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GSPS DACs Enabling Ultra-Wide Bandwidth Applications

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High Speed Converters

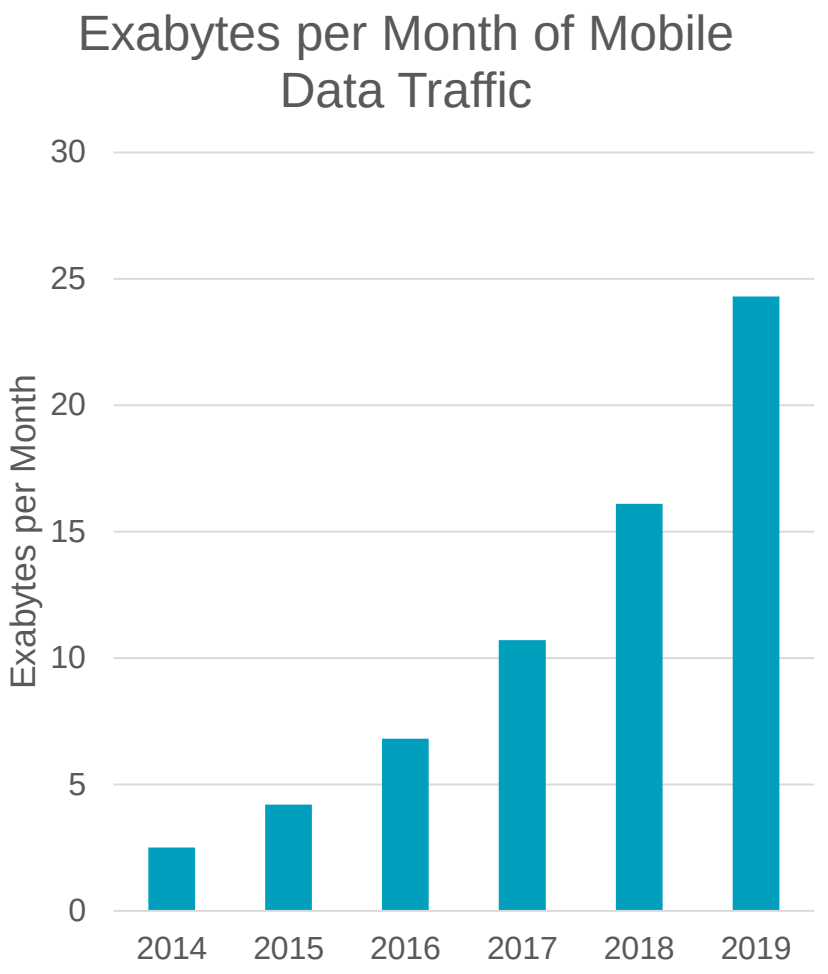
2/11/2016

Agenda

- GSPS Converter End Application Markets Overview
- Communication Backhaul Solutions
  - Wireless Backhaul Choices
  - Market Shares and Trends
- System Spec Review
- System Architectures
- Data Converters
- Questions and Comments

Data Demand Is Projected to Grow through 2020

- Cisco Visual Networking Index (2/2015)
  - Mobile Data usage CAGR 57% for 2014 – 2019
  - Driven by smart mobile devices (smartphones, M2M, tablets) that use mobile networks
- Ericsson Mobility Report (6/2014):
  - Mobile subscribers will grow from 5 billion in 2010 to 9.2 billion in 2020
  - 80% of those will be broadband
- Ericsson, Towards Microwave 2020 report (2014)
  - From 2008 through 2019, 50% of mobile network backhaul will be wireless/microwave



Source: Cisco VNI, 2015

*1 Exabyte = 1M Terabytes

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Backhaul Solutions

GSPS Converter End Application Markets Overview

Application Market	Channel Bandwidth	Allocation Bandwidth
Cellular Communications (LTE/GSM)	200kHz/20MHz	75MHz/100MHz
Traditional PtP Microwave	3.5MHz-112MHz	500MHz – 3GHz
E-Band PtP Microwave	250MHz – 2GHz	10GHz
Cable Television	6 MHz/8MHz	~1 – 1.4 GHz
Military/Radar	Narrow to wide	~2 GHz to wide
Instrumentation	Narrow to wide	~2 GHz

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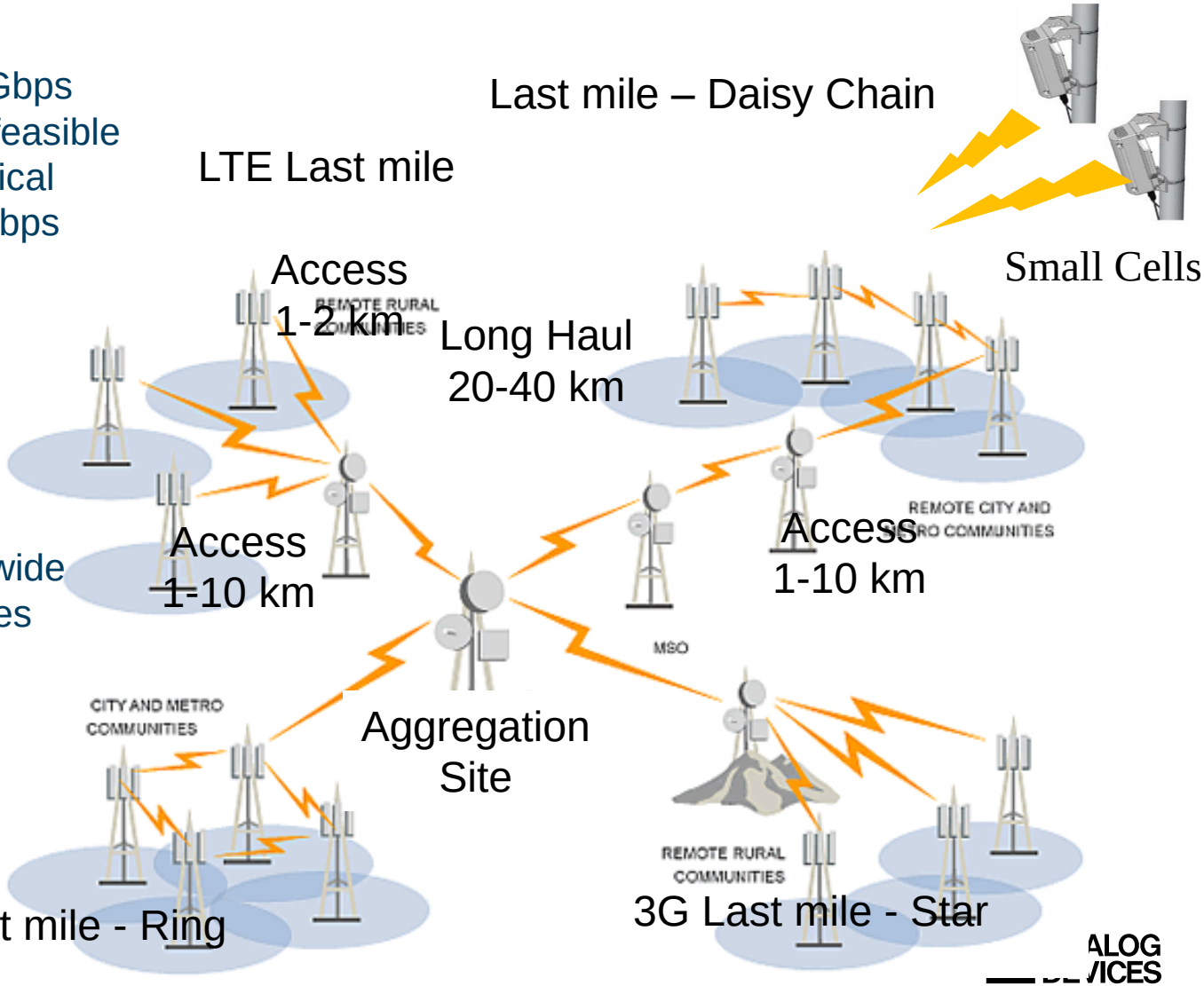
Microwave Backhaul for Cellular Networks

Today's option when …

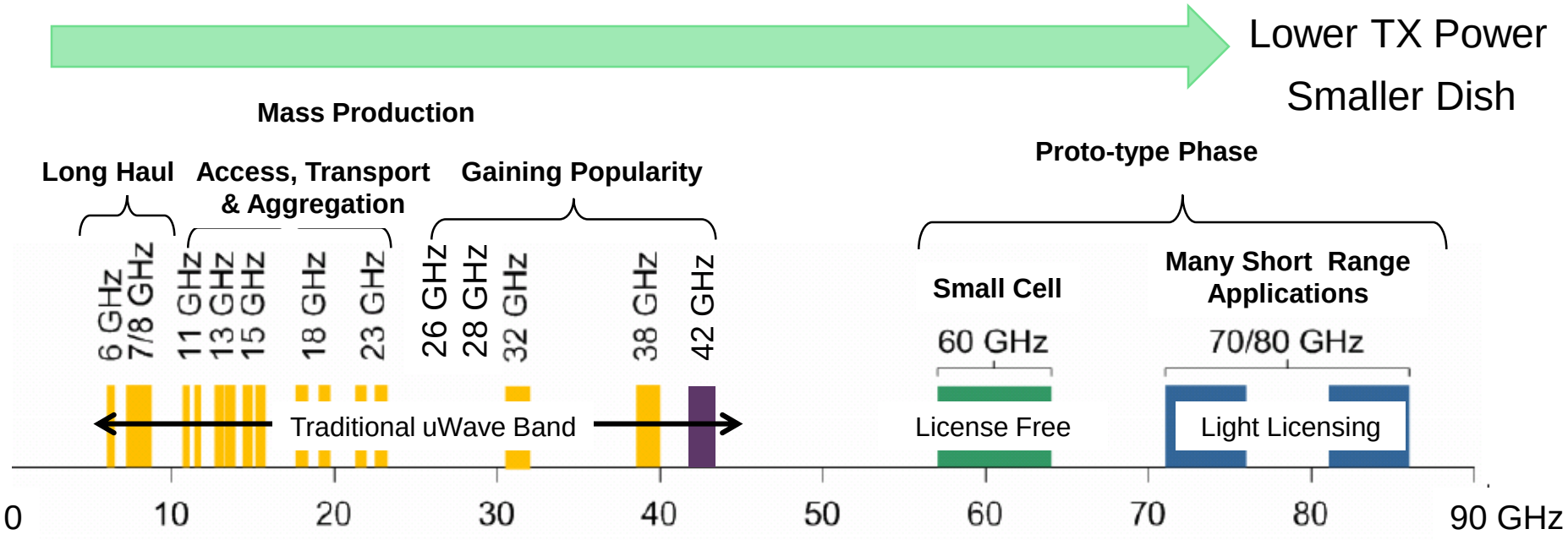
- Capacity need is < 1-2 Gbps
- Fiber or copper are not feasible
- Rapid deployment is critical
- Future will require > 2 Gbps

How Many …

- Millions deployed worldwide
- Support 50% of Cell-Sites



Transmission Frequencies



500MHz → 3GHz BW
6-42 GHz
3.5 to 112 MHz Channels
1-2 Gbps Capacity
Up to 40km
Long Haul
3G Access

7 GHz BW
V-Band
User-defined
<1 Gbps
<1km
Small-Cell

10 GHz BW
E-band
250-1000 MHz
<10Gbps
<3km
Aggregation
LTE-A Access

Wireless Backhaul Solution

Spectrum Band	6-42GHz (Traditional Band)	60GHz (V-Band)	70-80GHz (E-Band)	Sub-6GHz (RF Frequency Bands)
LOS/NLOS	LOS	LOS	LOS	NLOS
Channel Size	Up to 112MHz	50MHz	50, 250, 500, 1000MHz	Up to 40MHz
TDD/FDD	FDD	FDD	FDD	TDD
Modulation	Up to 2048QAM	Up to 256QAM	Up to 256QAM	Up to 256QAM
Capacity	Up to 500mbps	330mbps in 50MHz	Up to 10 gbps	>500mbps
Hop Length	Tens of km	Up to 1km	Up to 4km	Up to 4km
Form Factor	Split IDU/ODU; AOR	All-in-one integrated	AOR and antenna	All-in-one integrated
Architecture	PTP	PTP	PTP	PTP/PMP

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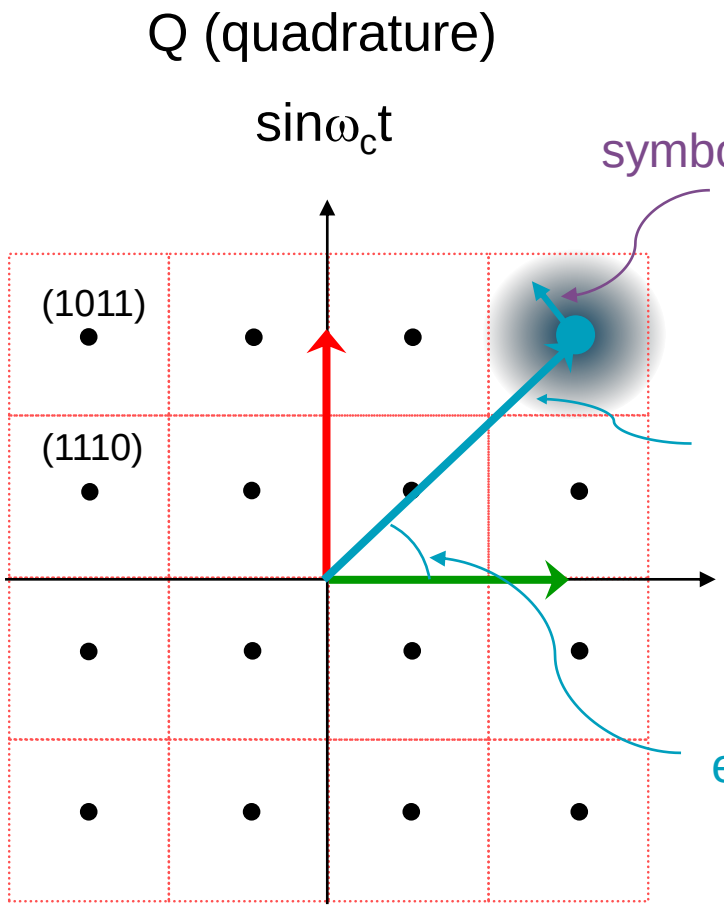
System Spec Review

