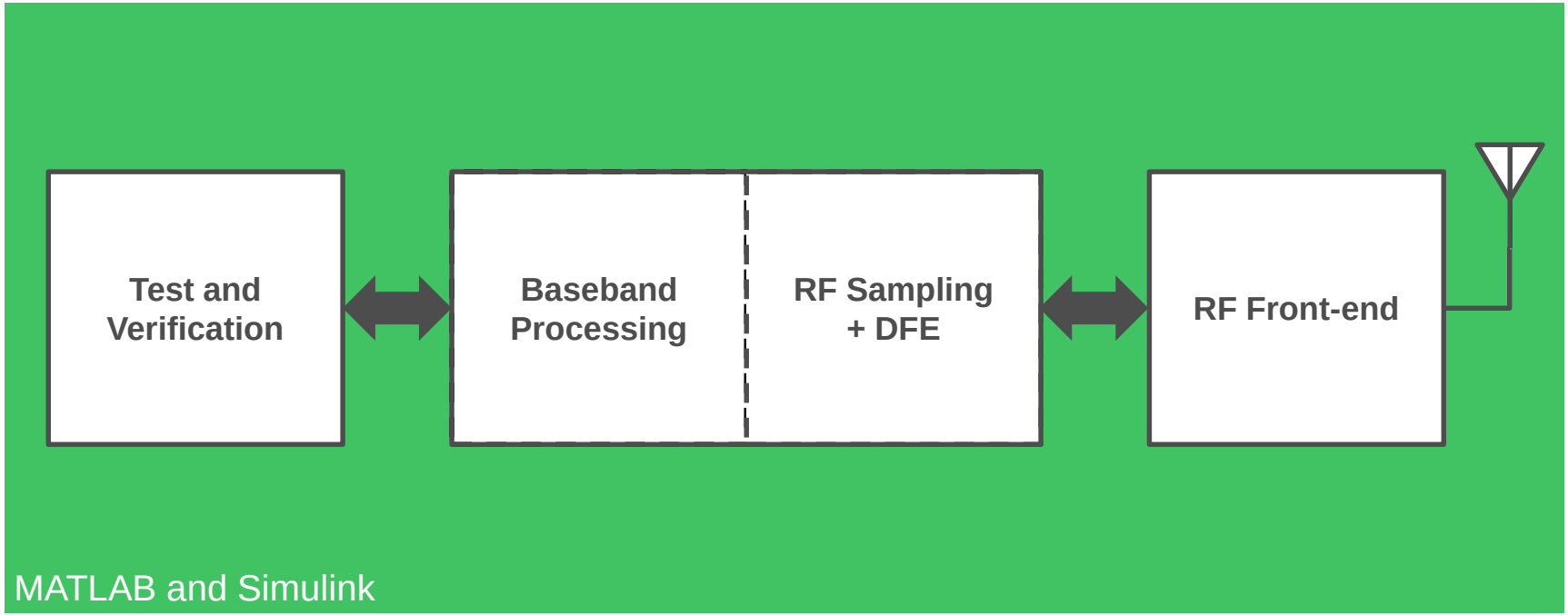
MATLAB EXPO 2019

Verify 5G System Performance Using Xilinx RFSoC and Avnet RFSoC Development Kit

Matt Brown

Elements of an RF Development System

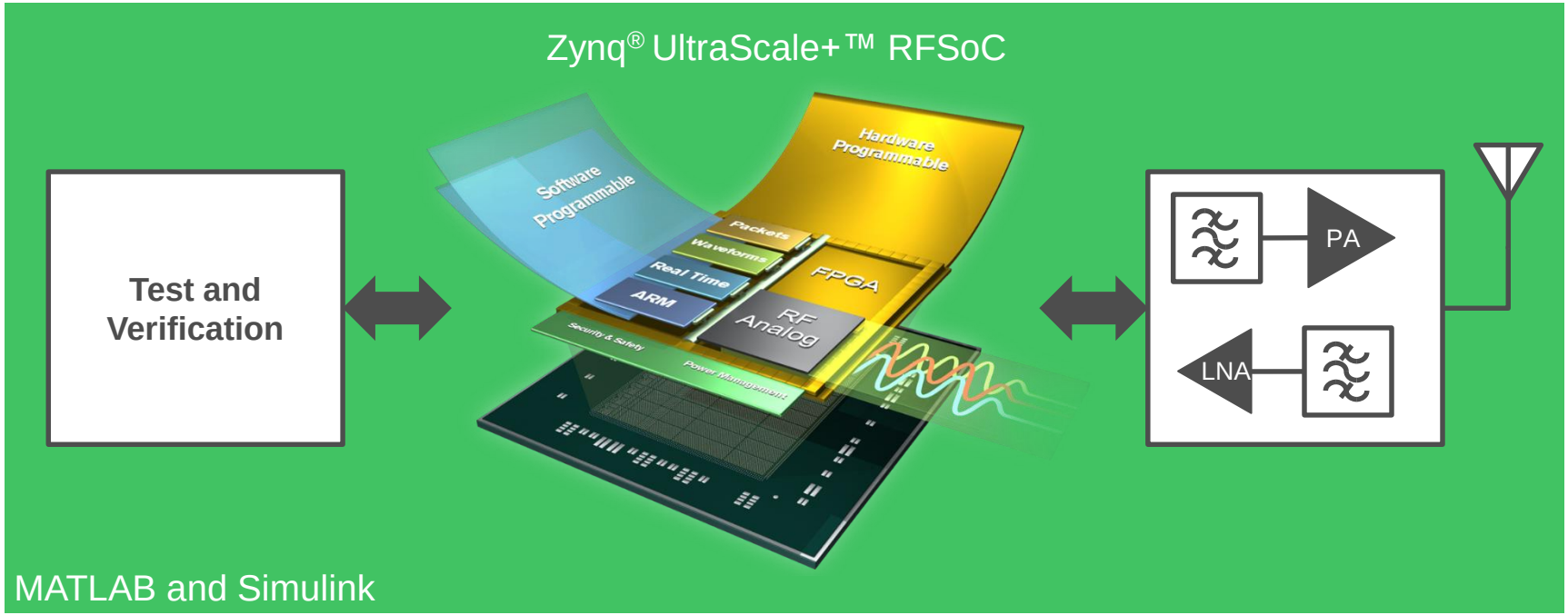
Modeling and simulation of the entire signal chain



