The trend of technology convergence between RF test and high-speed digital signal test in emerging fields

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TestConX中国 China

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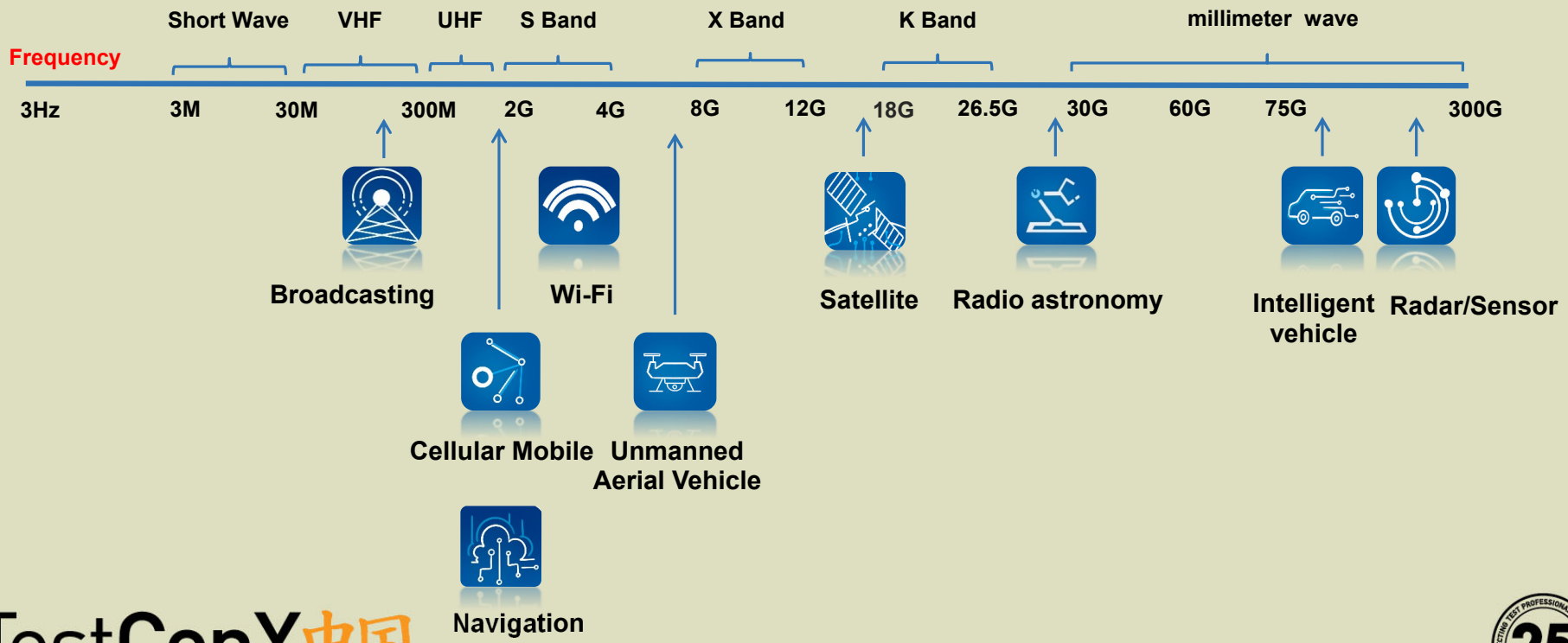
MET Measurements, Experiments and Tests

Outline

- **Applications for RF and high-speed devices**
- The convergence trend of DUTs in emerging fields
- The convergence trend reflected in the technological evolution of the tester itself
- Some typical cases

RF Test Applications

RF | High Speed Interface



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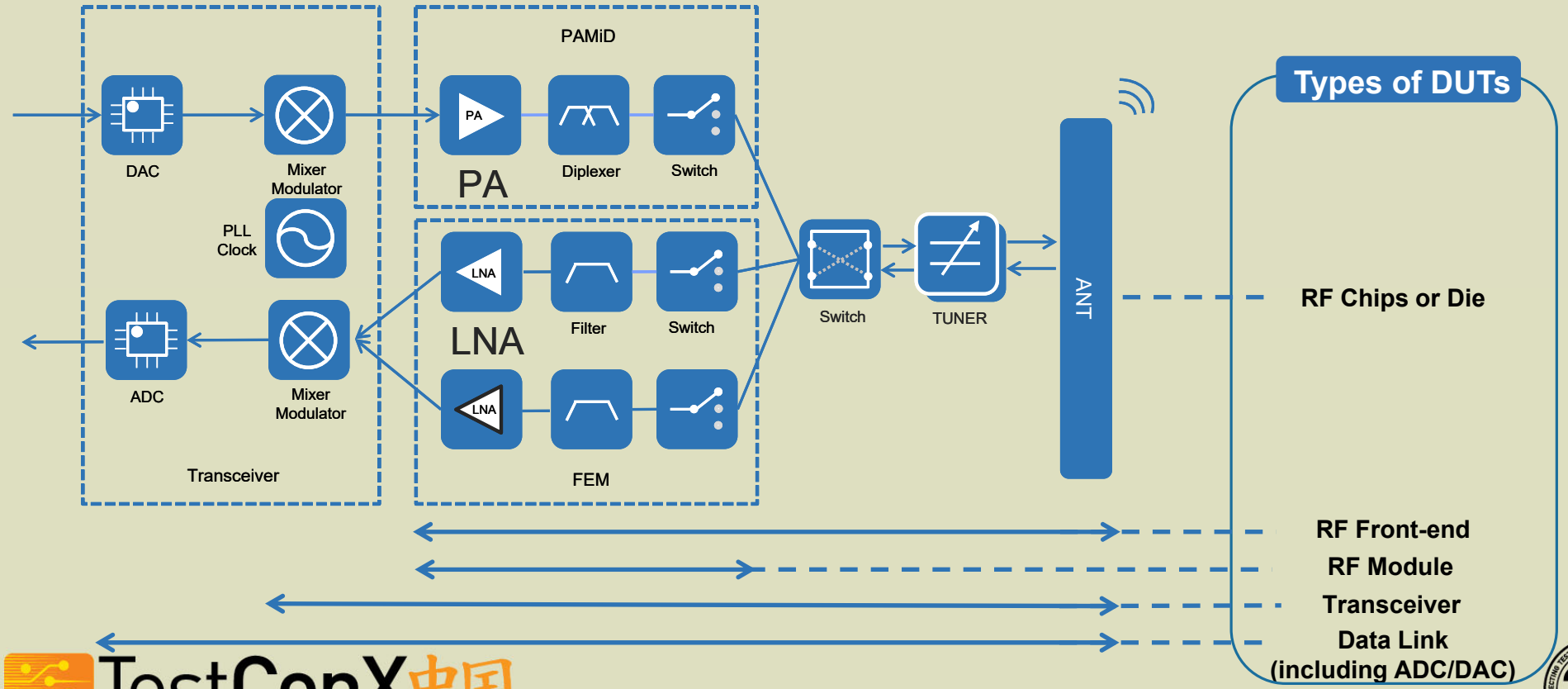
DUTs Category



