車聯網時代之車載通訊的蛻變與挑戰
- 車用乙太網路測試

Rohde & Schwarz Taiwan Ltd.
Oscilloscope
Andy Lin

ROHDE&SCHWARZ
Make ideas real

AGENDA

- Automotive In-Vehicle Network trends
- Introduce to Automotive Ethernet
- Automotive Ethernet Test Requirement
  - Compliance Test
  - Automotive bus protocol Decode
  - EMI debugging
- Summary

AUTOMOTIVE TRENDS

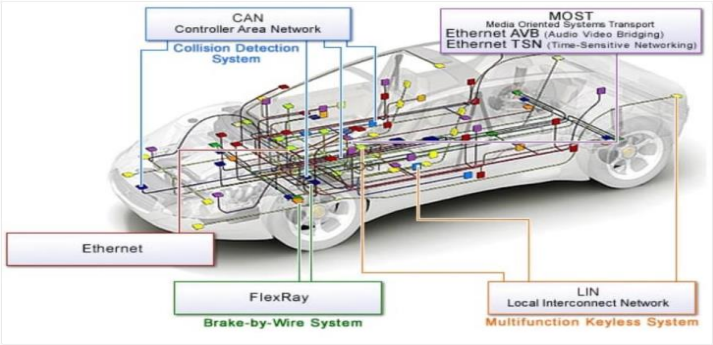
Autonomous Driving

Electric Cars

Connectivity

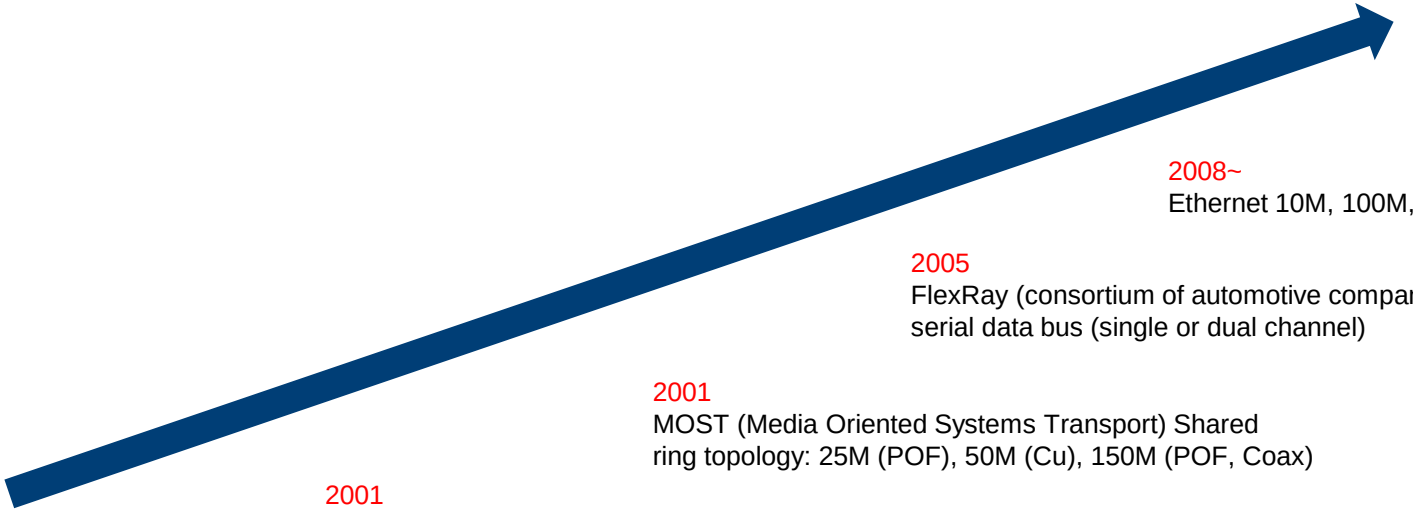
AUTOMOTIVE BUS

	LIN	CAN	FlexRay	MOST	Automotive Ethernet
Datarate	1-20kbps	125-1000kbps	10Mbps	25-150Mbps	10M-10Gbps
Phyical media	Single wire	Twisted pair wires	Twisted pair wires	Plastic Optical Fibers Unshielded Twisted Pair	Unshielded Twisted Pair
Network topology	Bus	Bus	Bus Star and combinations of Bus Star	Ring	Star
Application	LIN is a single master vehicale LAN protocol offering an cxcellent cost-to-performance ratio. It is used for applications such as actuator control based on switch or sensor input.	CAN is currently the standard protocol for vehicle LANs. It is used for the mail networks as well as the powertrain system, chassis system, and body system.	Flexray is a high-speed communication protocol that combines flexibility and excellent reliability. Technology based on Flexray is in active development both in Japan and oversea for a variety of applications, including next-generation X-by-wire systems and backbone systems.	MOST is a vehicle multimedia network standard that enables transfer and control of high-quality audio, video, and data. It was established by MOST cooperation, and organization with leading carmakers and equipment manufactures, as its members, and is designed to simplify connection of multimedia devices in vehichles.	Ethernet has gained attention as a protocol for fault diagnostics via electronic control units connecting system engine, chassis, and body systems to the network.



