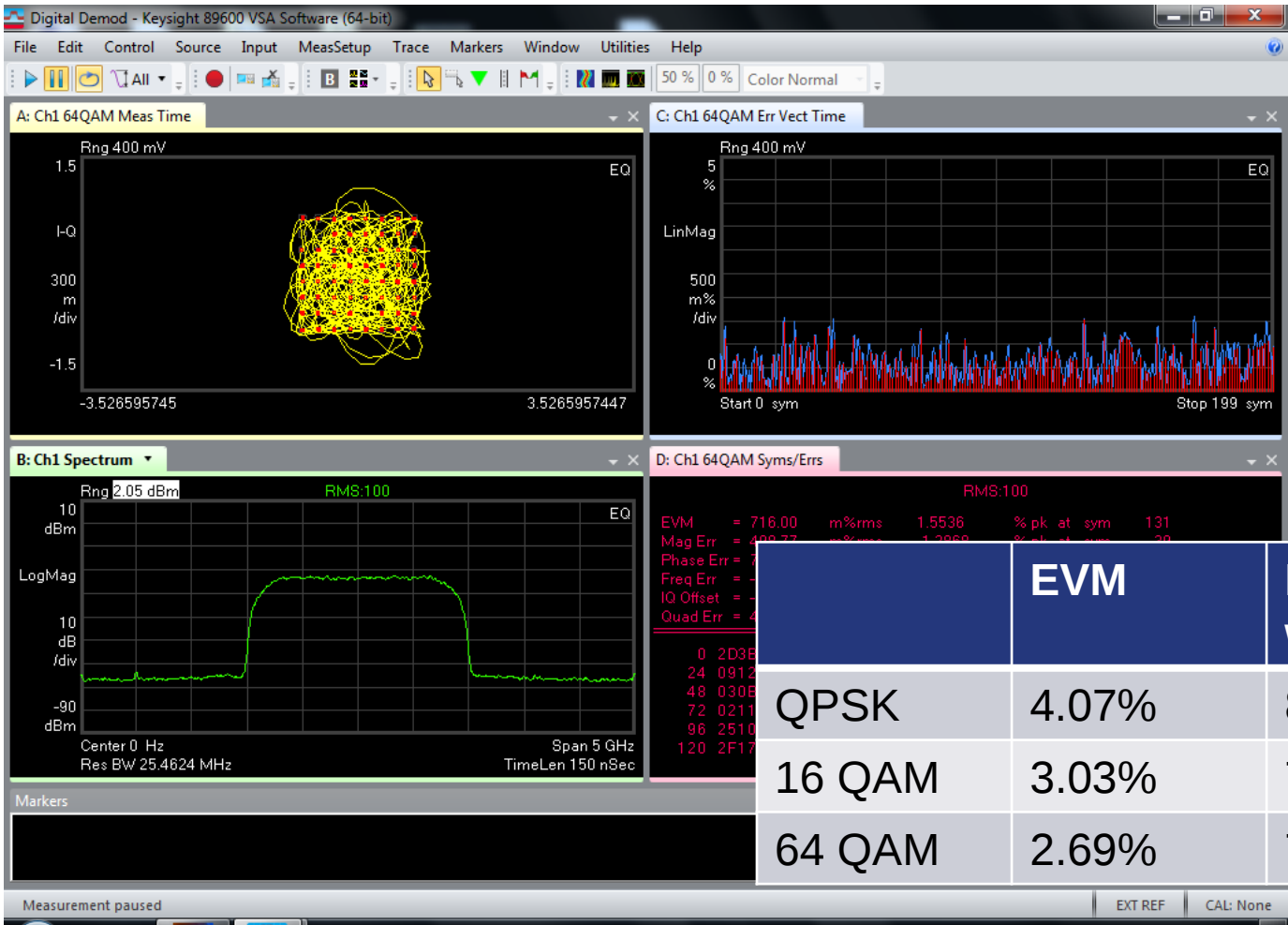
5G, WiGig, Automotive Radar

Wideband communication testing can be broken into at least 3 categories

- Logic Analyzers for digital baseband analysis
- Analog Baseband analysis
- RF/IF signal analysis
- mmW/RF signal analysis in E-band (60-90 GHz)