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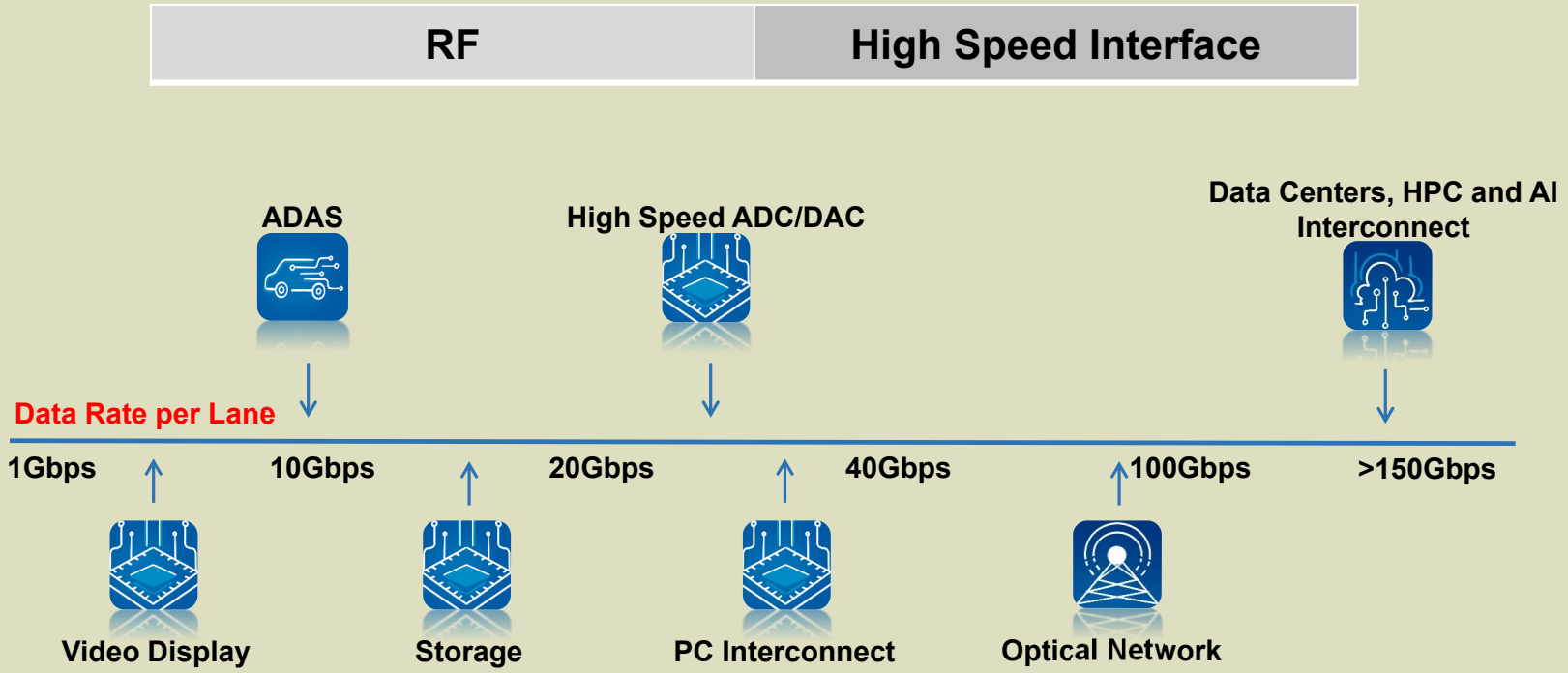
High Speed Test Applications



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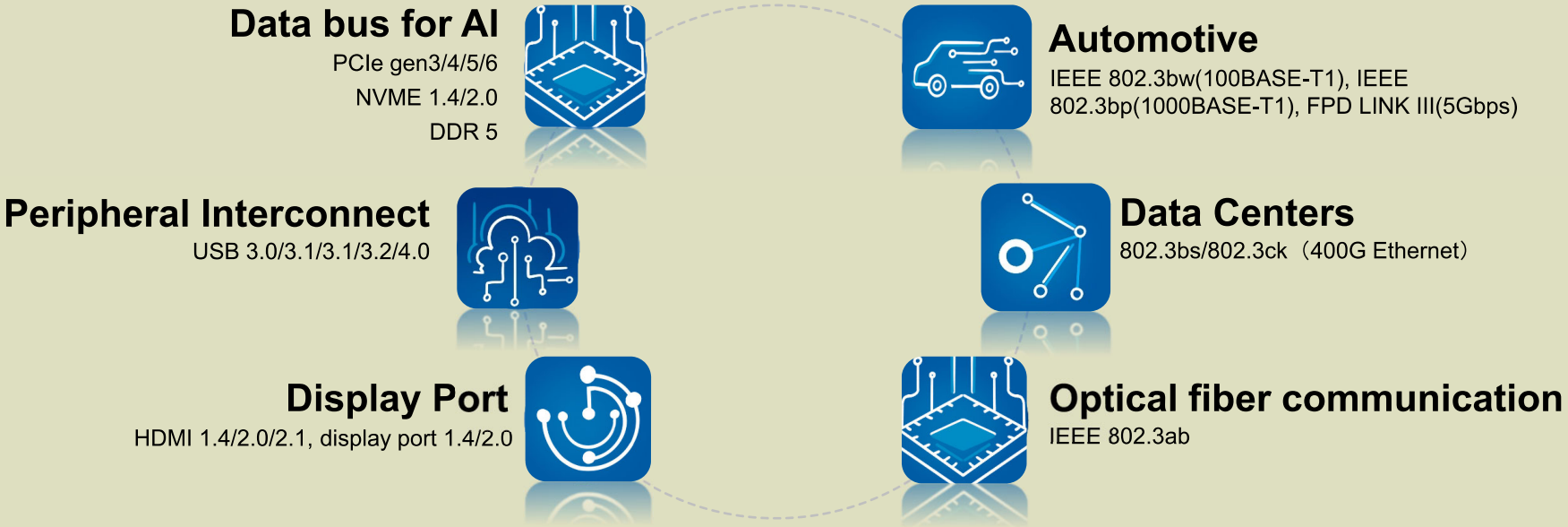
DUTs Category