Source : Renesas

AUTOMOTIVE BUS EVOLUTION



2008~
Ethernet 10M, 100M, 1G, 2.5/5/10G, & 10G+

2005
FlexRay (consortium of automotive companies) 10M serial data bus (single or dual channel)

2001
MOST (Media Oriented Systems Transport) Shared ring topology: 25M (POF), 50M (Cu), 150M (POF, Coax)

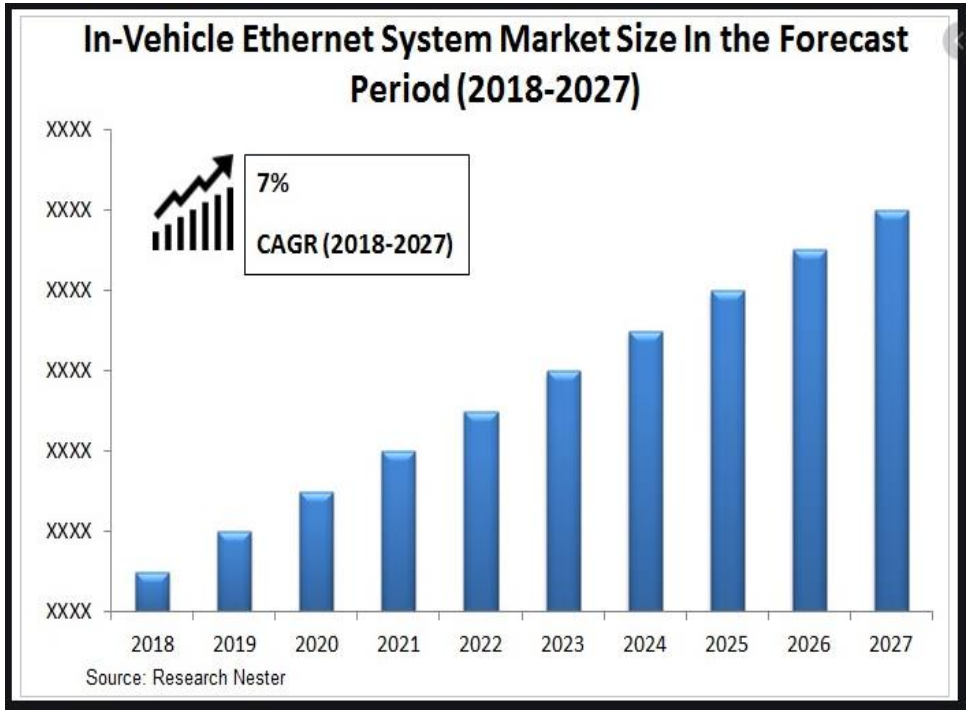
2001
LVDS (Low-voltage differential signaling) / SerDes (Serializer / De-serializer) Point-to-point links (1-12G) for cameras and displays

1991
CAN (Controller Area Network) (500K - 2M)
Low-speed serial data bus (<1K)

AUTOMOTIVE ETHERNET MARKET SIZE

- The global automotive Ethernet market size is expected to grow at a CAGR 7% during the forecast period (2018-2027)

- Growth factors for market include lower deployment cost, increase in production of vehicles, and rise in implementation of ADAS and infotainment system.



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ONGOING PROBLEMS WITH WIRED COMMUNICATION

- Much higher demand for high speed data communication
- Safe communication is needed (ASIL) for autonomous driving
- Security is needed
- 20-100 kg cable tree is too expensive
- Electric motors are coming
- EMI problems start to exist
- …

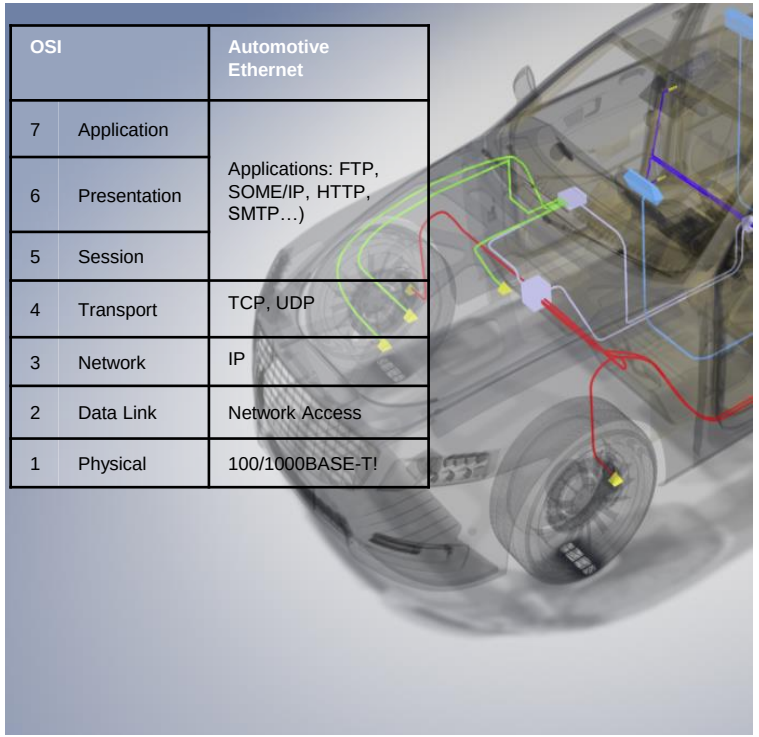
Possible Solutions:

