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IF IT'S NOT MIPI, IT'S NOT MOBILE

MIPI A-PHY Automotive Industry Forum

26 January 2022

Agenda

- Welcome
- Overview of MIPI A-PHY & v1.1 enhancements
  - MIPI Automotive SerDes Solutions (MASS)
  - A-PHY system modeling
  - Profile 2 architecture
  - Summary
  - Q&A on A-PHY v1.1
- Future A-PHY requirements: An interactive session
- Q&A on next-generation A-PHY
- Closing remarks

SPEAKERS

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Welcome

Peter Lefkin

MIPI Alliance Managing Director

MIPI A-PHY Overview

Raj Kumar Nagpal
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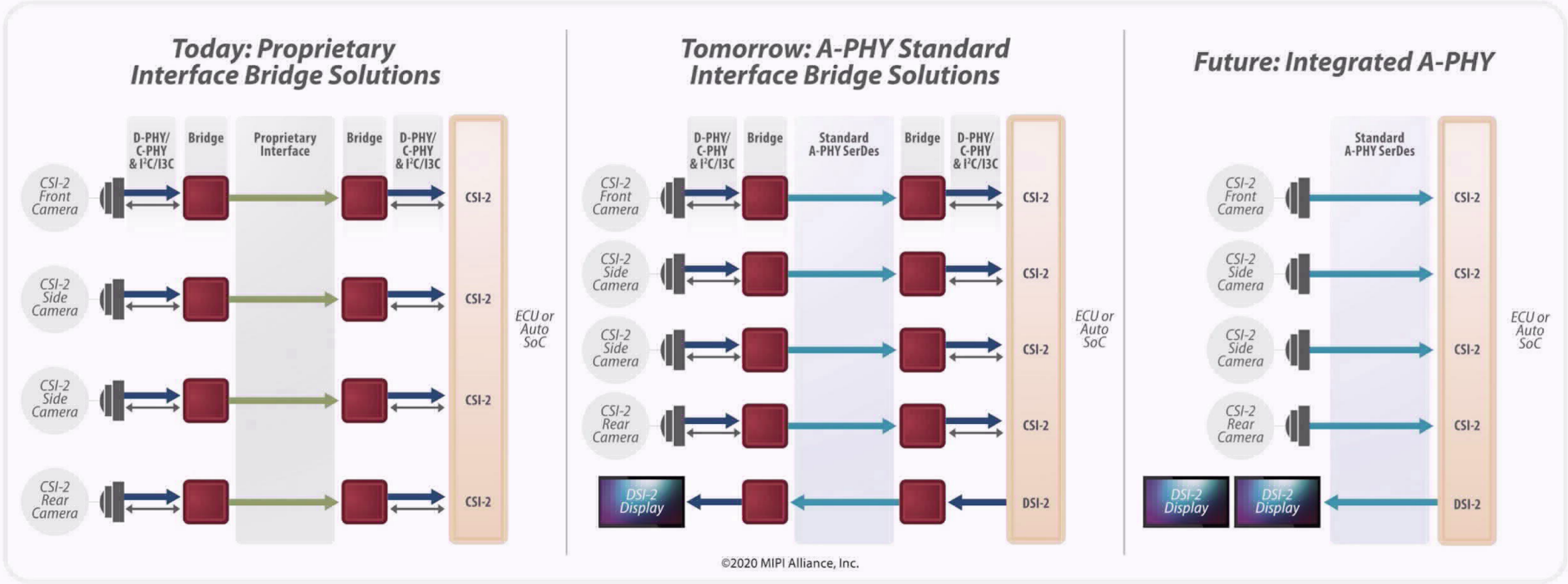
MIPI A-PHY Overview



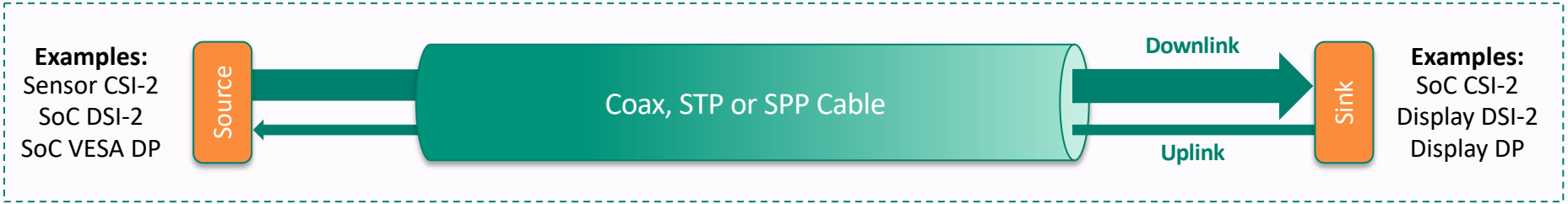
Lower cost through standardization and economies of scale

Lower cost/eBOM through integration

ECU: Electronic Control Unit **SoC:** System On Chip

MIPI A-PHY – Automotive Long-Reach PHY

The first industry-standard *long-reach* asymmetric SerDes physical layer specification targeted for ADAS/ADS surround sensor applications and infotainment display applications



A-PHY v1.0 offers:

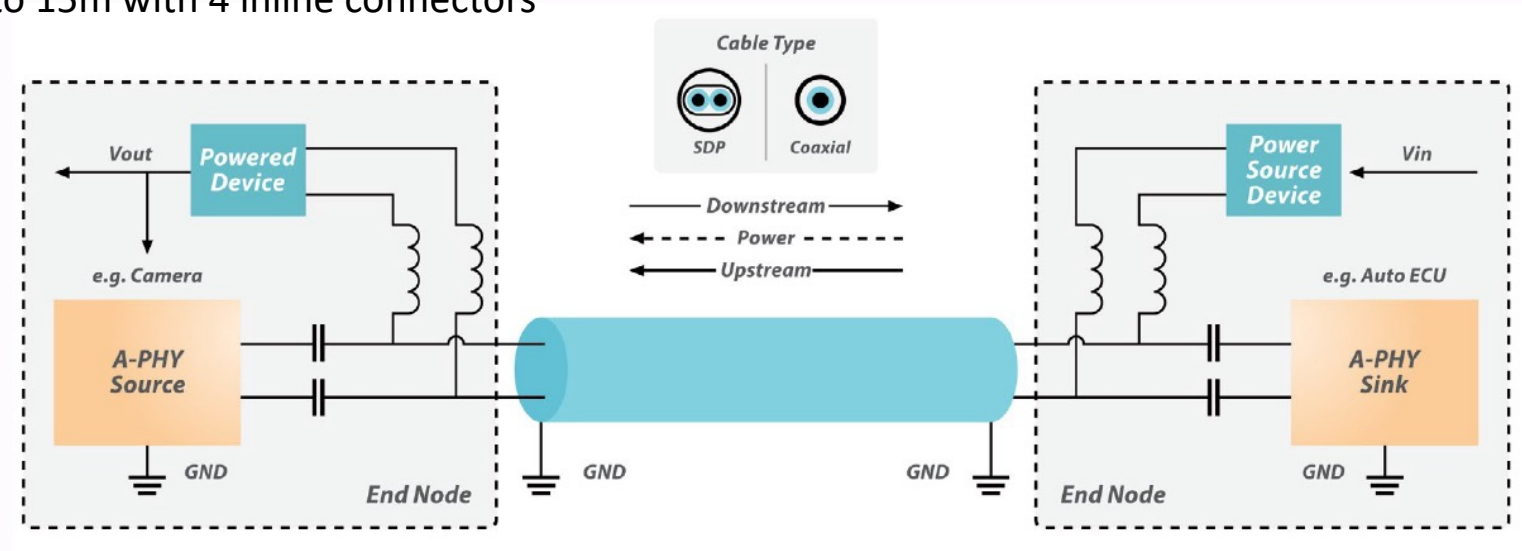
- Direct coupling to native CSI-2/DSI-2/DP-eDP protocols
- High performance of up to 16 Gbps over 10-15m
- High noise immunity, ultra low PER (< 10^{-19})
- Supports bridge-based and endpoint integration
- Support for automotive coax and STP\SPP channels
- Power over cable