Dense QAM Increases Spectral Efficiency

2^L QAM ↔ L (bits/symbol)

QPSK	L=2	
16QAM	L=4	↑100%
64QAM	L=6	↑ 50%
256QAM	L=8	↑ 33%
1024QAM	L=10	↑ 25%
4096QAM	L=12	↑ 20%



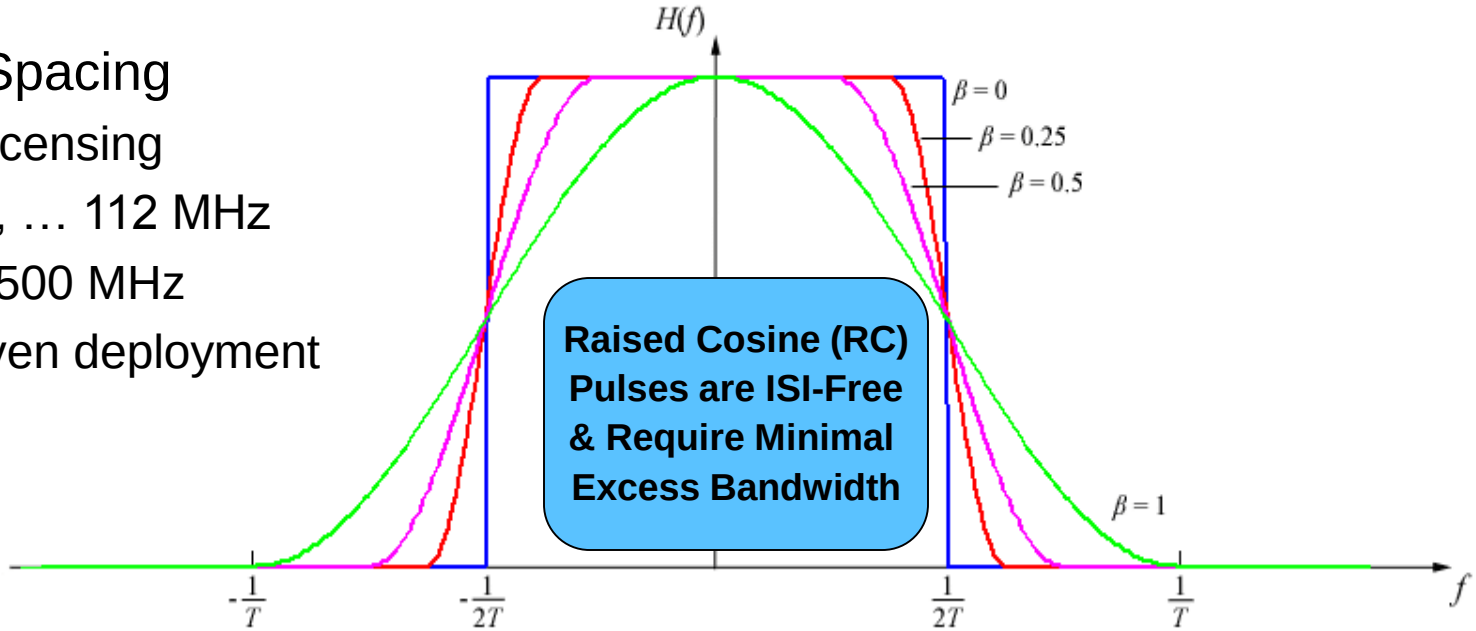
Higher QAM Trend

- ✓ **Increased capacity**
- × **Diminishing returns**
- × **+6 dB/step more SNR**
- × **Increased peak-average**
- × **More sensitive to impairments**
- × **Lower system gain**

$$RF(t) = I(t)\cos\omega_c t + Q(t)\sin\omega_c t$$

Bandwidth vs. Channel Spacing

- CS: Channel Spacing
  - Allocated by licensing
  - Traditional 3.5, … 112 MHz
  - E-band 250, 500 MHz
  - Fixed for a given deployment
- R_s
  - Determined by equipment
  - β ~ 0.12 RC factor
  - 50Msym/s ↔ 56MHz
  - IF BW ~ R_s
  - I/Q BW ~ $R_s/2$



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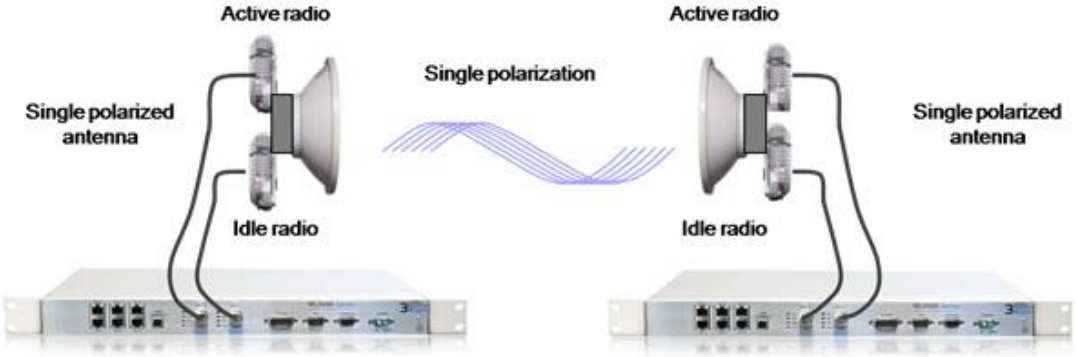
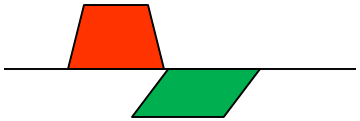
Methods of Multiplying Data Capacity

Adjacent Channel Co-Polarization

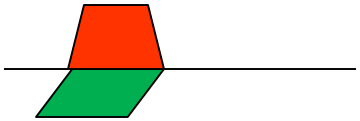


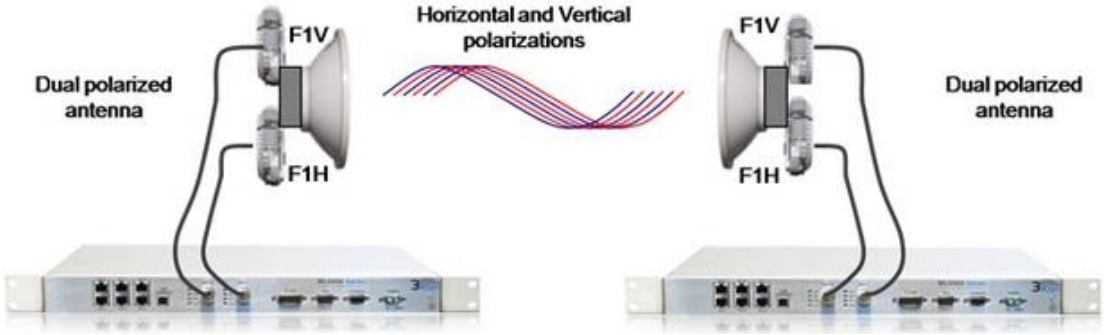
1+1 Configuration uses a second microwave radio for redundancy (idle) or for 2x capacity (active at different frequency)

Adjacent Channel Alt. Polarization



Co-Channel Dual Polarization





2+0 Configuration w/ XPIC requires 2 radios/systems operating at the same frequency but different or cross polarization: XP

XPIC refers to Interference Cancellation of cross polarization (XP) signals that cross-contaminate in the channel or antenna → 2x radios + modem algorithm

Capacity Estimation

- Raw bit rate (Mbps) = L (bits/sym) x CS/(1+β) x # radios
  - # radios can be 2 if XP or bonding are used
  - QPSK/3.5MHz → 2 x 3.5/1.12 = 6.25 Mbps
  - 1024QAM/112MHz/XP → 10 x 112/1.12 x 2 = 2Gbps
  - 64QAM/500MHz → 8 x 400 = 3.2 Gbps (E-band)

- Actual payload bit rate is complex:
  - FEC consumes 10% “light” to 50% “heavy” of capacity in exchange for system gain ↔ link range/antenna size
  - Network management data is added to payload, about 5%
  - Compression of data and headers → 5% gain in practice

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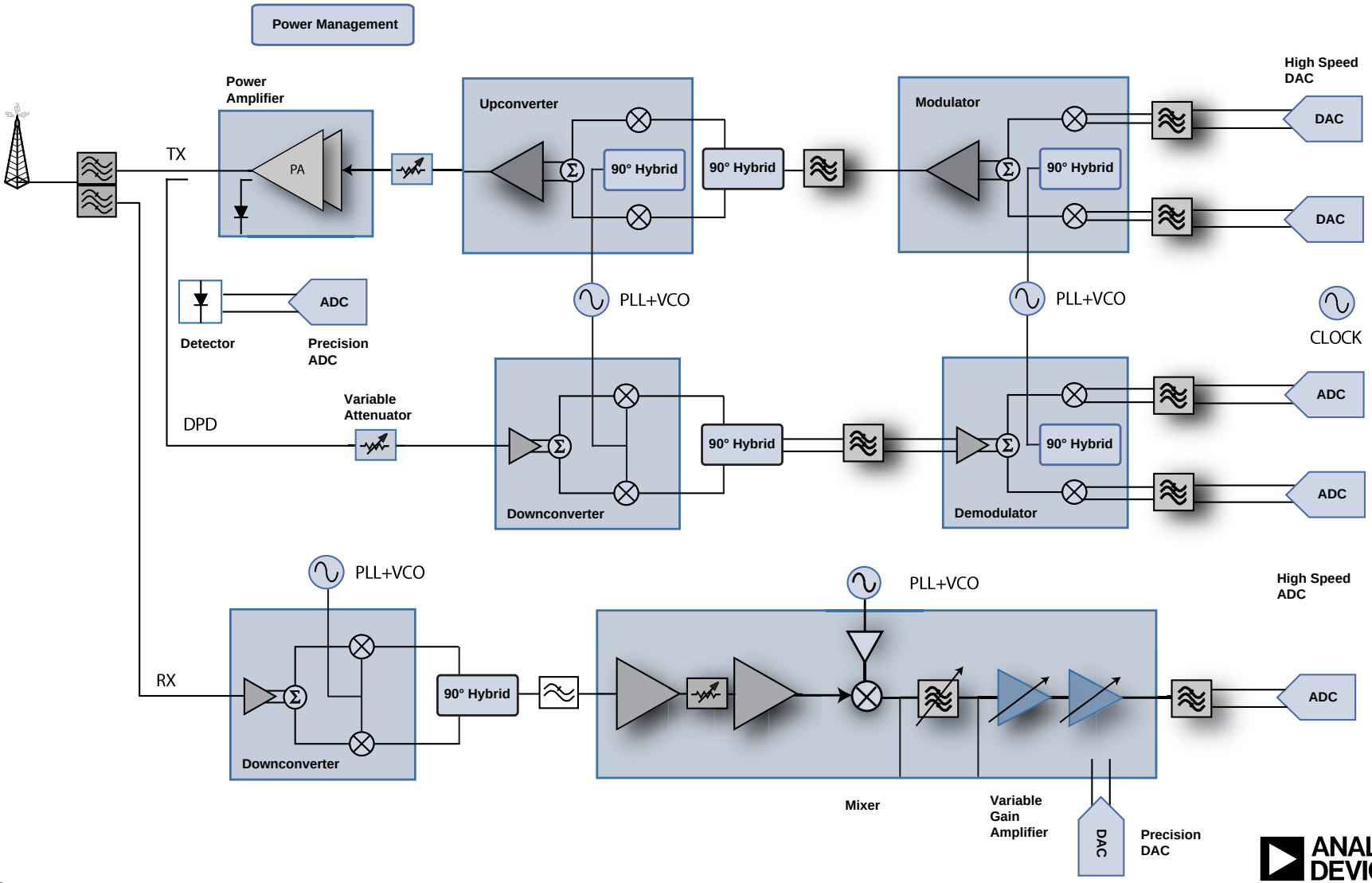
System Architectures