- Ethernet (BroadR-Reach) will be widely used and rapidly adopted
- Introduce 48 V
- Measure, measure, measure……

OUR PERCEPTION OF THE AUTOMOTIVE ETHERNET MARKET

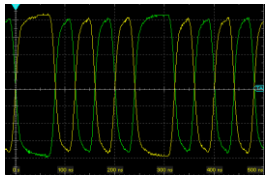
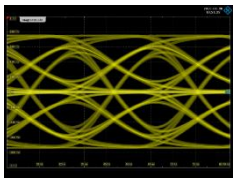
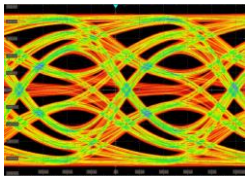
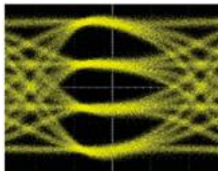
- Higher data throughput is required for ADAS like rear view or surround view camera systems
- Industry standards need to be integrated to save cost: 100BASE-T1 instead of MOST
- Reuse of TCP/IP in different application (flashing, camera, smart antennas) helps to reduce complexity
- Ethernet standards like Audio Video-Bridging, Time Sensitive Networks enable new applications
- Unshielded Twisted Pair cabling to save cost

OSI		Automotive Ethernet
7	Application	Applications: FTP, SOME/IP, HTTP, SMTP…)
6	Presentation	
5	Session	
4	Transport	TCP, UDP
3	Network	IP
2	Data Link	Network Access
1	Physical	100/1000BASE-T!



AUTOMOTIVE ETHERNET STANDARD

- Standards: 10Base-T1S(IEEE 802.3cg), 100Base-T1(IEEE 802.3bw), 1000Base-T1(IEEE 802.3bp), NGBase-T1(IEEE 802.3ch, In progress)
- Higher data throughput is required for ADAS like rear view or surround view camera systems
- Reduce bus technologies used to save cost. No MOST, FlexRay,…
- Unshielded Twisted Pair cabling to save cost

10BASE-T1S	100BASE-T1	1000BASE-T1	Multi-gig
802.3cg First PHY prototypes Multidrop PoDL	802.3bw Established & On the road	802.3bp 1 PHY released several in dev. SOP expected 2020	2.5/5/10GBASE-T1 STP cable 802.3ch spec expected 2020
			
12.5 MHz	66 MHz	750 MHz	1.4/2.8/5.6GHz

Symbol Rate

AUTOMOTIVE ETHERNET SUMMARY

	10Base-T1S	100Base-T1	1000Base-T1	NGBase-T1
Datarate	10Mbps	100Mbps	1Gbps	2.5/5/10Gbps
Symbol rate	12.5MHz	66.66MHz	750MHz	1.4/2.8/5.6GHz
Coding	4B/5B, Differential Manchester Encoding(DME)	PAM3	PAM3	PAM4
Voltage	1Vpp	2.2Vpp	1.3Vpp	1.3Vpp
Communication	Half Duplex or Full Duplex	Full Duplex	Full Duplex	Full Duplex
Configuration	Point to Point Multidrop	Point to Point	Point to Point	Point to Point
Cable length	15/25m	15m	15m	15m
Cable type	24-26 AWG	Unshielded twisted pair	Unshielded twisted pair	Unshielded twisted pair
Application	Audio, Parking ECU, Engine ECU, Body ECU..	Infotainment, Driver Assistance systems	Infotainment, Driver Assistance systems	Infotainment, Driver Assistance systems, ECU to ECU

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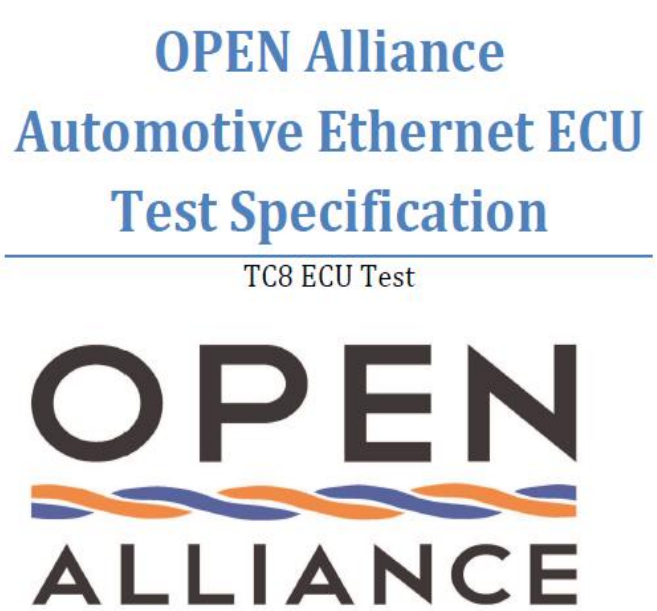
AUTOMOTIVE ETHERNET COMPLIANCE