PER: Packet Error Rate
STP: Shielded Twisted Pair
SPP: Shielded Parallel Pair

ADAS: Advanced Driver Assistance System
ADS: Autonomous Driving System
SoC: System On Chip

A-PHY Interconnect and PoC Support

- A-PHY is a single lane, point-to-point, serial communication technology
- Support for multiple cable types – SDP/Coax
- Power over cable supported
- Up to 15m with 4 inline connectors



PoC: Power over Cable
SDP: Shielded Differential Pair

A-PHY v1.0 Performance- and Immunity-Based Profiles

Performance Variance and Scalability

- A-PHY scales up the bandwidth without changing the cables and connectors by increasing the PAM level

Noise Immunity (EMC RF Ingress) Variance

- Different OEMs have different requirements
- MIPI-conducted EMC tests at independent labs evaluating noise levels and shielding effects degradation after mechanical stress and aging

Two Performance / Noise Immunity Profiles

- **Profile 1:** Optimized for low cost/power implementations for lower gears with lower noise immunity and target PER $<10^{-9}$
- **Profile 2:** Optimized for vehicle lifespan, link robustness for all gears with high noise immunity and target **PER $<10^{-19}$**

Interoperability

- Full inter-profile interoperability
- A-PHY device supporting Gear N (N could be 1–5) shall support all lower gears

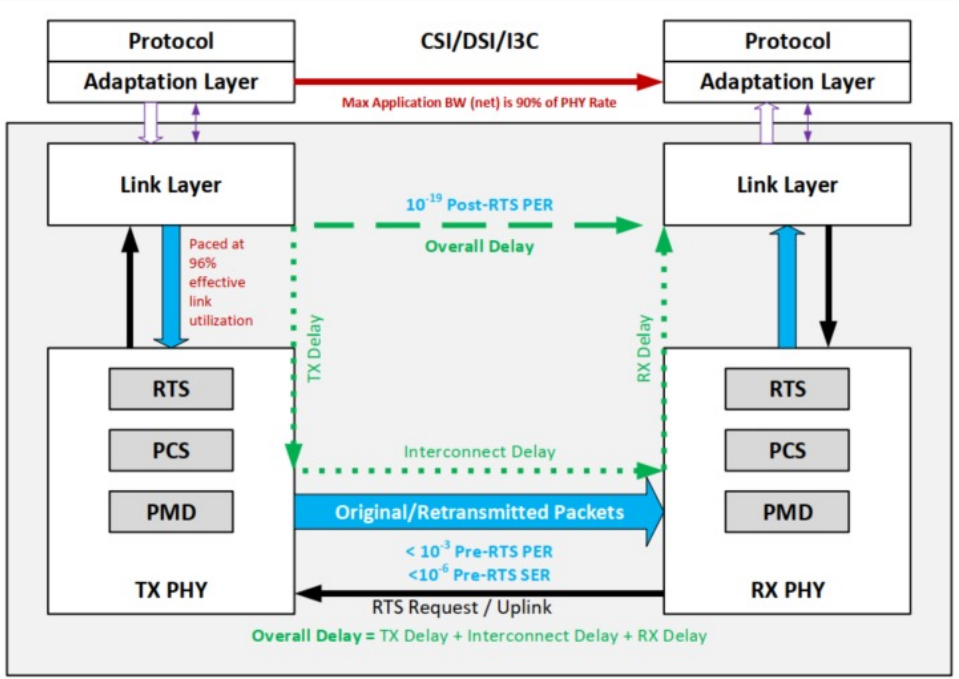
MIPI A-PHY v1.0 Performance

Downlink Gear Data Rate	*Modulation*	*Modulation Bandwidth* (GHz)	*Max Net App Data Rate* (Gbps)
G1 2 Gbps	NRZ-8B/10B	*1*	*1.5*
G2 4 Gbps	NRZ-8B/10B	*2*	*3*
G3 8 Gbps	PAM4	*2*	*7.2*
G4 12 Gbps	PAM8	*2*	*10.8*
G5 16 Gbps	PAM16	*2*	*14.4*
Uplink 100Mbps	NRZ-8B/10B	*0.05*	*55 Mbps*

What Makes MIPI A-PHY So Robust and Efficient?

RTS + NBIC

- **Time bounded local PHY-level retransmission**
  - Only within pre-defined “Overall Delay” (~6µs@G5)
  - Local: Transparent to the upper layers
  - Local: Happens within a single A-PHY hop
- **Dynamic modulation for retransmitted packets with better error resistance**
- **Highly resilient**
  - Overcomes large thousands symbols-long error bursts
  - Multiple 10s mV, instantly attacking NBI peaks
- **High reliability → PER < 10^{-19}**
- **Low overhead → 90% net data rate**

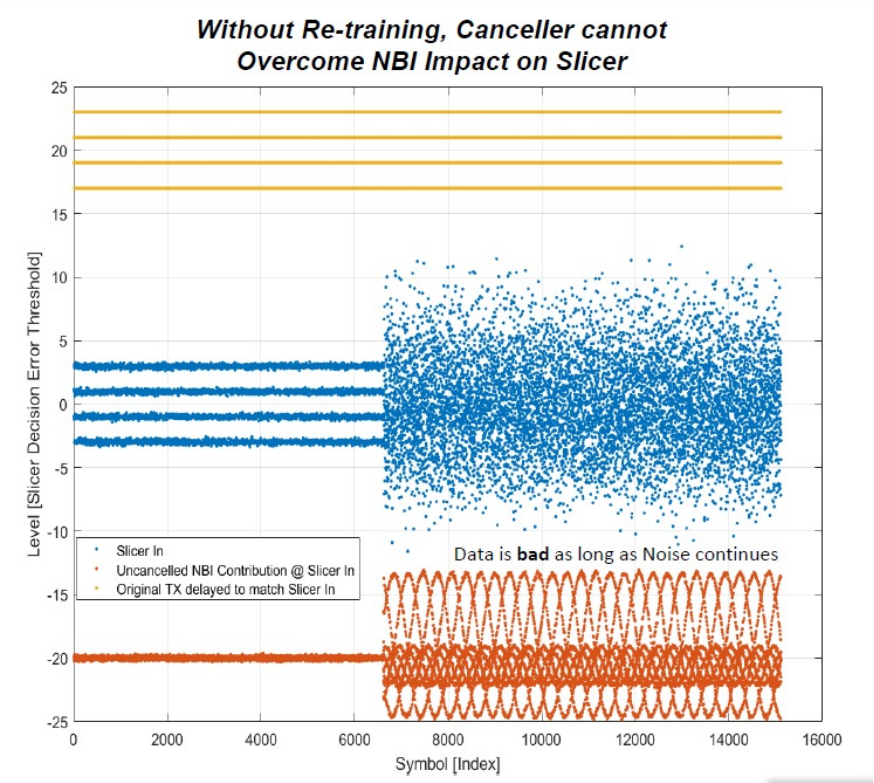


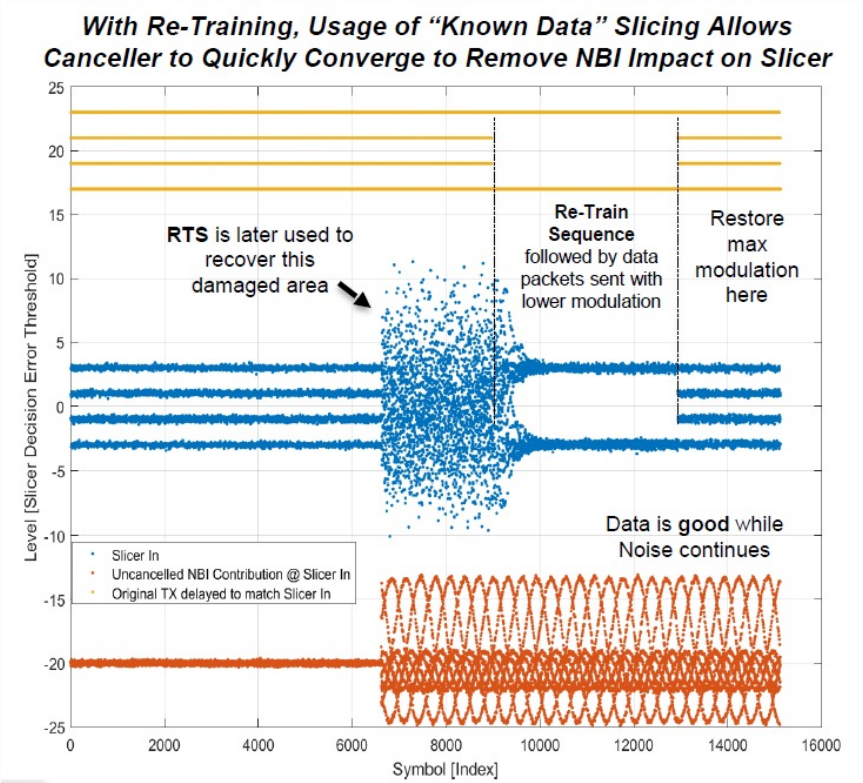
High throughput automotive links are EMI-limited — not AWGN limited