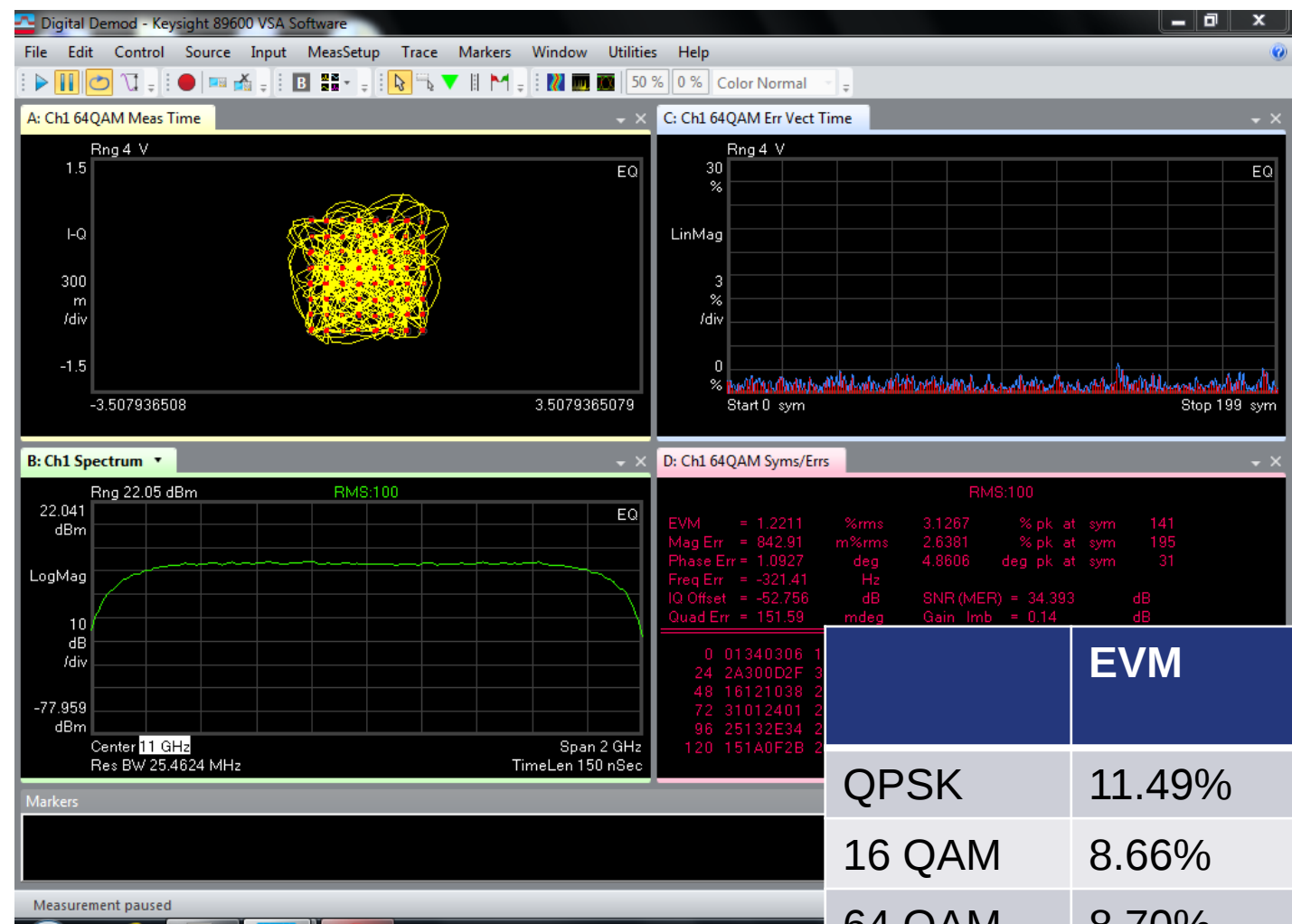


Baseband Analysis

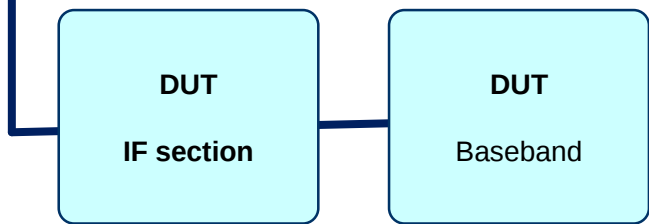


DUT
Baseband

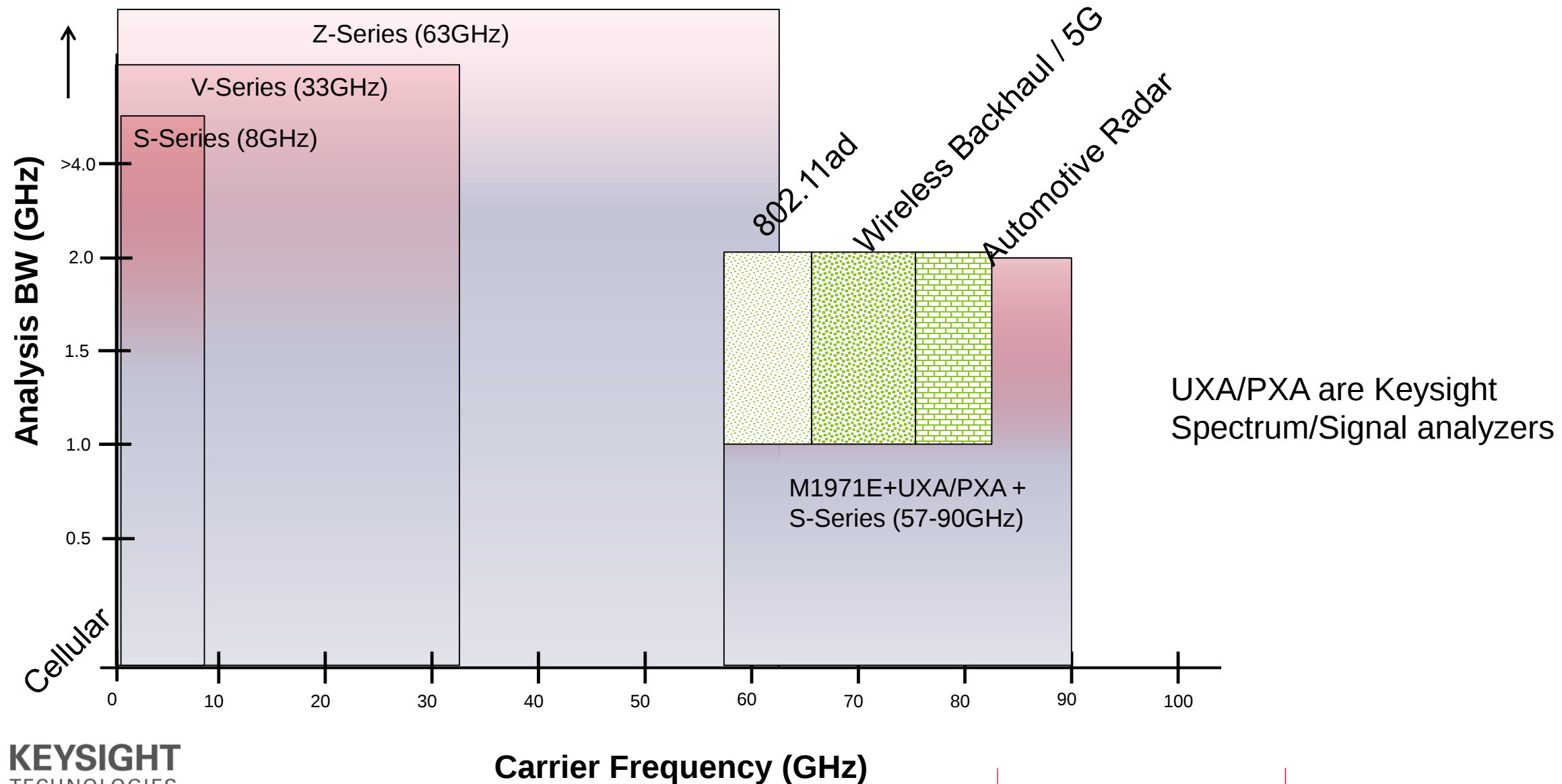
IF Signal Analysis



	EVM	EVM w/EQ
QPSK	11.49%	1.77%
16 QAM	8.66%	1.37%
64 QAM	8.70%	1.22%



Wideband Applications that only Oscilloscopes Can Address



Introducing new E-Band WB smart mixers

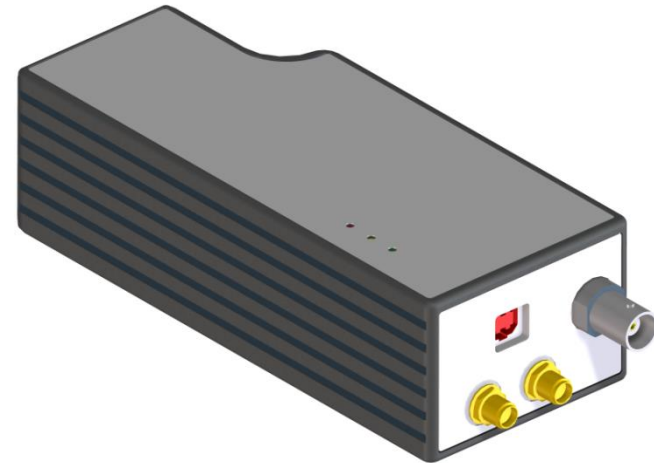
Model #: M1971E