RF	High Speed Interface



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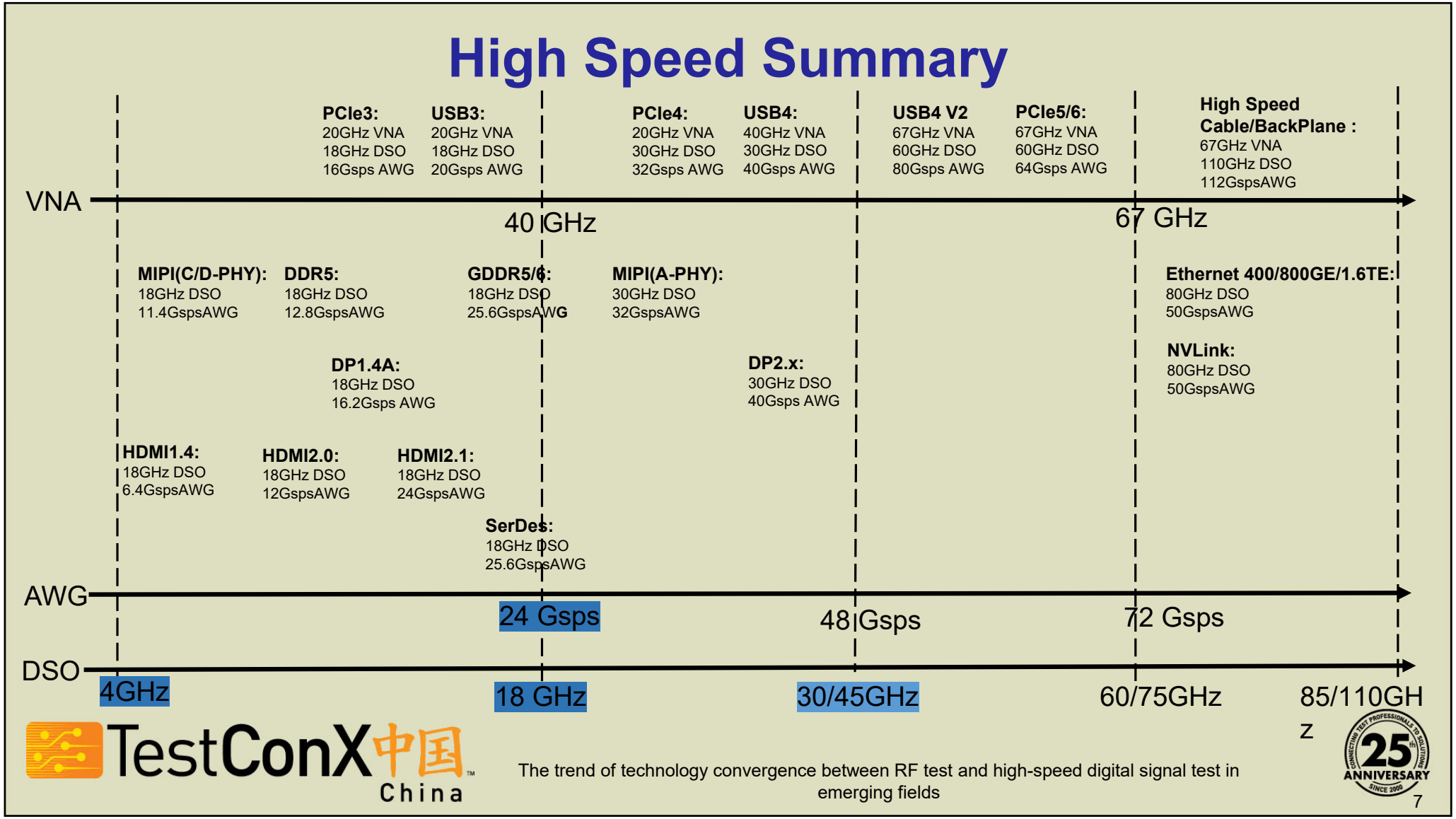
High Speed Summary
PCIe3:
20GHz VNA
18GHz DSO
16Gsps AWG
USB3:
20GHz VNA
18GHz DSO
20Gsps AWG
PCIe4:
20GHz VNA
30GHz DSO
32Gsps AWG
USB4:
40GHz VNA
30GHz DSO
40Gsps AWG
USB4 V2
67GHz VNA
60GHz DSO
80Gsps AWG
PCIe5/6:
67GHz VNA
60GHz DSO
64Gsps AWG
High Speed Cable/BackPlane :
67GHz VNA
110GHz DSO
112GspsAWG
VNA
40 GHz
67 GHz
MIPI(C/D-PHY):
18GHz DSO
11.4GspsAWG
DDR5:
18GHz DSO
12.8GspsAWG
GDDR5/6:
18GHz DSO
25.6GspsAWG
MIPI(A-PHY):
30GHz DSO
32GspsAWG
Ethernet 400/800GE/1.6TE:
80GHz DSO
50GspsAWG
NVLink:
80GHz DSO
50GspsAWG
DP1.4A:
18GHz DSO
16.2Gsps AWG
DP2.x:
30GHz DSO
40Gsps AWG
HDMI1.4:
18GHz DSO
6.4GspsAWG
HDMI2.0:
18GHz DSO
12GspsAWG
HDMI2.1:
18GHz DSO
24GspsAWG
SerDes:
18GHz DSO
25.6GspsAWG
AWG
24 Gsps
48 Gsps
72 Gsps
DSO
4GHz
18 GHz
30/45GHz
60/75GHz
85/110GHz
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TECHNOLOGY and INNOVATION

RF Tester for

WiFi Chips/Devices

5G NR Chips/Devices

Satcom Chips/Devices

Radar(mmW) Chips

GNSS Chips.

High Speed Interface Tester for

USB4/USB4 V2

PCIe

DDR5

HDMI/DP/MIPI

Serdes(Automotive)

Data Center Interconnection

AI Interface

Backplane

High Speed Ethernet

Test Cards

DSO

AWG

VST

VSA

HSIO

VNA

VSG

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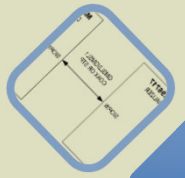
Outline

- Applications for RF and high-speed devices
- **The convergence trend of DUTs in emerging fields**
- The convergence trend reflected in the technological evolution of the tester itself
- Some typical cases

Covergence trends in DUTs in emerging fields

Take two types of DUTs as examples



02

01

High speed serial interface

- PCIe
- USB V4
- HDMI/DP
- MIPI
- Automotive SerDes
- High-speed Ethernet

RF sampling ADC/DAC

- WiFi SoC
- Cellular base stations
- radar
- UAV broadband data link
- Optoelectronic interface
- Test equipment

Typical applications

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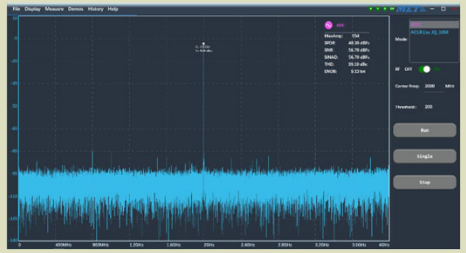
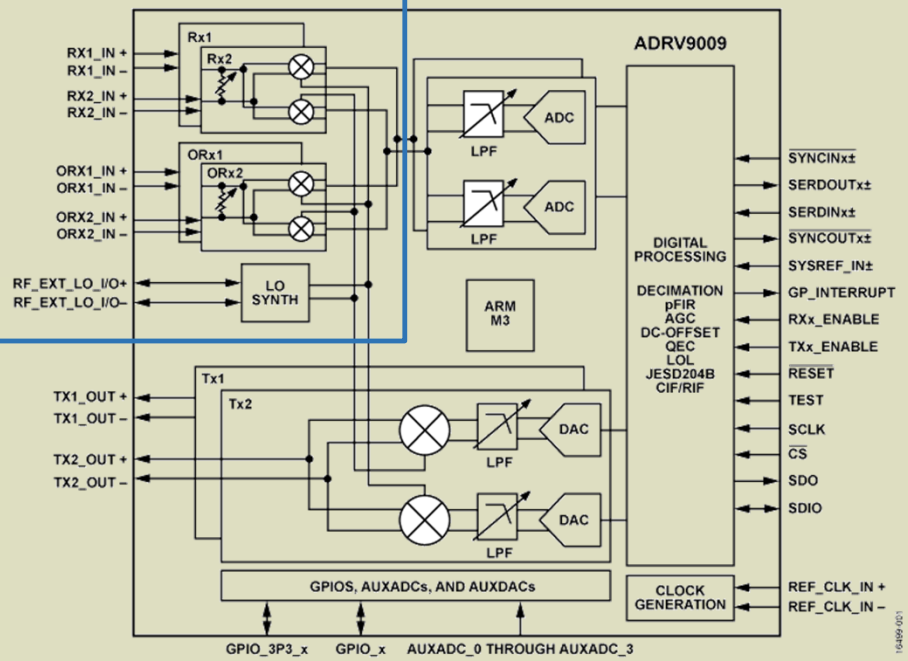
Example A: RF Transceiver



Rx RF spec.