10Base-T1S	100Base-T1	1000Base-T1	NGBase-T1
• PHY & Protocol IEEE 802.3cg • Open Alliance TC14	• PHY & Protocol IEEE 802.3bw • Open Alliance TC1	• PHY & Protocol IEEE 802.3bp • Open Alliance TC12	• PHY & Protocol IEEE 802.3ch (in progress) • Open Alliance TC in progress

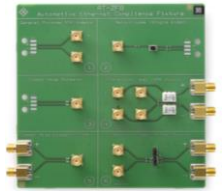
TC8 ECU Specification

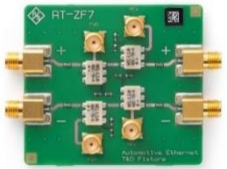
AUTOMOTIVE ETHERNET ECU TEST SPECIFICATION

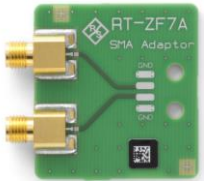
- **Transmitter** tests only !
- Transmitter electrical test include:
  - Transmitter outpout droop
  - Transmitter Timing Jitter in MASTER Mode
  - Transmit Clock Frequency
  - Transmitter Power Spectral Density (PSD)
  - Transmitter Distortion
  - MDI return Loss
  - MDI Mode conversion
  - MDI Common Mode emission



R&S COMPLIANCE SOLUTION





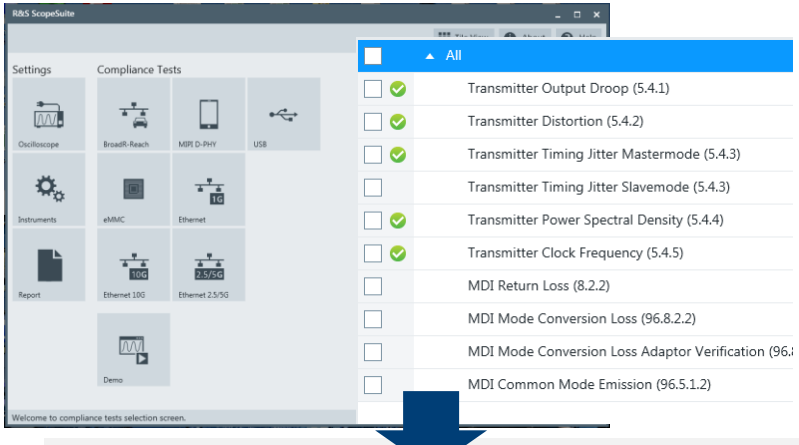


10Base T1S Recommended Equipment:
- R&S®RTO oscilloscope min. 600 MHz
- R&S®RTO-B4 OCXO
- R&S®RTO-K89 100Base-T1 Compliance SW
- R&S®RT-ZF7/8 Compliance Test Fixture
- R&S®RT-ZD10 Active differential probe
- R&S®RTO-B6 Arbitrary Waveform Generator
- R&S®ZND Vector Network Analyzer
- R&S®ZND-K5

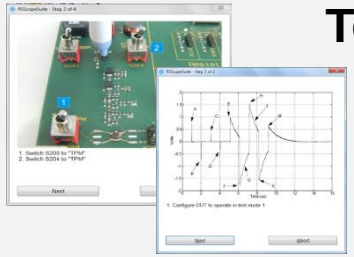
100Base T1 Recommended Equipment:
- R&S®RTO oscilloscope min. 600 MHz
- R&S®RTO-B4 OCXO
- R&S®RTO-K24 100Base-T1 Compliance SW
- R&S®RT-ZF7/8 Compliance Test Fixture
- R&S®RT-ZF3 Frequency Converter
- R&S®RT-ZD10 Active differential probe
- R&S®RTO-B6 Arbitrary Waveform Generator
- R&S®ZND Vector Network Analyzer
- R&S®ZND-K5

1000Base T1 Recommended Equipment:
- R&S®RTO oscilloscope min. 2 GHz
- R&S®RTO-B4 OCXO
- R&S®RTO-K87 1000Base-T1 Compliance SW
- R&S®RT-ZF7/8 Compliance Test Fixture
- R&S®RT-ZF6 Frequency Converter
- R&S®RT-ZD30 Active differential probe
- R&S®RTO-B6 Arbitrary Waveform Generator
- R&S®ZND Vector Network Analyzer
- R&S®ZND-K5

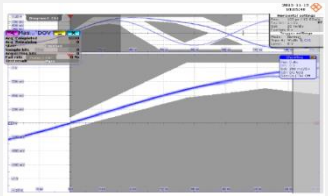
R&S COMPLIANCE SOLUTION



Test



Guided steps



Auto measurements

Pass-Fail results

	Test	Description	Run	Result	Detail
☐	Output Droop		1	✓	2/2
☐	Transmitter Distortion No TX_TCLK No Disturber		1	✓	11/11
☐	Transmitter Timing Jitter Mastermode		1	✓	1/1
☐	Power Spectral Density		1	✗	0/1
☐	Power Spectral Density		2	✓	1/1
☐	Transmitter Clock Frequency		1	✓	1/1