NBI: Narrow Band Interferences
NBIC: Narrow Band Interferences Canceller
PCS: Physical Coding Sub-Layer
PMD: Physical Media Dependent
RTS: Re-Transmission Sub-Layer
AWGN: Additive White Gaussian Noise

To Speed Up/Ensure JITC Convergence, JITC Re-training Is Used

Example: 4GBaud PAM4, 40mVpeak 3 Tone NBI, instant attack, without re-training





JITC: Just In Time Canceller

A-PHY v1.1

A-PHY v1.1 enhancements:

- 200 Mbps double rate uplink (U2)
- Optional PAM4 modes for G1 & G2
- Adds STQ cable support (see next slide)

Enhanced Performance Variance and Scalability

Expands PAM4 encoding to lower gears, reducing the operating signal rate of these gears and allowing implementation of A-PHY using lower cost legacy cables and connectors.

Same High Noise Immunity (EMC RF Ingress)

Supports same high noise immunity with an ultra-low packet error rate ($< 10^{-19}$) ➔ built for vehicle lifespan support

Interoperability and Compatibility

- A-PHY v1.1 backward compatible with v1.0
- A-PHY v1.0 forward compatible with v1.1

A-PHY guarantees full inter-profile interoperability; devices will support all the various gears below them

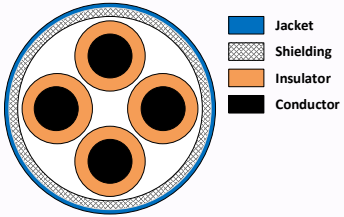
MIPI A-PHY Performance

A-PHY v1.1 enhancements shown in orange

Downlink Gear Data Rate	Modulation	Modulation Bandwidth (GHz)	Max Net App Data Rate (Gbps)
G1 2 Gbps	NRZ-8B/10B	1	1.5
	PAM4 (Optional)	0.5	1.8
G2 4 Gbps	NRZ-8B/10B	2	3
	PAM4 (Optional)	1	3.6
G3 8 Gbps	PAM4	2	7.2
G4 12 Gbps	PAM8	2	10.8
G5 16 Gbps	PAM16	2	14.4

Uplink Gear Data Rate	Modulation	Modulation Bandwidth (MHz)	Max Net App Data Rate (Mbps)
U1 100 Mbps	NRZ-8B/10B	50	55
U2 200 Mbps	PAM4-8B/10B	50	125

A-PHY v1.1 Adds Support for STQ Cables



- Supports Star Quad (STQ) shielded dual differential pair (i.e., 4 conductor) cables and high-speed data (HSD) connectors
- Referred to as ”Q-Port” within the A-PHY Working Group
- Efficient size, cost and weight compared to two separate shielded differential pair (SDP) cables

A-PHY v1.1 STQ Cable Configuration Examples

Example 1: Dual Downlink Configuration Up to 32 Gbps Downlink 100/200 Mbps Uplink	Source → STQ Cable → Pair#0: G5 – 16 Gbps Downlink & U1/2 Uplink; Pair#1: G5 - 16 Gbps Downlink → Sink
Example 2: Asymmetric Configuration Up to 16 Gbps Downlink Up to 4 Gbps Reverse Downlink	Source → STQ Cable → Pair#0: G5 – 16 Gbps Downlink; Pair#1: G2 – 4 Gbps Reverse Downlink → Sink
Example 3: Symmetric Configuration Up to 16 Gbps Downlink Up to 16 Gbps Reverse Downlink	Source → STQ Cable → Pair#0: G5 – 16 Gbps Downlink; Pair#1: G5 – 16 Gbps Reverse Downlink → Sink

MIPI Automotive SerDes Solutions (MASS)

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MIPI Automotive SerDes Solutions (MASS) in the Car

Electronic Control Unit (ECU)

- Advanced driver assistance system (ADAS) based on sensor feeds
- Produces display feeds