MathWorks AVNET

Elements of an RFSoC Development System

Modeling and simulation of the entire signal chain



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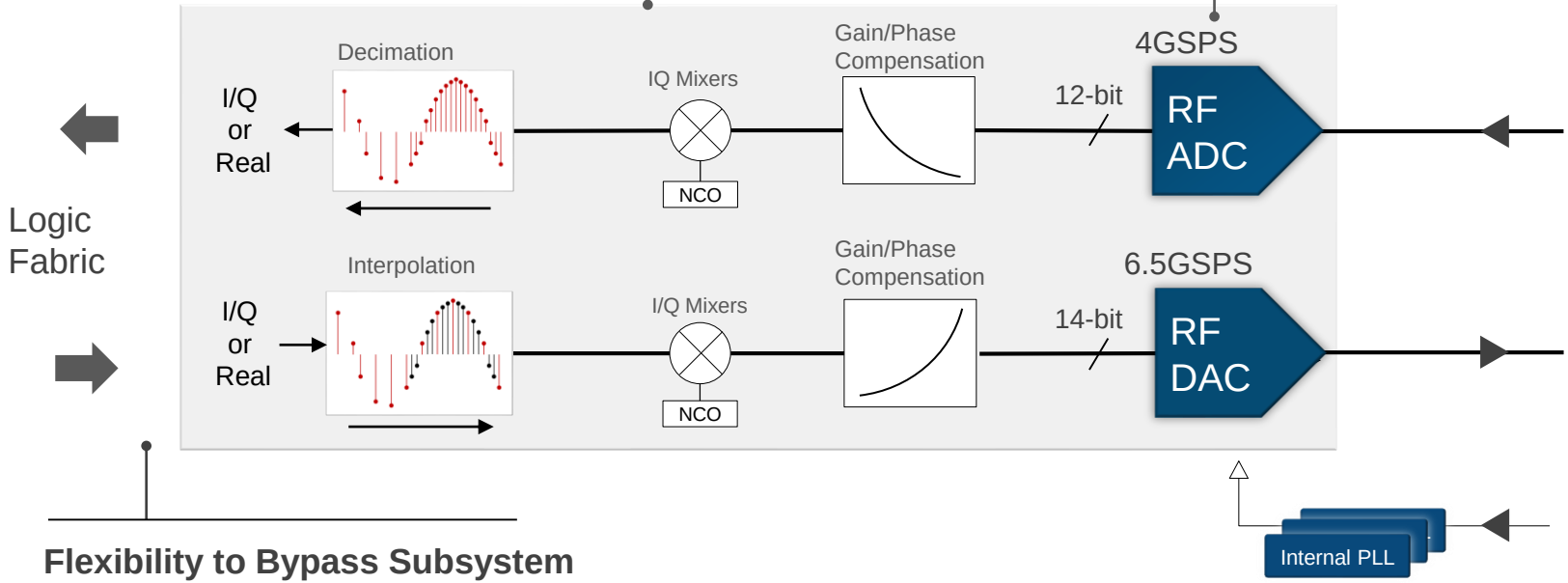
Signal Processing from RF Front-End to Digital

Digital Mixing and Filtering

- A complete DSP subsystem
- Digital Up-Conversion and Down-Conversion

Direct-Sampling

- High channel count
- Multiple Configurations



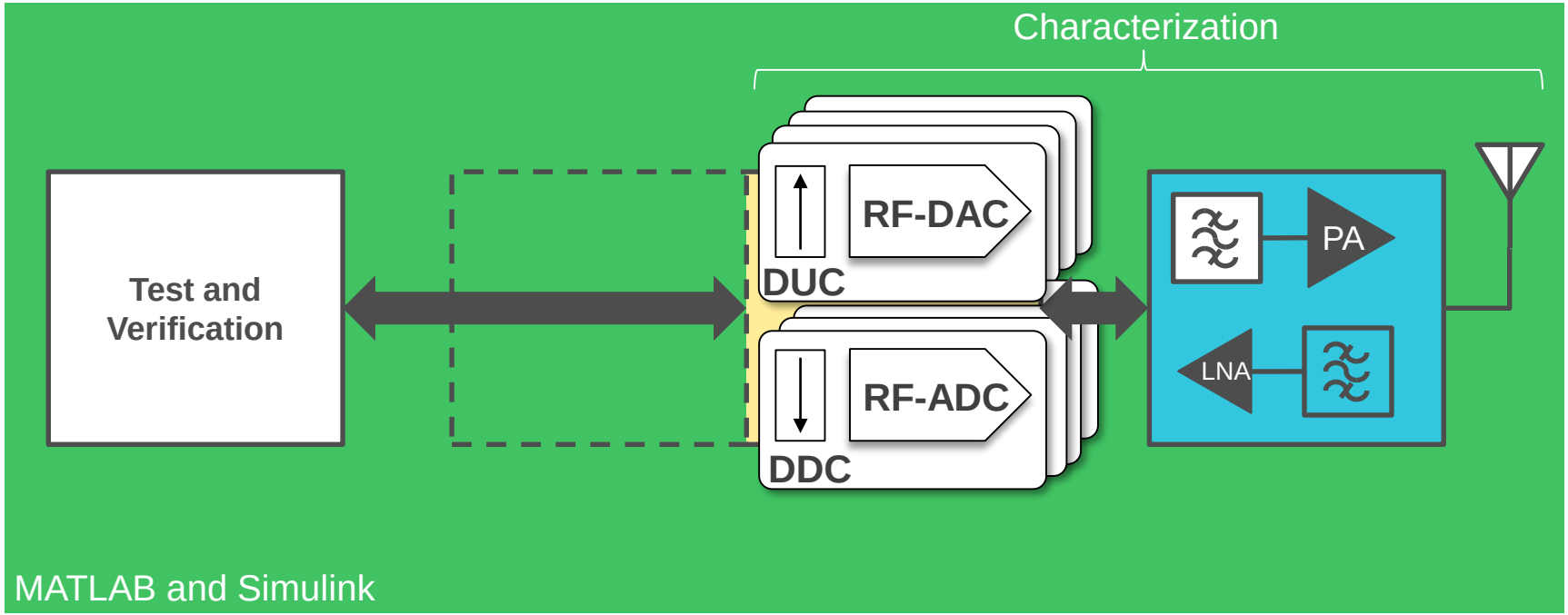
Flexibility to Bypass Subsystem

- Optionally bypass subsystem for fully custom signal conditioning
- Not possible with discrete converters (I/O limitation)

Communication-Grade PLLs

Utilize lower frequency on-board clocks

How Do We Characterize RF Hardware?



