Automotive Ethernet Test Challenges and Solution

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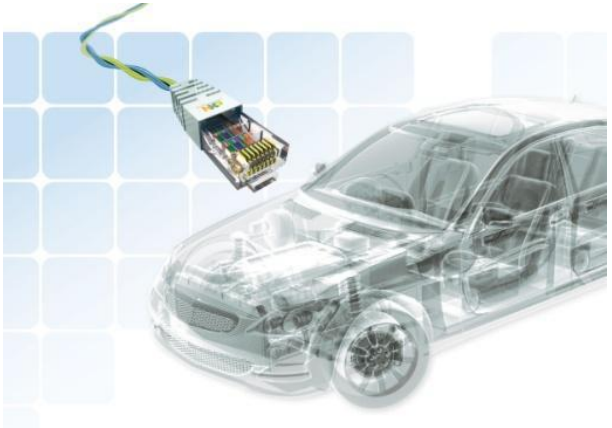
AE/Keysight	

Contents

- **Automotive Ethernet introduction**
- **Automotive Ethernet Test Challenges**
- **Automotive Ethernet Test Solution**



Reference: IEEE 802.3bw-2015,
IEEE 802.3bp-2016,
OABR TC1/TC8/TC12

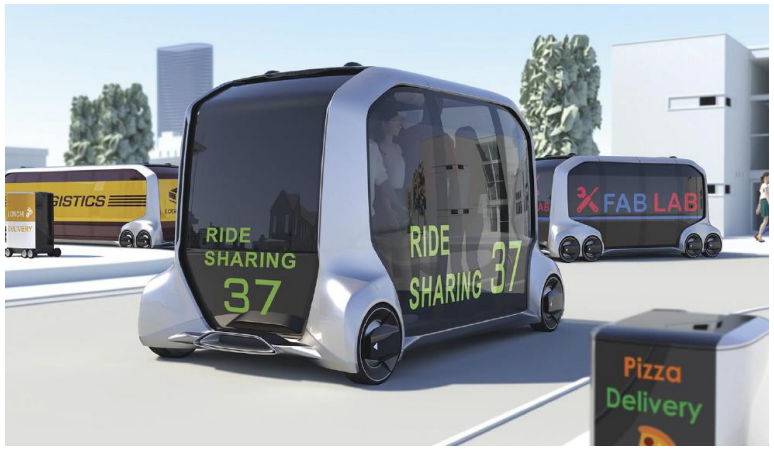
It’s Going To Happen

Data Source: WHO, US EPA

Autonomous Driving System

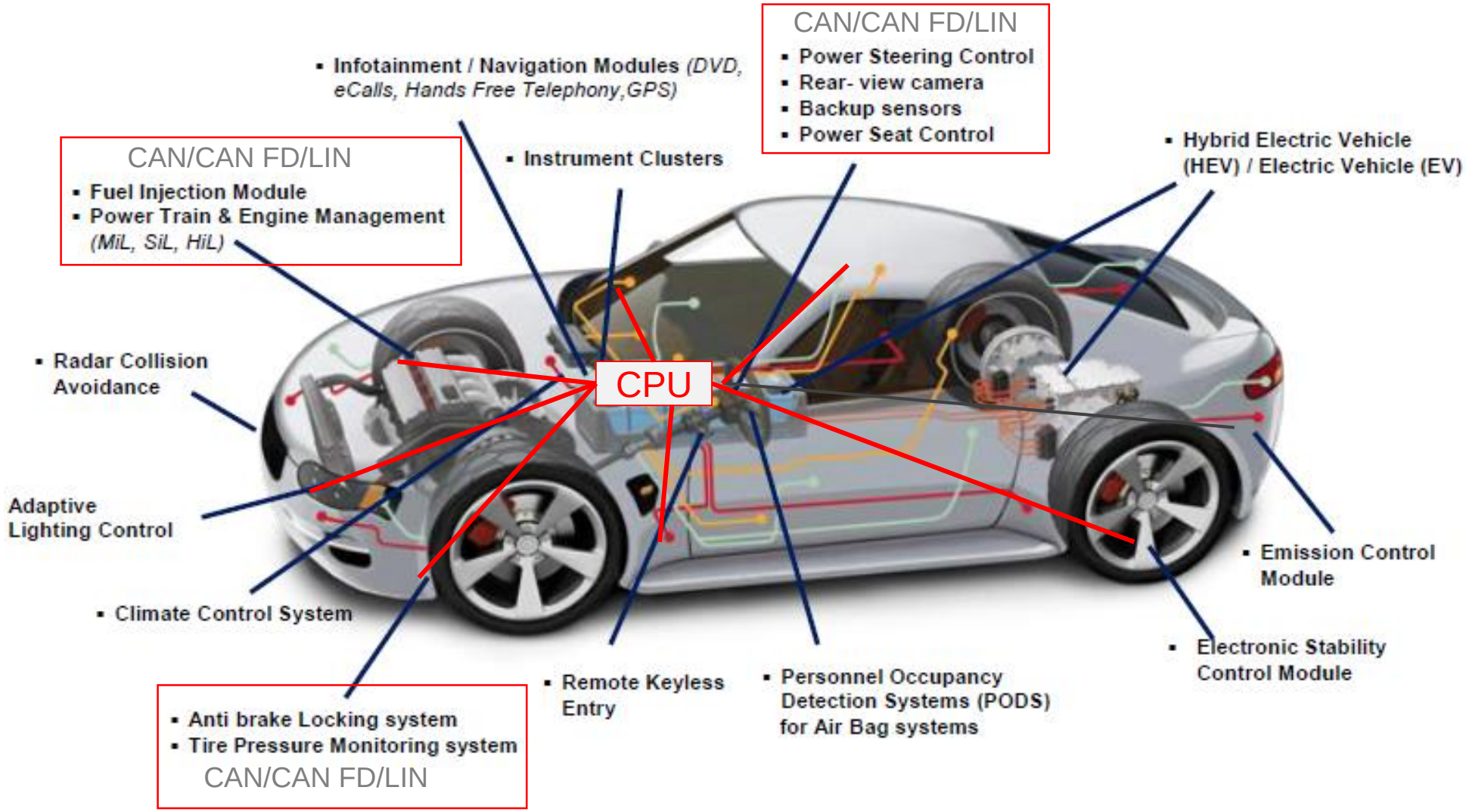
ADVANTAGES

- Safer world with 90% fewer car accidents
- More productive life from less traffic congestion and driving time
- Better energy efficient transportation and environmental benefits
- More efficient car-sharing and car-utility
- Better urban land utilization
- More innovations, investments and newer business models
- And, more