Microwave Radio Signal Chain and Control Path



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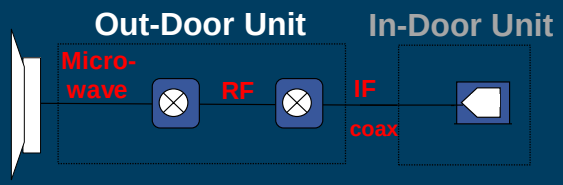
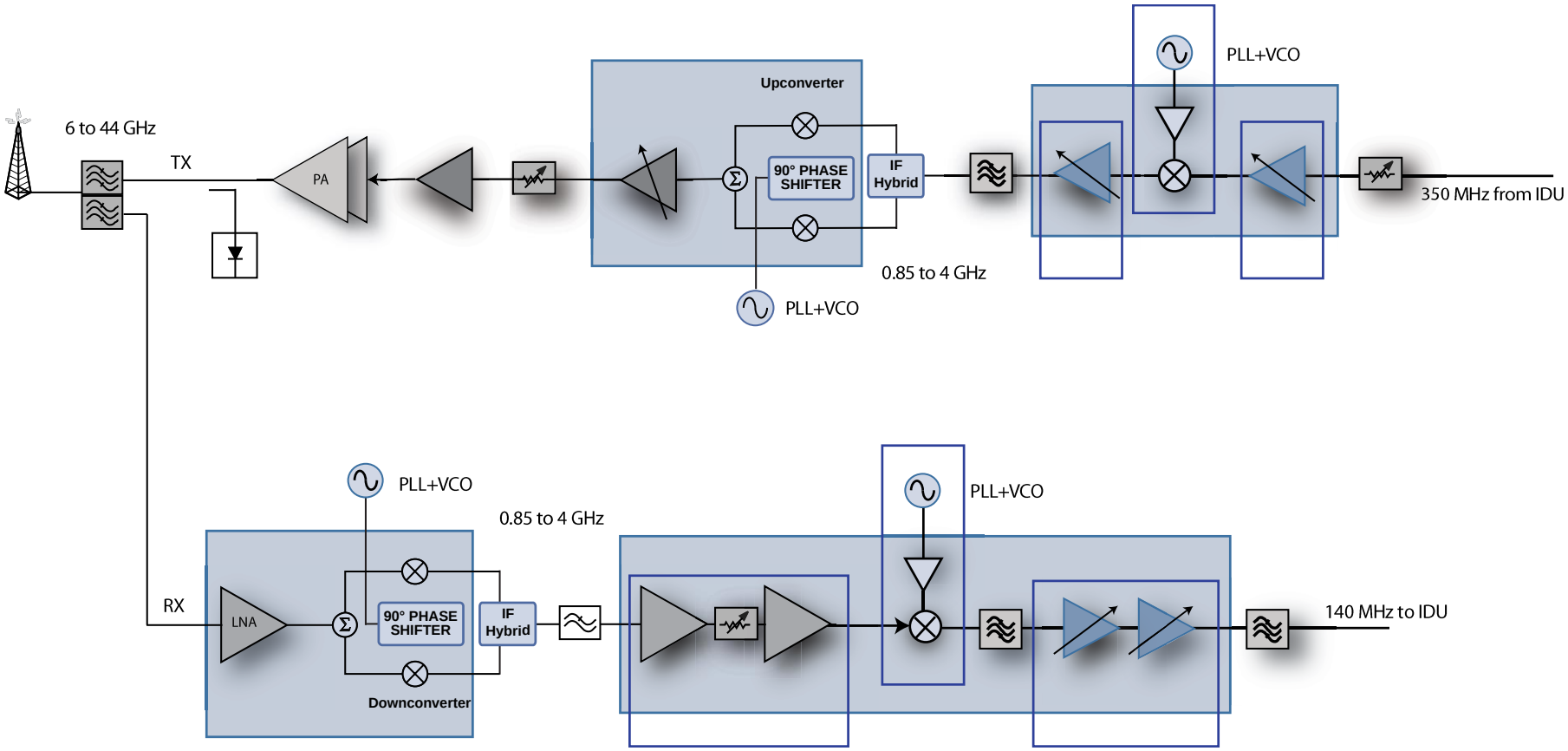
Legacy Band Split ODU
6 to 44 GHz





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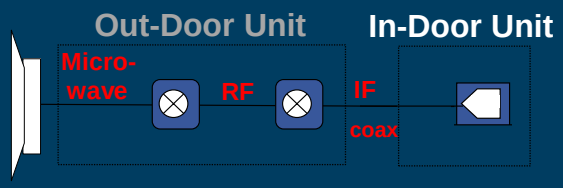
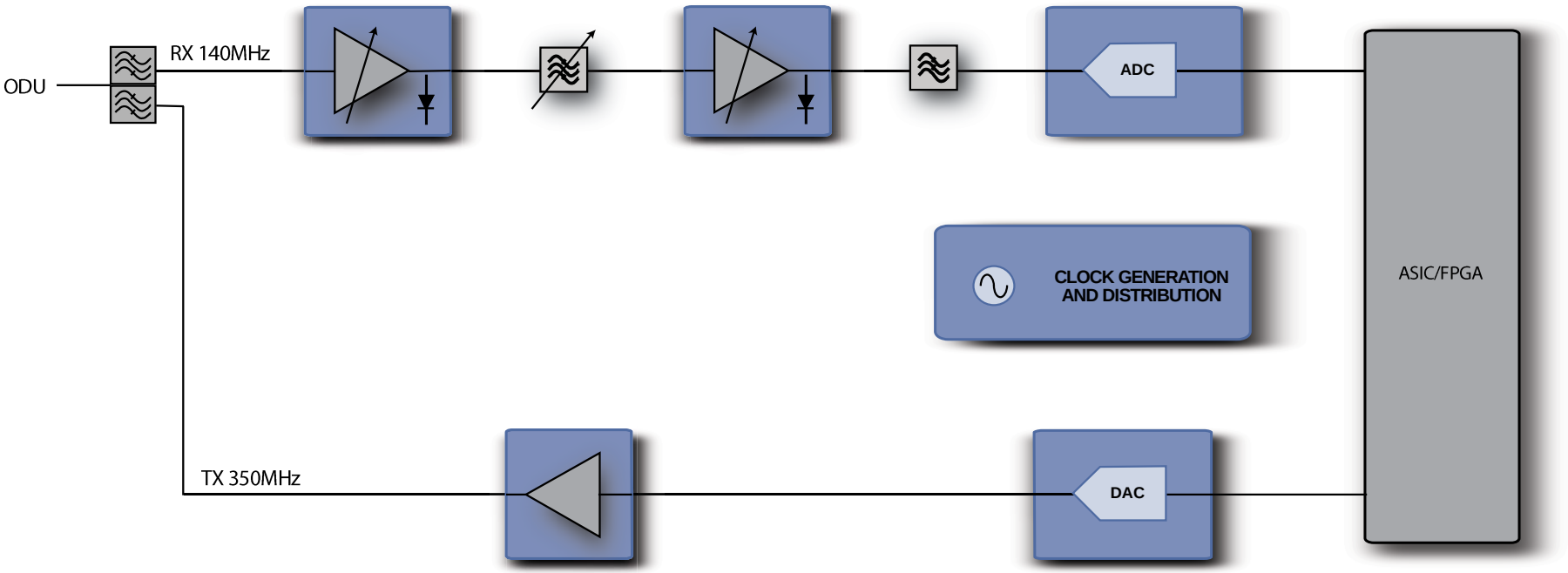
Legacy Band Split IDU



AD9643 (dual, LVDS)
AD9613 (dual, LVDS)

AD9250 (dual, JESD204B)
AD6673 (dual, JESD204B)
AD9234 (dual, JESD204B)
AD9680 (dual, JESD204B)
AD6674 (dual, JESD204B)
AD6676 (single, JESD204B)



AD9142A (LVDS)
AD9154 (JESD204B)
AD9152 (JESD204B)

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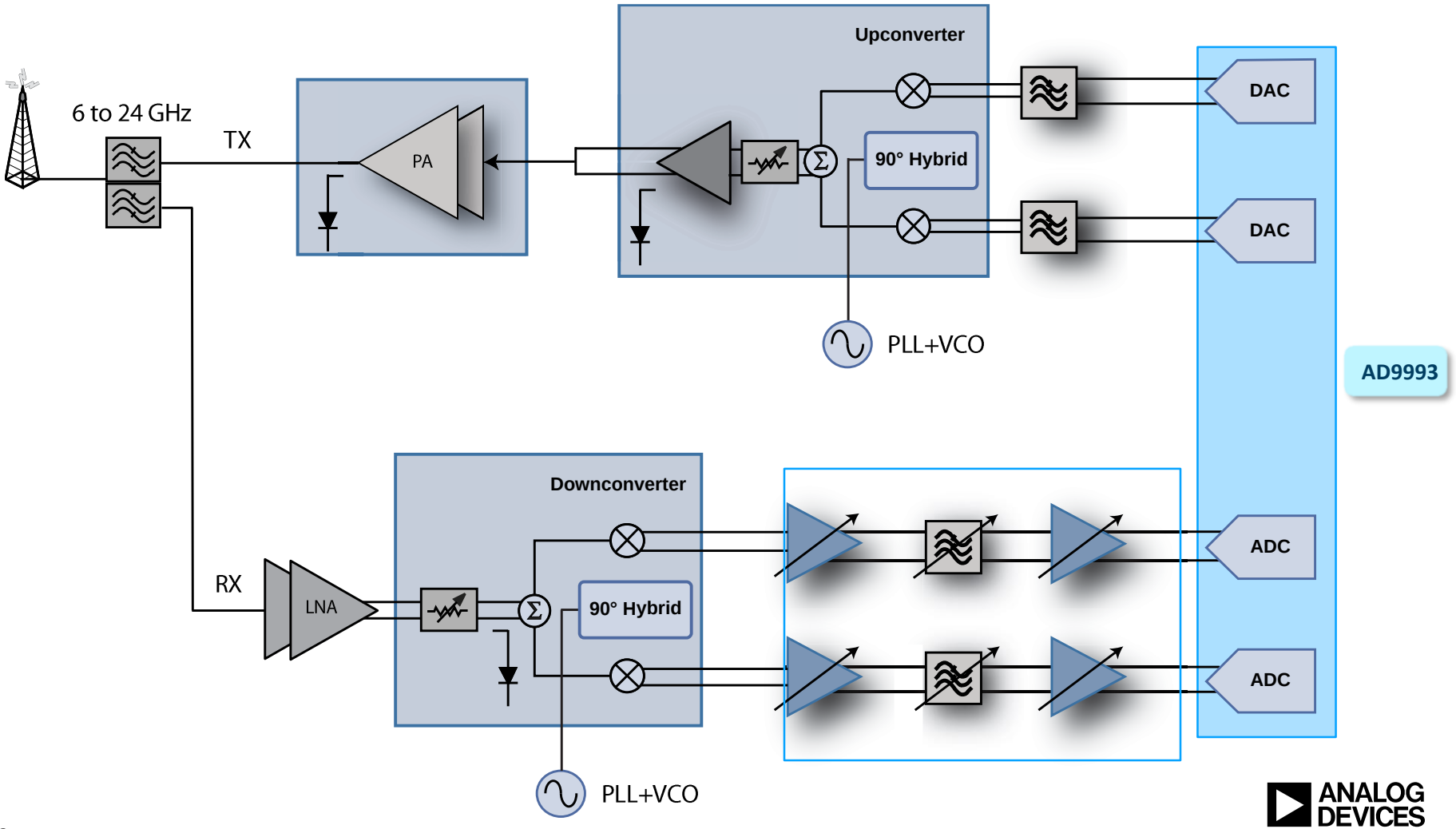
Legacy Band Full ODU
6 to 24 GHz



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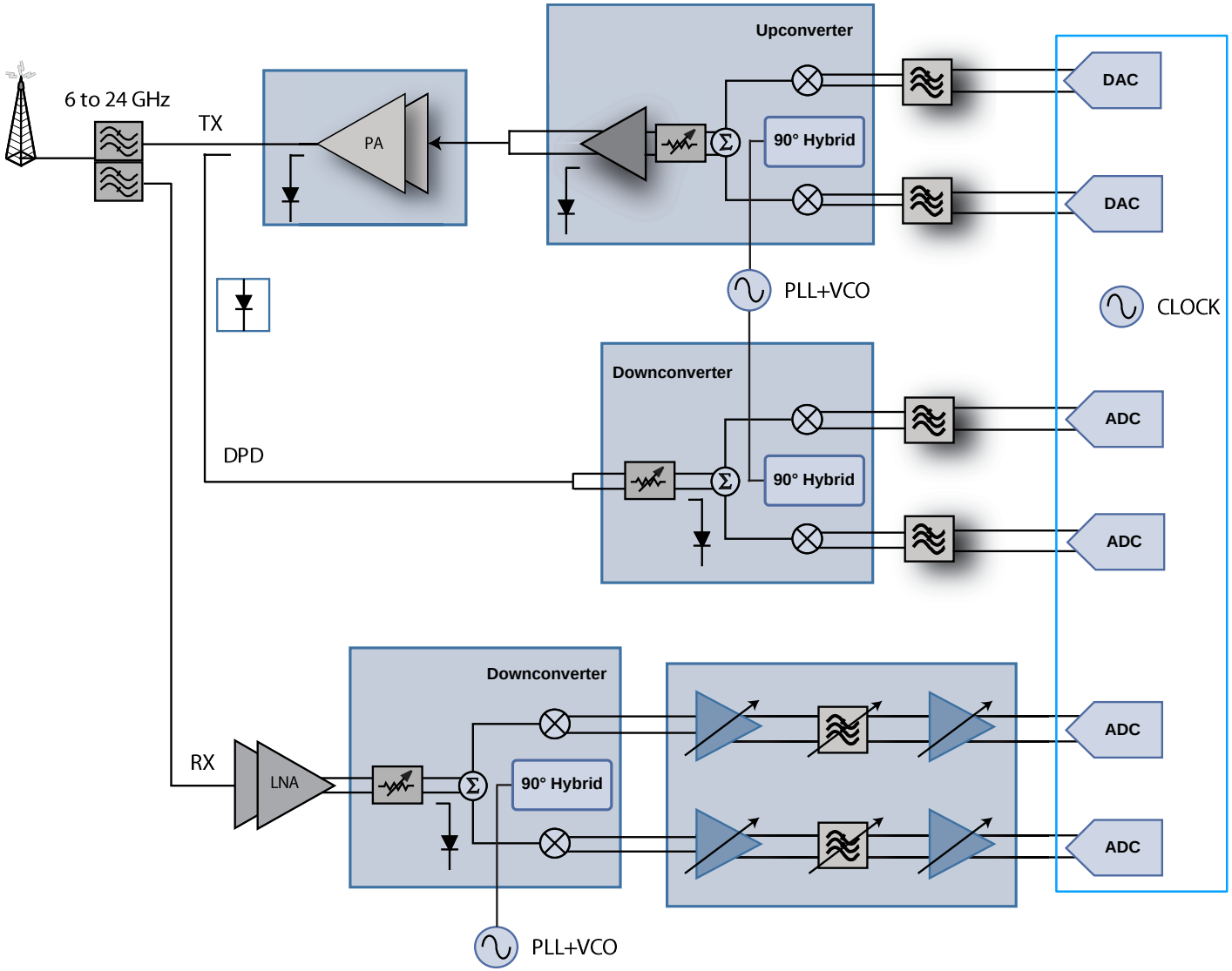
Legacy Band Full ODU with DPD
6 to 24 GHz