- Channel
  - Center Frequency
  - ORx Bandwidth
  - Flatness @ any xM BW
  - Phase linearity
- ORx Gain
  - Gain Control Range
  - Gain Resolution
- Distortion
  - Alias Band Rejection
  - 2/3nd Input Intermodulation Intercept Point (IIP2/3)
  - 3rd/5th/7Th-order Intermodulation Product (IM3/5/7)
  - Receiver Band Spurs
  - 2nd/3rd/ Harmonic Distortion (HD2/3)
  - Image Rejection (IRR)
  - LO Leakage (LOL)
  - Tx-to-ORx Isolation
  - ORx-to-ORx Isolation



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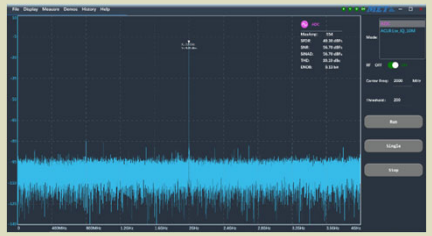
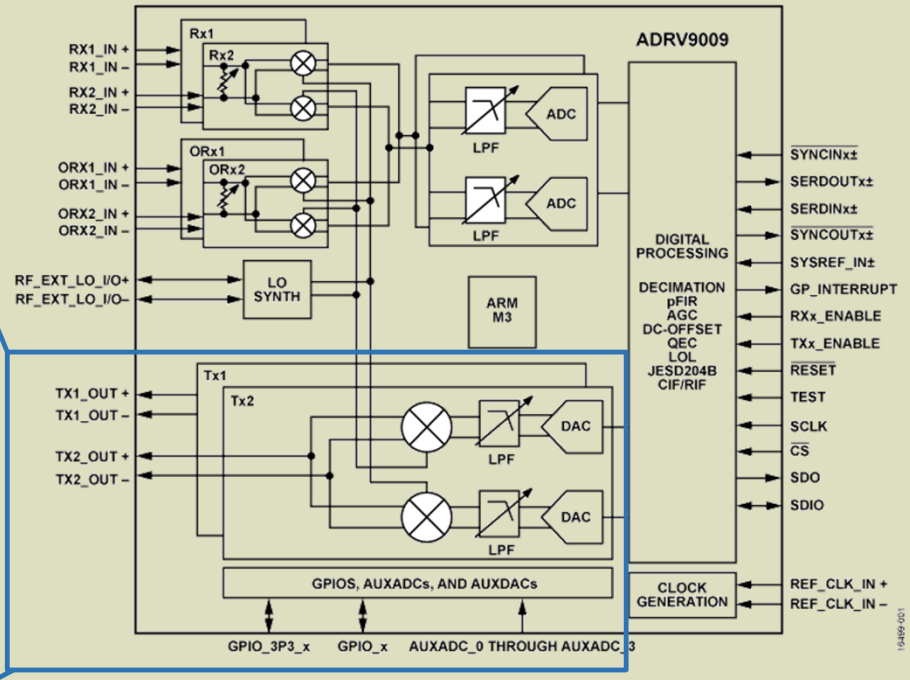
Example A: RF Transceiver



Tx RF spec.

- Channel
  - Center Frequency
  - Tx Synthesis Bandwidth
  - Tx Large Signal Bandwidth
  - Flatness @ any xM BW
  - Phase linearity
- Tx Attenuation
  - Atten. Control Range/ Resolution
  - Atten. INL/DNL
  - SPI to Atten. timing
  - ……
- Distortion
  - Adjacent Channel Leakage Ratio (ACLR)
  - In Band Noise Floor
  - Out of Band Noise Floor
  - Interpolation Images
  - Tx-to-Tx Isolation
  - Image Rejection (IRR)
  - 3rd Output Intermodulation Intercept Point (OIP3)
  - LO Leakage (LOL)
  - Error Vector Magnitude (EVM)
- Maximum Output Power



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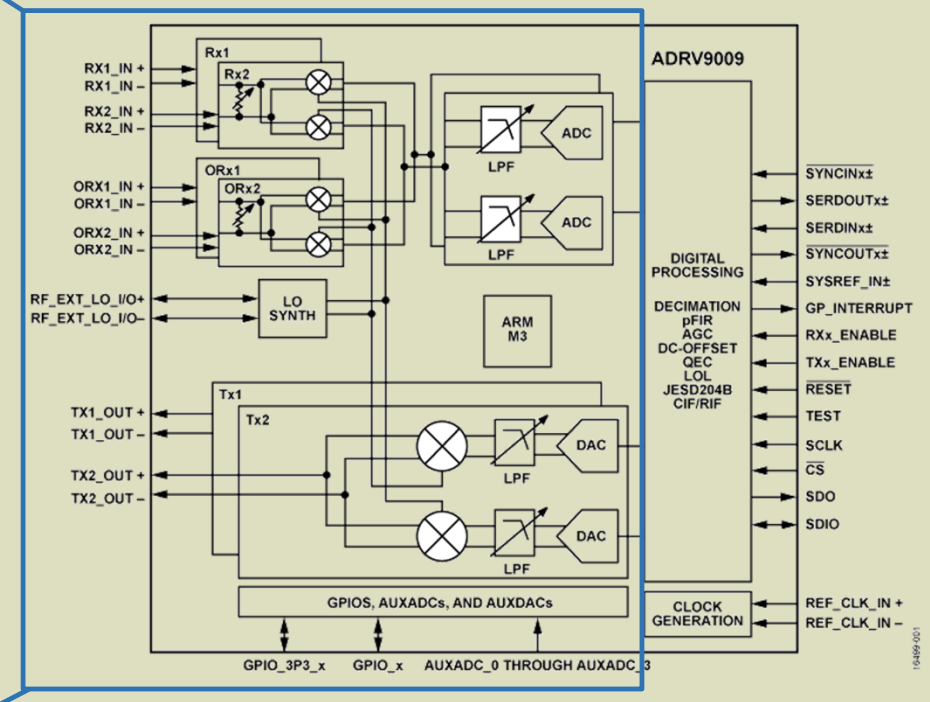
Example A: RF Transceiver

State of the art

- RF Frequency: 18GHz
- Bandwidth: up to 12GHz
- SFDR: over 70dB
- PN: -140dBc @1GHz @1kHz
- EVM: over -50dB @WiFi 7