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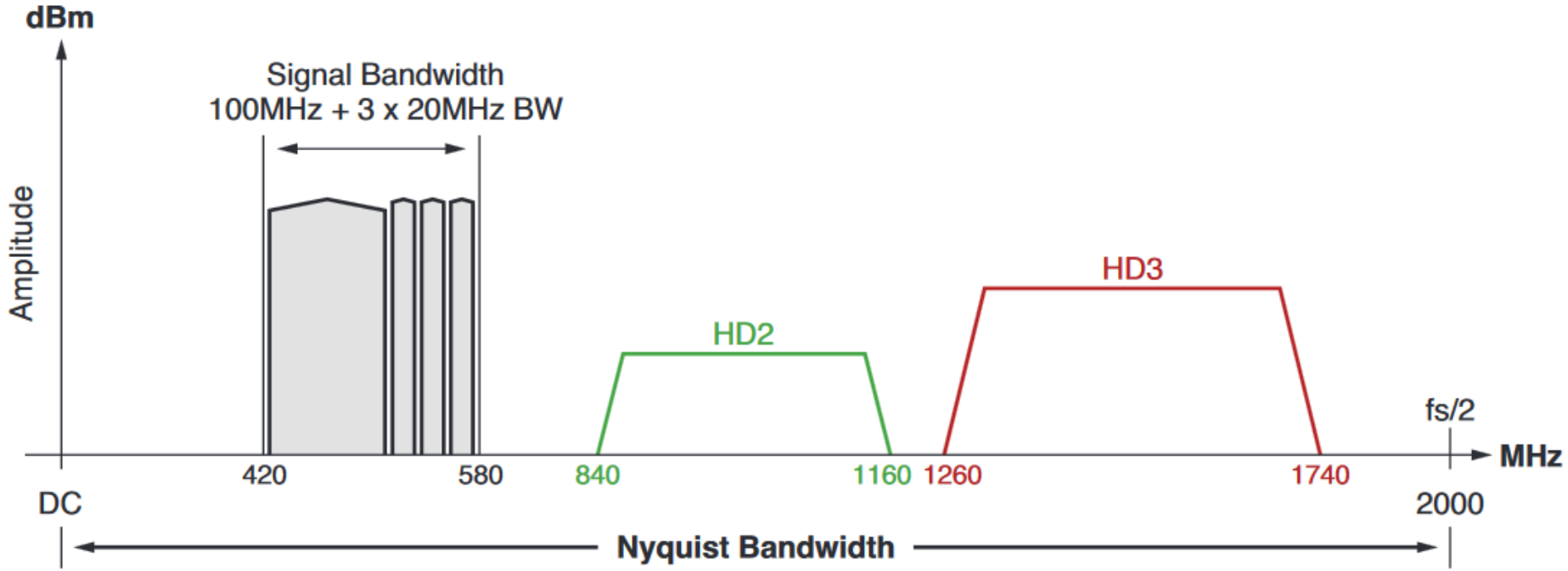
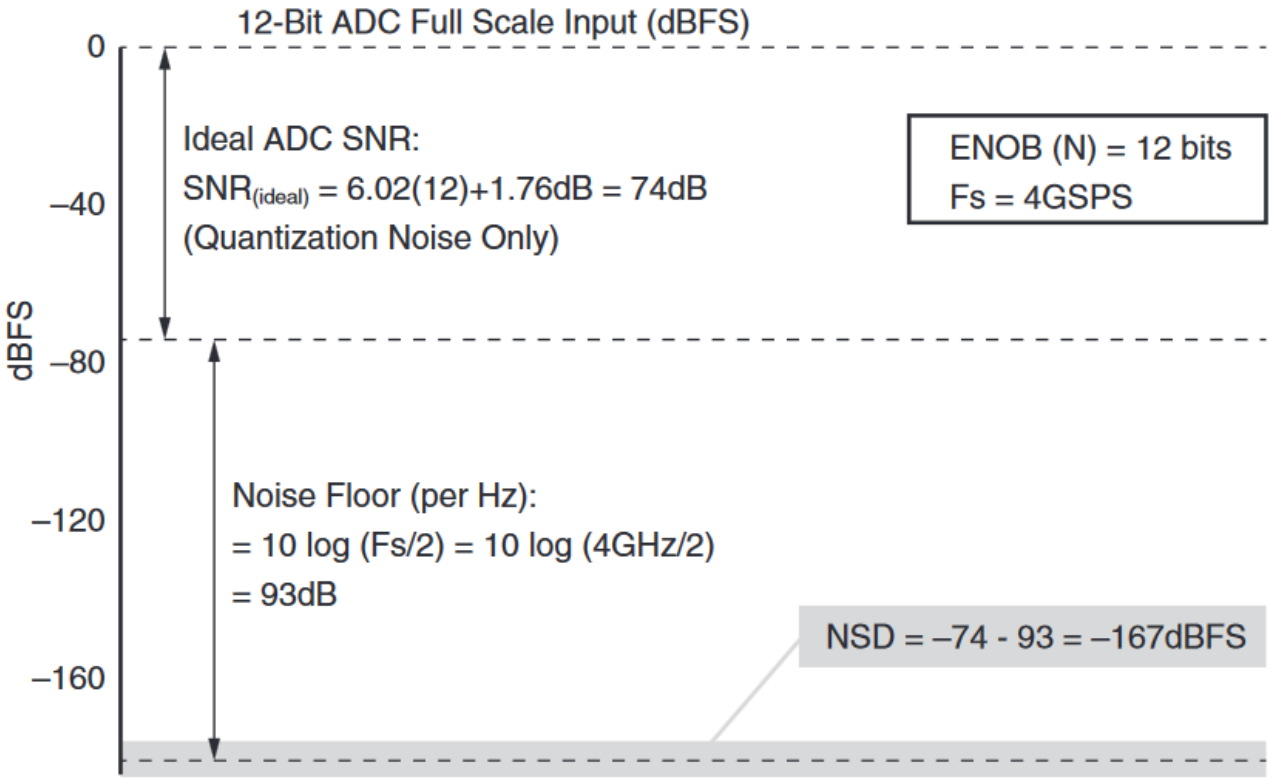
Characterize 5G NR at the Band of Interest



Noise Spectral Density



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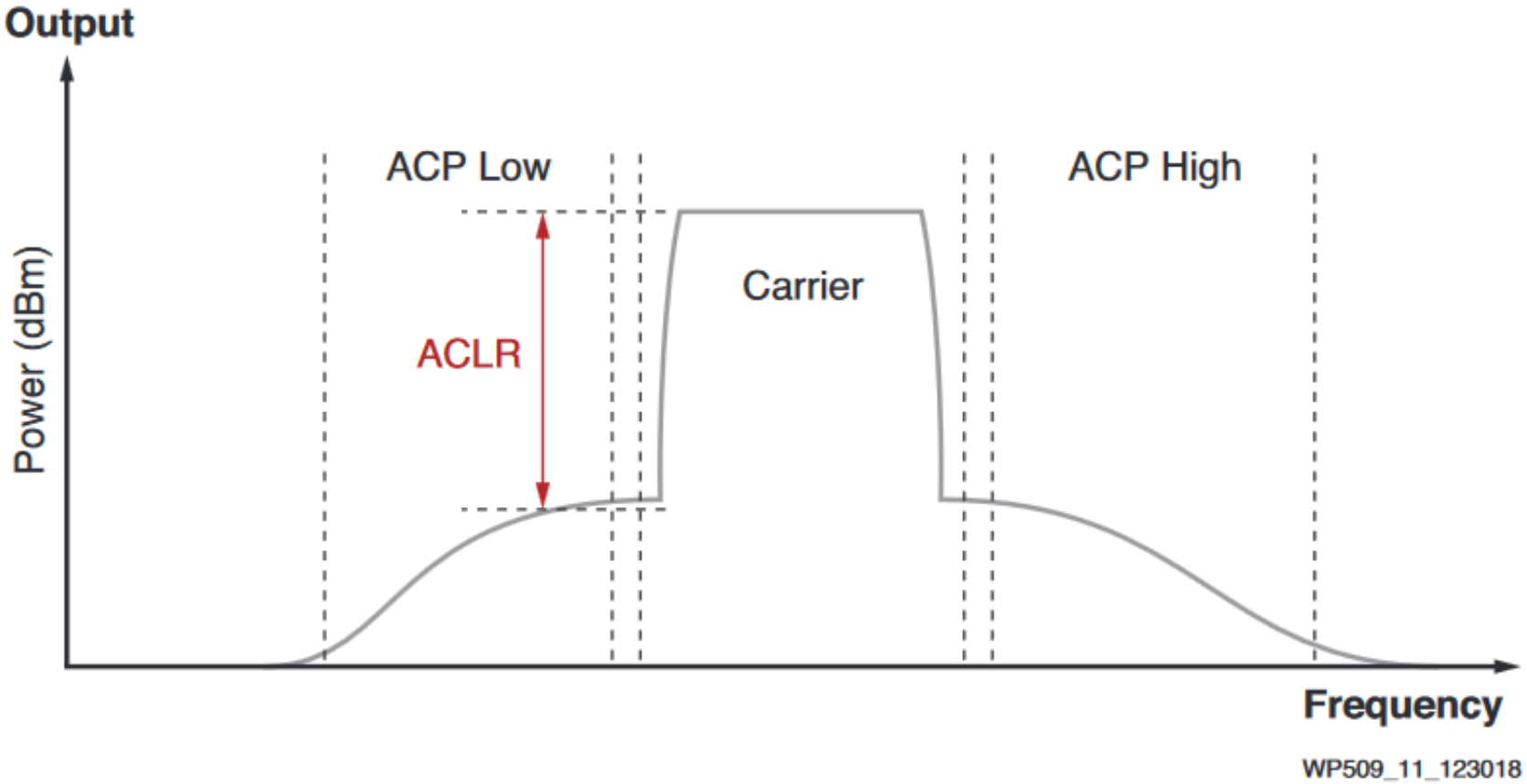
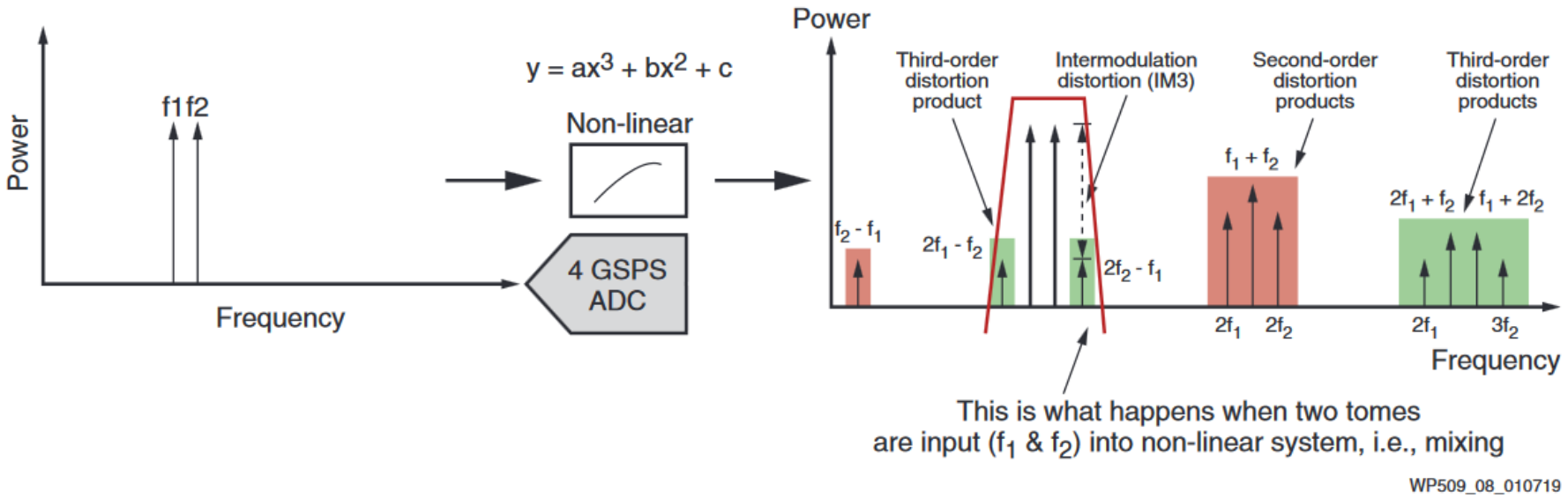
Adjacent Channel Leakage Ratio (ACLR)