E-band Extended Bandwidth “Smart” USB Mixers

Application: Wide bandwidth (2 GHz) modulation for the following segments :

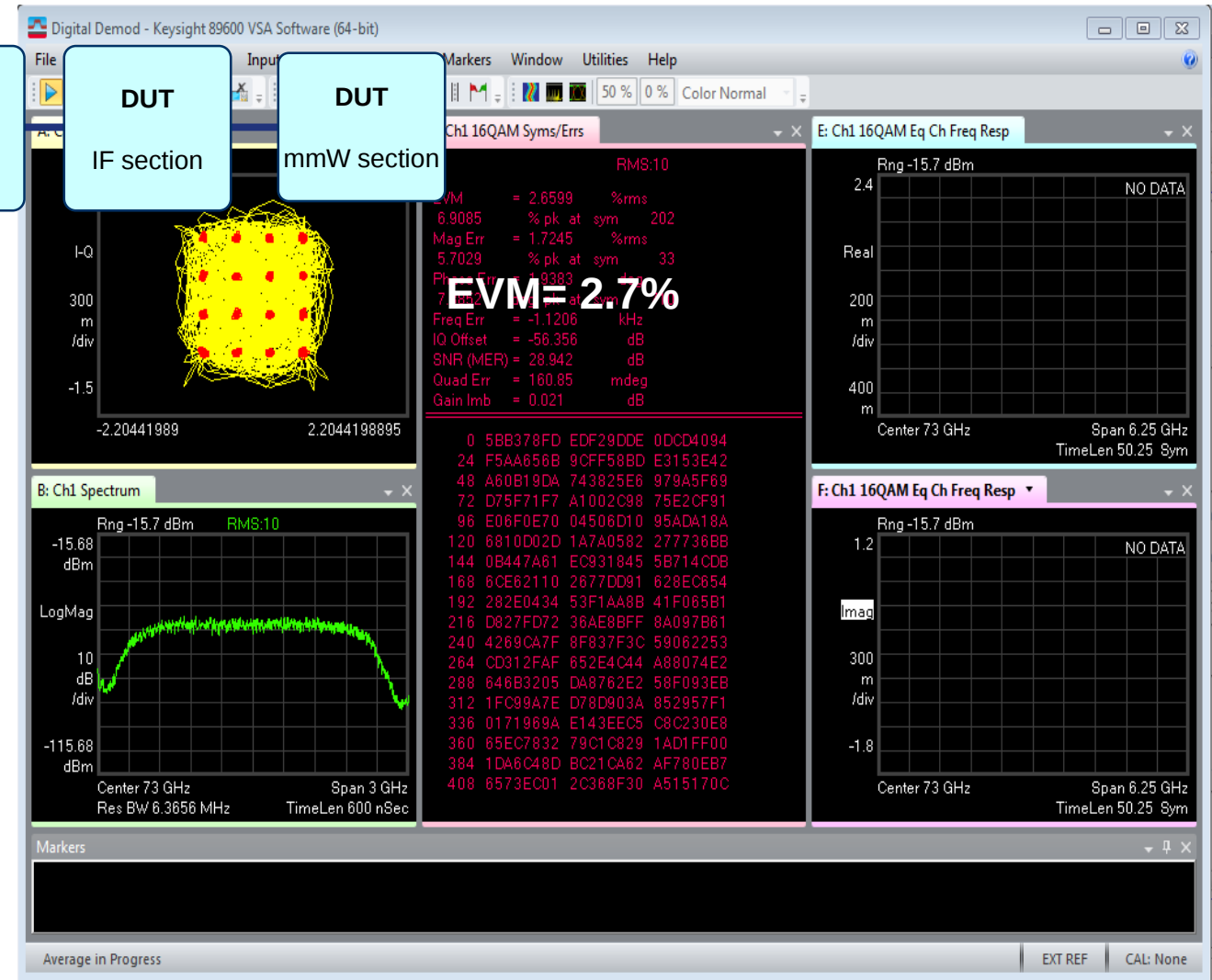
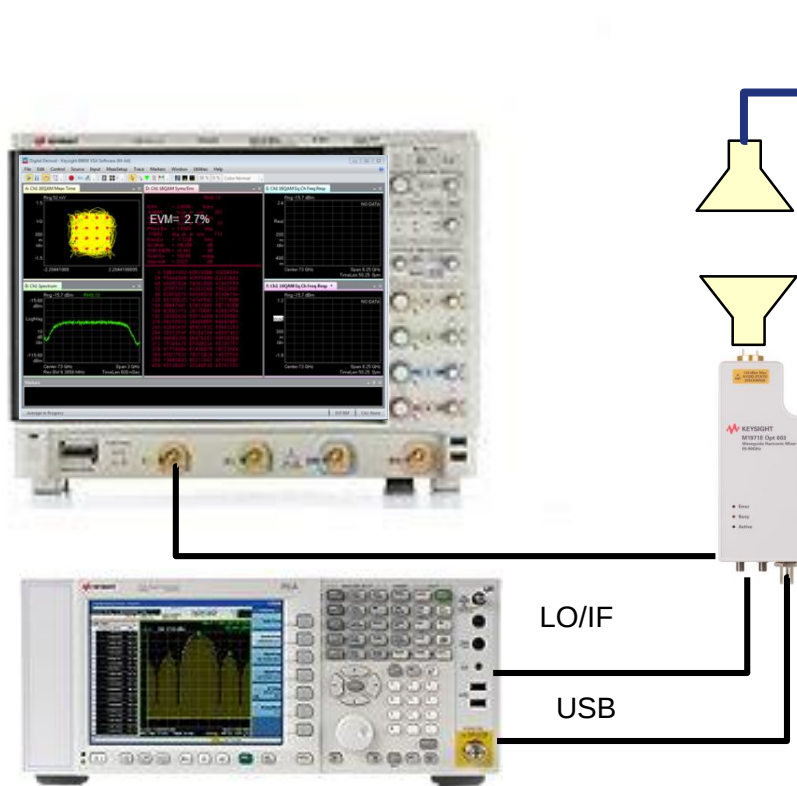
- | | |
|------------------------|------------------------------|
| • 57-66 GHz | 802.11ad / WiGig |
| • 60 GHz | Unlicensed Wireless Backhaul |
| • 71-76 GHz, 81-86 GHz | Licensed Wireless Backhaul |
| • 76-81 GHz | Automotive Radar |