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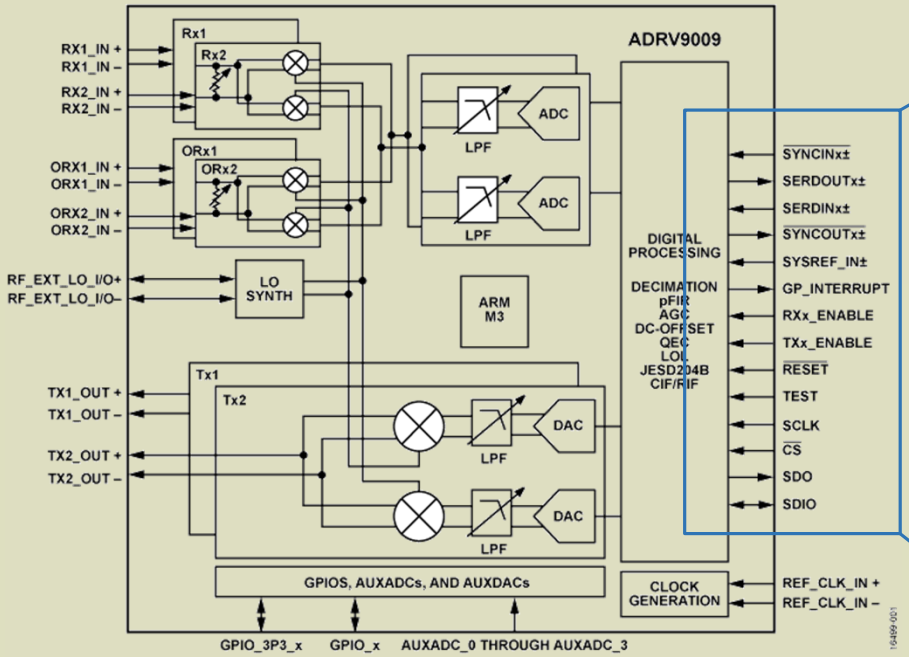
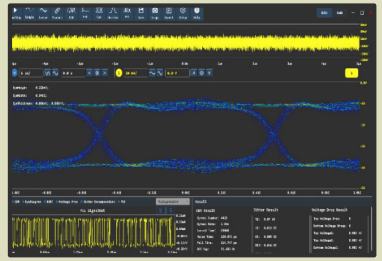
Example A: RF Transceiver





JESD204B/JESD204C

Supports **0.3125 - 32 GBaud** output with 1 Baud symbol rate stepping.

capability of **jitter and noise injection.**

Supports fixture and channel embedding/de-embedding functions

Supports clock data recovery (**CDR**)

Eye diagram test: automatically measures eye height, eye width, eye thickness and jitter, supports user-defined eye diagram templates;

Jitter analysis: support for RJ/PJ/DDJ/DCD and other jitter term decomposition

Equalizer simulation: Built-in CTLE/FFE/DFE/Bessel Thomson and other common digital equalizers in the data path.

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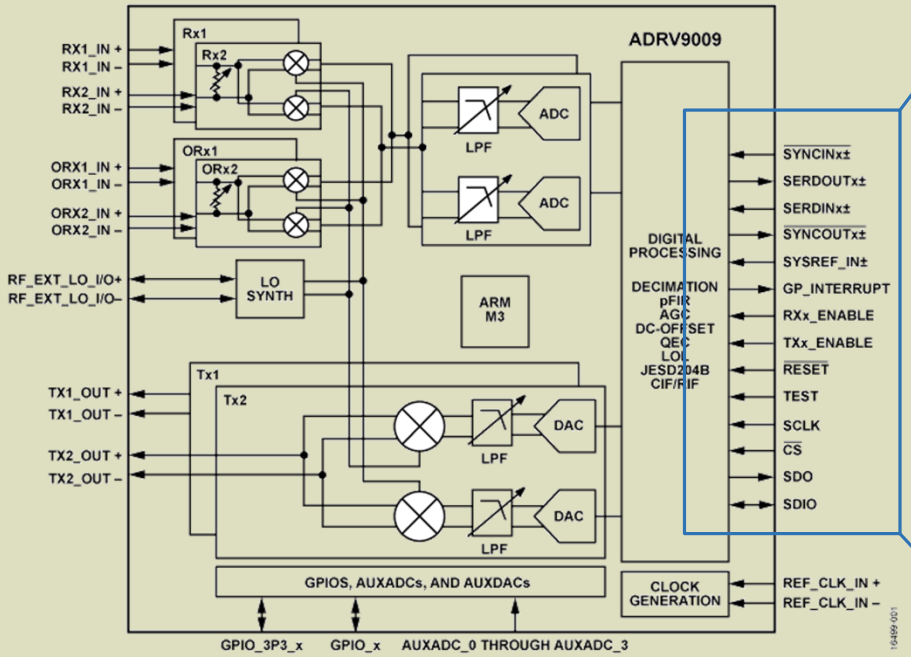
Example A: RF Transceiver



State of the art

- Data Rate per Lane: up to 32Gbps
- Tx FFE（Min.）: 9.5dB
- Rx CTLE（Min.）: 12dB
- Num. of Rx DFE taps（Min.）: 14
- Encoding：8b/10b、64b/66b、64b/80b

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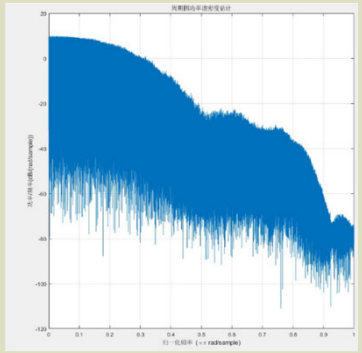
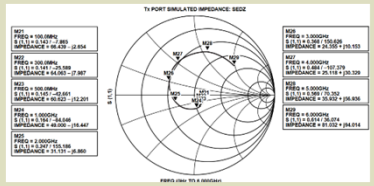
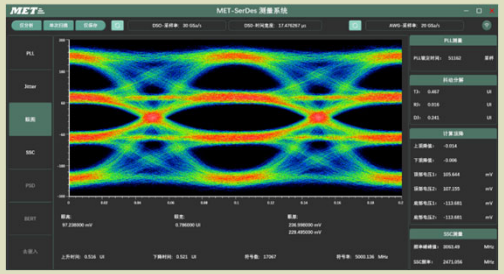
Example B: Automotive SerDes