IM3



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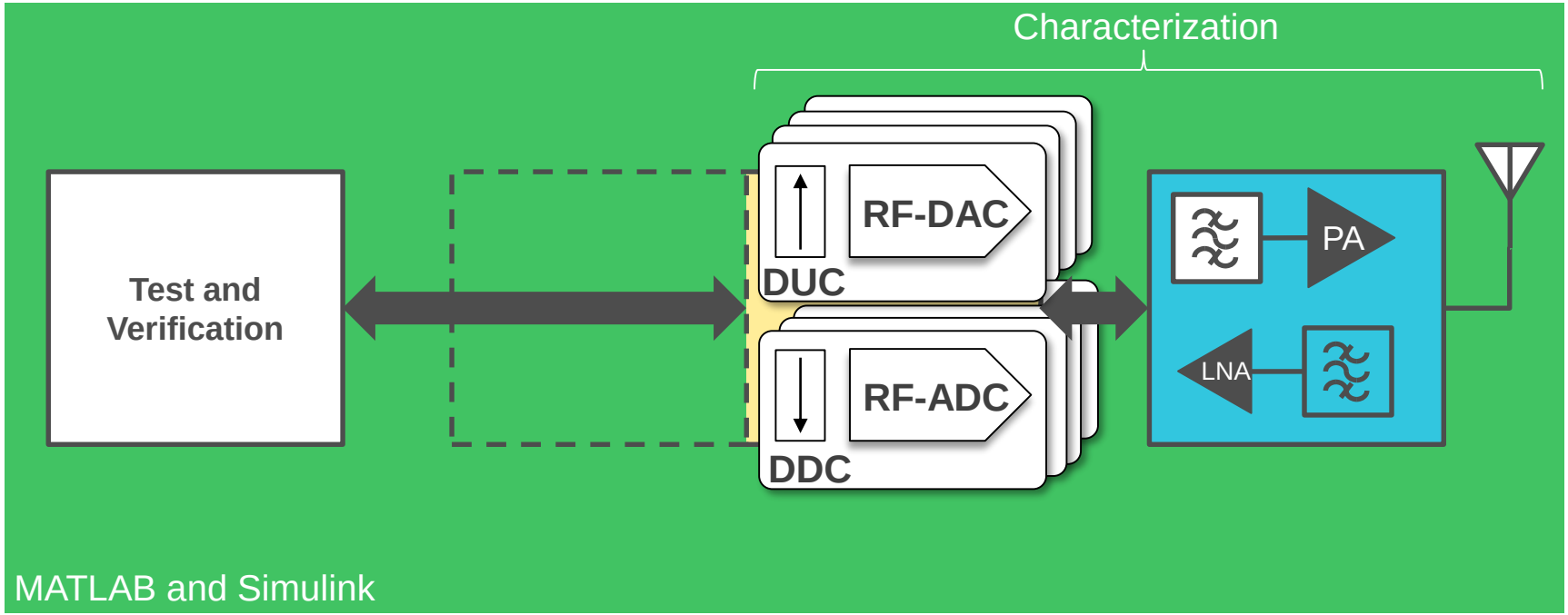
How Do We Characterize RF Hardware?



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Avnet Products & Emerging Technologies Group

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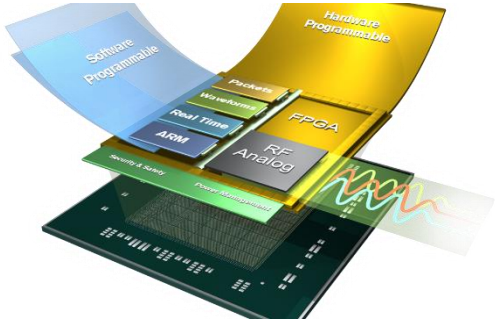
A History of SoC Abstraction