AD9142A (LVDS)
AD9154 (JESD204B)
AD9152 (JESD204B)

AD9993

AD9643 (dual, LVDS)
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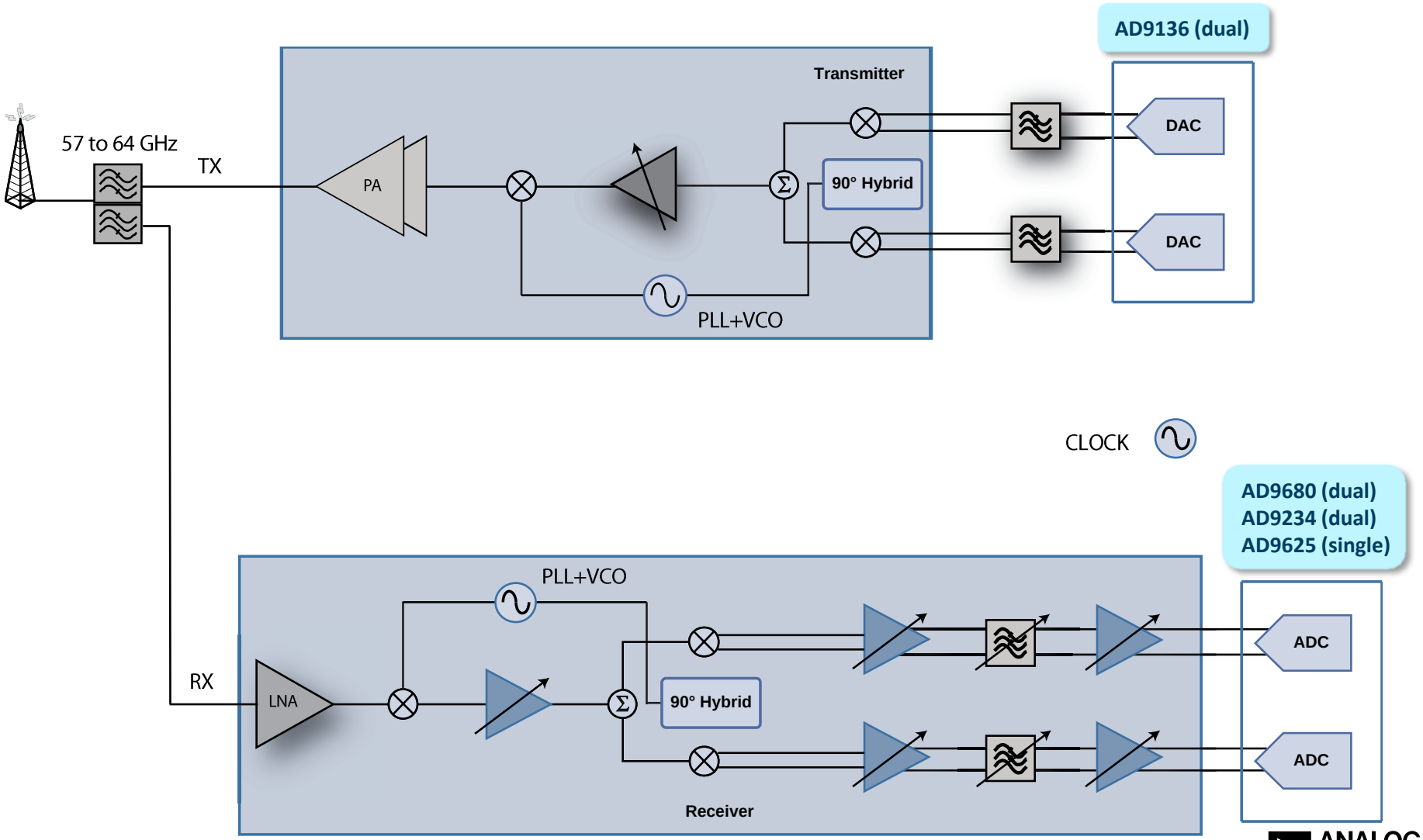
AD6676 (single, JESD204B)

V-Band Full Outdoor Unit



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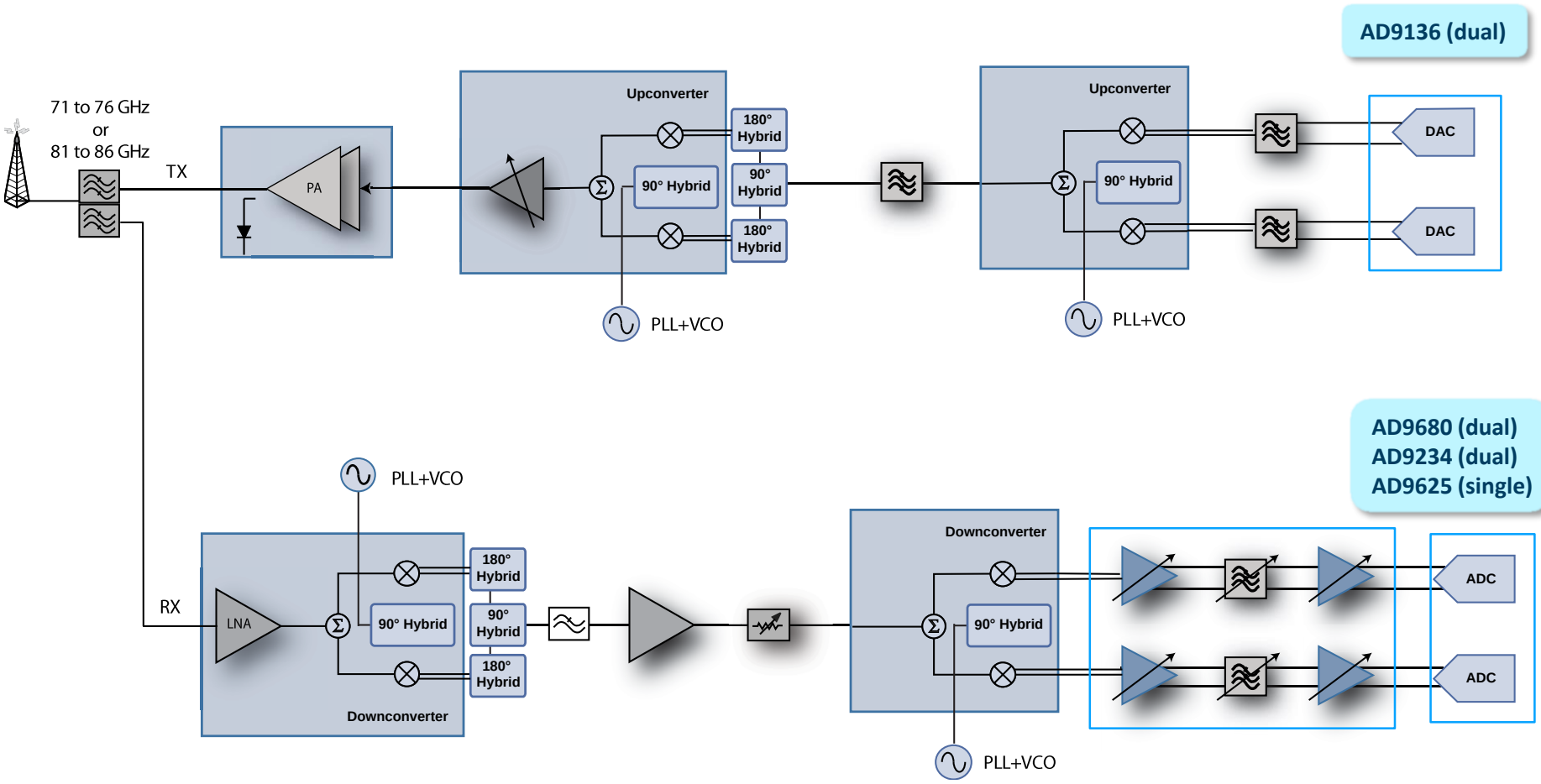
E-Band Full Outdoor Unit
Single Conversion Architecture



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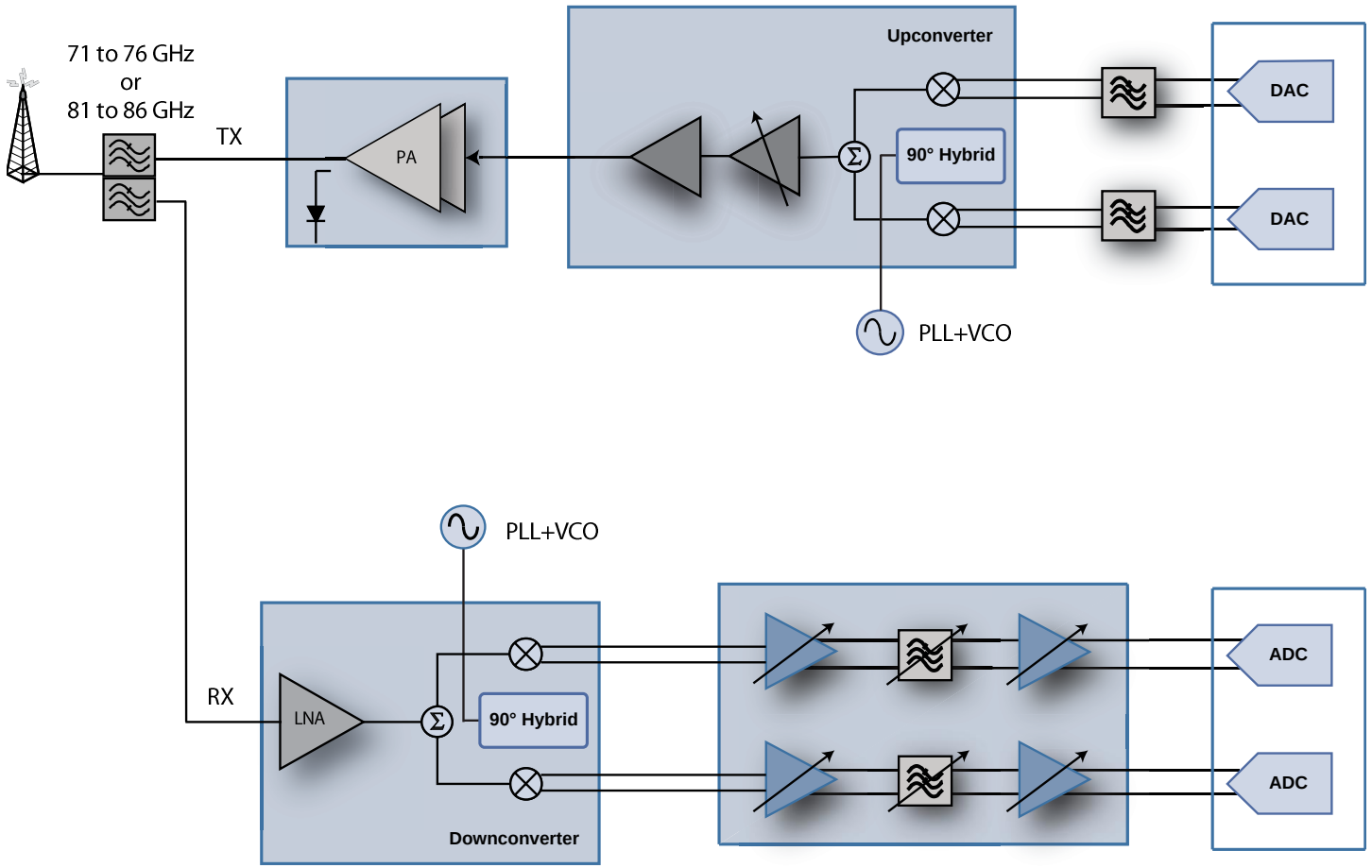
E-Band Full Outdoor Unit
Direct Conversion Architecture