***To complete wide
bandwidth
mm- Wave analysis***



mmW/RF Signal Analysis, E-Band 60-90 GHz

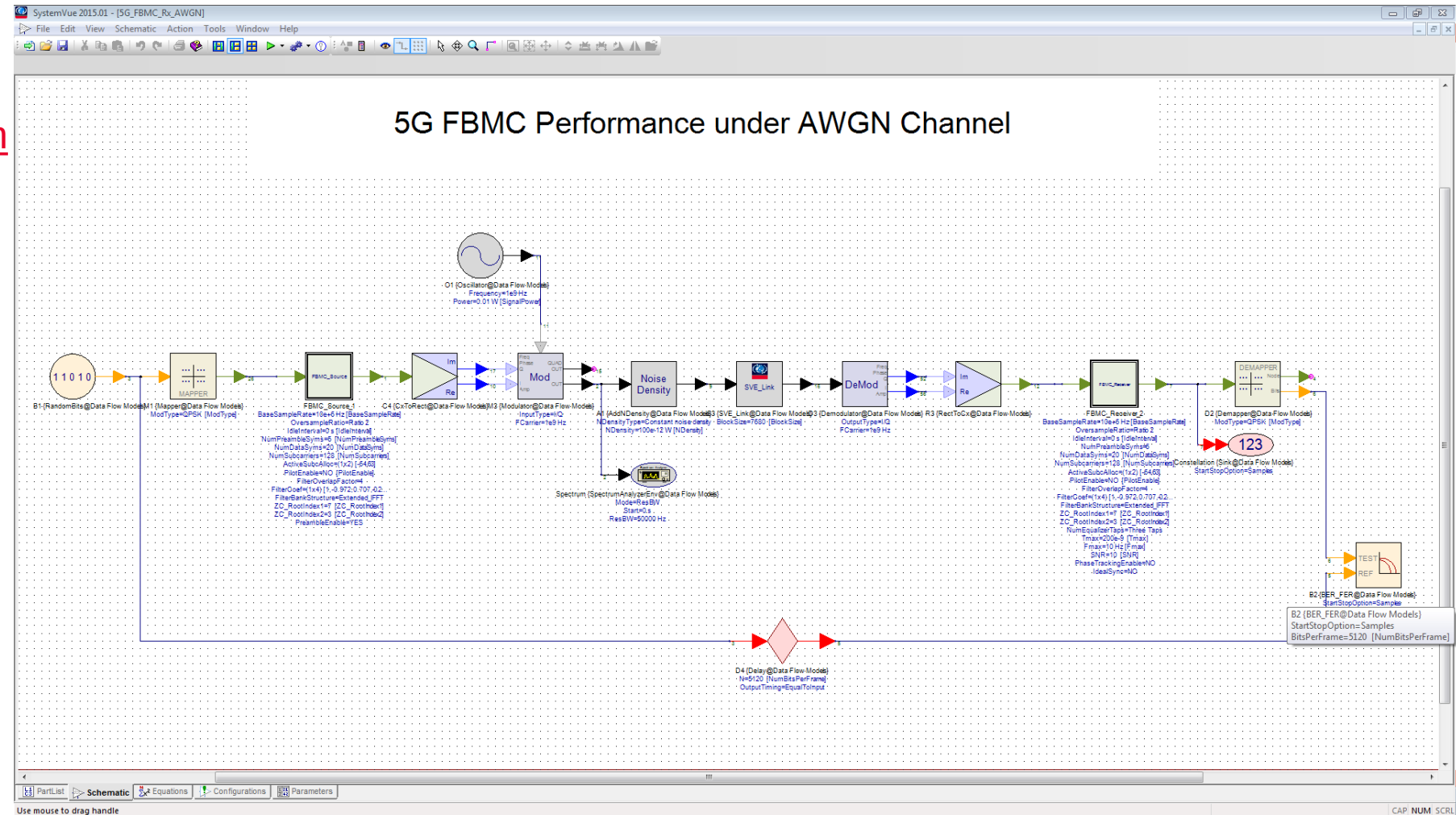
73 GHz Measurements



5G Test Bed Solution

SystemVue 5G Exploration Library

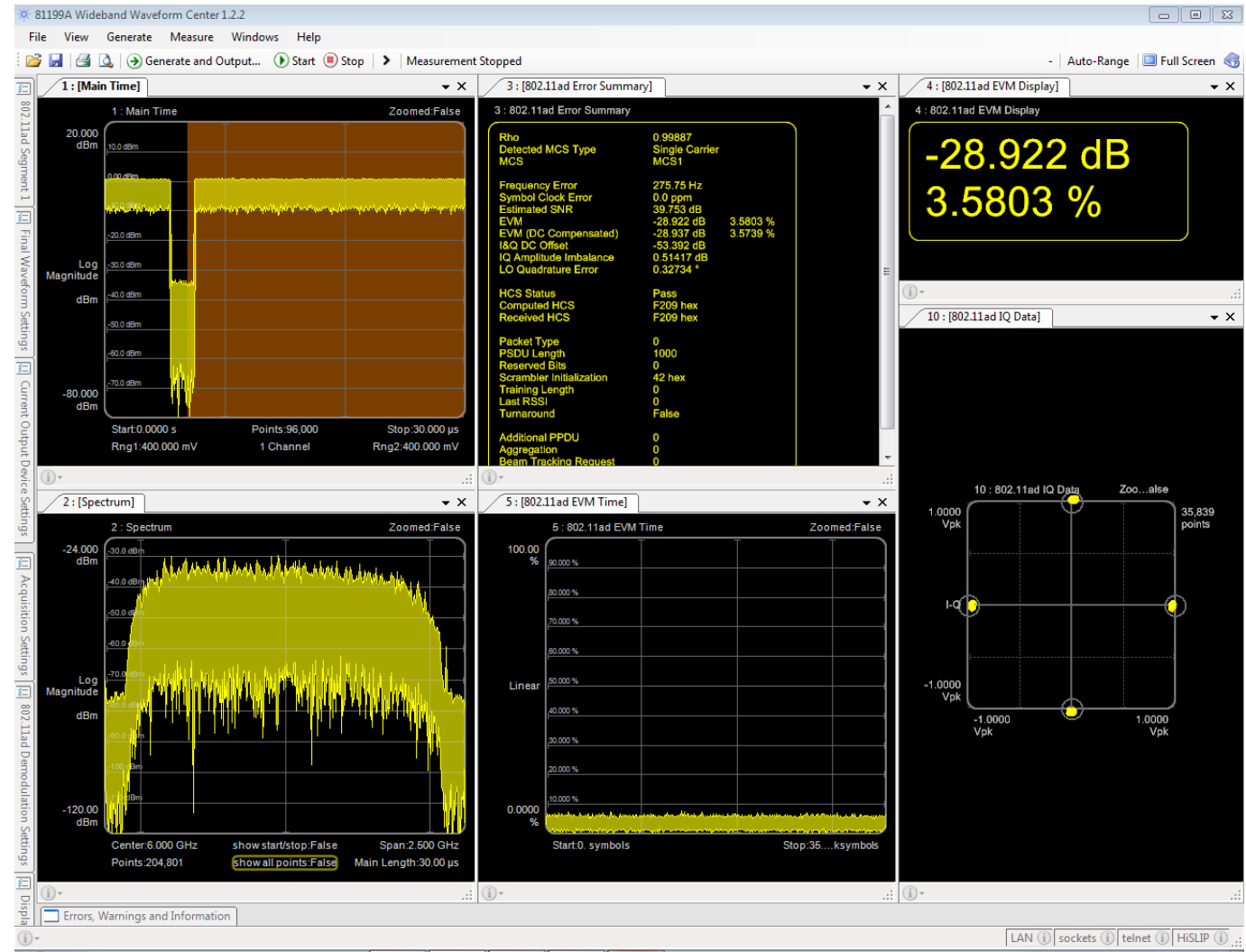
- [5G Whitepaper](#)
- [Keysight 5G solution video](#)
- [5G @ IMS demo video](#)