Report

- Screenshot
- Measurement result
- Pass-Fail result
- Test summary

TESTING EXAMPLE
- POWER SPECTRAL DENSITY

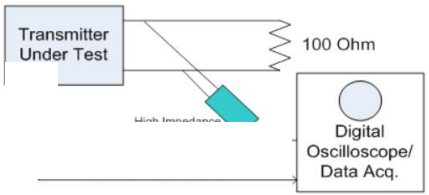
- Test Mode 5 (idle frames)

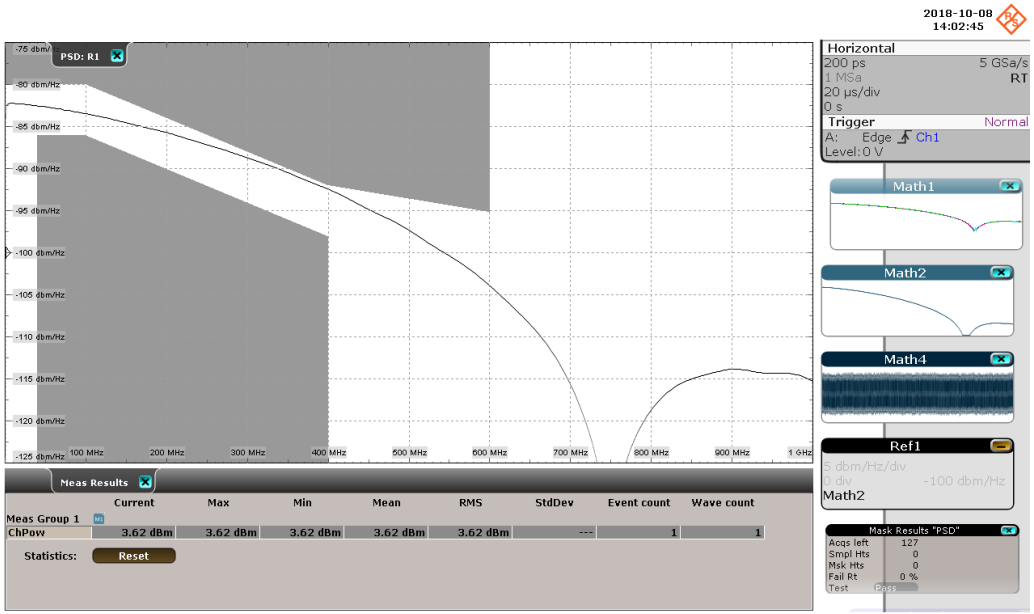
- Specification: limits

$$UpperPSD(f) = \begin{cases} -80 & \text{dBm/Hz} \quad 0 < f \le 100 \\ -76 - \frac{f}{25} & \text{dBm/Hz} \quad 100 < f \le 400 \\ -85.6 - \frac{f}{62.5} & \text{dBm/Hz} \quad 400 < f \le 600 \end{cases}$$

$$LowerPSD(f) = \begin{cases} -86 & \text{dBm/Hz} \quad 40 < f \le 100 \\ -82 - \frac{f}{25} & \text{dBm/Hz} \quad 100 < f \le 400 \end{cases}$$

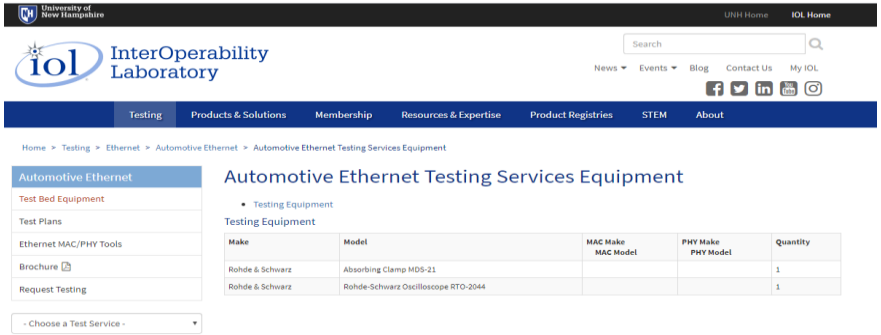
- Test Setup:



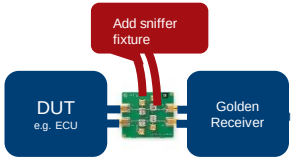


UNH-IOL

美國新罕布夏大學互通測試實驗室,專門為網路和儲存產業提供測試及標準相容性服務



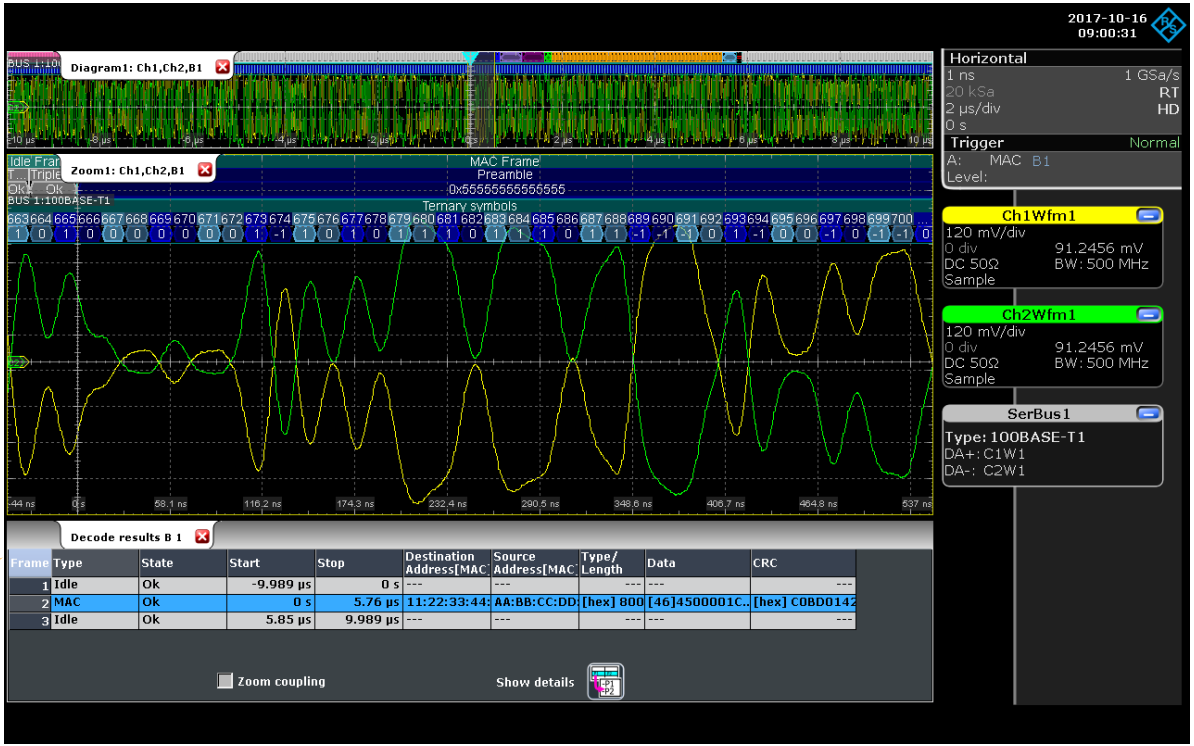
DEBUG AUTOMOTIVE ETHERNET WITH DECODER



Ternary signals

Real bus signal

Decode table with full information



AUTOMOTIVE ETHERNET BUS QUALITY WITH A DECODER

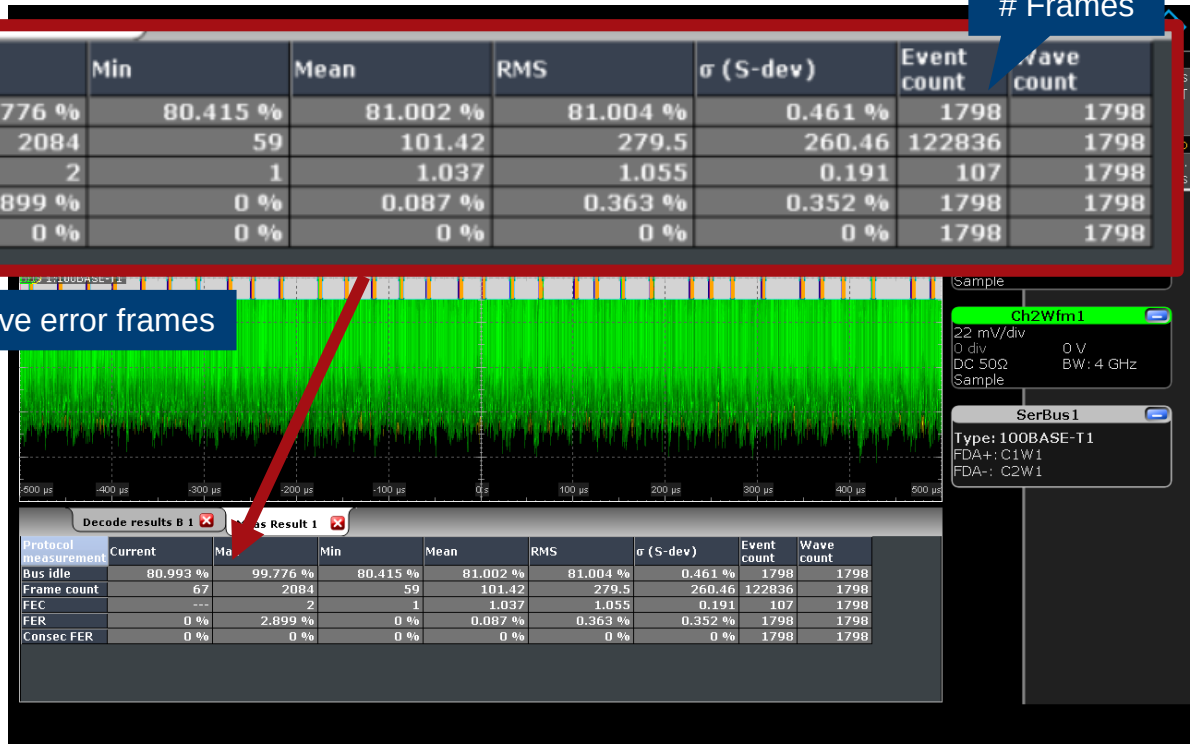
Bus Idle %

Frames

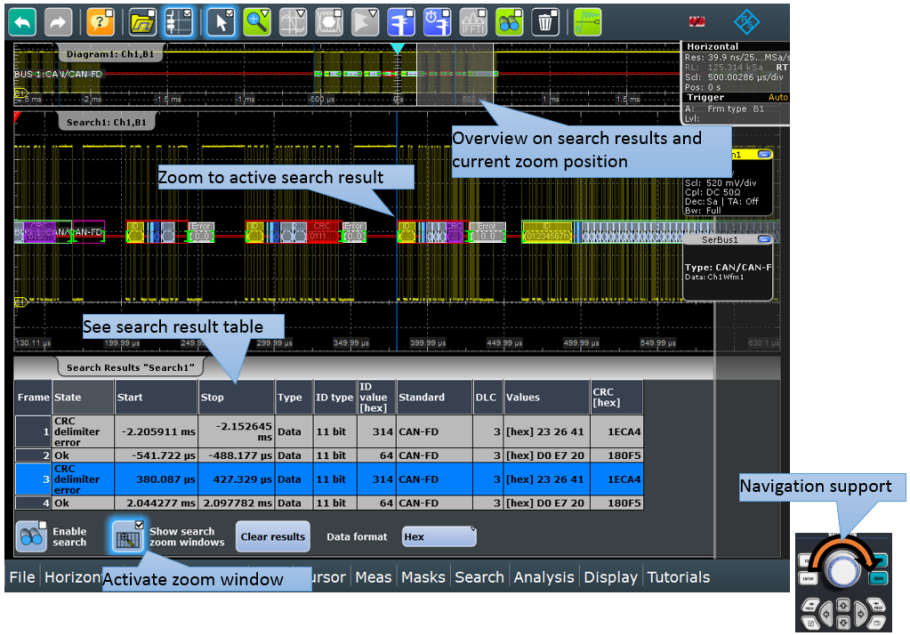
Protocol measurement	Current	Max	Min	Mean	RMS	σ (S-dev)	Event count	Wave count
Bus idle	80.993 %	99.776 %	80.415 %	81.002 %	81.004 %	0.461 %	1798	1798
Frame count	67	2084	59	101.42	279.5	260.46	122836	1798
FEC	---	2	1	1.037	1.055	0.191	107	1798