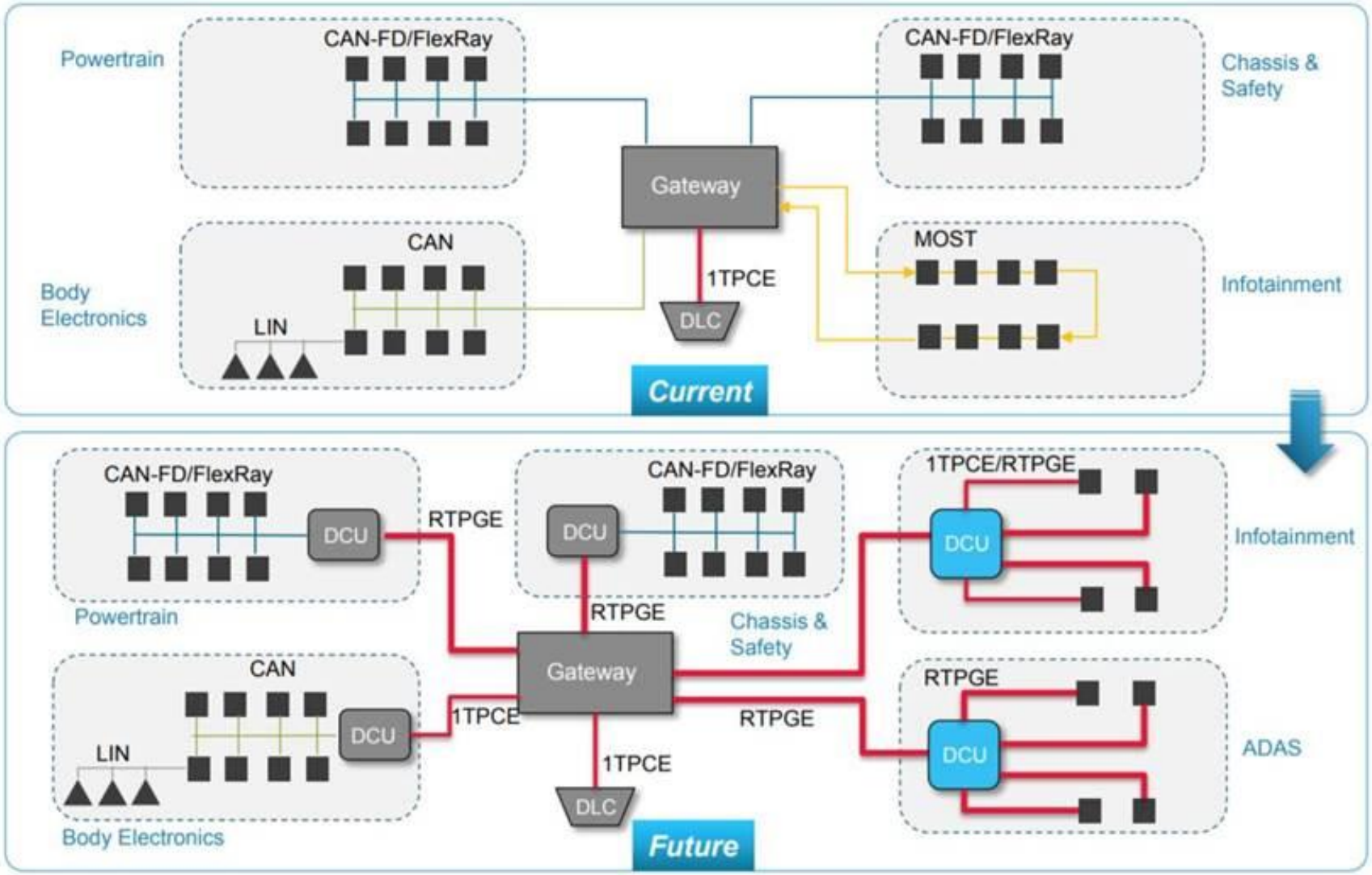
Future Car Network

ETHERNET IS THE BACKBONE



Automotive Ethernet into the future

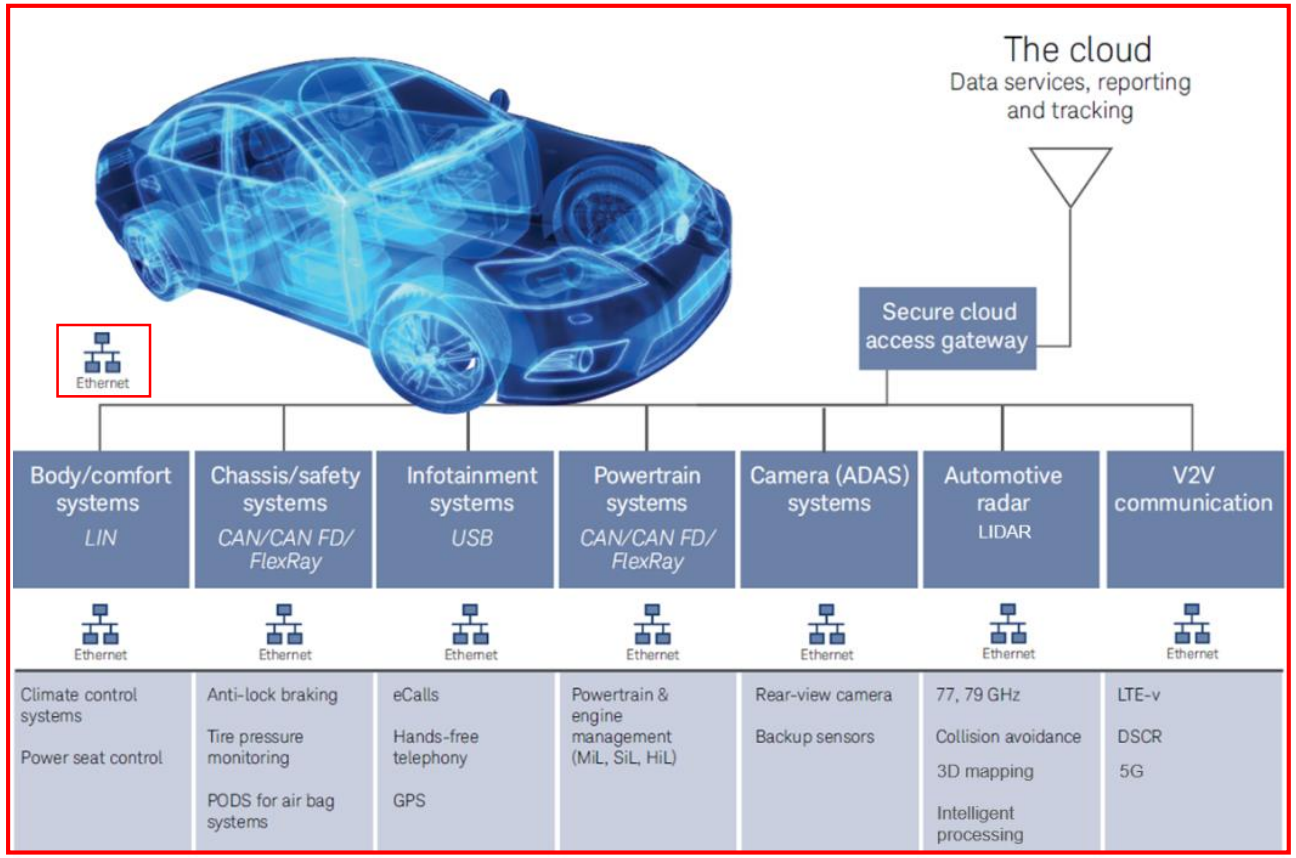
HOW USE WILL EVOLVE

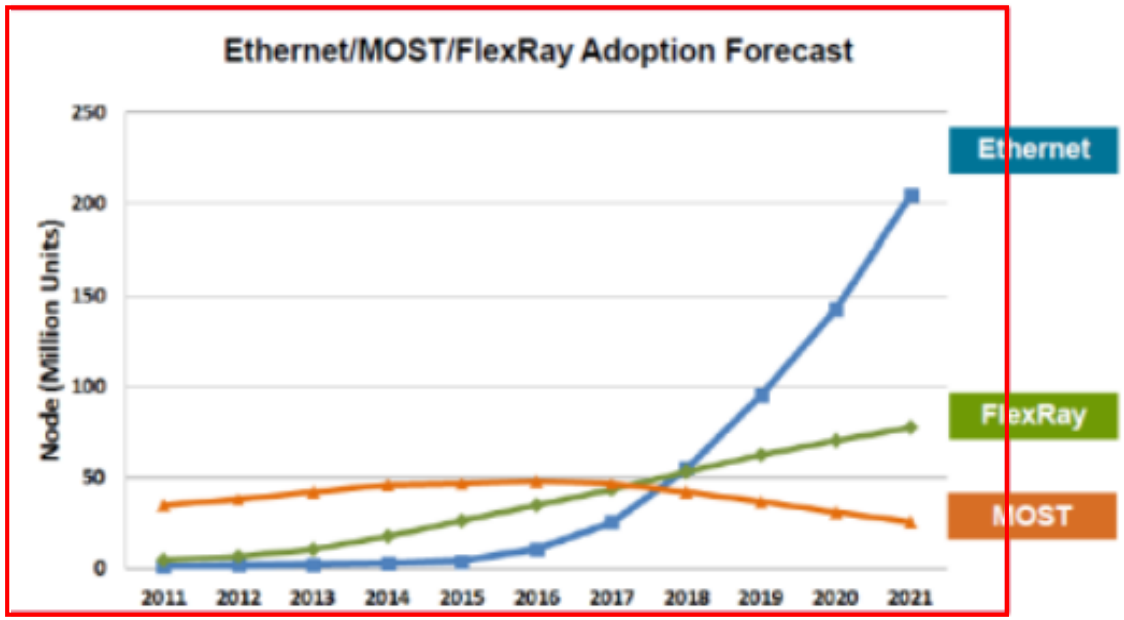


1TPCE = 1 Twisted Pair [c] 100Mb/s Ethernet

RTPGE = Reduced Twisted Pair Gigabit Ethernet

What is Automotive Ethernet ?





Ethernet adoption forecast

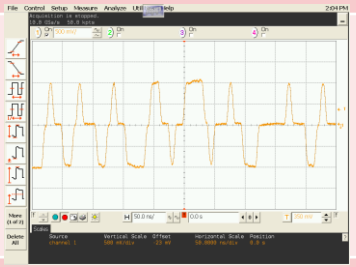
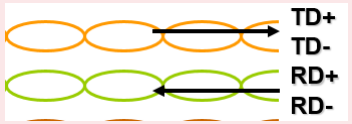
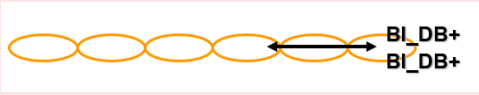
(Source: High-speed automotive bus demand estimates 2015 by Strategy Analytics)

Why does we need Automotive Ethernet ?

100BASE-T1 VS 100BASE-TX

- **Cable weight**
  - 100BASE-T1 is a physical full-duplex standard
  - Only a single unshielded-twisted pair cable is needed
- **Immunity and Emissions requirements**
  - CISPR25 Class 5
  - PAM3 for noise immunity
- **Proven technology**
  - Decades of development
  - Standardized interface
  - MAC can remain the same
    - Transparent to CPU/MCU/FPGA

Fast Ethernet vs Automotive Ethernet

	Ethernet 100BASE-TX (IEEE802.3)	Automotive Ethernet 100BASE-T1 (IEEE802.3bw)	Automotive Ethernet 1000BASE-T1 (IEEE802.3bp)