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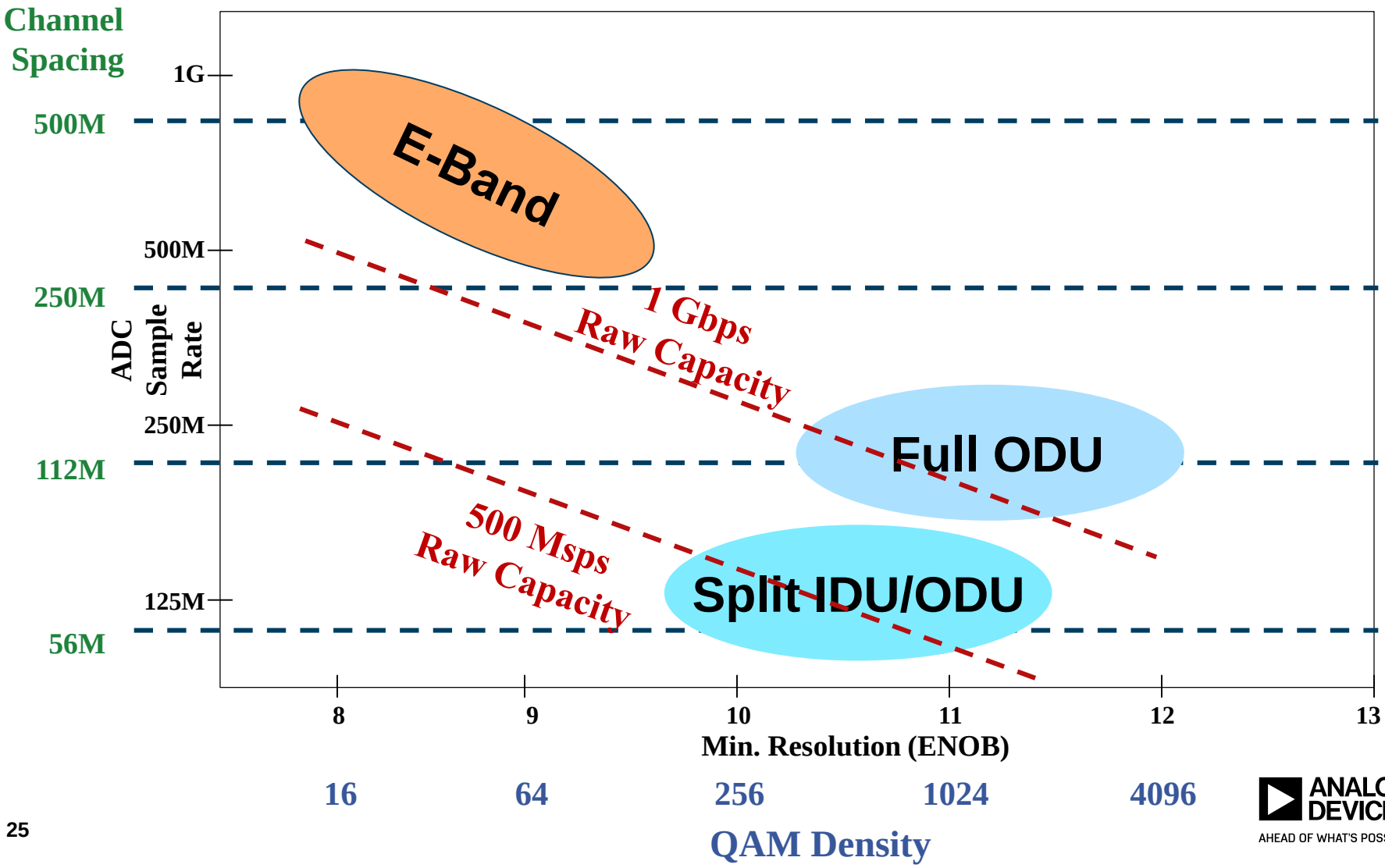
High-Speed ADCs

ADC Requirements for Baseband Sampling



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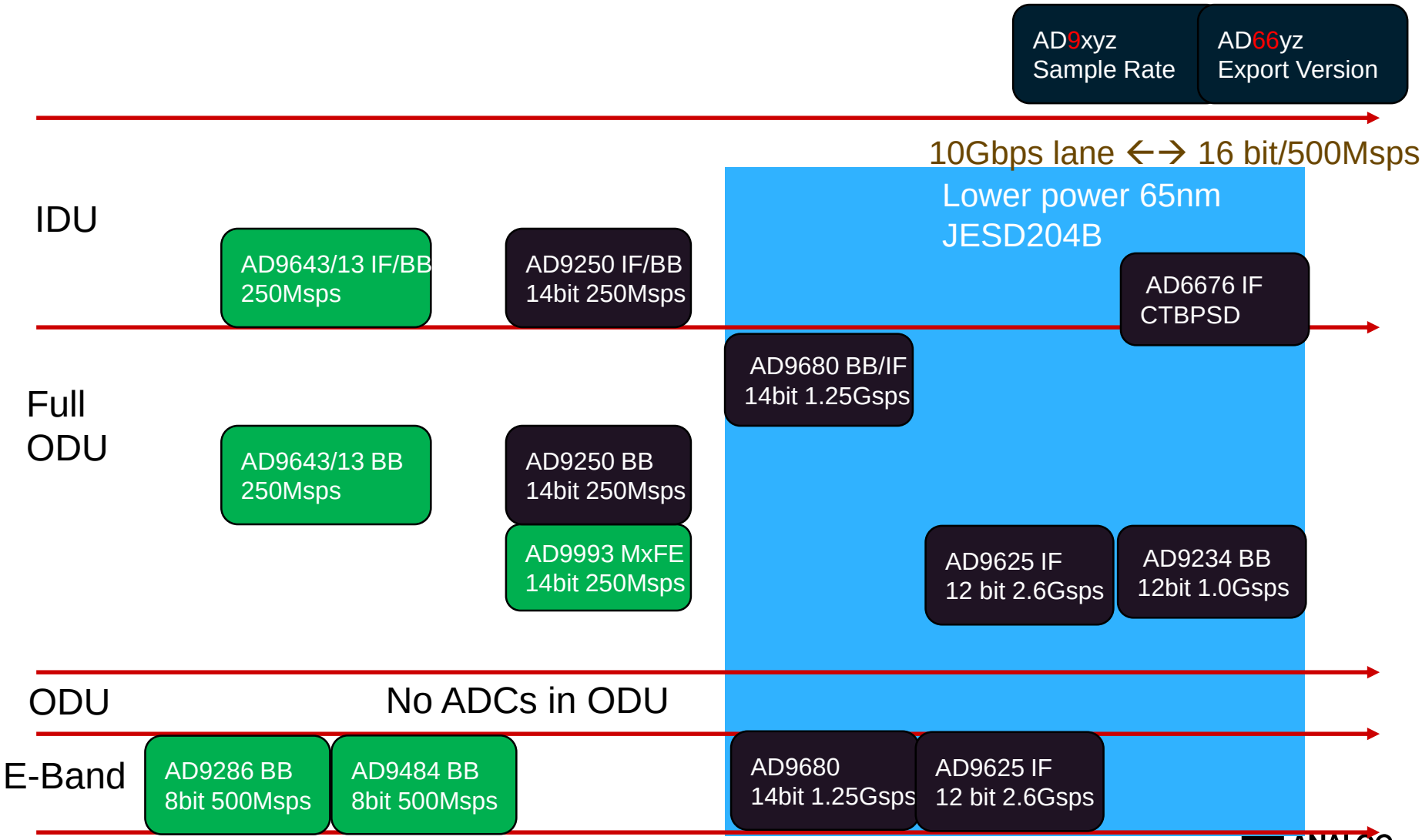
14/12 bit Pipeline ADC (LVDS, SERDES)



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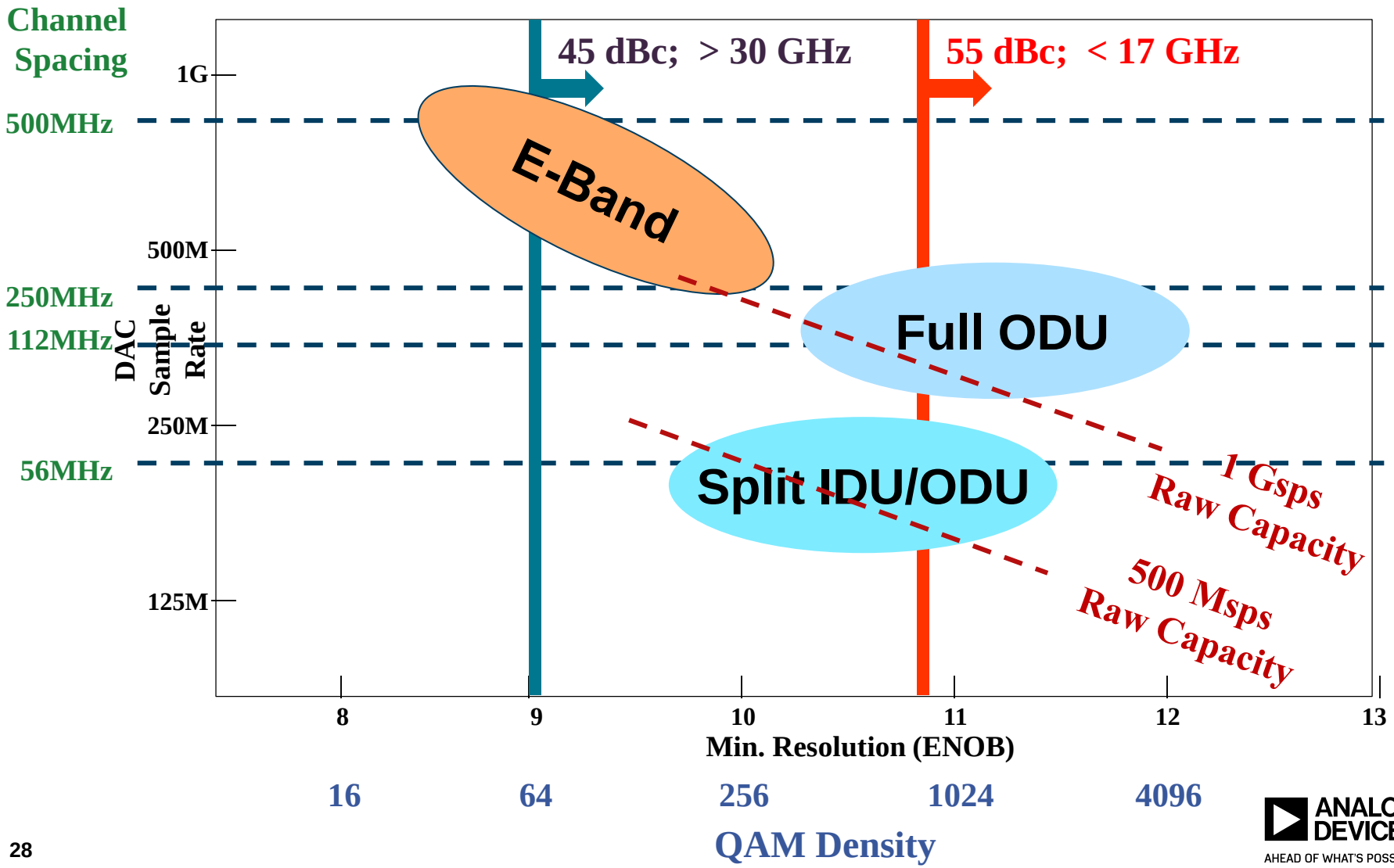
High-Speed DACs