2010 — 2016 — 2019

ARM9 | **DSP**

RF XCVR

RFSoC



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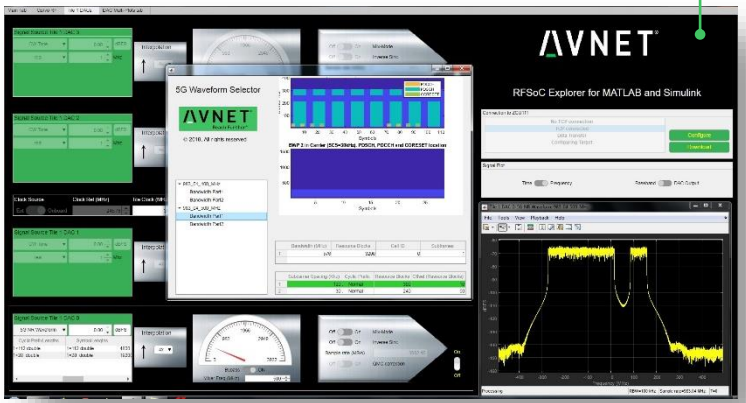
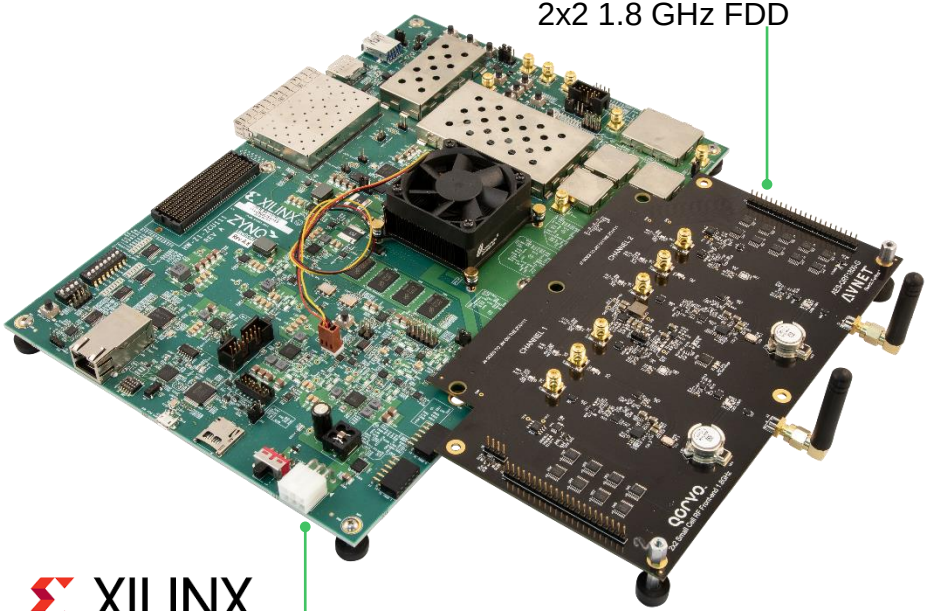
Explore Zynq UltraScale+ RFSoC from Antenna to Digital

AVNET
RFSoC Explorer®



qorvo
Small Cell RF Front End
2x2 1.8 GHz FDD



XILINX
Zynq® UltraScale+™ RFSoC
ZCU111 Evaluation Kit

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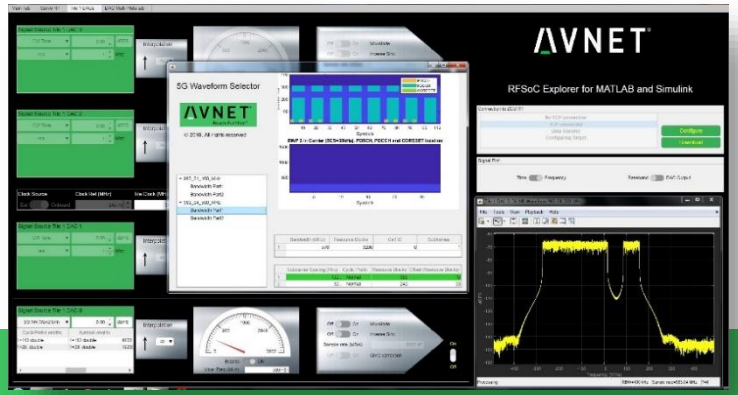
Abstracting the Hardware

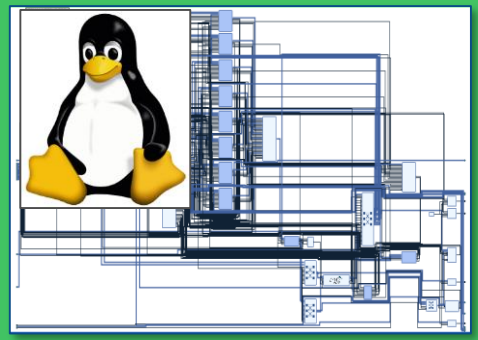


MATLAB System Objects

```
classdef AddOne < matlab.System
% ADDONE Compute an output value that

    methods (Access = protected)
        % Implement algorithm. Calcula
        function y = stepImpl(~,x)
            y = x + 1;
        end
    end
end
```

Custom Boot Image



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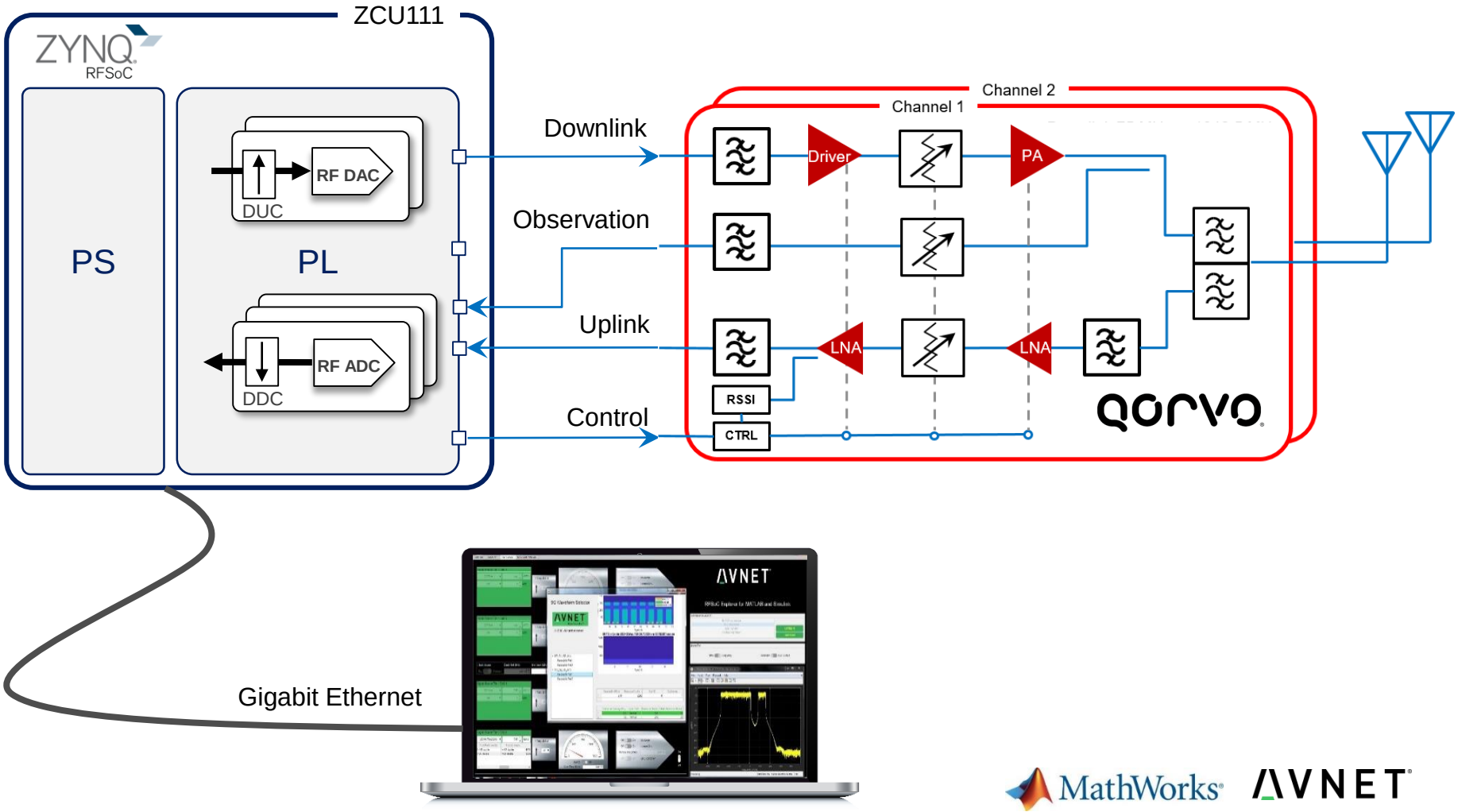
ZCU111
ZYNQ
RFSoC
PS
PL
RF DAC
DUC
RF ADC
DDC
Downlink
Observation
Uplink
Control
Channel 2
Channel 1
Driver
PA
LNA
LNA
RSSI
CTRL
qorvo
Gigabit Ethernet
AVNET
MathWorks
AVNET