81199A Wideband Waveform Center GUI

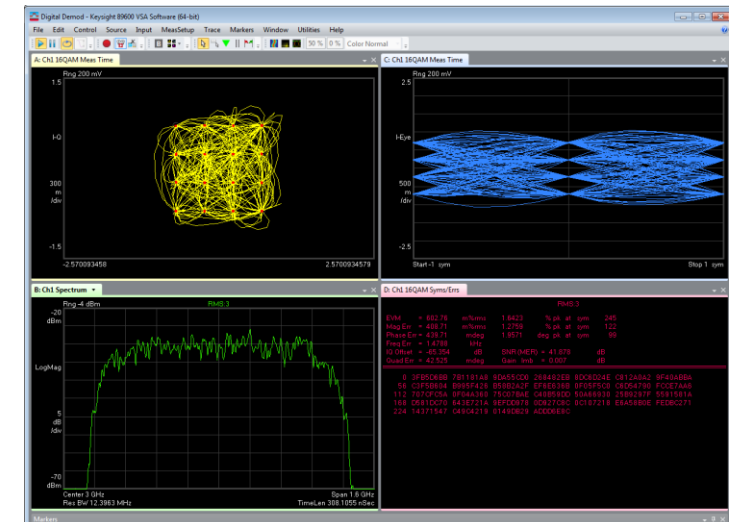
Generation and Analysis Software for 802.11ad / WiGig

WiGig application note



Agenda

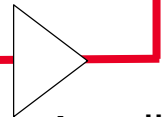
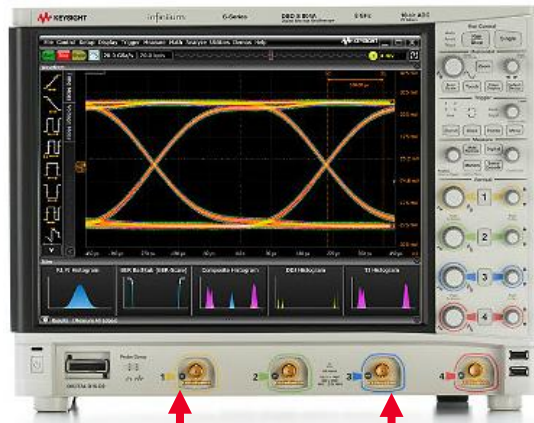
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PA test driven into compression