Sensors

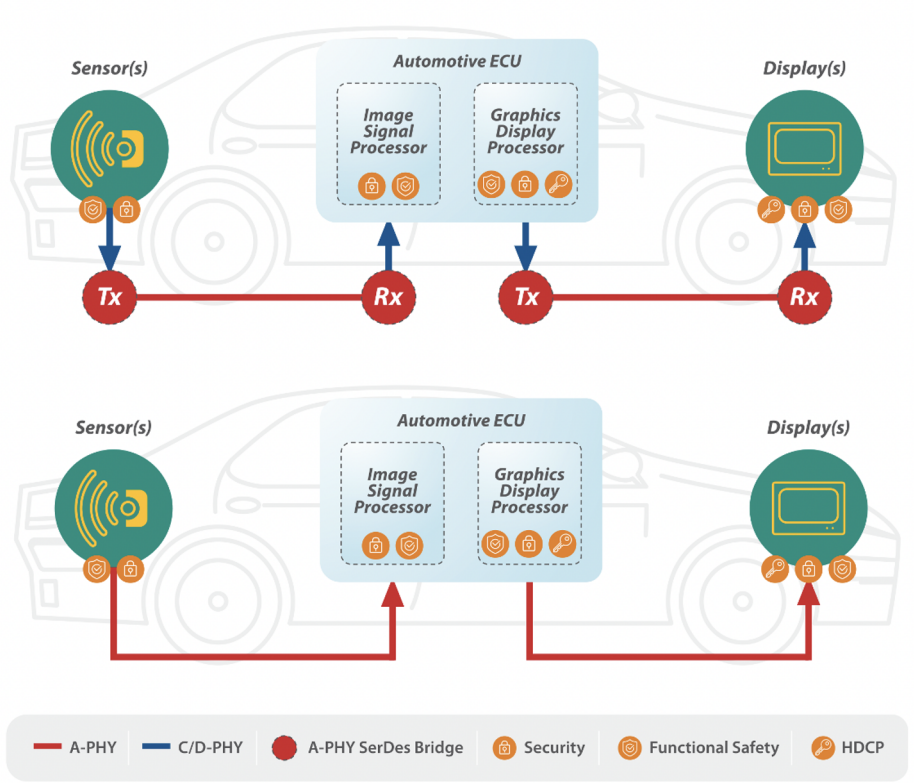
- Camera
- Lidar

Displays

- Dashboard
- Console
- Side-view mirrors
- Entertainment

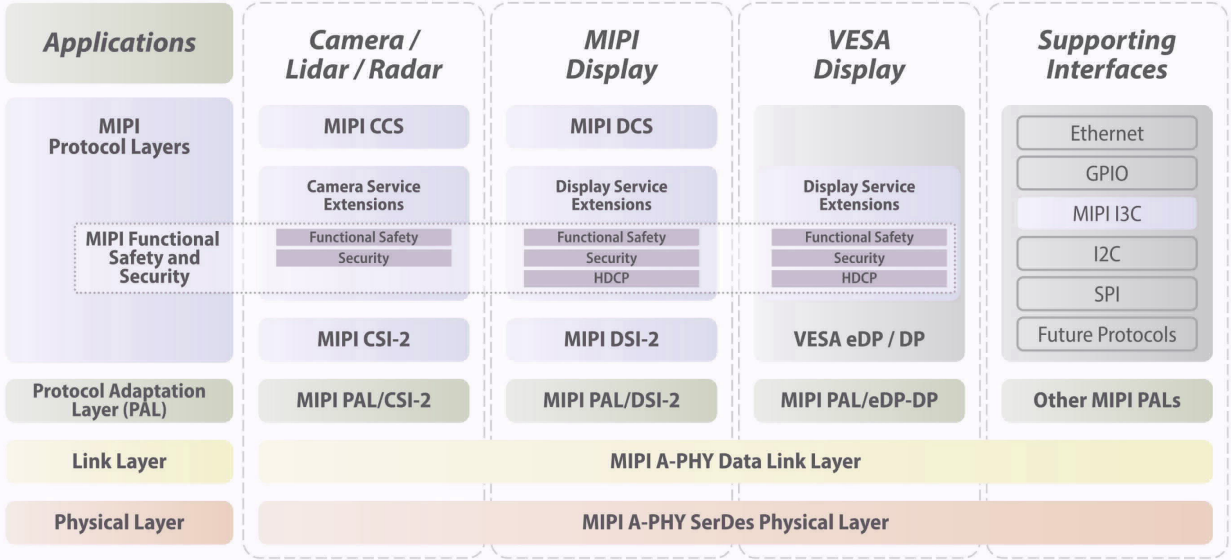
(Optional) A-PHY bridges

- Translates between short-range MIPI C-PHY / D-PHY & long-range MIPI A-PHY



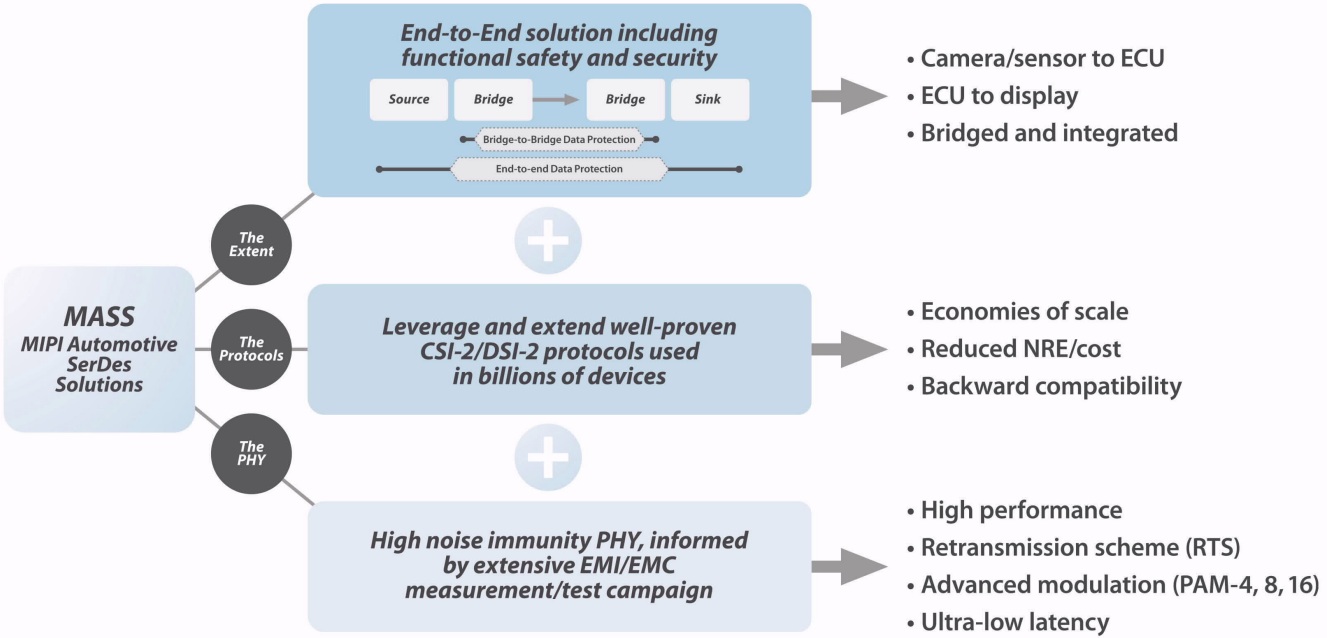
A-PHY is the Foundation of MASS

- Direct coupling to native MIPI protocols (i.e., CSI-2, DSI-2)
- End-to-end functional safety
- End-to-end security (WIP)
- Multiple supporting interfaces:
  - I2C
  - GPIO
  - Ethernet
  - MIPI I3C (WIP)
  - SPI (WIP)



MASS Guiding Principles

- **A-PHY**
  - Long-reach PHY (15m)
  - v1.0: 2-16 Gbps (Coax, SDP)
  - v1.1: up to 32Gbps (STQ)
- **PALs: Protocol Adaptation Layers**
  - MIPI CSI-2, DSI-2 and I3C
  - VESA eDP/DP
  - Ethernet, I2C, GPIO
- **Service extensions for end-to-end FuSa and Security**
  - CSE: Camera Service Extensions
  - DSE: Display Service Extensions
  - MIPI Security Specification



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MIPI A-PHY System Modeling

(Models are available to MIPI members)

Profile 1 ADS Model

4.1.1 End-To-End Validation Model

Figure 1 shows a complete end-to-end model used to validate the operation of Profile 1 solutions.

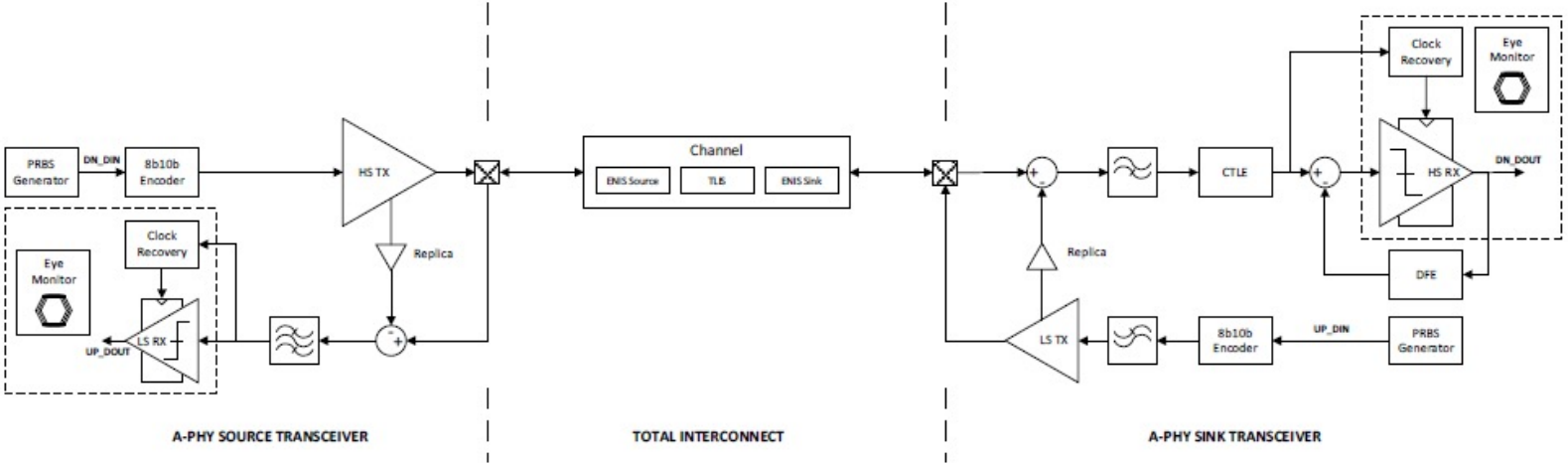


Figure 1 System Validation Model

4.1.3.1 ADS Model

The equivalent ADS Model for Downlink validation is shown in ***Figure 3***.