Data Rate	100 Mbps	100 Mbps	1000 Mbps
Modulation	MLT3 @125MBd/s 	PAM3 @ 66.667MBd/s 	PAM3 @ 750 MBd/s 
Encode	4B/5B	4B/3B	80B/81B
Length	100 m	15 m	
Connector	RJ45	Not Defined Depending on OEMs and models	
Cable	Two Twisted Pair Single Direction 	One Twisted Pair Bi Directional 	

IEEE 802.3bw vs 802.3bp

100BASE-T1 VS 1000BASE-T1

	100BASE-T1	1000BASE-T1
IEEE standard	802.3bw	802.3pb
Data rate	100 Mbps	1000 Mbps
Symbol rate	66.66 MHz	750 MHz
DUT clock	66.66 MHz	125 MHz
Coding	PAM3	PAM3
Disturbing signal (TM4)	5.4 Vpp @ 11.11 MHz	3.6 Vpp @ 125 MHz
Length	15 m (copper)*	15 m (copper)*

*40m is also supported for the link segment in applications requiring additional physical reach (industrial and automation controls and transportation – aircraft, railway, bus, heavy trucks.)

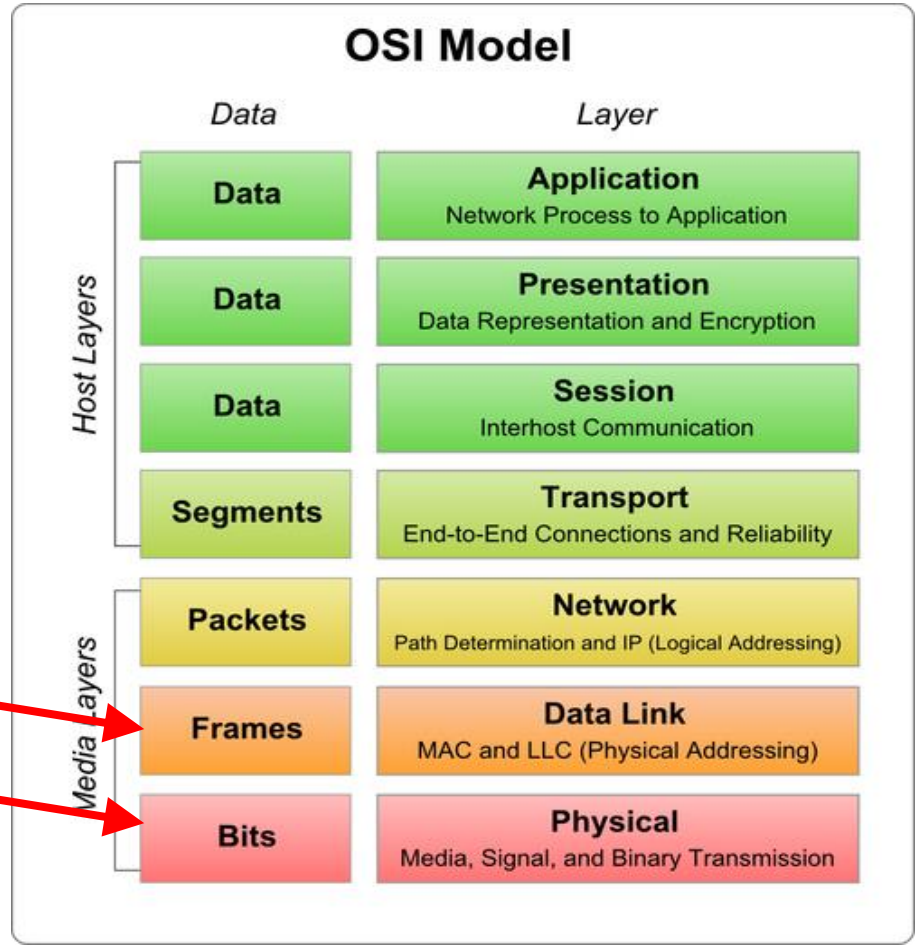
Networking and Ethernet PHYs

LEVERAGING EXISTING TECHNOLOGY LAYERS

- OSI Model describes the different layers of a networking system according to their functions
- Each layer communicates with layers above and below
- Information is passed via a Protocol Data Unit (PDU)
- Every layer will re-format and process the PDU before sending it over to the other layer.