FER	0 %	2.899 %	0 %	0.087 %	0.363 %	0.352 %	1798	1798
Consec FER	0 %	0 %	0 %	0 %	0 %	0 %	1798	1798

Frame error rate

Rate of consecutive error frames



RTO AND RTE T&D OPTION
POWERFUL FUNCTIONALITY

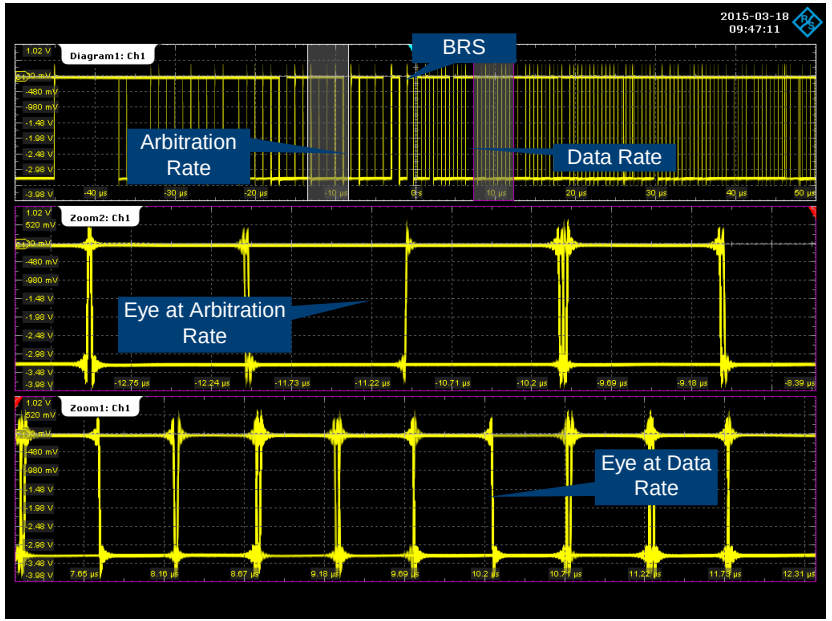


	Decode	Decode Table	Trigger	Label Support	Symb. T&D	Search	Autoset	Compliance
I2C	X	X	X	X		X		
UART/SPI	X	X	X					
LIN	X	X	X	X		X		
CAN/CAN-FD	X	X	X	X	X	X		
FlexRay	X	X	X	X		X		
SENT	X	X	X	X	X	X		
Audio (I2S)	X	X	X	X*				
MIL/ARINC	X	X	X	X		X		
Ethernet (10/100)	X	X		X		X		X
MIPI-RFFE	X	X	X	X		X		
Manchester/NRZ	X	X	X**					
8b/10b	X	X				X	X	
MDIO	X	X				X		
USB (1.0/1.1/2.0/HSIC)	X	X				X		X