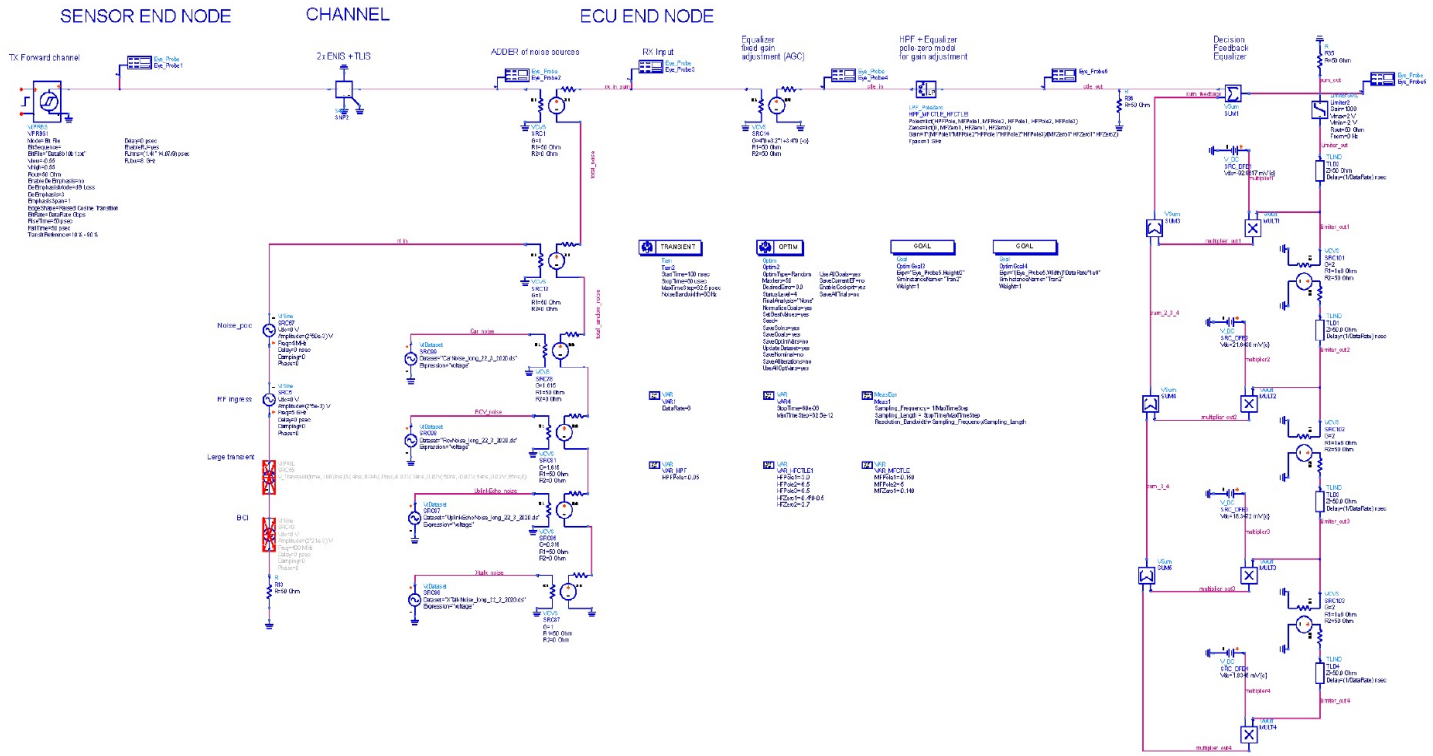
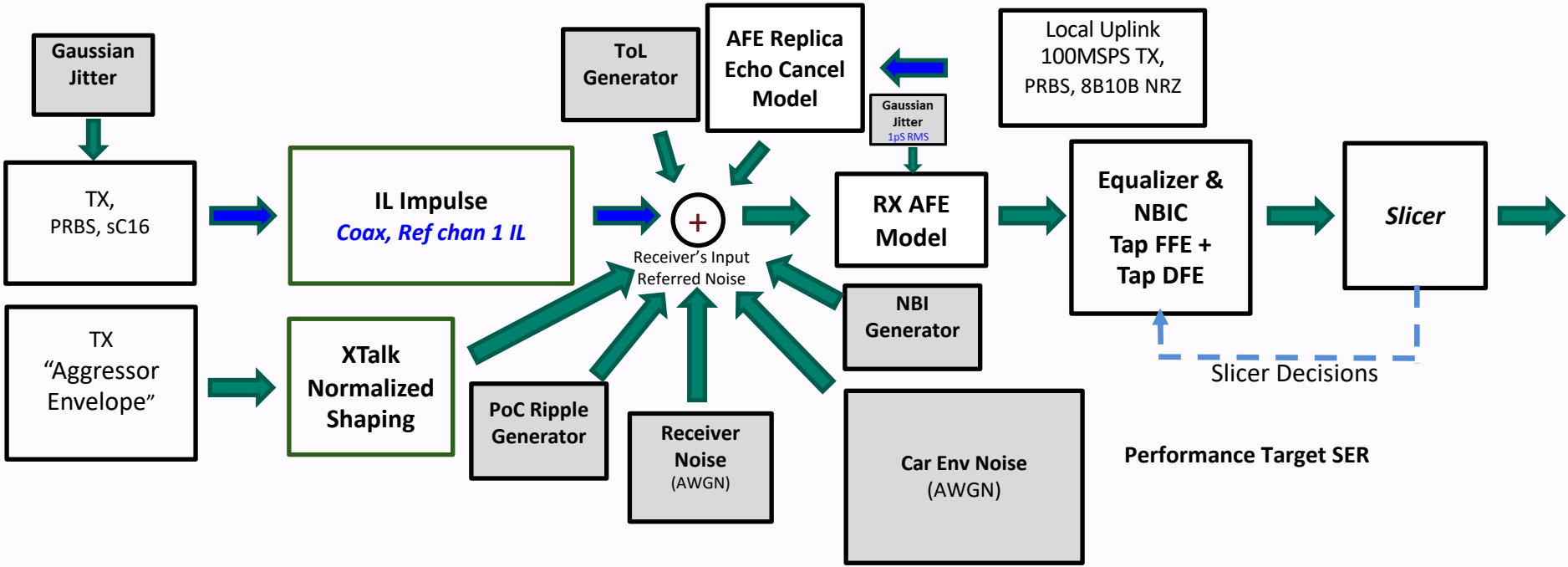


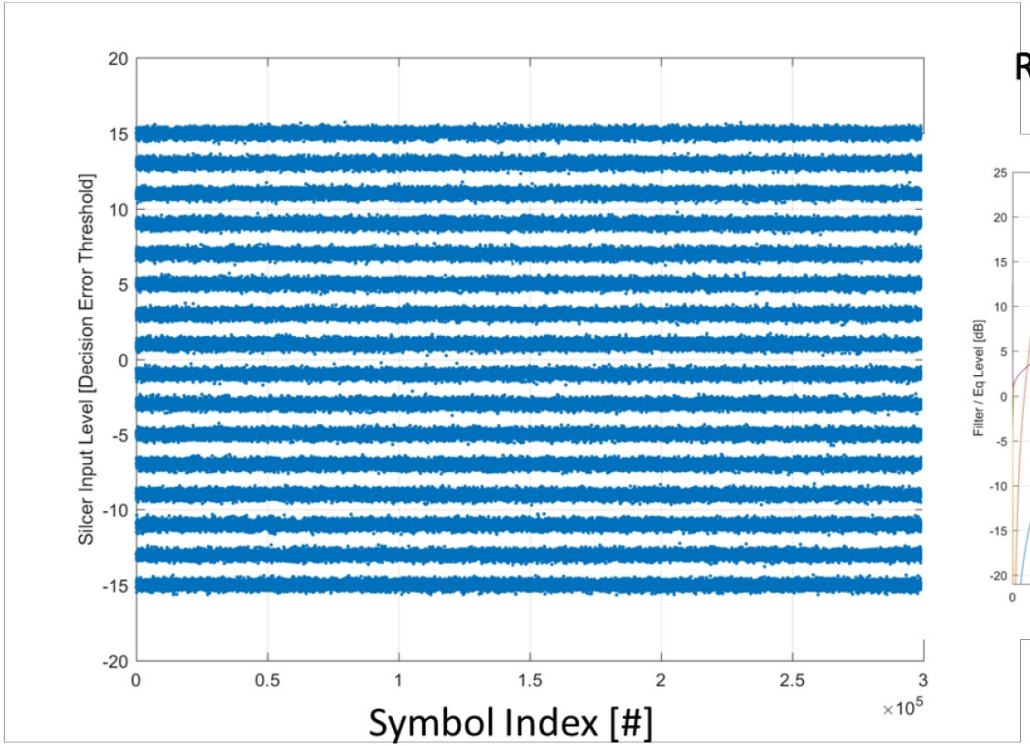
Figure 3 ADS Model for Downlink Validation, Gear 3 Example Setup