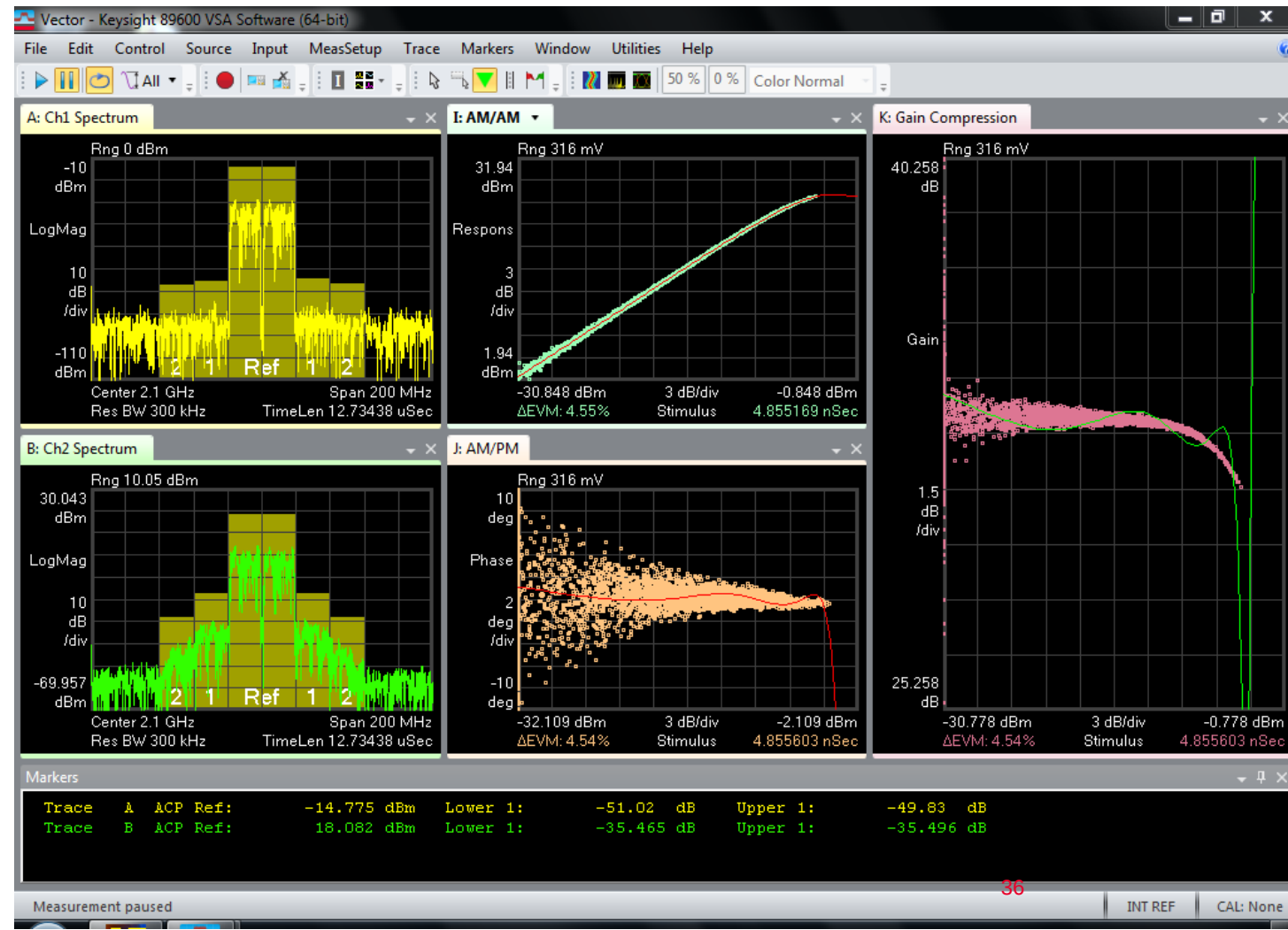
2x20 MHz LTE R10 CC 2100MHz / S-Series

S-Series Oscilloscope



Amplifier

Vector signal generator



SatCom Wideband Channel Quality

1.4 GHz bandwidth satellite channel

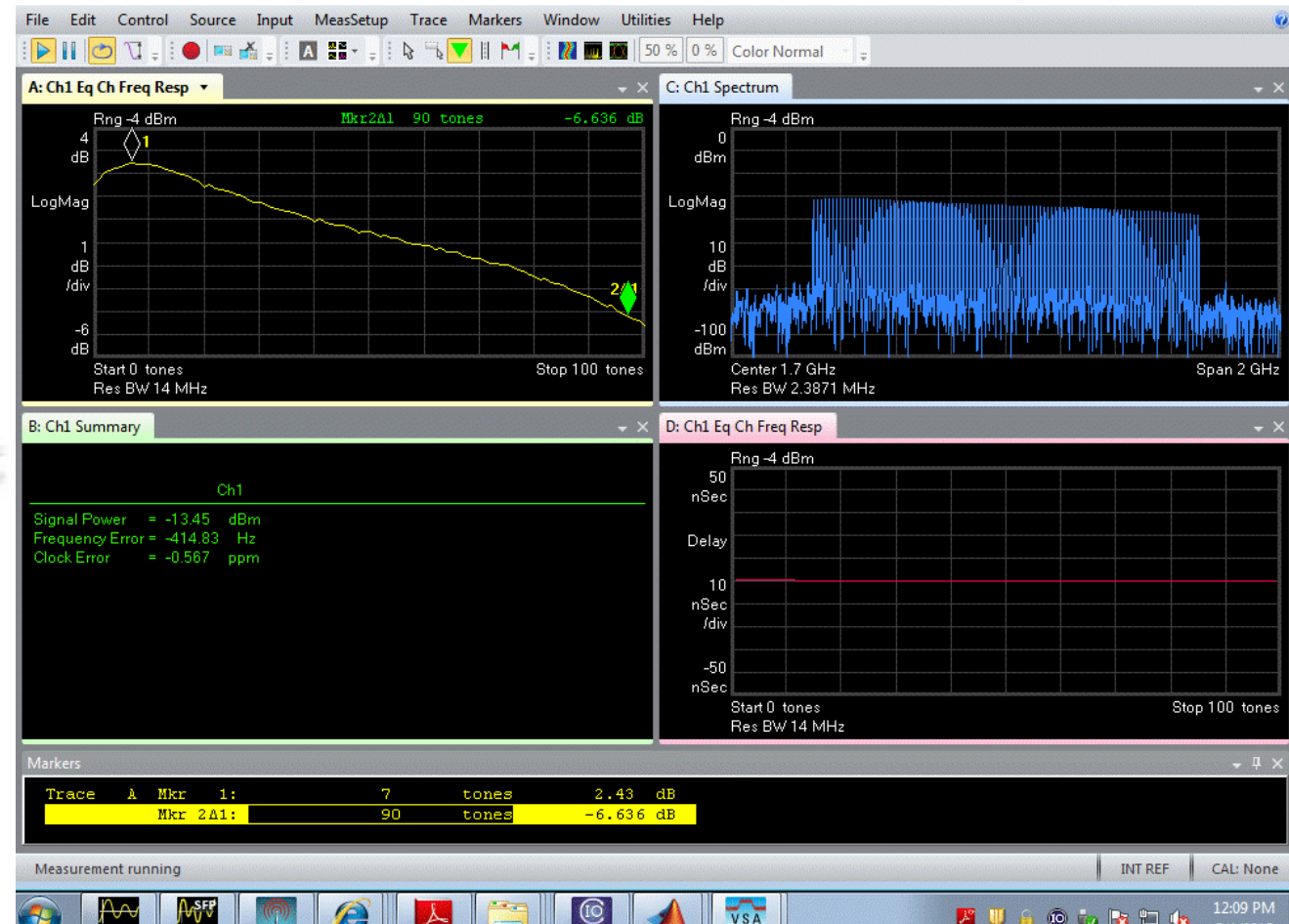
Calibrated wideband signal generator



V-Series Oscilloscope