Ethernet MACs operate on Layer 2

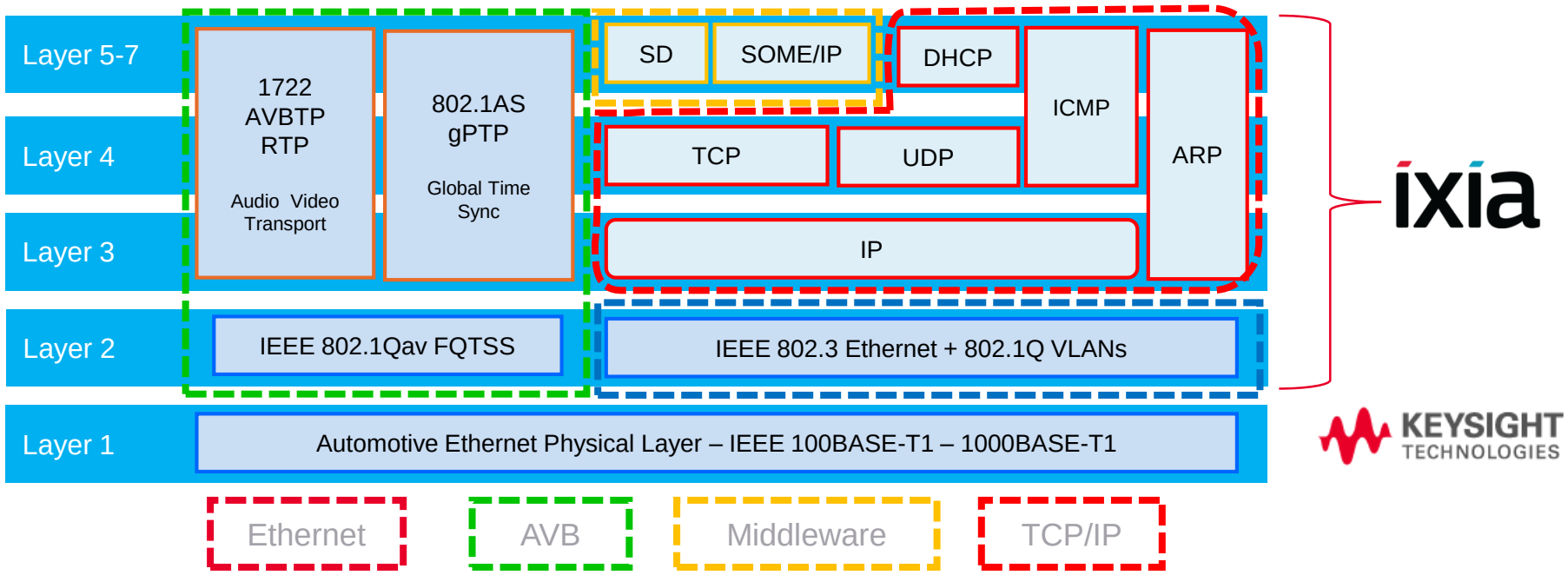
Ethernet PHYs operate on Layer 1



Complete Test Coverage

HOW KEYSIGHT AND KEYSIGHT FIT TOGETHER, LAYER 1-7

OSI分层



Ixia Hardware Platforms for AVB/TSN

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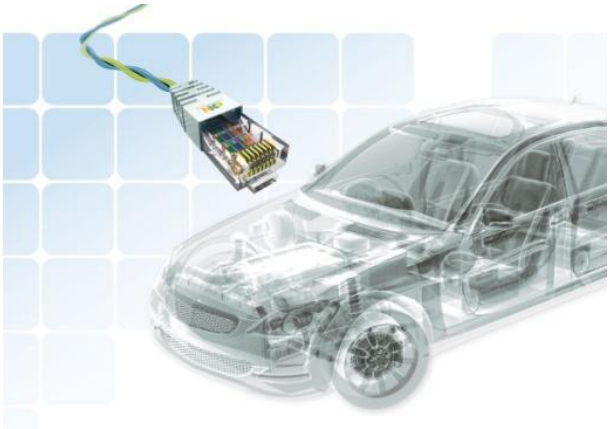
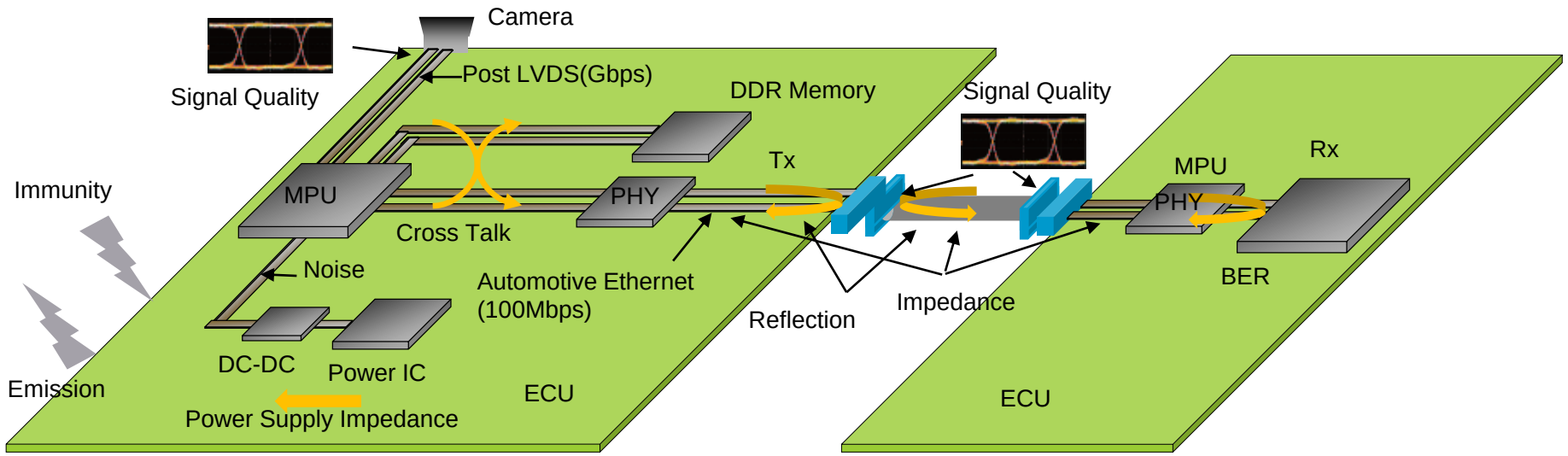
- Automotive Ethernet Test Solution