DAC Requirements for Baseband Sampling



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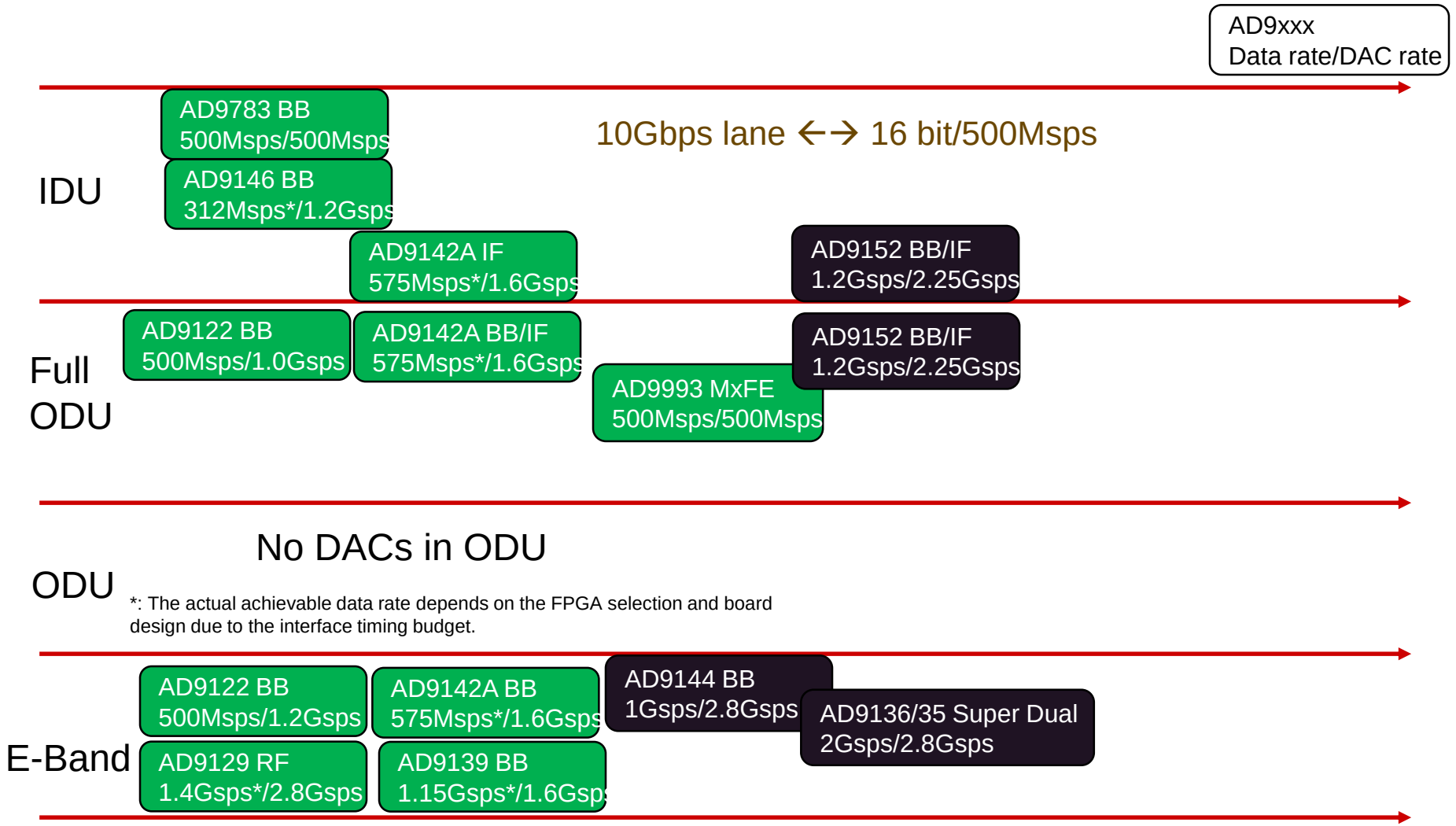
16 bit DAC (LVDS, SERDES)

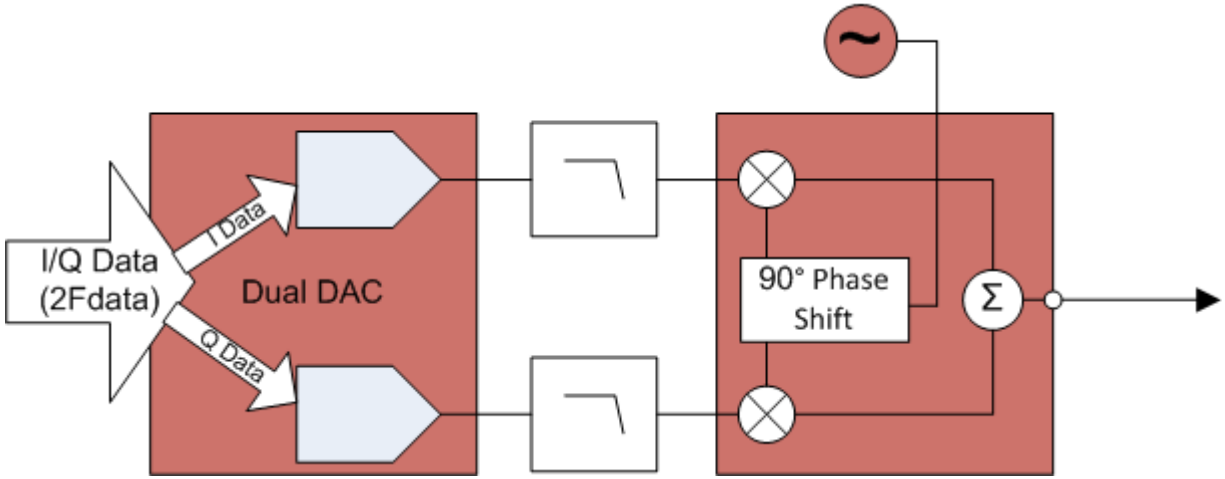


LVDS IF DAC Selection Guide for PtP

	AD9122	AD9142A	AD9139	AD9129	AD9993 MxFE
# of channels	2	2	1	1	2 DAC / 4 ADC
Resolution	16	16	16	14	14 / 14
Max I/Q Data Bandwidth	500MHz	575MHz	1.15GHz	1.4GHz	500MHz / 250MHz
Max DAC Sample Rate	1.2GHz	1.6GHz	1.6GHz	2.8GHz	1GHz / 1GHz
On-chip Digital Modulation	Y	Y	N	N	N
On-chip PLL	Y	Y	Y	N	Y
Power Consumption	Moderate	Low	Moderate	Low	Low

- IF DACs support both traditional band microwave systems as well as some lower channel separation E-Band point-to-point systems

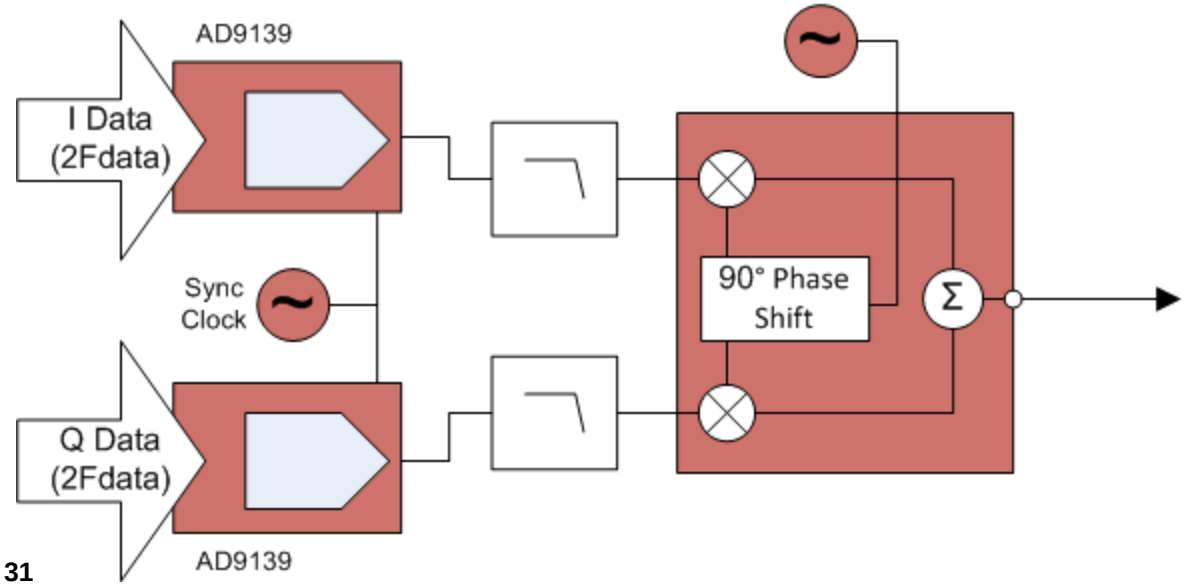
Moving to Wide-Band Applications w/ LVDS



Max Data Rate

AD9125: 250MSPS

AD9142A: 575MSPS



Max Data Rate

AD9139: 1.15GSPS

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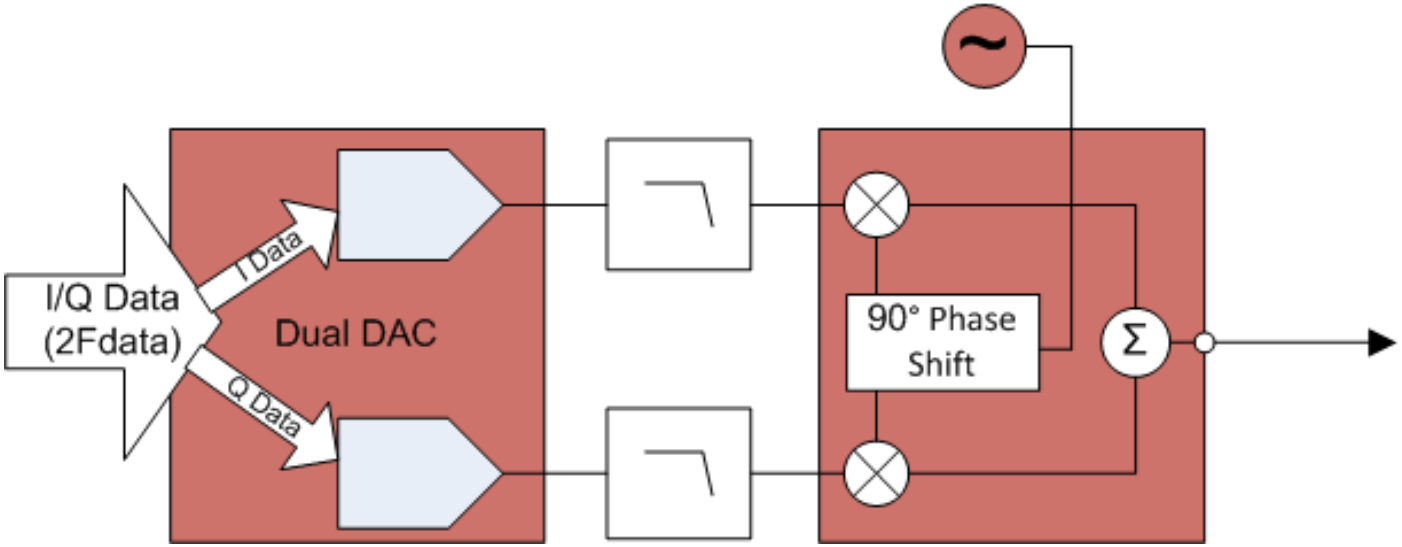
Wide-Band Applications w/ JESD204B



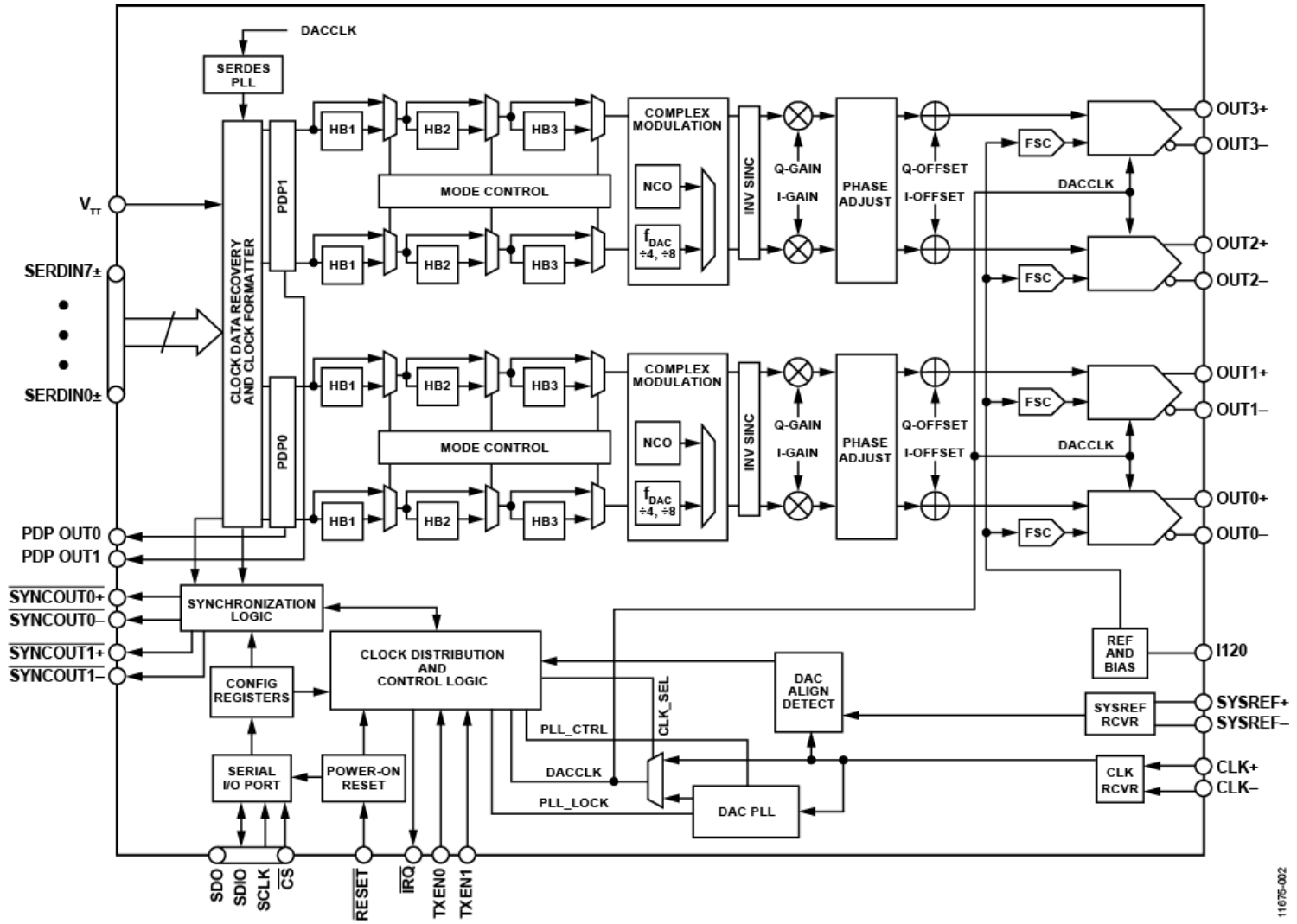
Max Data Rate	
AD9154, AD9144:	1GSPS
AD9152:	1.1GSPS
AD9136, AD9135:	2.1GSPS