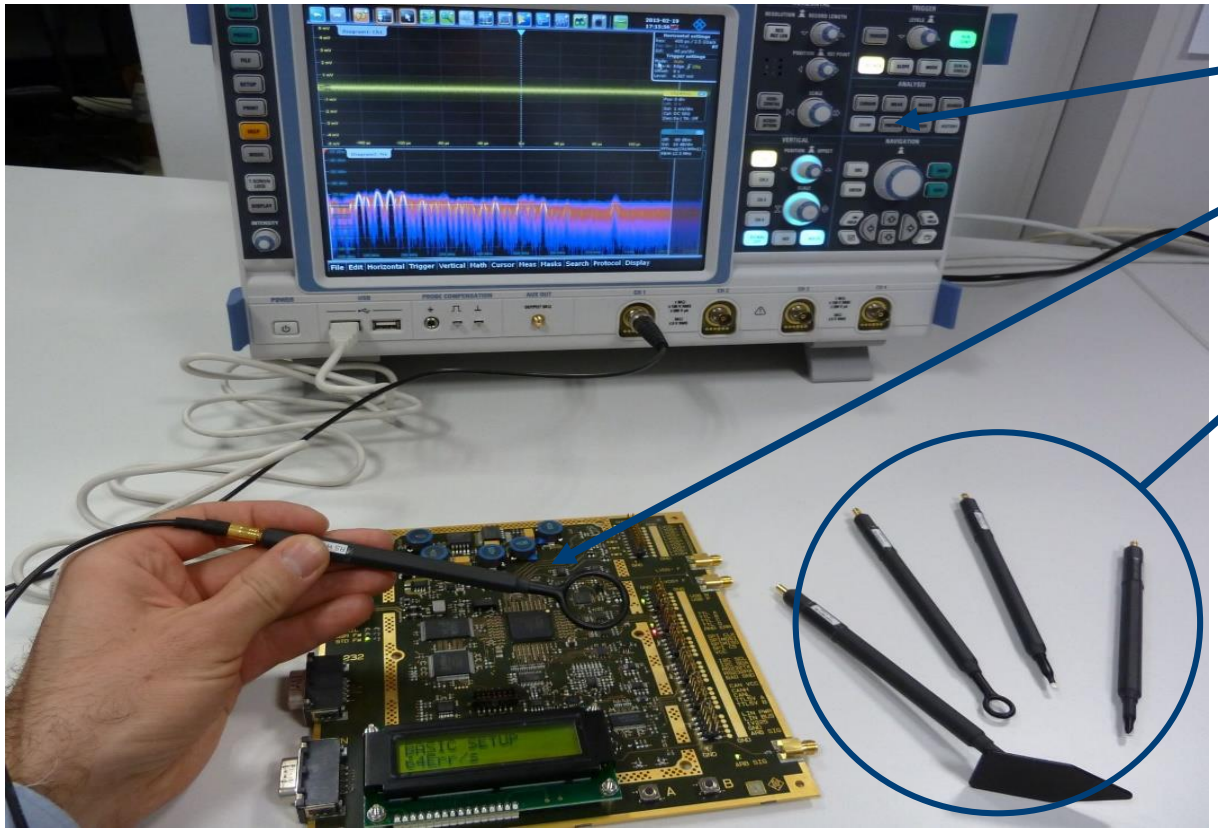
*: analog display support
**: serial pattern trigger support

SIGNAL INTEGRITY TESTING WITH EYE MEASUREMENT

- Eye measurement help to identify signal problems like runts or glitches
- CAN has 2 data rates- so a simple eye does not help
- CAN FD Eyes need to be separated between Arbitration Rate and Data Rate



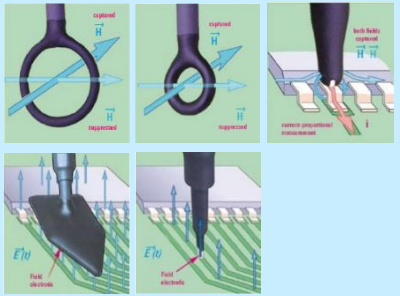
EMI DEBUGGING: EQUIPMENT



R&S ® RTO

Near-field sniffer Probes R&S ® HZ-15

E- and H-field



30 MHz – 1 GHz

Can be used down to 100 kHz

Optional:
R&S ® HZ-16
Preamplifier

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SUMMARY

- The next few years will see significant sustained growth in the extent and importance of Ethernet networking in vehicles
- Cover all of Automotive Ethernet compliance test specification
- Accurately Protocol decode & Bus performance analysis solution for Automotive Ethernet

Thank You

10 YEARS
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OSCILLOSCOPES

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Make ideas real