Reference: IEEE 802.3bw-2015,
IEEE 802.3bp-2016,
OABR TC1/TC8/TC12

High frequency board design challenges



■ Noise
- International Standard
- OEM Standard

■ Bus
- Signal Quality
- Tx Test
- Rx Test

■ Link Segment
- Impedance
- Cross Talk
- Reflection
- Loss

■ DC Power Supply
- Signal Quality
- Impedance
- Noise
- DC-DC

Required Tests For Compliance

100BASE-T1 TRANSMITTER TESTS

Category	Test mode	Test Items	Test Description	Measurement Equipment
Transmitter 100Base-T1 IEEE Std 802.3bw-2015	Test mode 1	96.5.4.1	Transmitter Output Droop	Oscilloscope (1GHz or better, 20Mpoints)
	Test mode 2	96.5.4.5	Transmit Clock Frequency Master (test mode 2) Slave (test mode 3)	Oscilloscope
	Test mode 2/ Salve Mode	96.5.4.3	Transmitter Timing Jitter Master TxOut Jitter (test mode 2) Slave TX-TCLK Jitter (Salve Mode)	Oscilloscope
	Test mode 4	96.5.4.2	Transmitter Distortion	Oscilloscope + AWG
	Salve Mode	96.8.2.1	MDI Return Loss	+ Vector Network Analyzer
	Test mode 5	96.5.4.4	PSD (Power Spectral Density)	Oscilloscope / Spectrum Analyzer (1GHz)
	Test mode 5	96.5.6 (IEEE)	Transmitter Peak Differential Output **	Oscilloscope

Required Tests For Compliance

ECU TRANSMITTER TESTS

Category	Test mode	Test Items	Test Description	Measurement Equipment
Transmitter ECU Test Spec V2.0	Test mode 1	OABR_PMA_Tx_01	Transmitter Output Droop	Oscilloscope (1GHz or better, 20Mpoints)
	Test mode 2	OABR_PMA_Tx_03	Transmit Clock Frequency Master (test mode 2)	Oscilloscope
	Test mode 2	OABR_PMA_Tx_02	Transmitter Timing Jitter Master TxOut Jitter (test mode 2)	Oscilloscope
	Test mode 4	OABR_PMA_TX_08	Transmitter Distortion	Oscilloscope + AWG
	Slave Mode	OABR_PMA_TX_05 OABR_PMA_TX_06	MDI Return Loss MDI Mode Conversion	+ Vector Network Analyzer
	Test mode 5	OABR_PMA_TX_04	PSD (Power Spectral Density)	Oscilloscope / Spectrum Analyzer (1GHz)

Required Tests For Compliance

1000BASE-T1 TRANSMITTER TESTS

Category	Test mode	Test Items		Measurement Equipment
Transmitter 100Base-T1 IEEE Std 802.3bp-2016	Test mode 1	97.5.3.6/97.5.2	TX_TCLK Frequency	Oscilloscope
	Test mode 1	97.5.3.3	Transmit Clock Jitter (MASTER/SLAVE)	
	Test mode 2	97.5.3.6/97.5.2	Transmit Clock Frequency (MASTER)	Oscilloscope
	Test mode 2	97.5.3.3	MDI Output Jitter (MASTER)	
	Test mode 4	97.5.3.2	Transmitter Distortion	Oscilloscope + AWG
	Slave Mode	97.7.2.1	MDI Return Loss	+ Vector Network Analyzer
	Test mode 5	97.5.3.4	PSD (Power Spectral Density)	Oscilloscope + Spectrum Analyzer (1GHz)
	Test mode 5	97.5.3.5	Transmitter Peak Differential** Output	Oscilloscope
	Test mode 6	97.5.3.1	Transmitter Output Droop	Oscilloscope (2.5GHz or better, 20Mpoints)

Required Tests for Compliance

100BASE-T1 LINK SEGMENT AND RECEIVER

	Target Specification	Parameter	Measurement Equipment
Link segment tests	**Definition for Communication Channel ver 2.0**	**5.1.1 Cable Test** CIDM, IL, RL, LCL, LCTL	4port Vector Network Analyzer with opt TDR is required. *Both differential reflection and transmission have to be measured*
		5.1.2 Connector Test CIDM, Intra Pair Skew, IL, RL, LCL, LCTL	
		5.1.3 Whole Communication Channel Test CIDM, IL, RL, LCL, LCTL	
		5.2.2 Connector Test for Alien Crosstalk ANEXT, AFEXT, ANEXTDC, AFEXTDC	
		5.2.3 Whole Communication Channel Test (4 around 1) PSANEXT, PSAACRF, ANEXTDC, AFEXTDC	

	Target Specification	Parameter
Receiver tests	IEEE802.3bw 2015	96.5.5.1 – Bit Error Rate Verification,…
	IEEE802.3bp 2016	97.5.4.1 – Bit Error Rate Verification,…

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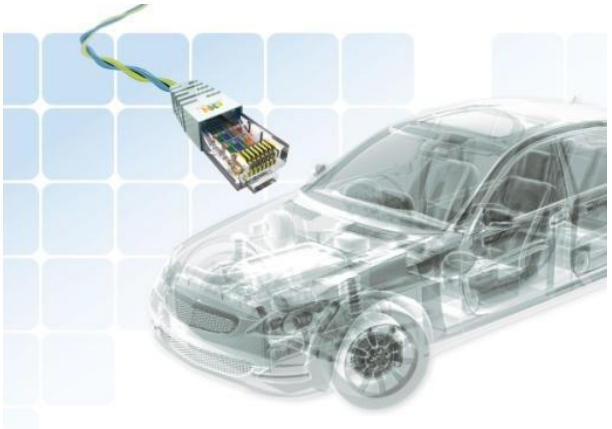
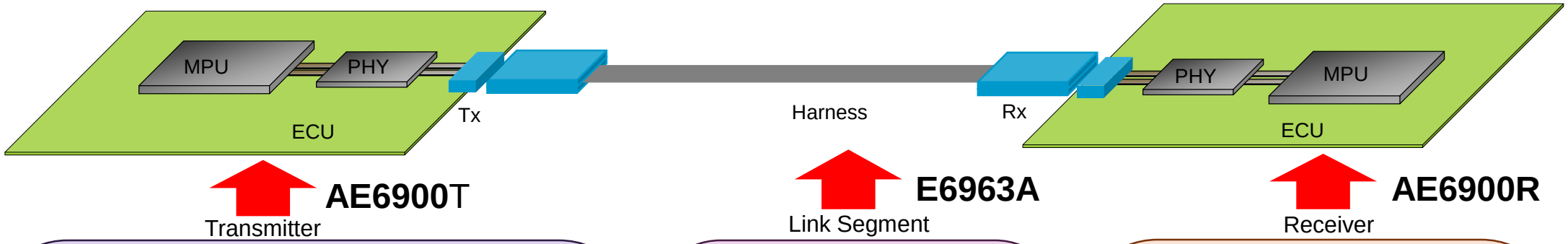


Reference: IEEE 802.3bw-2015,
IEEE 802.3bp-2016,
OABR TC1/TC8/TC12

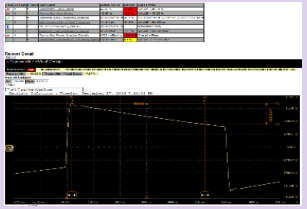
Physical Layer Validation -Transmit - LINK - Receiver

AE6900T/E6963A/AE6900R



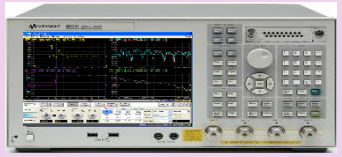
S series Scope
for Signal Quality

E5071C Network Analyzer
For Sdd11, Sdc11



AE6910T
Compliance Test Software

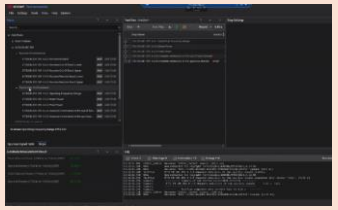
D9020AUTP 100Base-T1
Protocol Decode and Trigger



E5071C opt TDR

E6963A
Compliance Test Software

Gaussian Noise Generator



Rx Compliance Test Software
automated control of BER measurements

Automotive Ethernet Tx Solutions

AE6900T TX TEST

- What is it?