Profile 2 Architecture

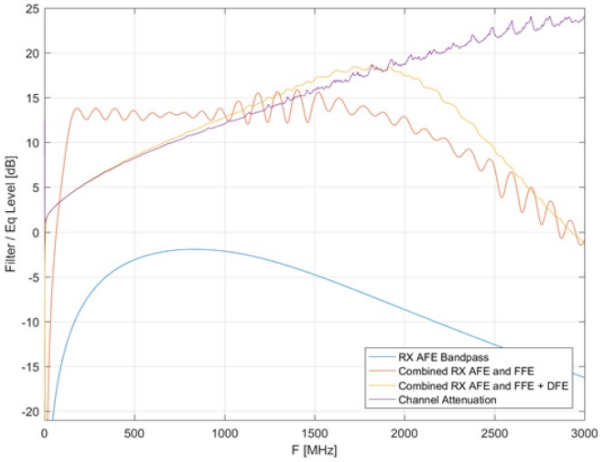
G5: sC16, 500mVpp Downlink, Time Domain Simulation

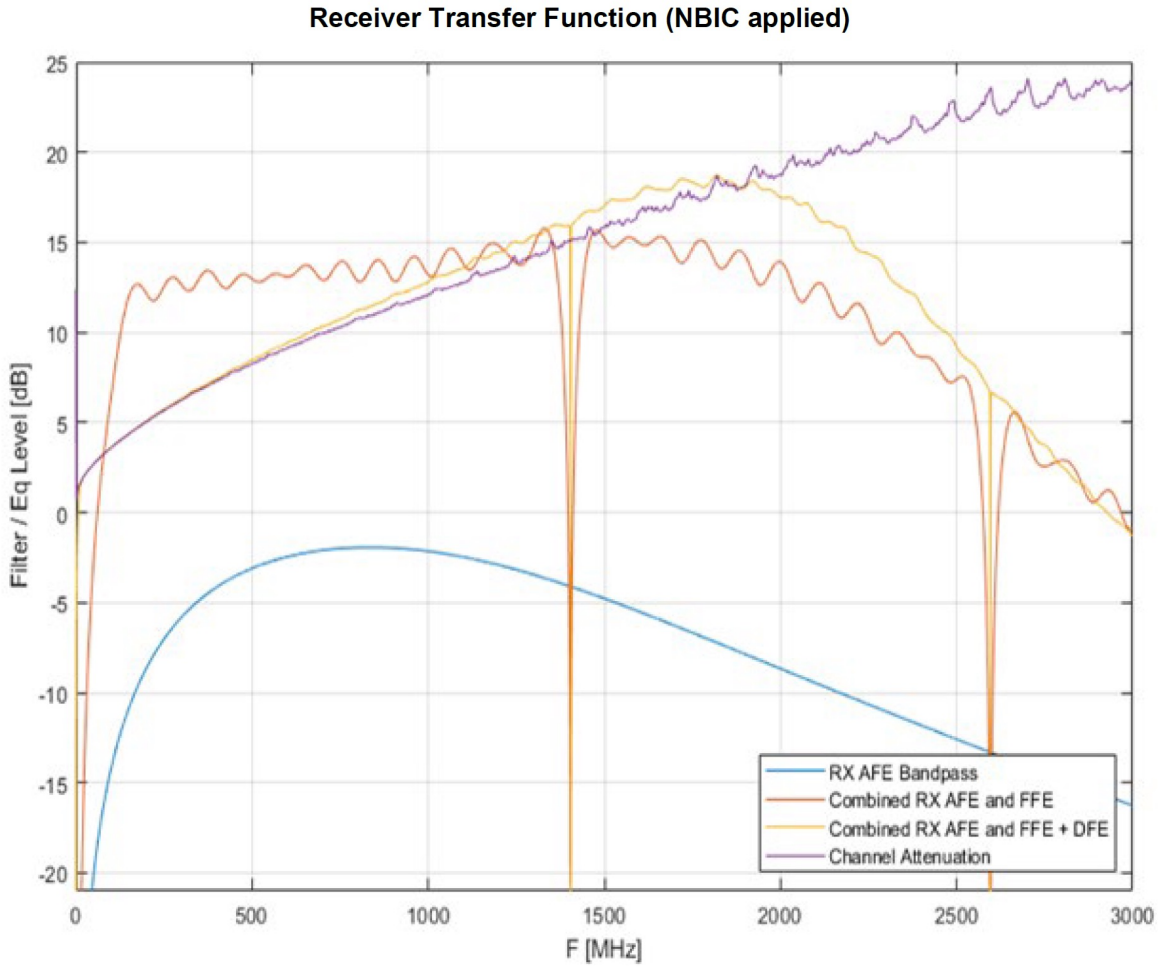


Step1: Pure RX Signal & Fixed Noises (wide band noises + PoC), Slicer Input After Equalizer, 44-Tap FFE, 84-Tap DFE (FFE and DFE are used for NBI Canceller)



RX AFE, FFE only Equalizer and 1/Channel Responses




Receiver Transfer Function (NBIC applied)
Filter / Eq Level [dB]
F [MHz]
25
20
15
10
5
0
-5
-10
-15
-20
0
500
1000
1500
2000
2500
3000
RX AFE Bandpass
Combined RX AFE and FFE
Combined RX AFE and FFE + DFE
Channel Attenuation

545

Summary

Summary

- **Established ecosystem with multiple vendors working on A-PHY compliant chipsets**
- **Clear and forward-looking roadmap and planning**
  - A-PHY v1.0 - Released in 2020
  - A-PHY v1.1 – Released in December 2021
  - A-PHY “Next” – Work has started in the MIPI A-PHY Working Group
  - New PALs – Expending support for command-and-control interfaces, such as SPI and Ethernet
- **Supporting multiple advanced use cases with clear advantages of an industry standard**
  - “Error-free” links
  - Seamless integration
  - Interoperability and forward compatibility

Q&A

Next-Generation A-PHY: An Interactive Session

Edo Cohen
Co-Chair, MIPI A-PHY Working Group
Valens Semiconductor

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A-PHY Next Generation – Main Goals

- **Specification update focused on emerging architecture and use cases**
  - Zonal architecture and SDV (software-defined vehicle)
  - Modern automotive cockpit environments
- **Maintain backward compatibility to A-PHY v1.0/v1.1**
  - A-PHY v1.0/v1.1 will be forward compatible with next A-PHY specification
- **No changes in the upper layers**
  - Easy migration with minimal impact at system level
- **Maintain high EMC resilience and low packet error rate**

A-PHY Next Generation – Main New Features

- **Double Downlink throughput**
  - Up to **32Gbps** (28.8Gbps net data rate) per single lane
- **Uplink throughput increase**
  - Up to 1.6Gbps (1.166Gbps net data rate)
- **Enhance interface support**
  - Add 1Gb Ethernet support (based on the new uplink BW)
  - Other interfaces may be added based on market demand
- **Expand A-PHY secure control**
  - Enable support of a secure A-PHY network

Downlink Gear Table (A-PHY v1.1)

Downlink Gear	Modulation	Modulation Bandwidth [GHz]	Data Rate [Gbps]	Max Net App Data Rate [Gbps]
G1	NRZ-8B/10B	1	2	1.5
	PAM4	0.5		1.8
G2	NRZ-8B/10B	2	4	3
	PAM4	1		3.6
G3	PAM4	2	8	7.2
	NRZ-8B/10B	4		6
G4	PAM8	2	12	10.8
G5	PAM16	2	16	14.4

Downlink Gear Table (A-PHY Next Generation)