Avnet RFSoC Explorer for MATLAB and Simulink

File | Main Tab | Qorvo RF | Tile 1 DACs | DAC Multi-Plots tab | Tile 3 ADCs

Signal Source Tile 1 DAC 3

CW Tone | -Inf | dBFS
complex | 1 | Mhz

Interpolation: 4x

Fine | IQ->Real
Analog Fc (MHz): 0

Off On Mix-Mode
Off On Inverse Sinc
Sample rate (MS/s): 6389.76
Off On QMC correction

On / Off

Signal Source Tile 1 DAC 2

CW Tone | 0.00 | dBFS
complex | 1 | Mhz

Interpolation: 8x

Fine | IQ->Real
Analog Fc (MHz): 1842

Off On Mix-Mode
Off On Inverse Sinc
Sample rate (MS/s): 6389.76
Off On QMC correction

On / Off

Clock Source: Ext / Onboard
Clock Ref (MHz): 245.76
Tile Clock (MHz): 6389.76
Internal PLL: Bypass / Enable

Signal Source Tile 1 DAC 1

CW Tone | -Inf | dBFS
complex | 1 | Mhz

Interpolation: 4x

Fine | IQ->Real
Analog Fc (MHz): 0

Off On Mix-Mode
Off On Inverse Sinc
Sample rate (MS/s): 6389.76
Off On QMC correction

On / Off

Signal Source Tile 1 DAC 0

CW Tone | -Inf | dBFS
complex | 1 | Mhz

Interpolation: 4x

Fine | IQ->Real
Analog Fc (MHz): 0

Off On Mix-Mode
Off On Inverse Sinc
Sample rate (MS/s): 6389.76
Off On QMC correction

On / Off

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RFSoC Explorer for MATLAB and Simulink

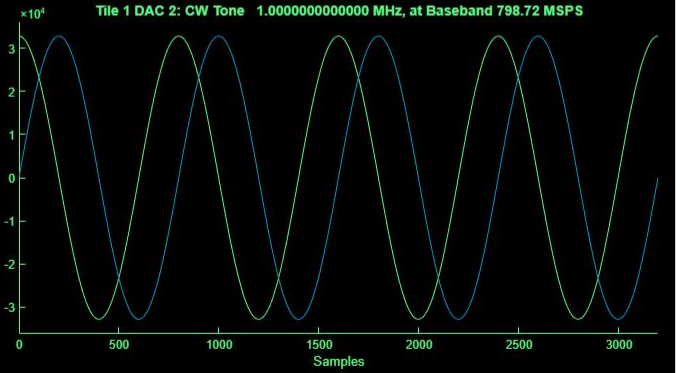
Connection to ZCU111

No TCP connection
TCP connected
Data Transfer
Configuring Target

Configure
Download

Signal Plot

Time / Frequency
Off On
Baseband / DAC Output
Spectrum Analyzer



Type here to search

1:42 PM
11/4/2019

Avnet RFSoC Explorer for MATLAB and Simulink

File | Main Tab | Qorvo RF | Tile 1 DACs | DAC Multi-Plots tab

Signal Source Tile 1 DAC 3
CW Tone | -Inf | dBFS
complex | 1 | Mhz
Interpolation 4x
-1597 0 1597 -3195 3195
Fine | IQ->Real
Analog Fc (MHz) 0
Off On Mix-Mode
Off On Inverse Sinc
Sample rate (MS/s) 6389.76
Off On QMC correction
On Off

Signal Source Tile 1 DAC 2
LTE Waveform | 0.00 | dBFS
TMN | BW | NDLRB | Cell
1.1 | 20MHz | 100 | 1
Interpolation 4x
-1597 0 1597 -3195 3195
Fine | IQ->Real
Analog Fc (MHz) 1843
Off On Mix-Mode
Off On Inverse Sinc
Sample rate (MS/s) 6389.76
Off On QMC correction
On Off

Clock Source: Ext Onboard
Clock Ref (MHz): 245.76
Tile Clock (MHz): 6389.76
Internal PLL: Bypass Enable

Signal Source Tile 1 DAC 1
CW Tone | -Inf | dBFS
complex | 1 | Mhz
Interpolation 4x
-1597 0 1597 -3195 3195
Fine | IQ->Real
Analog Fc (MHz) 0

Signal Source Tile 1 DAC 0
CW Tone | -Inf | dBFS
complex | 1 | Mhz
Interpolation 4x
-1597 0 1597 -3195 3195
Fine | IQ->Real
Analog Fc (MHz) 0
Off On QMC correction
Off

LTE Downlink E-TM Generator
Generate downlink test model (E-TM) waveforms. These are specified in TS36.141 (section 6) for testing the downlink transmitter characteristics.

Test model	1.1
Bandwidth	1.4MHz
Cell identity	1
Duplex mode	FDD
Number of subframes	10
Windowing (samples)	0
Waveform output variable	tmwaveform
Resource grid output variable	tmgrid
E-TM configuration output variable	tmconfig

Generate waveform | Help

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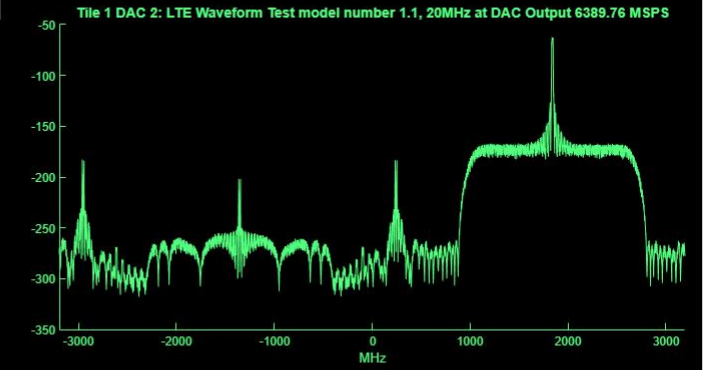
RFSoC Explorer for MATLAB and Simulink

Connection to ZCU111
No TCP connection
TCP connected
Data Transfer
Configuring Target
Configure
Download