❖**Complete compliance software for both 1000BASE-T1 & 100BASE-T1 transmit tests**

❖**Industry-first Protocol trigger & decode software**

❖**All software, accessories and necessary hardware are structured under one model number.**

- Why Buy?

❖**To ensure compliance to 100BASE-T1,1000BASE-T1 IEEE standards and OABR ECU TC8**

❖Easy to follow test setup and configuration directions

❖**Pass/Fail report with margin analysis**

❖**Save time for other tasks**

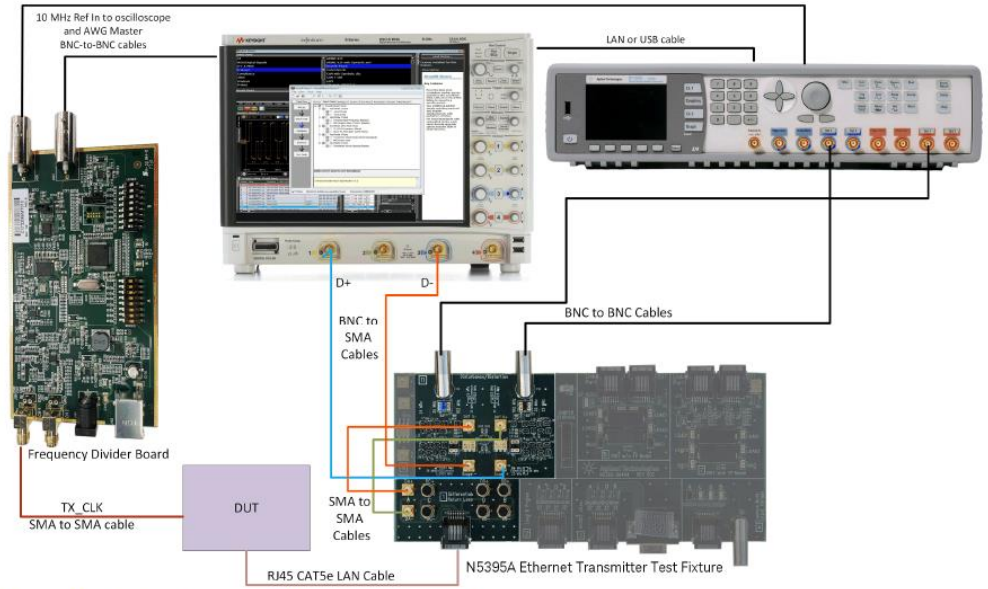


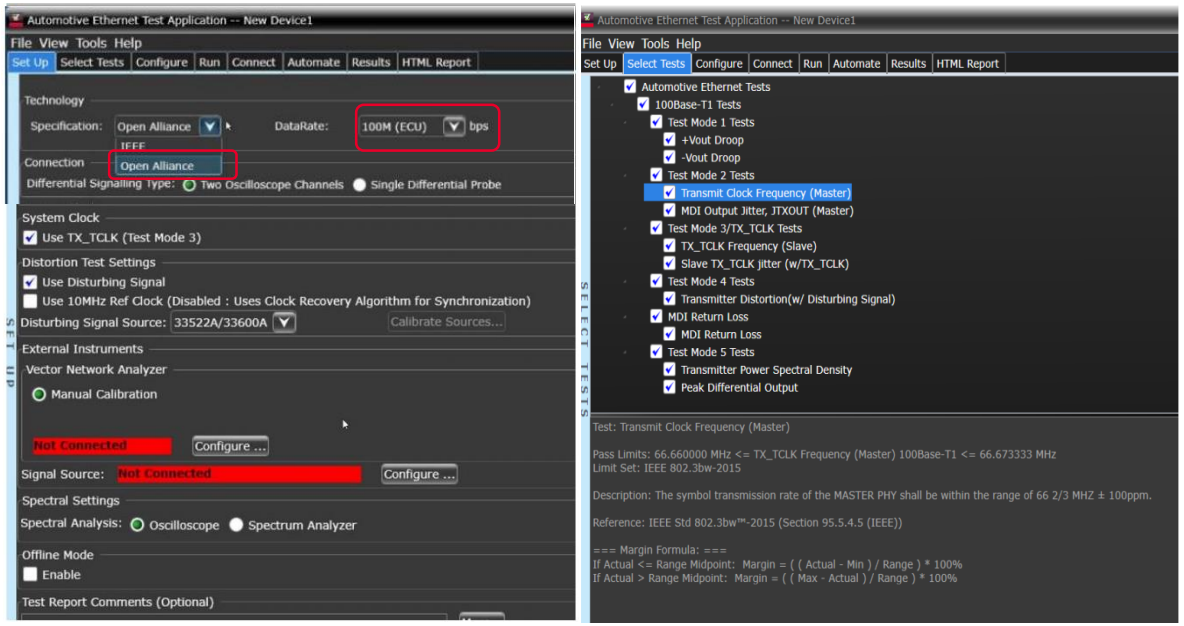
Figure 34 Test Setup for 10 MHz Frequency Reference

Hardware configurations are different for different tests

- Transmitter general setup = scope + compliance software + Ethernet test fixture
- Transmitter Power spectral Density test = scope + optional SA + Ethernet test fixture
- Transmitter Return loss test = scope + VNA + Ethernet test fixture
- Transmitter distortion test = scope + AWG + freq divider card + Ethernet test fixture

ECU Tx Compliance Test

- Maximum Transmitter Output Droop
  - Positive droop test
  - Negative droop test
- Transmitter Timing Jitter
  - Master jitter timing test
  - Slave jitter timing test
- Transmit Clock Frequency
  - Slave Transmit Clock Frequency
  - Master Transmit Clock Frequency
- Transmitter Distortion
  - *Added frequency divider*
- Transmitter Power Spectral Density
- MDI Return Loss
- MDI Mode Conversion
- MDI Common Mode Emission