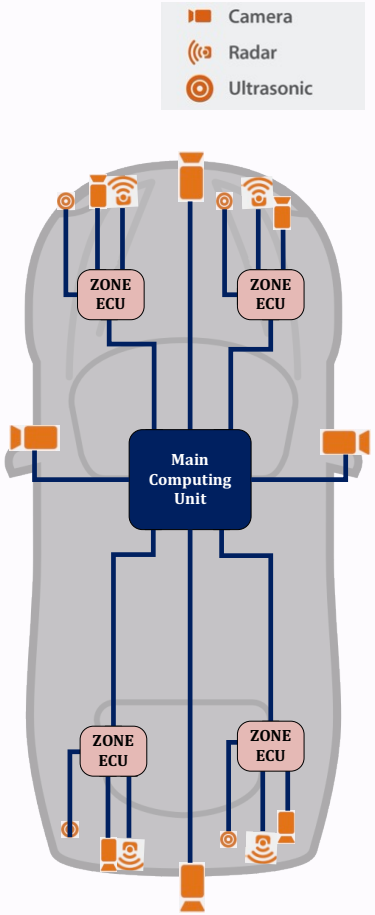
Downlink Gear	Modulation	Modulation Bandwidth [GHz]	Data Rate [Gbps]	Max Net App Data Rate [Gbps]
G1	NRZ-8B/10B	1	2	1.5
	PAM4	0.5		1.8
G2	NRZ-8B/10B	2	4	3
	PAM4	1		3.6
G3	PAM4	2	8	7.2
	NRZ-8B/10B	4		6
G4	PAM8	2	12	10.8
G5	PAM16	2	16	14.4
G6	PAM8	4	24	21.6
G7	PAM16	4	32	28.8

Uplink Gear Table (Initial Proposal)

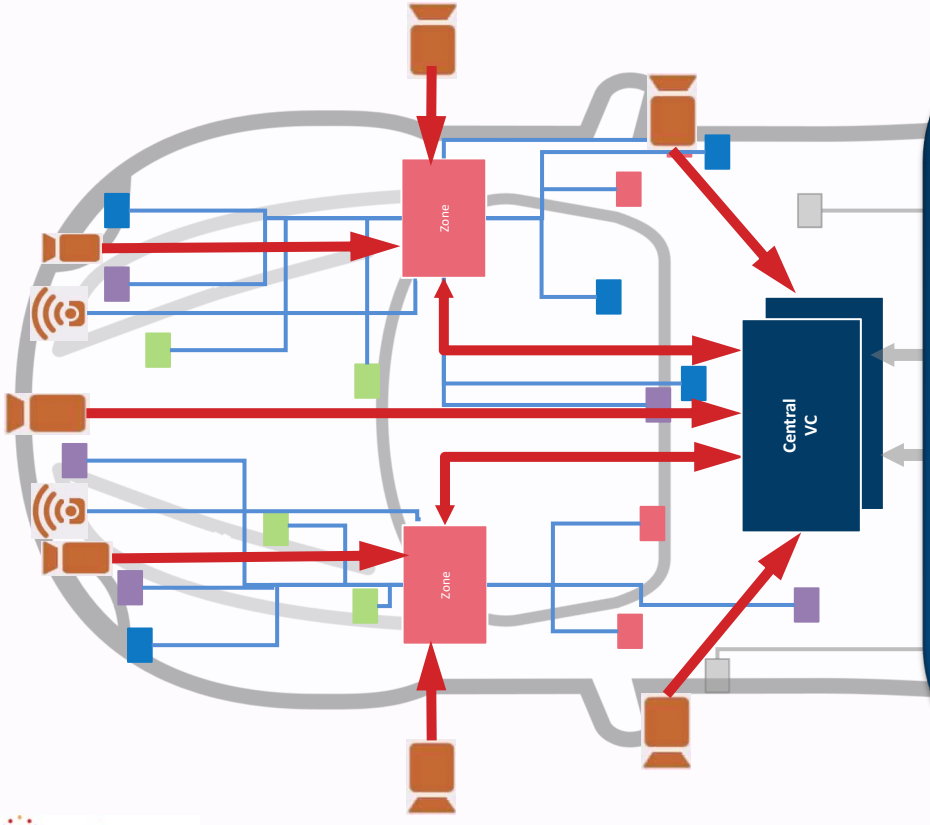
Uplink Gear	Modulation	Modulation Bandwidth [MHz]	Data Rate [Mbps]	Max Net App Data Rate [Mbps]
U1	NRZ-8B/10B	50	100	53
U2	PAM4-8B/10B	50	200	125
U3	PAM4-8B/10B	400	1600	1166

Zonal Architecture

- Zonal architecture is adopted by many OEMs, many times in conjunction with SDV.
  - Aggregation of sensors and actuators in spatial proximity by zone ECUs
  - Unlike domain architecture that integrates functions by specific domains (e.g., ADAS)
- The aggregation of the local devices is relatively low bandwidth (i.e., < 1Gbps) except for cameras and other emerging new sensors as radar and lidar
- These new sensors are asymmetric, driving high-speed data toward the zone ECU and main ECU, and require only low bandwidth control data, with low latency
- A-PHY as a highly asymmetric PHY is well-situated to support use cases of zonal architecture that require high-speed data aggregation to the main computing unit



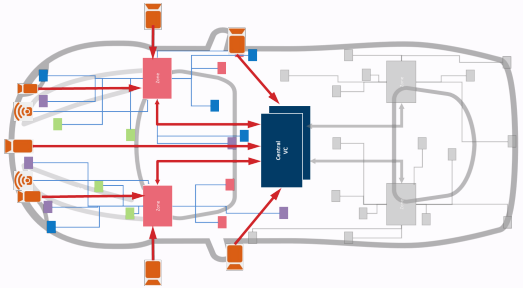
A-PHY-Based Zonal Architecture – Example



- Focus on front end of vehicle to reduce clutter
- Each zone ECU aggregates multiple sensors and actuators
- Very high-speed data in direction of central computing unit
  - Camera (could be more than one)
  - Radar
  - Lidar
- Bidirectional information up to 1Gbps is supported for the aggregation of low-speed sensors and actuators