Channel of interest

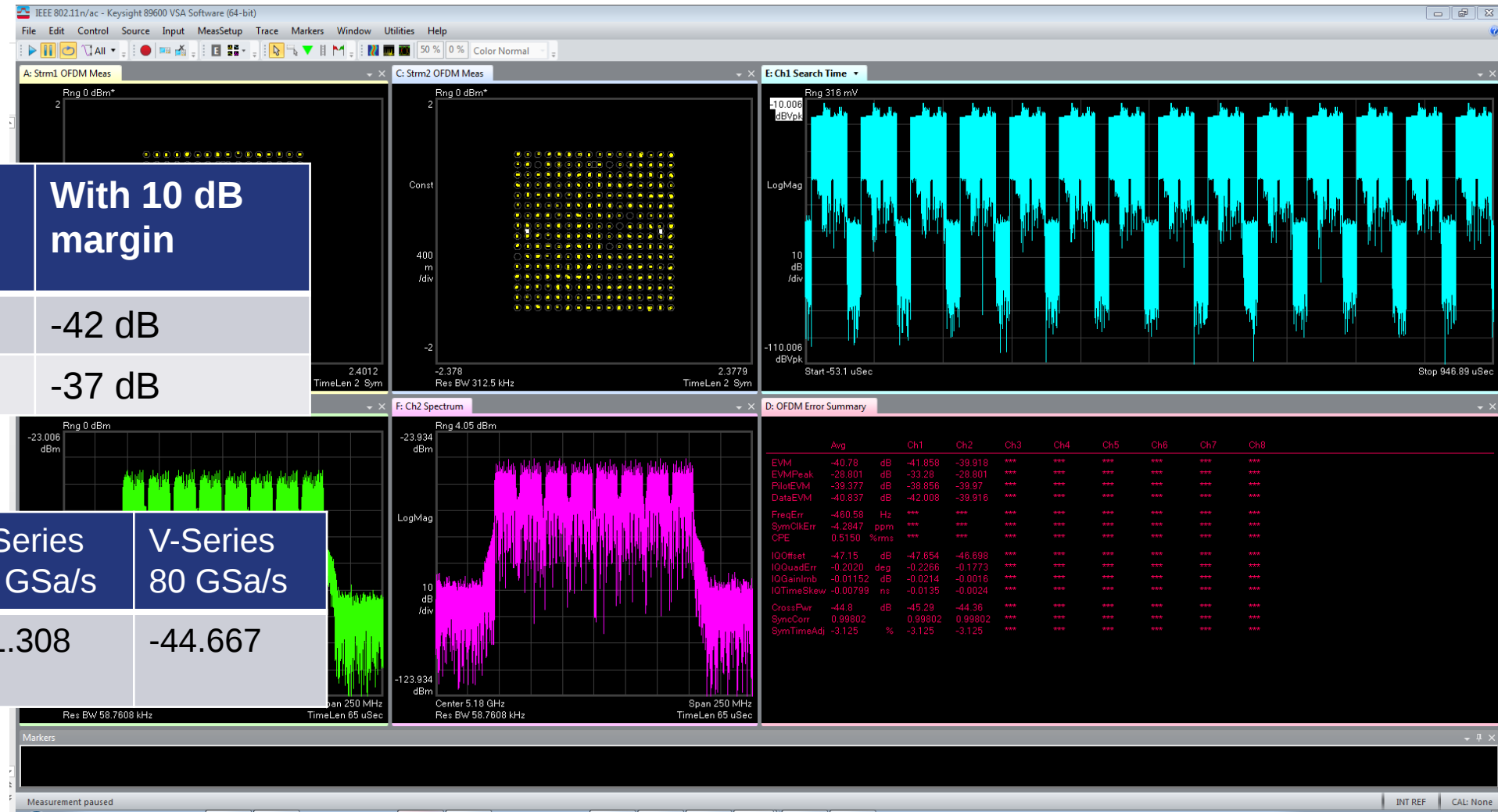


802.11ac 5.18 GHz 160 MHz 2x2 -10dBm MCS 8

-40.78 dB EVM / S-Series

Modulation	Required EVM	With 10 dB margin
256 QAM	-32 dB	-42 dB
64 QAM	-27 dB	-37 dB

	S-Series 20GSa/s	V-Series 20 GSa/s	V-Series 80 GSa/s
EVM (dB)	-40.78	-41.308	-44.667



What have we seen?