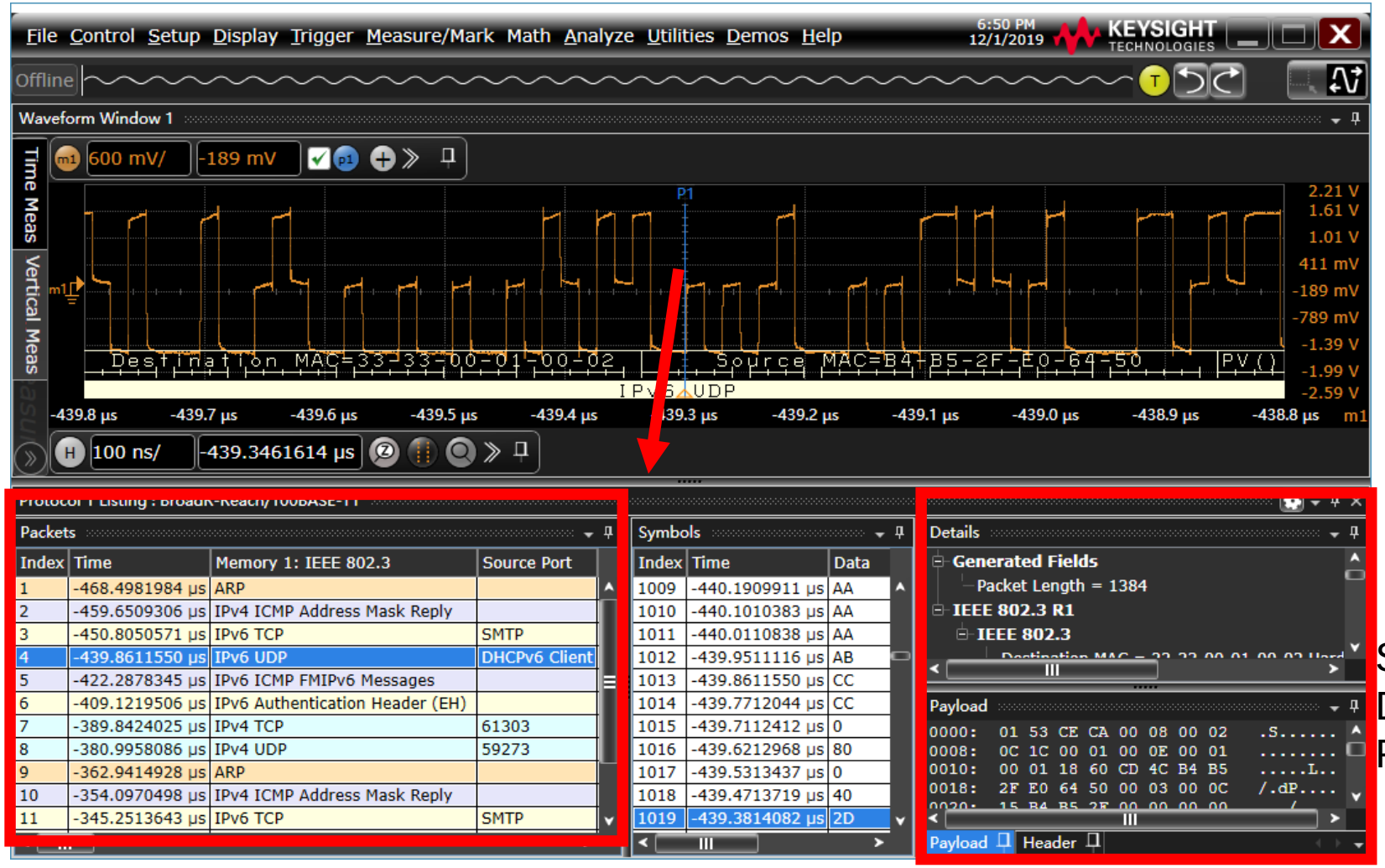


Measurement equipment:

- **Oscilloscope (1GHz or better, 20Mpoints)**
- **DSOS104A or better**

D9020AUTP 100Base-T1 Protocol Decoding and Trigger Software

Blue marker in the Waveform window that time correlates the waveform with the Packets and Symbols Listing

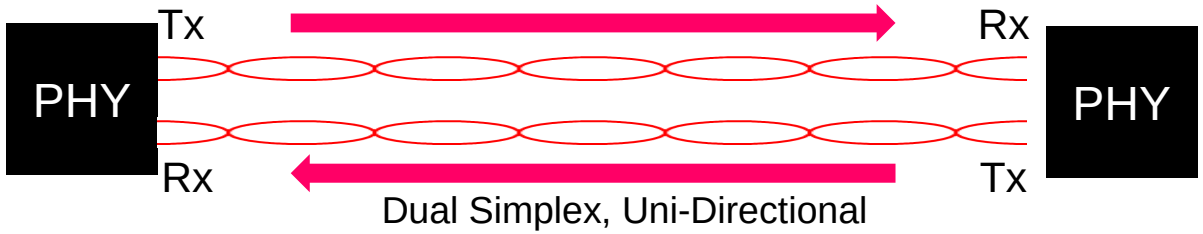


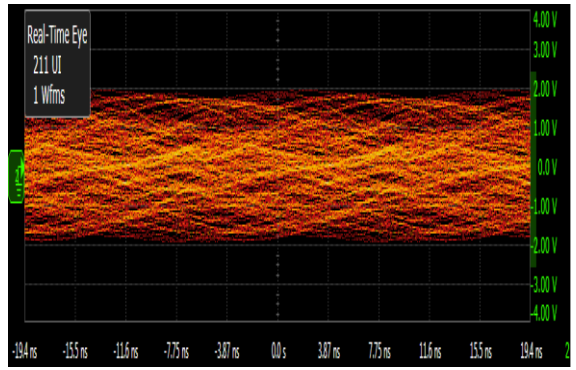
Selected Packet Details Payload/Header

Bidirectional signal

CREATES ISSUES FOR PROTOCOL AND ANALYSIS

Normal Ethernet 100BASE-TX



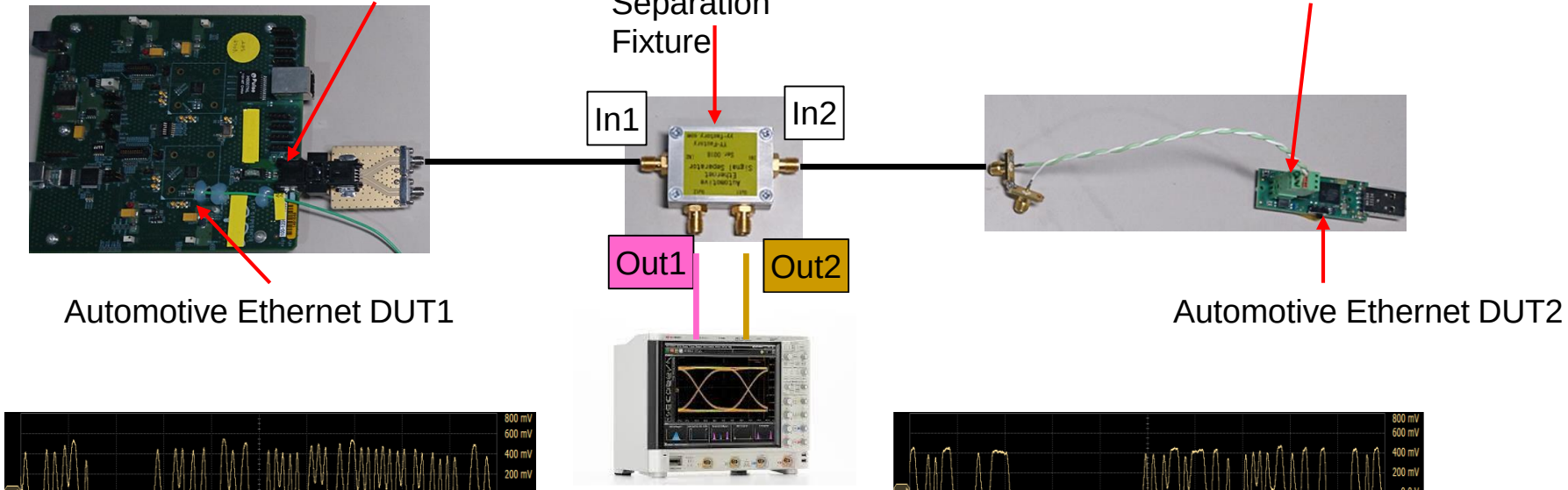


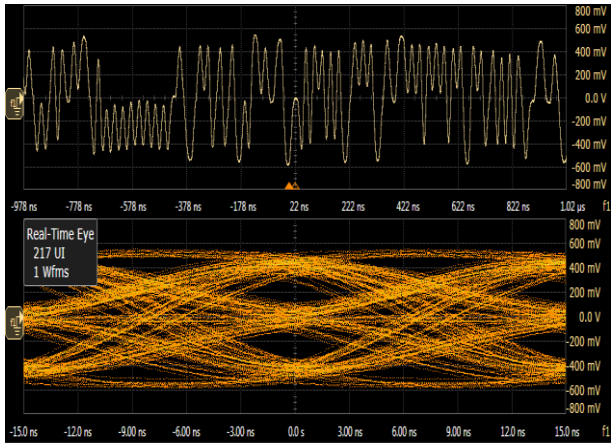
The Actual mixed waveform of DUT1 and DUT2.
Cannot be evaluated without separation.`