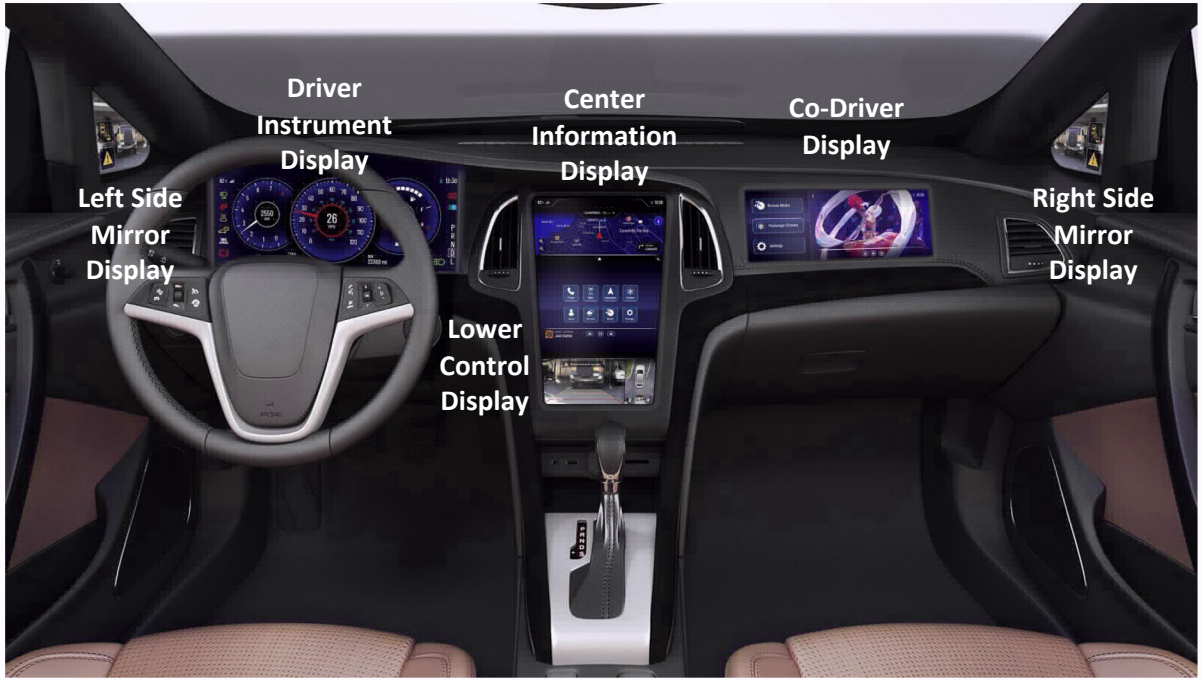
A-PHY

A-PHY-Based Zonal Architecture



- Simplification of zonal ECU
  - Low computing overhead
  - Lower protocol overhead – Maintain native protocols for MIPI CSI-2 (e.g., camera) or Ethernet (e.g., lidar)
  - Designed for ultra-low PER at high noise environment for the entire lifespan of the vehicle
- Future-looking design and easy migration path
  - Scalable downlink speed from 2Gbps to 64Gbps over a single cable
  - Flexible and rich protocol support
  - Layered security scheme supporting variety of use cases
  - Embedded functional safety
- Guaranteed interoperability and backward/forward compatibility

Modern Automotive Cockpit Displays



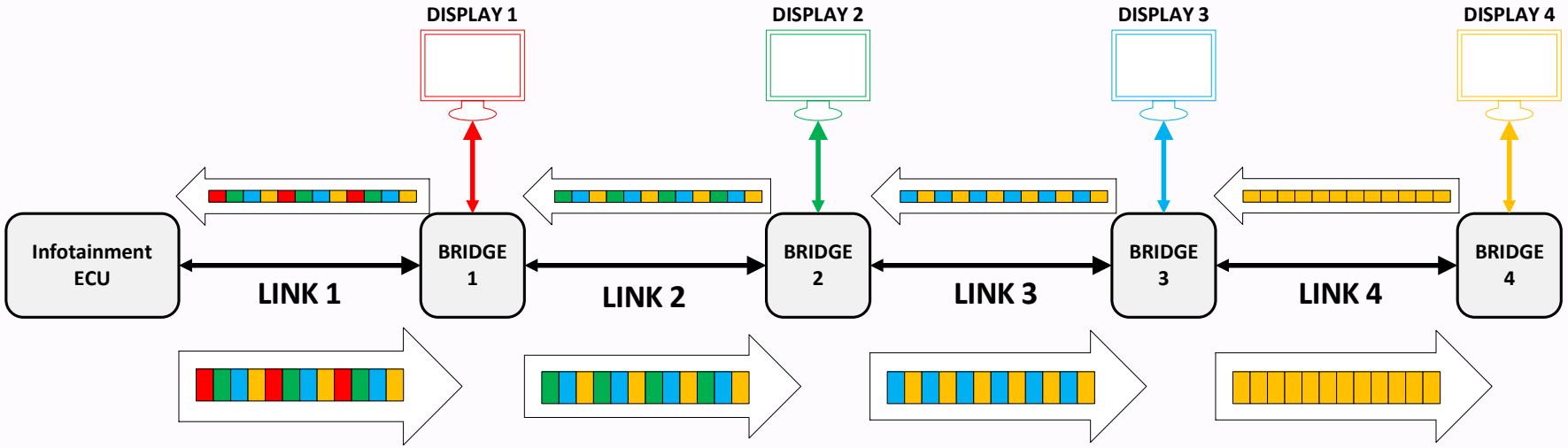
Display Type	Example Size (Inches)	Example Resolution
Left and Right-Side Mirror Displays	7”	1280x800
Driver Instrument Display	12.3”	3840x1440
Center Information Display	12.3”	3840x2160
Extended Co-Driver display	12.3”	3840x2160
Lower Control Display	12.4”	3840x2160

Modern Automotive Cockpit Displays

- Multiple connectivity schemes including daisy chain
- Up to **64Gbps** non-compressed data in single port
  - Up to **192Gbps with VESA DSC compression** with no additional overhead in single port
- Flexible uplink up to 1.6Gbps
  - Enable internal DMS[2] camera
- Ultra low PER[1] for the entire vehicle lifespan (zero errors)
- End-to-end functional safety
- End-to-end advanced layered security
- Multiple protocol support (e.g., DSI, DisplayPort)

(1) PER – Packet Error Rate
(2) DMS – Driver Monitoring System

Daisy Chain – General Structure



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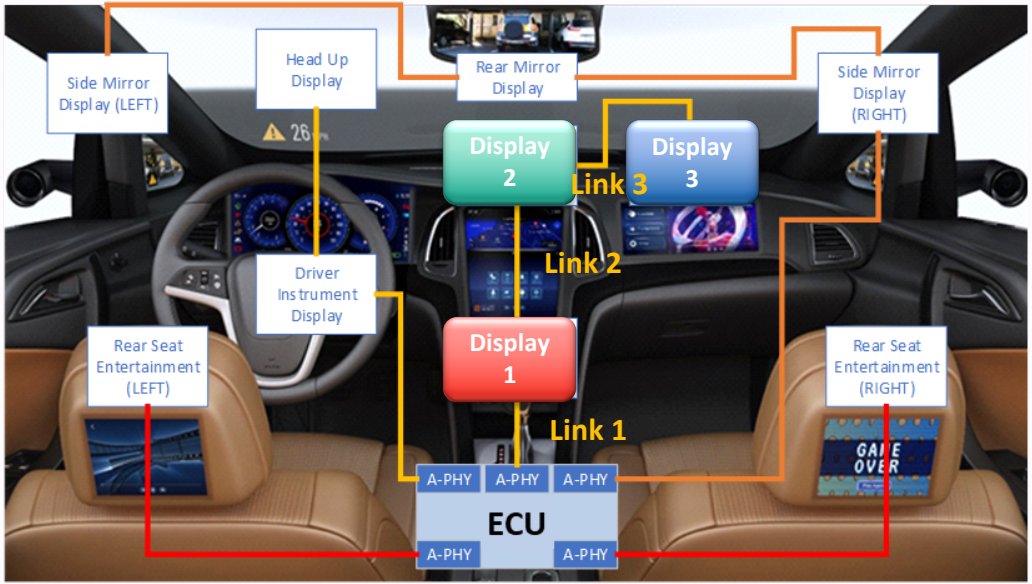
Daisy Chain Example

Config	Display 1 (LCD)	Display 2 (CID)	Display 3 (CDD)	Total BW Gbps
1	3840x2160	3840x2160	3840x2160	37.6
2	3840x2160	5120x2160	5120x2160	45.8
3	7680x2800	7680x2800	7680x2800	96.5



Config	DSC	Actual BW Gbps	Link 1	Link 2	Link 3
1	-	37.6	DL-G6	G7	G5
	+	12.5	G5	G4	G3
2	-	45.8	DL-G7	DL-G6	G6
	+	15.3	G6	G5	G3
3	-	96.5	Requires compression		
	+	32.2	DL-G6	G6	G4

Gear	Single Lane BW (Gbps)	Dual Lane BW (Gbps)
G1	2	4
G2	4	8
G3	8	16
G4	12	24
G5	16	32
G6	24	48
G7	32	64

Assumptions: Uncompressed 24-bit/pixel or DSC 8bpp, 60fps, CVT-2 Blanking overhead
DSC: VESA Display Stream Compression

Summary

- A-PHY is the first asymmetric long-reach optimized video transmission standard for the automotive market.
- Resilient and robust solution for the whole lifespan of the car, designed to meet the unique noise and stress challenges of the automotive world.
- MIPI Alliance is continuously working on A-PHY to meet the evolving needs of the market and to provide a complete package to support the ecosystem.
- Next-generation A-PHY will bring:
  - Higher speeds
  - More adaptation layers supporting more interfaces
  - Increased design flexibility
  - Enhanced security

Q&A

MIPI Automotive Resources

Information on A-PHY can be found at:

- MIPI A-PHY Specification Homepage
- MIPI White Paper: Introduction to MASS