Signal Plot
Time Frequency
Off On Baseband DAC Output
Spectrum Analyzer



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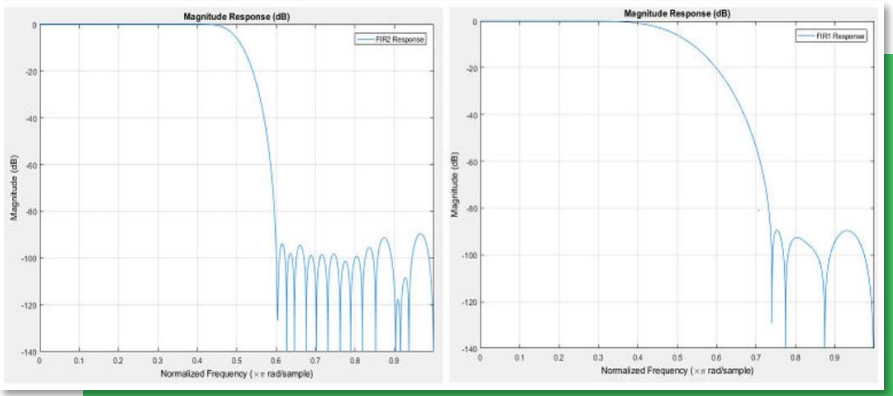
Modeling the Digital Up-Converter in RF-DAC Tile



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Avnet RFSoC Explorer for MATLAB and Simulink

File | Main Tab | Qorvo RF | Tile 1 DACs | DAC Multi-Plots tab | Tile 3 ADCs

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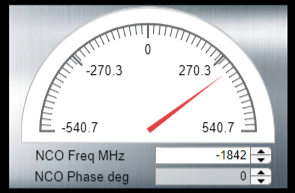
RFSoC Explorer® for MATLAB and Simulink

ADC23

ADC ENable: Off / On
Sample rate (MS/s): 1081.3440
Nyquist Zone: 4
Calibration Mode: 2
Analog Fc (MHz): 1842



NCO Freq MHz: -1842
NCO Phase deg: 0
Fine | Real->IQ

Decimation: 8x

Connection to ZCU111
No TCP connection
TCP connected
Data Acquisition
Configuring Target
Configure
Acquire
Single capture

Clock Source: Ext / Onboard
Clock Ref (MHz): 245.76
Tile Clock (MHz): 1081.344

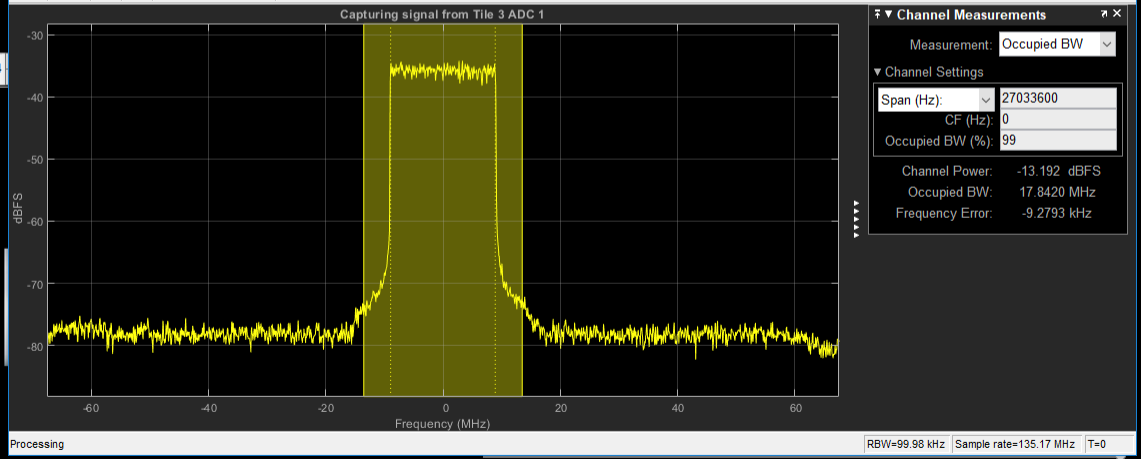
ADC01

ADC ENable: Off / On
Sample rate (MS/s): 1081.3440
Nyquist Zone: 1
Calibration Mode: 2
Analog Fc (MHz): -0

NCO Freq MHz: 0
NCO Phase deg: 0
Fine | Real->IQ

Spectrum Analyzer

File Tools View Playback Help



Processing | RBW=99.98 kHz | Sample rate=135.17 MHz | T=0

0 40 80 120 160 200 240 280 320 360 400 440 480 520 560 600 640 680 720 760 800 840 880 920 960 1000

Type here to search

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11/4/2019

Avnet RFSoC Explorer for MATLAB and Simulink

File | Main Tab | Qorvo RF | Tile 1 DACs | DAC Multi-Plots tab

Signal Source Tile 1 DAC 3

CW Tone | -Inf | dBFS | complex | 1 | Mhz

Interpolation 4x

-1597 0 1597 -3195 3195

Fine | IQ->Real | Analog Fc (MHz) 0

Off On Mix-Mode

Off On Inverse Sinc

Sample rate (MS/s) 6389.76

Off On QMC correction

On Off

Signal Source Tile 1 DAC 2

5G NR Waveform | 0.00 | dBFS

CW Tone | LTE Waveform | Wireless Waveform | 5G NR Waveform | MATLAB File | From PL DUT | From Simulink Model

Native Sampling Rate | Nfft

983.0400 | 8192

983.0400 | 32768

Interpolation 8x

Off On Mix-Mode

Off On Inverse Sinc

Sample rate (MS/s) 6389.76

On

Clock Ref (MHz) | Tile Clock (MHz)

Ext Onboard | 245.76 | 6389

Signal Source Tile 1 DAC 1

CW Tone | -Inf | dBFS | complex | 1 | Mhz

Interpolation 4x

Signal Source Tile 1 DAC 0

CW Tone | -Inf | dBFS | complex | 1 | Mhz

Interpolation 4x

AVNET®

RFSoC Explorer for MATLAB and Simulink

Connection to ZCU111

No TCP connection

TCP connected

Data Transfer

Configuring Target

Configure

Download

Signal Plot

Time Frequency Off On Baseband DAC Output

Spectrum Analyzer

Tile 1 DAC 2: 5G NR Waveform $983_{0}4_{5}00_{M}$Hz at Baseband 798.72 MSPS

-60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160

-400 -300 -200 -100 0 100 200 300 400

MHz

5G Waveform Selector

AVNET Reach Further™

BWP 1 in Carrier (SCS=120kHz). PDSCH, PDCCH and CORESET location

PDCCH | PDSCH | CORESET

Carrier RB

300 200 100

10 20 30 40 50 60 70 80 90 100 110

Symbols

BWP 2 in Carrier (SCS=30kHz). PDSCH, PDCCH and CORESET location

Carrier RB

1400 1200 1000 800 600 400 200

5 10 15 20 25

Symbols

983_04_400_MHz

Bandwidth Part1

Bandwidth Part2

983_04_500_MHz

Bandwidth Part1

Bandwidth Part2

	Bandwidth (MHz)	Resource Blocks	Cell ID	Subframes
1	504	2800	0	1

	Subcarrier Spacing (Khz)	Cyclic Prefix	Resource Blocks	Offset (Resource Blocks)
1	120	Normal	300	10
2	30	Normal	100	1000