JESD204B IF DAC Selection Guide for PtP

	AD9154	AD9144	AD9152	AD9136	AD9135
# of channels	4	4	2	2	2
Resolution	16	16	16	16	11
Max I/Q Data Bandwidth	1GHz	1GHz	1.2GHz	2.1GHz	2.1GHz
Max DAC Sample Rate	2.4GHz	2.8GHz	2.25GHz	2.8GHz	2.8GHz
Companion IQMOD	ADRF6720-2.7	ADRF6720-0.5, ADL5375-0.5	ADRF6720-2.7	ADRF6720-0.5, ADL5375-0.5	ADRF6720-0.5, ADL5375-0.5
MC-GSM Compliant output frequency	400MHz	150MHz	400MHz	150MHz	150MHz
Recommended Applications	MC-GSM/ 3G/4G/**PtP**	3G/4G/**PtP**	MC-GSM/ 3G/4G/**PtP**	3G/4G/ **E-band PtP**	3G/4G/ **E-band PtP**
On-chip Digital Modulation	Y	Y	Y	N	N
On-chip PLL	Y	Y	Y	Y	Y
Power Consumption	Moderate	Low	Moderate	Low	Low

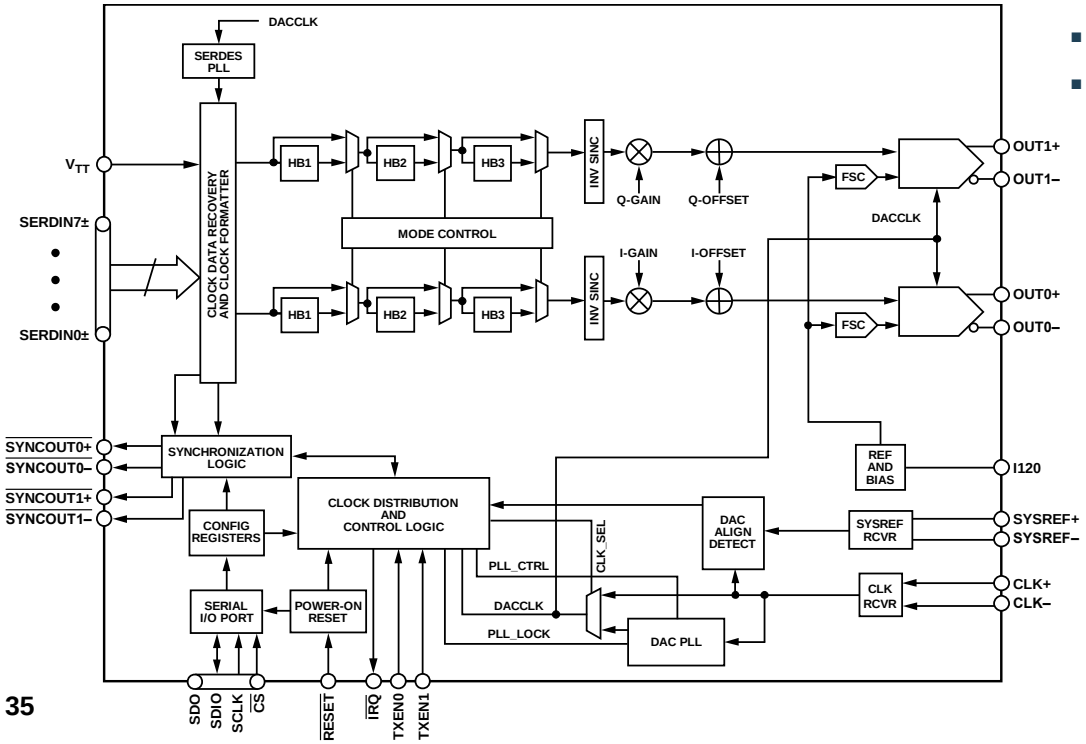
- IF DAC choice guided by application
  - High Complex-IF → AD9154 or AD9152
  - Zero IF or Low Complex-IF → AD9144
  - Wideband ZIP (E-Band) → AD9135 or AD9136

AD9144 Block Diagram



AD9135/AD9136: Dual 11-/16- bit 2.8 GSPS JESD204B DAC

- Support input data rate > 2GSPS
- 1×, 2×, 4×, 8× selectable interpolation modes
- 8 JESD204B SERDES lanes up to 10.6Gbps per lane
- Multiple chip synchronization
- Digital features: inverse sinc filter, digital gain/offset adjustments
- Integrated DAC clock PLL
- Transmit enable function
- Full scale output current: 13.9mA to 27.0mA

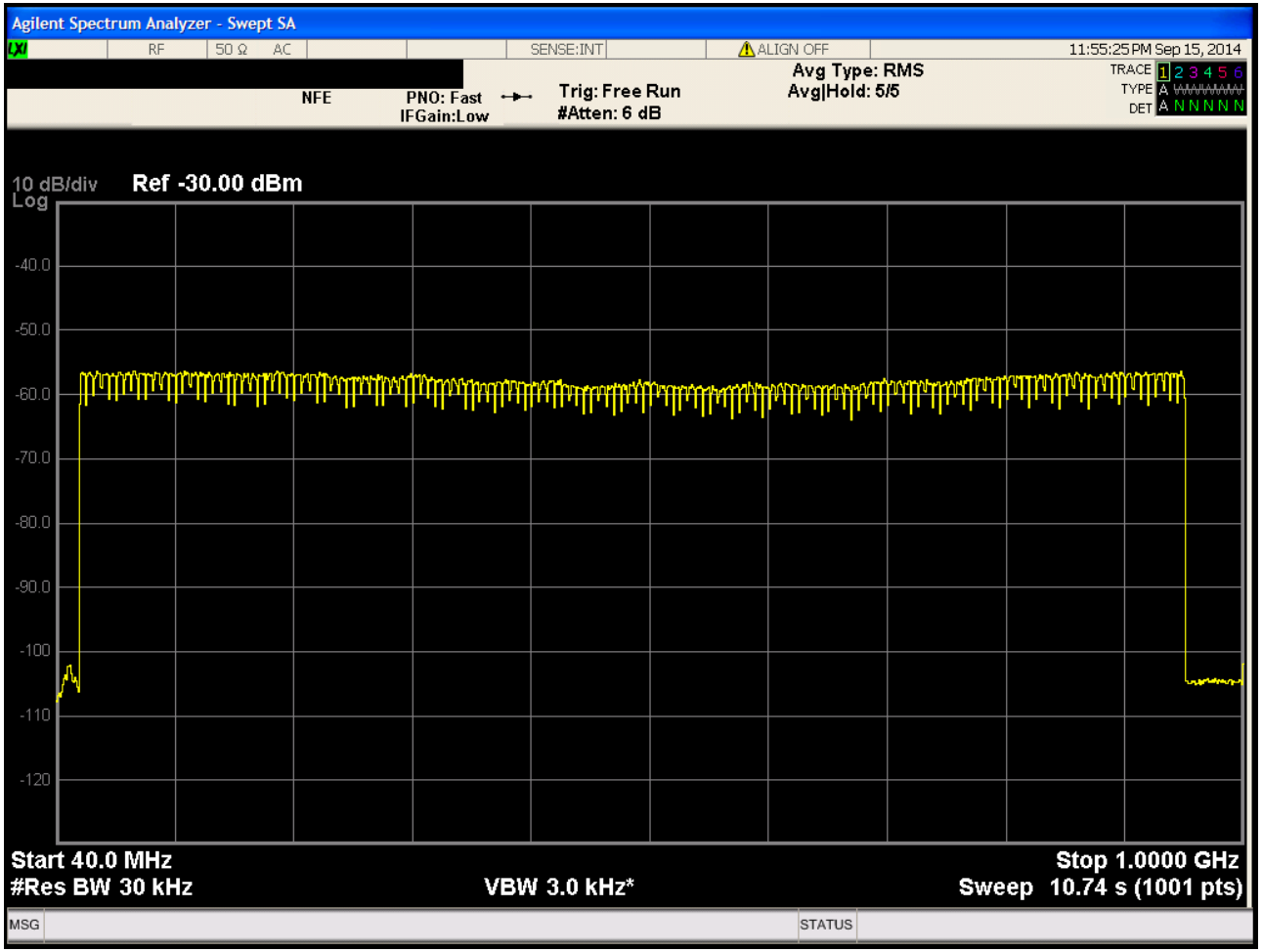


12578-002

- Performance @ 1.966GHz DAC:
  - SFDR: 82 dBc (-9dBFS tone @ 20MHz)
  - IMD: 90 dBc (-9dBFS two-tone @ 20MHz)
  - ACLR: 80dBc (1 carrier WCDMA @ 150MHz)
  - NSD: -163dBm/Hz (0dBFS tone @ 150MHz)
- Power: 1.42W @ 1.6GSPS full operating conditions
- Supplies:
  - 3.3V (analog, SERDES)
  - 1.2V (digital, SERDES, clocks)
  - 1.8V-3.3V (SPI range)

AD9136: Wide Transmit Bandwidth

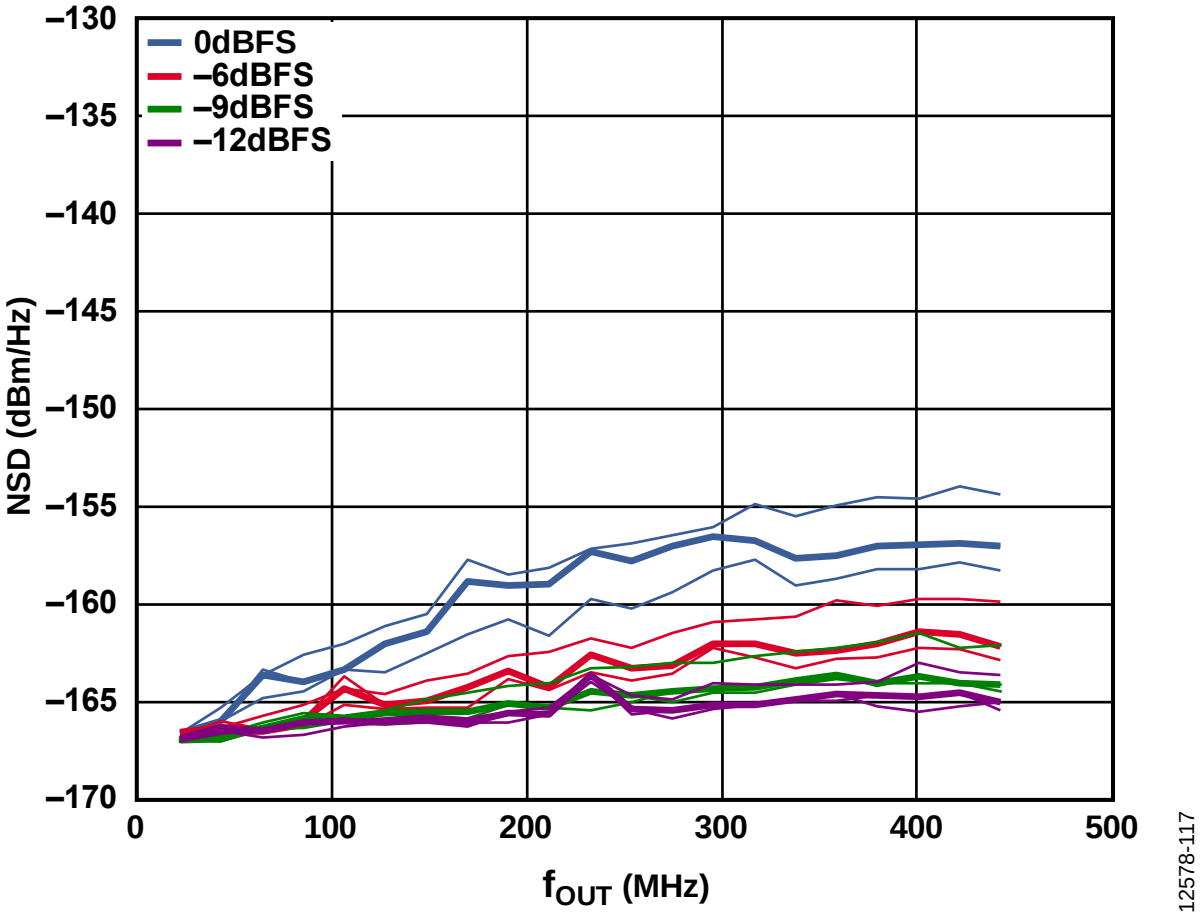
900MHz Bandwidth Output Signal using Inverse SINC



11675-433

f_{DAC} = 2GHz, 1x interpolation, Inverse Sinc Enabled,
SERDES Mode: L = 8 Lanes, M = 2 Converters