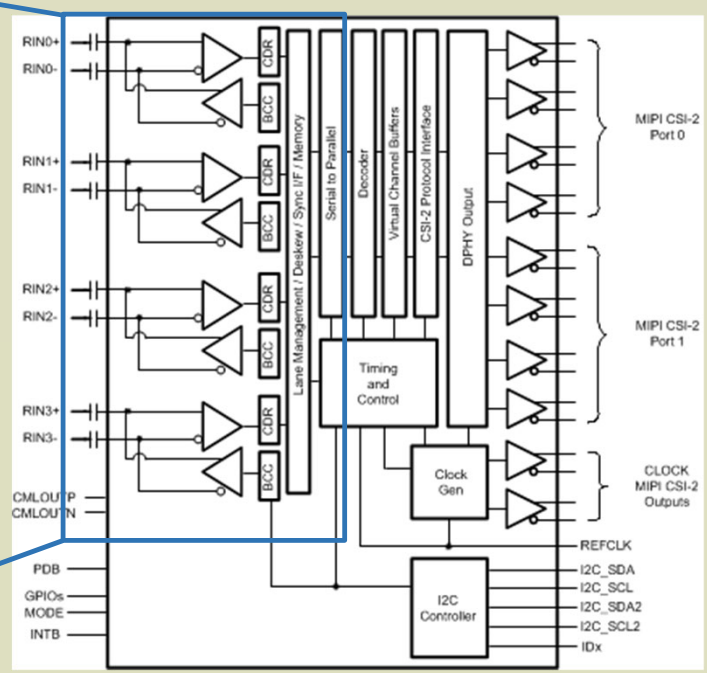
Frequency domain: DC-RF PSD



Port impedance



Time domain: PAM4 eye diagram



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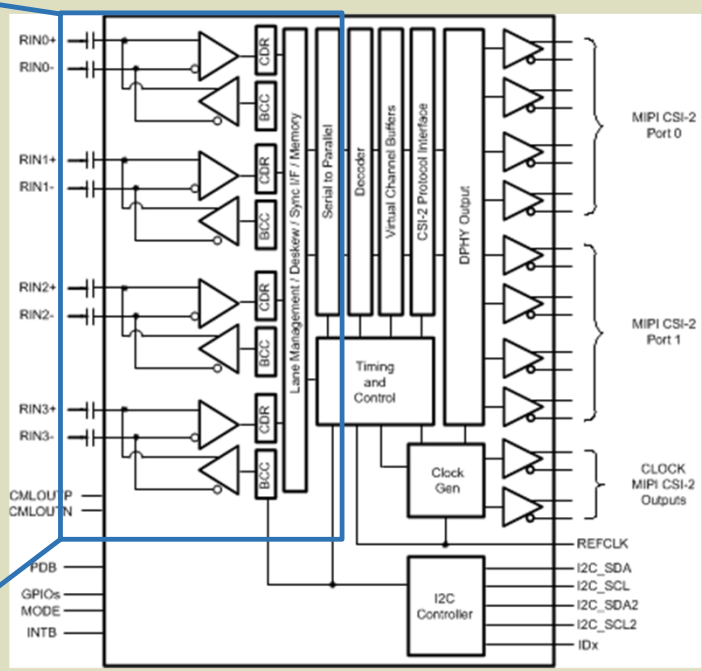
Example B: Automotive SerDes

State of the art

Version	Player	Application	DataRate per Lane
GSML	Maxim	U.S.,China	2-12Gbps
FPD-link	TI	U.S.,China	2-6Gbps
AHDL	AIM	China	Gen2:6Gbps NG:13-15Gbps
Norelsys	HSMT	China	2-12.8Gbps
APIX	Inova	EU	12Gbps
GVIF	SONY	JP(TOYOTA)	~8.63Gbps
Clockless Link	ROHM		2.7Gbps
	ON Semiconductor		
	Rambus		
	Automotive SerDes Alliance		2/4/8/12/16Gbps
A-PHY	MIPI		16Gbps



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Traditional digital tests and high-speed digital tests

In high-speed transmission scenarios:

★ Loopback tests alone cannot characterize the actual interconnection capability.

★ Harsh scenarios require stress tests such as jitter-tolerance.

★ Single defective device can cause more serious quality cost consequences.

★ There is no accurate quality control without accurate test results.

★ Adequate FT can simplify subsequent costly system-level testing.

Comparison of Loopback Test and PHY Test Capabilities

Test Categories	Symbol	Description	Loopback Test	PHY compliance test
Level Test	V_{OH}/V_{OL}	Output Level Voltage	✓	√
	V_{IH}/V_{IL}	Input Level Voltage	✓	√
	V_{IDTH}/V_{IDTL}	Differential Input Threshold	✓	√
	V_{OD}	Differential Voltages	✓	√
	V_{CM}	Common-Mode Voltages	✓	√
Timing Test	T_{Rise}/T_{Fall}	Rise/Fall Time	×	√
	δV	Slew Rate	×	√
	T_{Skew}	Data-to-Clock Skew	×	√
Clock Test	PN	PLL Phase Noise	×	√
	t_{RJ}	PLL Random Jitter	×	√
	JTF	PLL Jitter Transfer	×	√
Tolerance	J_{tol}	Jitter Tolerance	×	√
		Error Injection by Ratio/by Index	√	√
		Frequency Offset	×	√
		Noise/Sine Injection	×	√
		Channel Injection	×	√
		Channel De-embedding	×	√
	SSC	Spread Spectrum Clocking	×	√
		Eye Diagram Tolerance	✓	√
	EQ	Equalization	×	√
	ΔV_{CMF}	Common-Mode Interference	×	√
Measurement		CDR + Eye diagram Measurement	×	√
		Jitter Measurement	×	√
		Frequency Offset Measurement	×	√
		BER Measurement	√	√
		Voltage Droop Measurement	×	√

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Comparison of traditional digital tests and high-speed digital tests

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Outline

- Applications for RF and high-speed devices
- The convergence trend of DUTs in emerging fields
- **The convergence trend reflected in the technological evolution of the tester itself**
- Some typical cases

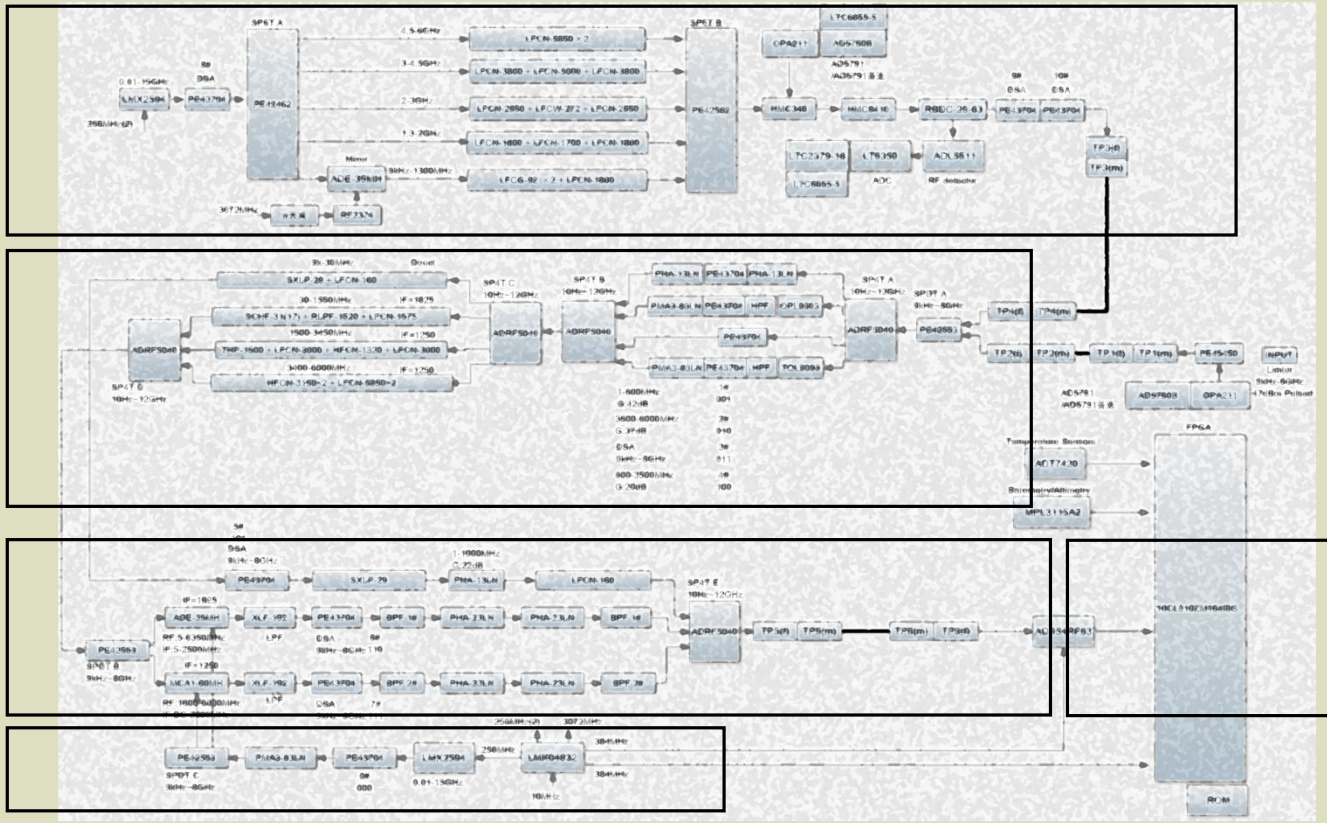
Iteration of the tester architecture itself