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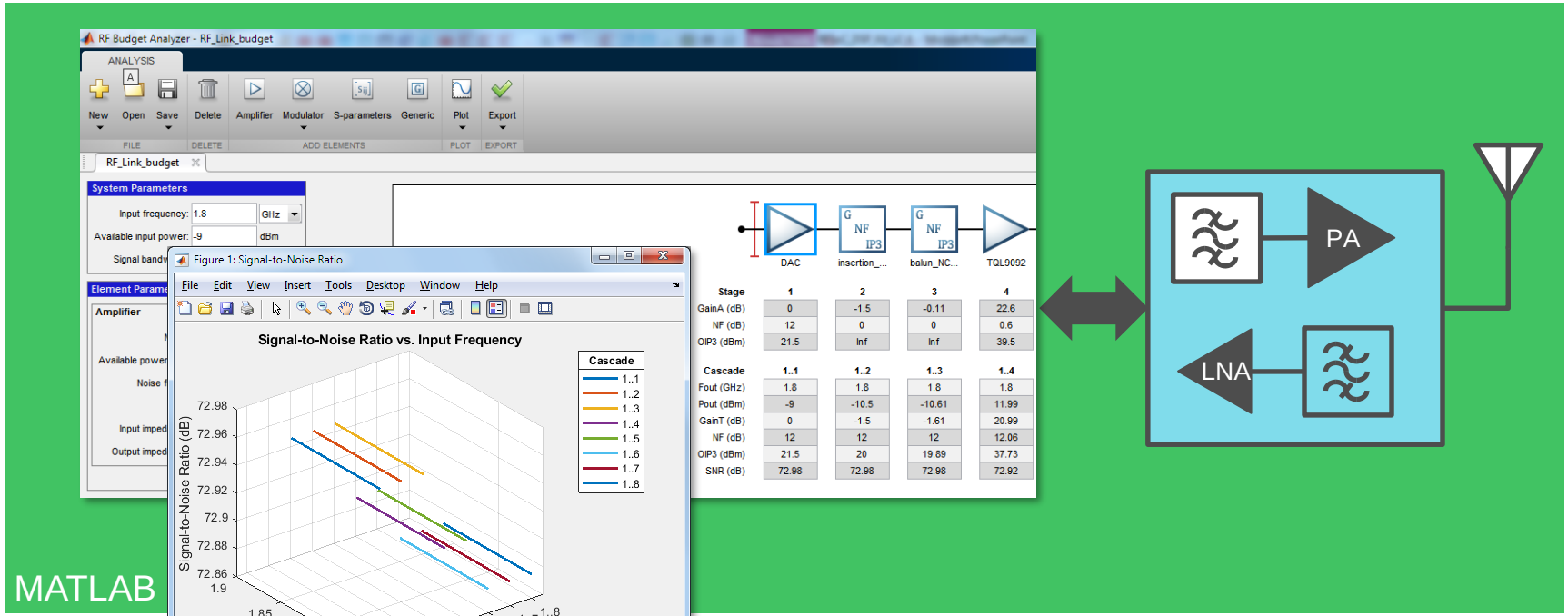
RF Link Budget Analysis of Qorvo Front End



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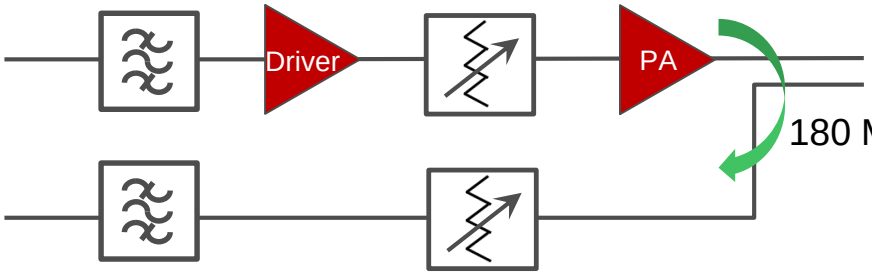
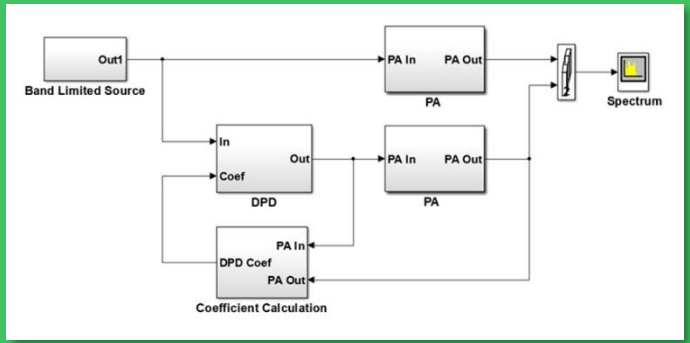
Next … Digital Pre-Distortion to Linearize the PA

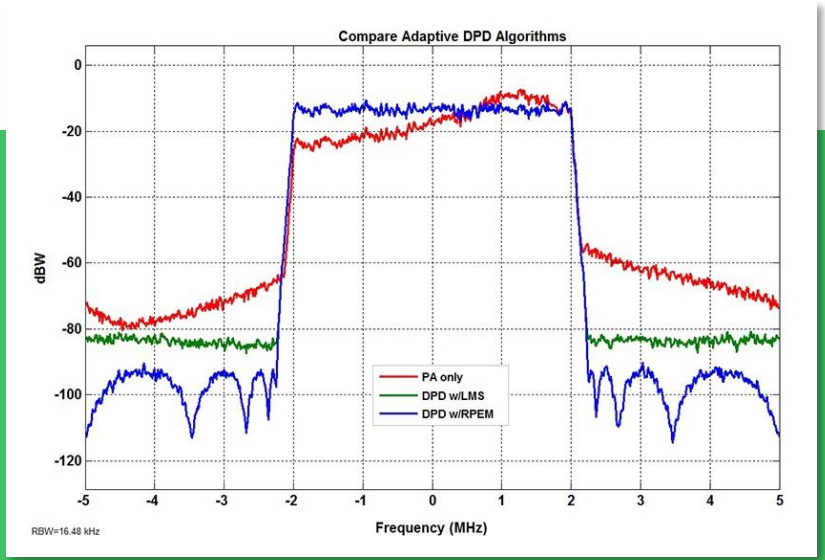


qorvo

180 MHz BW observation path

Simulink Adaptive DPD Modeling





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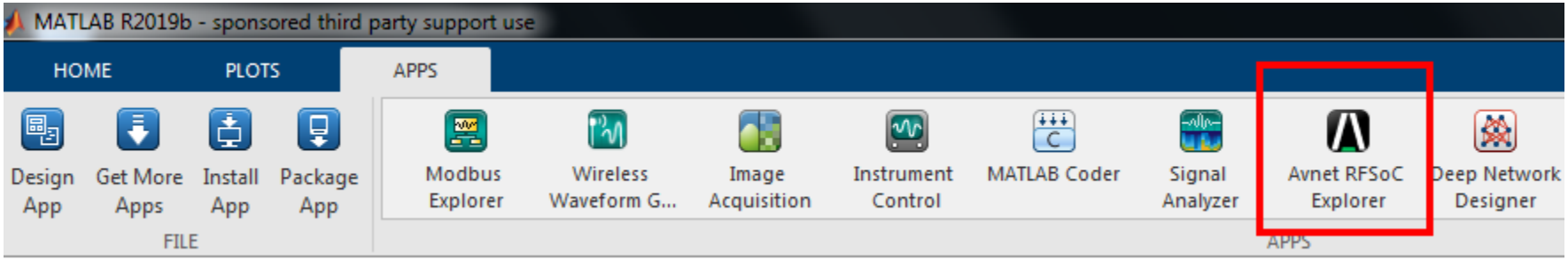
RFSoC Explorer in MATLAB Apps Store



avnet.com / rfsockit

Installation – MATLAB Apps & Add-Ons

Requires – Communications Toolbox Support Package for Xilinx Zynq-Based Radio

Free MATLAB Trial Package for Wireless Communications @ mathworks.com/rfsoc

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Thank You!