AD9136: Noise Spectral Density Performance



NSD Performance vs. Digital Back-off
f_{DAC} = 1966MHz

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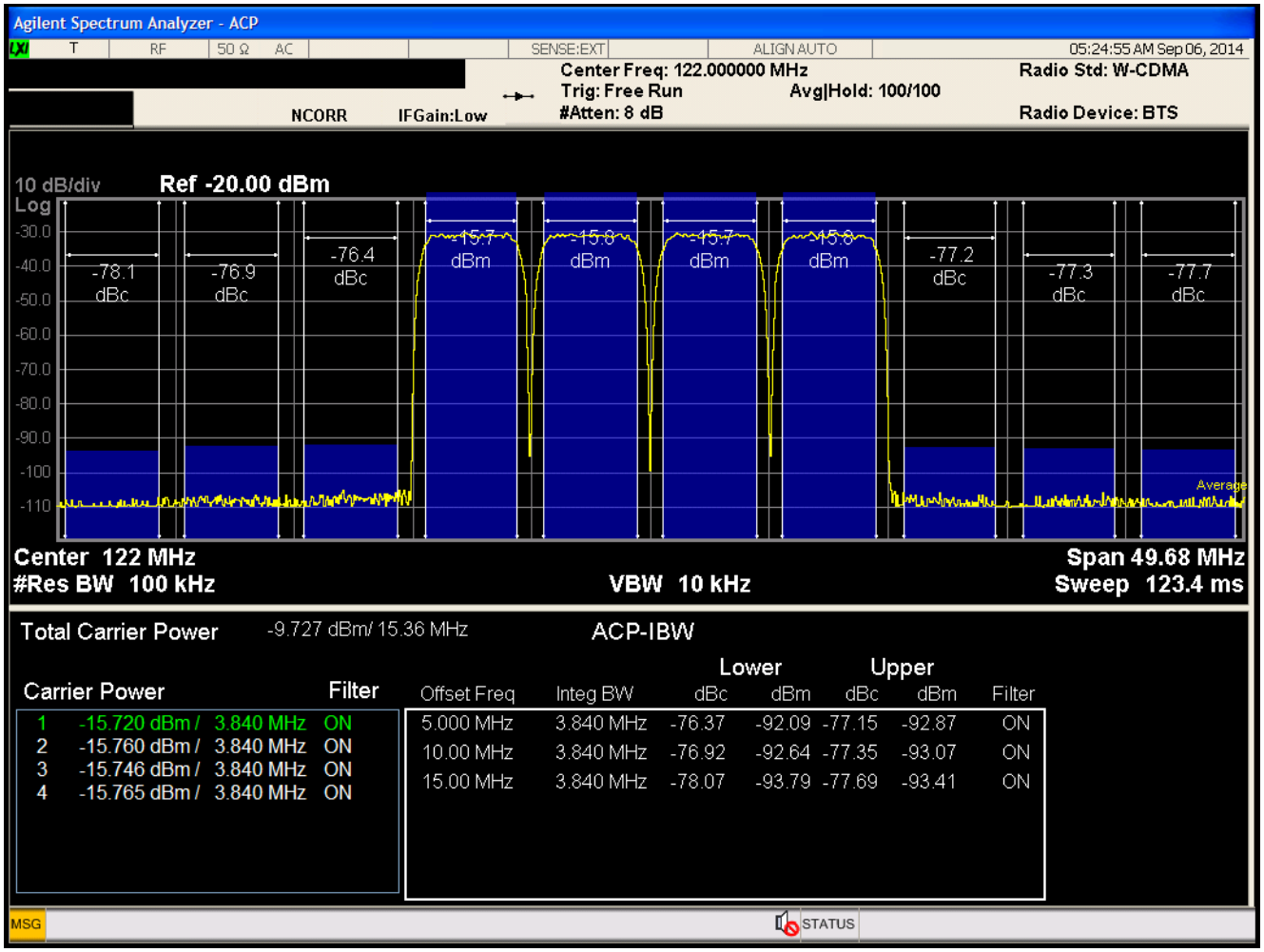
AD9136: ACLR Performance



12578-320

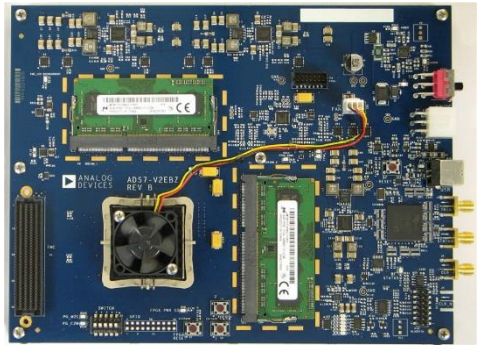
4-Carrier W-CDMA ACLR, PLL Reference Clock = 122MHz

f_{DAC} = 1966MHz, f_{OUT} = 122MHz, 4x Interpolation

Available IF DAC Evaluation Boards

DPG3 Compatible Board Name	Other ADI Components Included/ Evaluation Board Details
AD9136-EBZ AD9135-EBZ AD9144-EBZ AD9154-EBZ AD9152-EBZ	ADCLK925 clock buffer chip AD9516 clock distribution chip Evaluate DAC outputs directly
AD9144-M6720-EBZ AD9154-M6720-EBZ AD9152-M6720-EBZ	AD9516 clock distribution chip ADRF6720 quadrature modulator Access DAC outputs directly or DAC+MOD output

ADS7 Compatible Board Name (FMC)	Other ADI Components Included/ Evaluation Board Details
AD9136-FMC-EBZ AD9135-FMC-EBZ AD9144-FMC-EBZ AD9154-FMC-EBZ AD9152-FMC-EBZ	ADCLK925 clock distribution chip AD9516 clock distribution chip Evaluate DAC outputs directly Optimized power supply solutions FMC compatible, connect to any FPGA vendor platform



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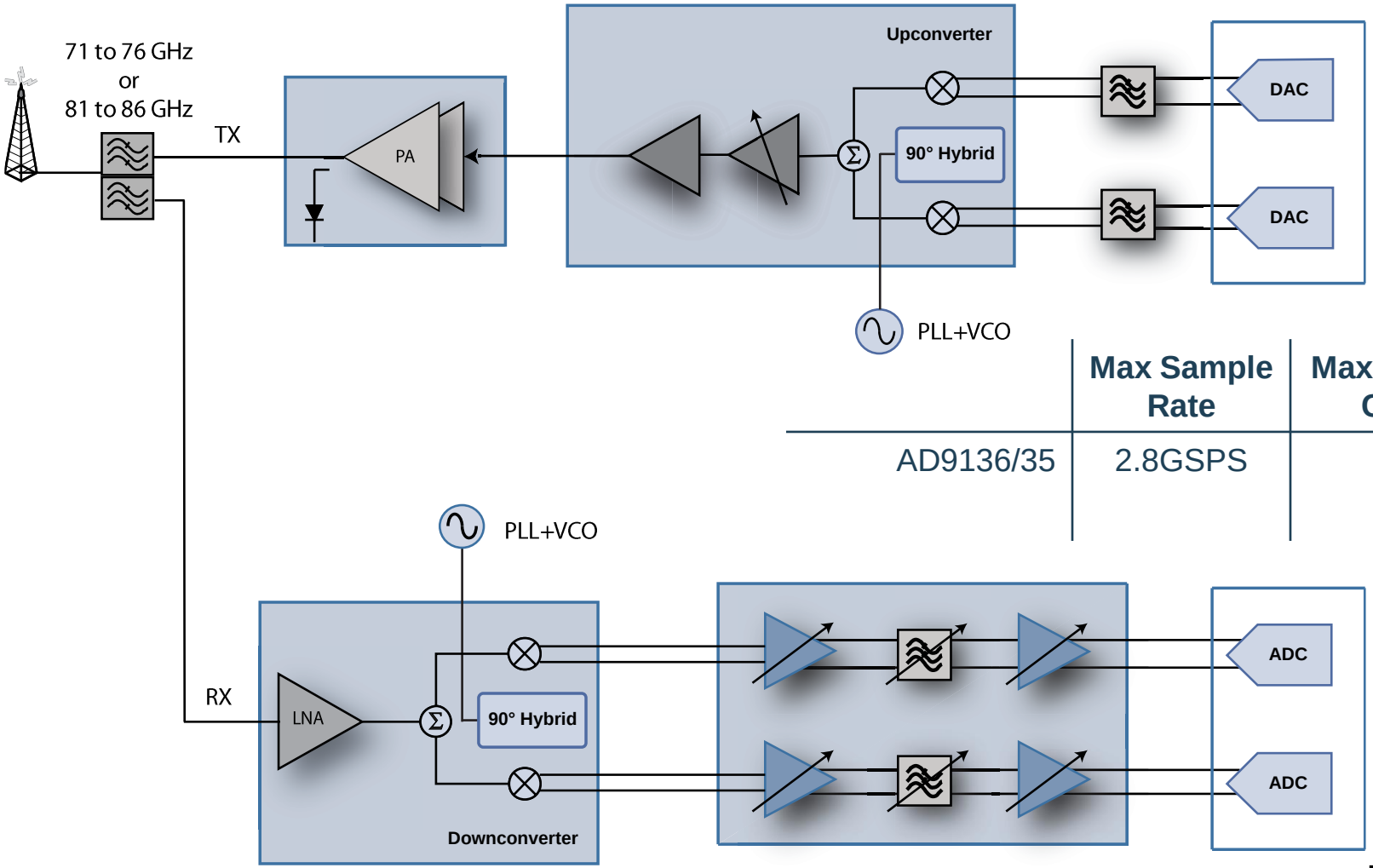
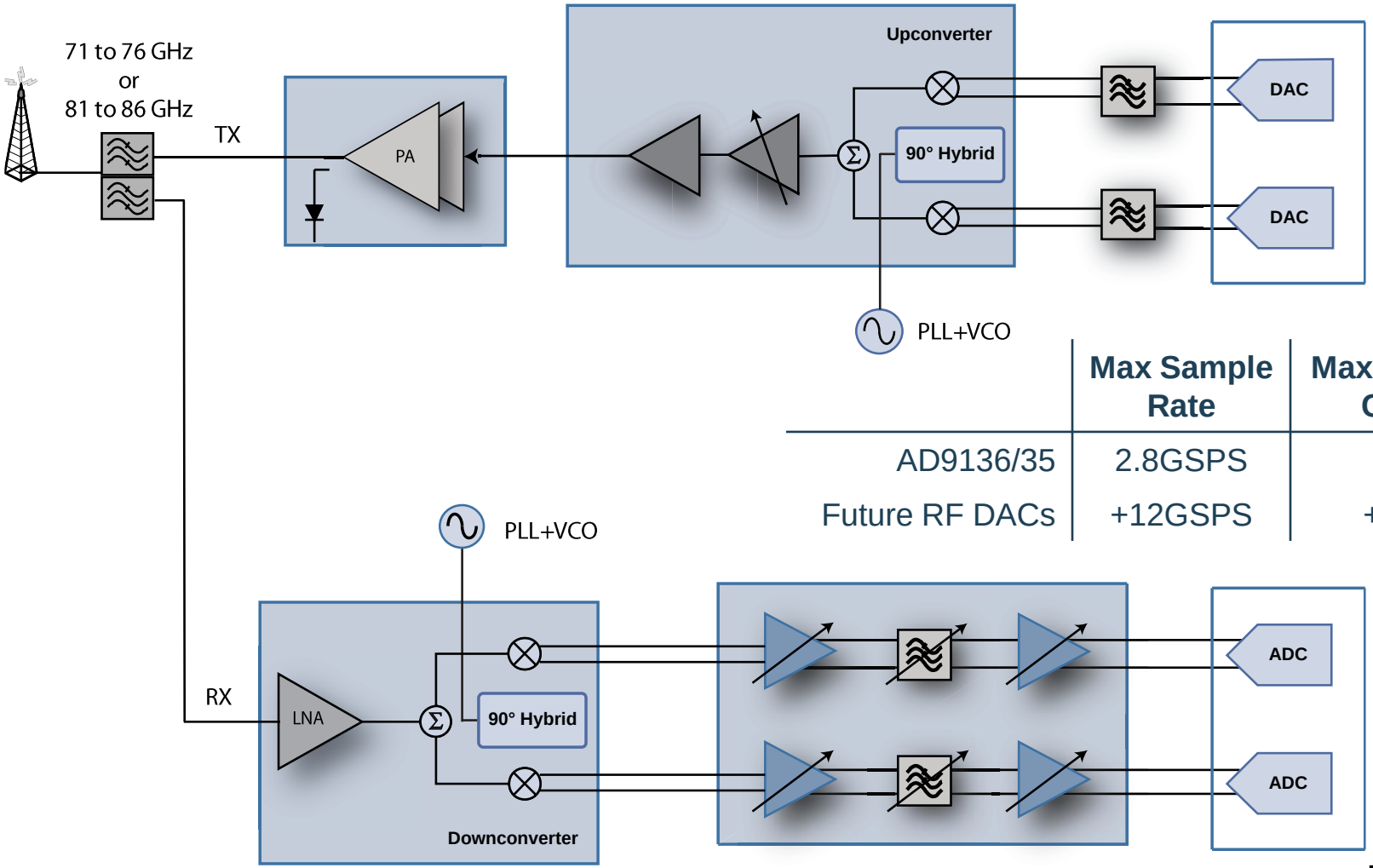
Next Generation High-Speed DAC Technology

IF DAC to RF DAC Technology Capabilities



	Max Sample Rate	Max Complex Ch BW
AD9136/35	2.8GSPS	1GHz

IF DAC to RF DAC Technology Capabilities



	Max Sample Rate	Max Complex Ch BW
AD9136/35	2.8GSPS	1GHz
Future RF DACs	+12GSPS	+5GHz

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