Reference source for calibration

Pre-processing and frequency conversion

IF filter banks

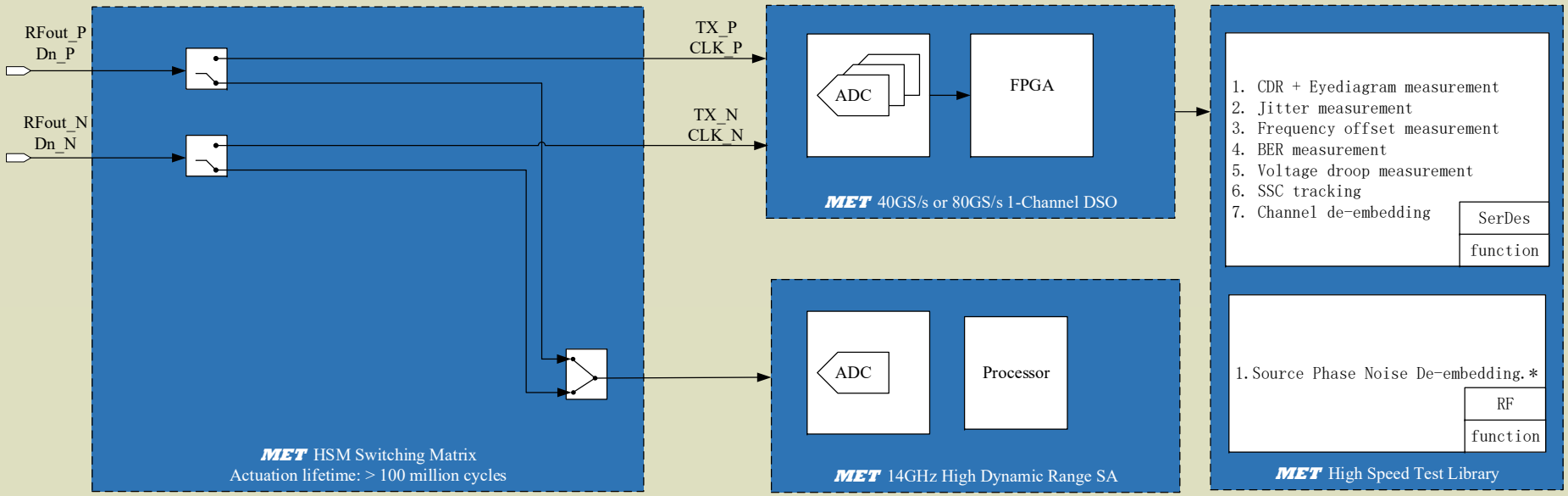
Clock management



ADC

Architecture diagram of the 6 GHz vector signal analyzer of the previous PXIe productions

An iteration of the tester architecture on RF-AD/DA



Architecture diagram of the 8 GHz vector signal analyzer of the current PXIe productions

Iteration of the tester architecture itself

01 Simplified transceiver structure:
- Lower costs
- More stability
- Better test repeatability
- Longer calibration intervals

02 Lower noise figure and better signal quality

03 Higher bandwidth

04 More flexible features

- Higher speed digital signal processing
- Requirement for System-level calibration
- Dynamic range is still insufficient

Traditional digital tests and high-speed digital tests

Test Categories	Symbol	Description	Loopback Test	PHY compliance test
Level Test	V_{OH}/V_{OL}	Output Level Voltage	×	√
	V_{IH}/V_{IL}	Input Level Voltage	×	√
	V_{IDTH}/V_{IDTL}	Differential Input Threshold	×	√
	V_{OD}	Differential Voltages	×	√
	V_{CM}	Common-Mode Voltages	×	√
Timing Test	T_{Rise}/T_{Fall}	Rise/Fall Time	×	√
	δV	Slew Rate	×	√
	T_{Skew}	Data-to-Clock Skew	×	√
Clock Test	PN	PLL Phase Noise	×	√
	t_{RJ}	PLL Random Jitter	×	√
	JTF	PLL Jitter Transfer	×	√
Tolerance	J_{tol}	Jitter Tolerance	×	√
		Error Injection by Ratio/by Index	√	√
		Frequency Offset	×	√
		Noise/Sine Injection	×	√
		Channel Injection	×	√
		Channel De-embedding	×	√
	SSC	Spread Spectrum Clocking	×	√
		Eye Diagram Tolerance	×	√
	EQ	Equalization	×	√
	ΔV_{CMF}	Common-Mode Interference	×	√
Measurement		CDR + Eye diagram Measurement	×	√
		Jitter Measurement	×	√
		Frequency Offset Measurement	×	√
		BER Measurement	√	√
		Voltage Droop Measurement	×	√

Outline

- Applications for RF and high-speed devices
- The convergence trend of DUTs in emerging fields
- The convergence trend reflected in the technological evolution of the tester itself
- **Some typical cases**

Products Serials Positioning

1. RF Integrated test/analyze System

Type-Code	Testing Capability	Applications
ARGOSY	• S Parameter • Linearity • Noise Figure • Phase Noise • RF Timing Seq. • Power Source • Vector Signal Analysis • temperature-related	• RF Semiconductor Device Screening • RF Semiconductor Device Analysis

Type-Code	Testing Capability	Applications
CARAVAN	• Transmitter • Receiver	• Navigation Test • Satellite Test • Avionics Test • Radar Test

2. RF Mass Production Test System

Type-Code	Applications
KNOX-F/M	• RF front-end chips
KNOX-PA	• RF PA/LNA
KNOX-PM	• RF front-end module

3. High-speed Test System

Type-Code	Applications
Avatar-MS	• ADC/DAC
Avatar-HS	• SerDes • PCIe/USB/NVME • IEEE 802.3

4. Customized Test System

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Products Serials Positioning

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Typical Products and Applications

ARGOSY-2000
Up to 40 GHz RF Integrated Tester & Analyzer

advantages 1 — Complete **all** the required RF test in one tester without experienced engineer.