Automotive Ethernet 100BASE-T1

Bidirectional Signal Method

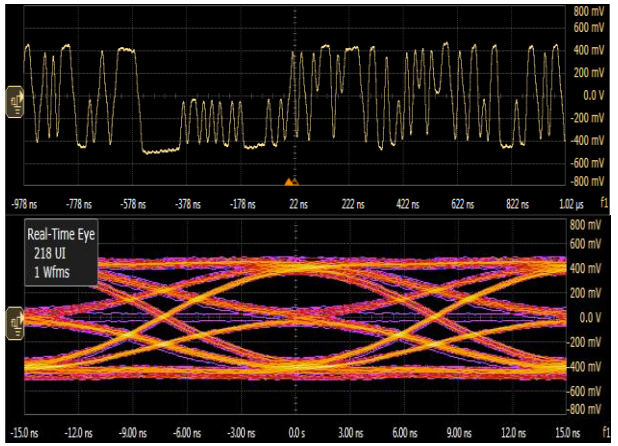
HARDWARE PLATFORM





Waveform and Eye Pattern of DUT1

（Out1 x TF11 + Out2×TF12）



Waveform and Eye Pattern of DUT2

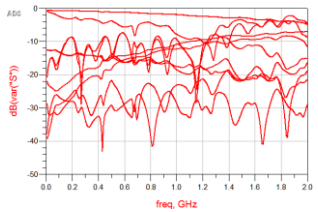
（Out2 x TF22 + Out1 x TF21）

DUT1 and DUT2 waveforms successfully separated

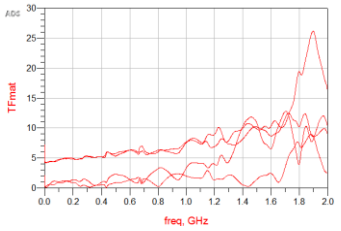
Bidirectional Signal Summary

MEASUREMENT AND ANALYSIS WITH FIXTURE +VNA+ADS+SCOPE

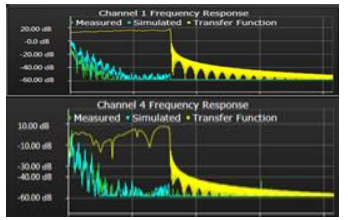
Separation Fixture



S-parameters of the Separation Fixture, measured with VNA



Transfer Functions for Separation calculated with ADS



Separated Waveform calculated with Infiniisim by applying the Transfer Functions

The S-Parameter and Transfer Function of the fixture are provided. But for a precise separation, you have better to calculate a new Transfer Function including the SMA cables used.

Mandotory Configuration

- **Automotive Ethernet Separation Fixture**
- **Infiniium Series Oscilloscope**
- **Infiniisim Waveform Simulation Tool**
- **SDA Eye Pattern Analysis Software**

Recommended Configuration

- **ENA Network Analyzer**
- **ADS Simulator**

Automotive Ethernet Test Solution

E6963A LINK SEGMENT TEST

What is it?

- ❖Industry-first automated test coverage for harness & connectors
- ❖Guided test setup and pass/fail report with margin analysis

Why Buy?

- ❖To ensure compliance to 100BASE-T1 Link segment tests
- ❖Save time from the manual calculation and extra work , configuration and testing up to 20 ports
- ❖Easy to follow test setup and configuration directions
- ❖Pass/Fail report with margin analysis - taking the manual error out

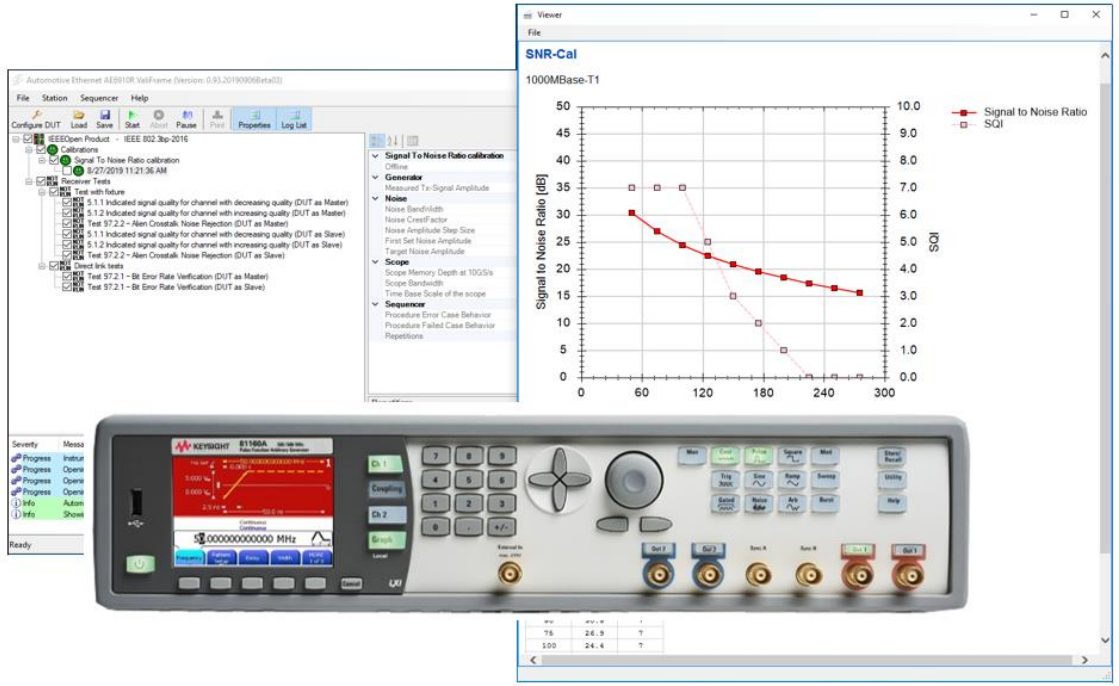
Hardware configuration

- Software runs on an ENA – E5071C

Automotive Ethernet Rx Solutions

AE6900R RX TEST

- **What is it?**
  - Complete compliance software 1000BASE-T1 receiver tests
  - Ethernet device as signal generator, noise generator
- **Why Buy?**
  - To ensure compliance to 100BASE-T1, 1000BASE-T1 IEEE standards
  - Easy to follow test setup and configuration directions
  - Low cost solution
  - Pass/Fail report with margin analysis
  - Save time for other tasks



KEYSIGHT
TECHNOLOGIES