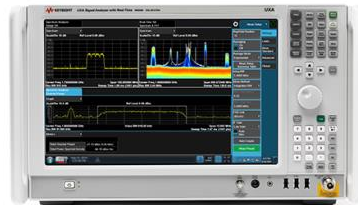
Scopes for RF measurements



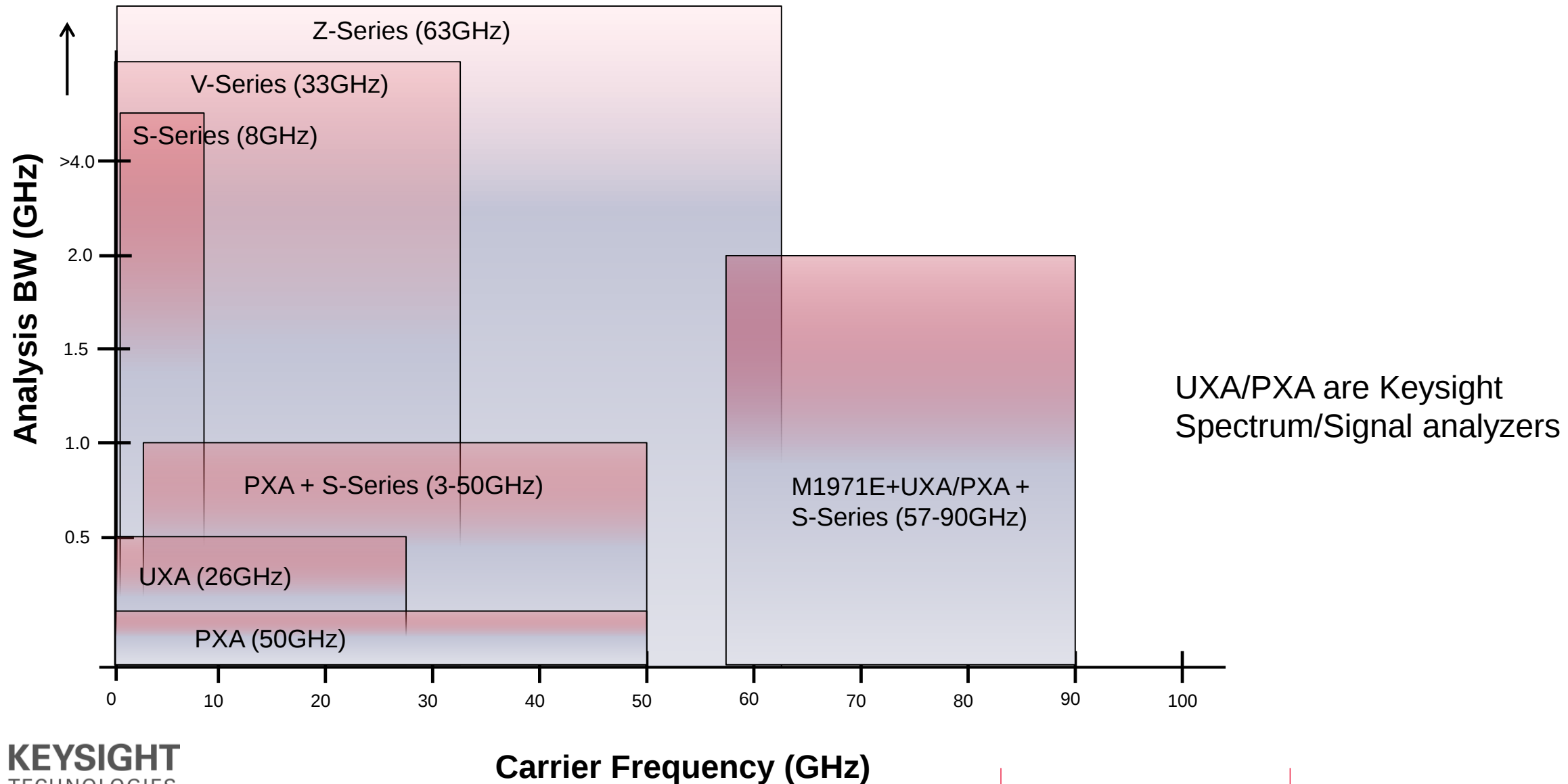
- New scopes make great, wideband RF receivers, that translate into excellent in-band RF measurements
- Oscilloscopes offer the widest analysis bandwidth to address the latest pulse and communications oriented applications
- The noise density of new scopes is better than you might have realized, making them applicable to small signal applications
- Scopes and Spectrum/Signal Analyzers each have their strengths for RF measurements
- Scopes combined with VSA software become a powerful wideband RF measurement suite

Keysight Oscilloscopes for High-Quality RF Measurements

- S-Series with up to 8 GHz bandwidth (2-ch)
- V-Series with up to 33 GHz bandwidth (2ch)
- Z-Series with up to 63 GHz bandwidth (2ch)
- Multi-instrument Reference solutions
 - Scope + PXA or UXA as down converter yields up to 1.1 GHz analysis bandwidth



Wideband Applications that only Oscilloscopes Can Address



Keysight's Oscilloscope Portfolio

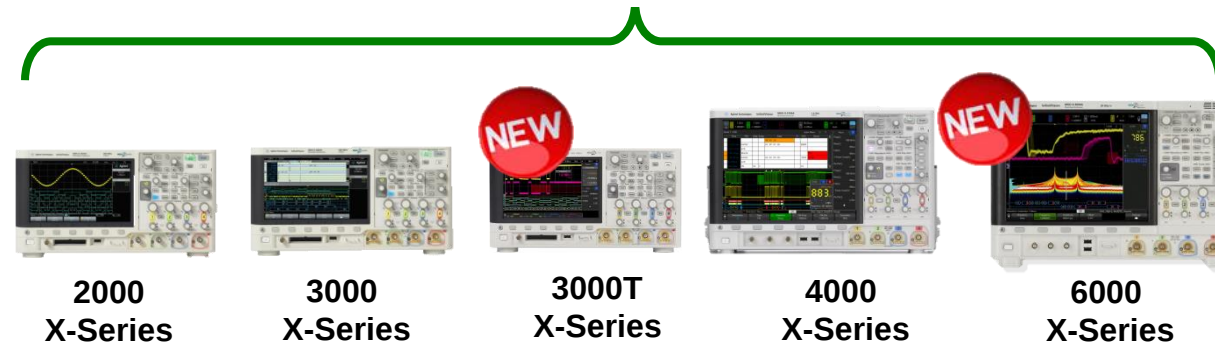
Extreme Value to Extreme Performance

Infiniium- Signal Integrity and Analysis

- 500 MHz to 63 GHz
- Detailed Analysis
- Deep memory
- Win7 OS

InfiniiVision – Designed for Value

- 70 MHz to 6 GHz
- Optimized for visualization
- Debug
- Embedded OS



More info / URL slide

Questions?