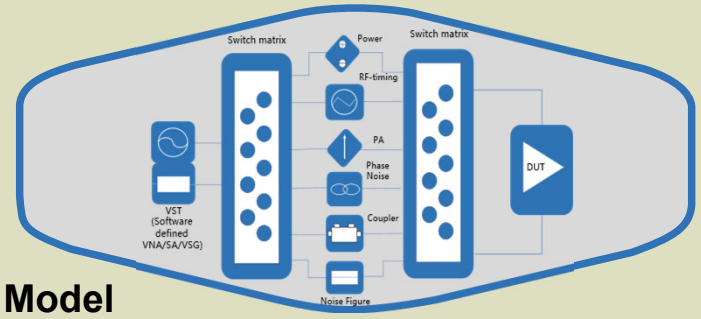
advantages 2 — Reduce the test **costs** by adopting software defined hardware.

advantages 3 — Accelerate the test **speed** by various featured test algorithm.

advantages 4 — Achieve **high-end** test by innovative test model without expensive instrument.

- High isolation and long-life switch matrix
- Cold-Source NF measurement
- Model based S-parameter test
- Low phase noise measurement
- RF Timing Analysis and Correction
- Load correction for unmanned operation

Test Features



Test Model

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Typical Products and Applications

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Typical Products and Applications

Knox-FPM2000
Up to 20GHz Filter/DiFEM/PAMiD Tester

advantages 1 — **Predicts** the packaged performance of the die under test.

advantages 2 — Reduces the test **costs** by customized hardware.

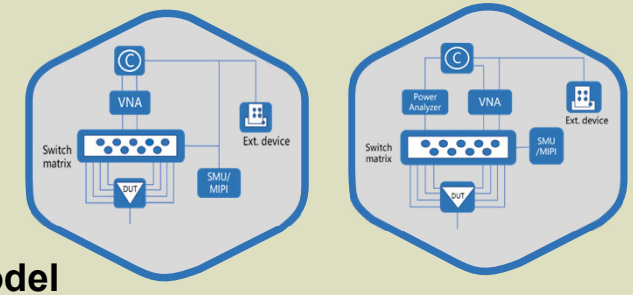
advantages 3 — Accelerates the test **speed** by AI based DUT model.

advantages 4 — **Dedicated** to the test requirements of filter/DiFEM/PAMiD with low costs.

- Load reflection correction
- De-embedding or embedding
- High-speed test of S-parameter
- Economical scalar power test up to 50dBm
- All-in-one calibration

Test Features

Test Model



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Typical Products and Applications

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Typical Products and Applications

Knox-PA2000
PA/LNA Tester

advantages 1 — High performance source with **pre-distortion.**

advantages 2 — **High output power** VNA up to 50dBm.

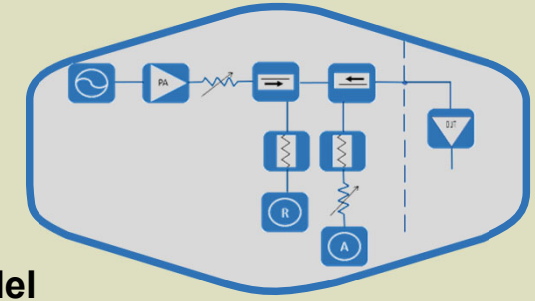
advantages 3 — High performance **cold source** noise figure test box.

advantages 4 — **Dedicated** to the test requirements of LNA/PA with low costs.

- RF source with digital pre-distortion
- Gamma power correction
- Configurable RF ports & multi-site parallel
- Economical scalar power test up to 50dBm
- High harmonic rejection test capability

Test Features

Test Model



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Typical Products and Applications

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Typical Products and Applications

Avatar-HS1000
High-speed Serial Link Tester

advantages 1 — SerDes at-speed test up to **12.5GBaud**, PCIe 3.0, USB 3, JESD204B, MIPI, etc.

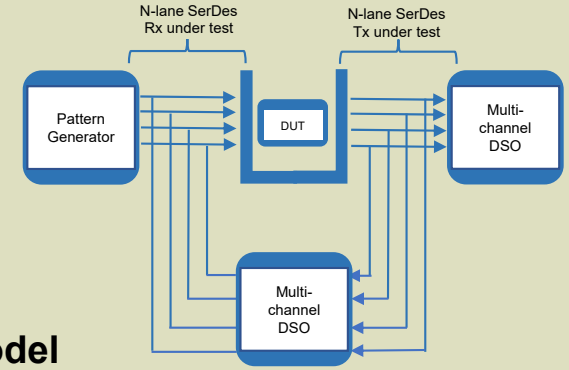
advantages 2 — **Full** test function: Tx/Rx return loss, Tx eye/jitter, Rx eye/JTOL, Tx EQ, Rx EQ.

advantages 3 — **Very low inherent jitter**, minimize bias in jitter measurement.

advantages 4 — Small form factor, allow multiple Serdes lanes(≥16) being tested **simultaneously.**

- High-speed analog front-end with CDR
- NRZ/PAM4 format support
- Cable & fixture removal capability
- Built-in DSP for CTLE/FFE/DFE emulation

Test Features



Test Model

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Typical Products and Applications

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Typical Products and Applications

Avatar-MS1000
High-speed ADC/DAC Tester

advantages 1 — Advanced digital **pre-distortion** (DPD) technique deliver high quality RF source

advantages 2 — **Instrument-grade** clocking capability minimizes systematic errors

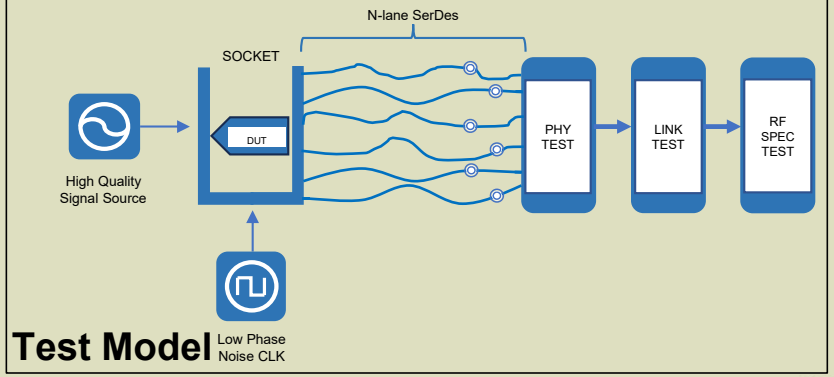
advantages 3 — Patented source **de-embedding** method to reach true DUT performance

advantages 4 — **Serdes PHY and LINK** test capabilities enable JESD204B compliance test

advantages 5 — **All-in-one**, dedicated solution eliminates need for expensive desktop instruments

- RF source with digital pre-distortion
- Low jitter clock with jitter injection
- De-embedded analog front end
- Independent SerDes test capability

Test Features



Test Model

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Special Part for Today

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