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

# A-PHY Transmitter and Receiver Compliance Testing

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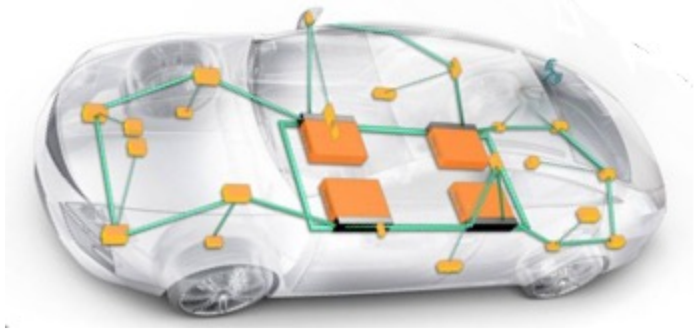
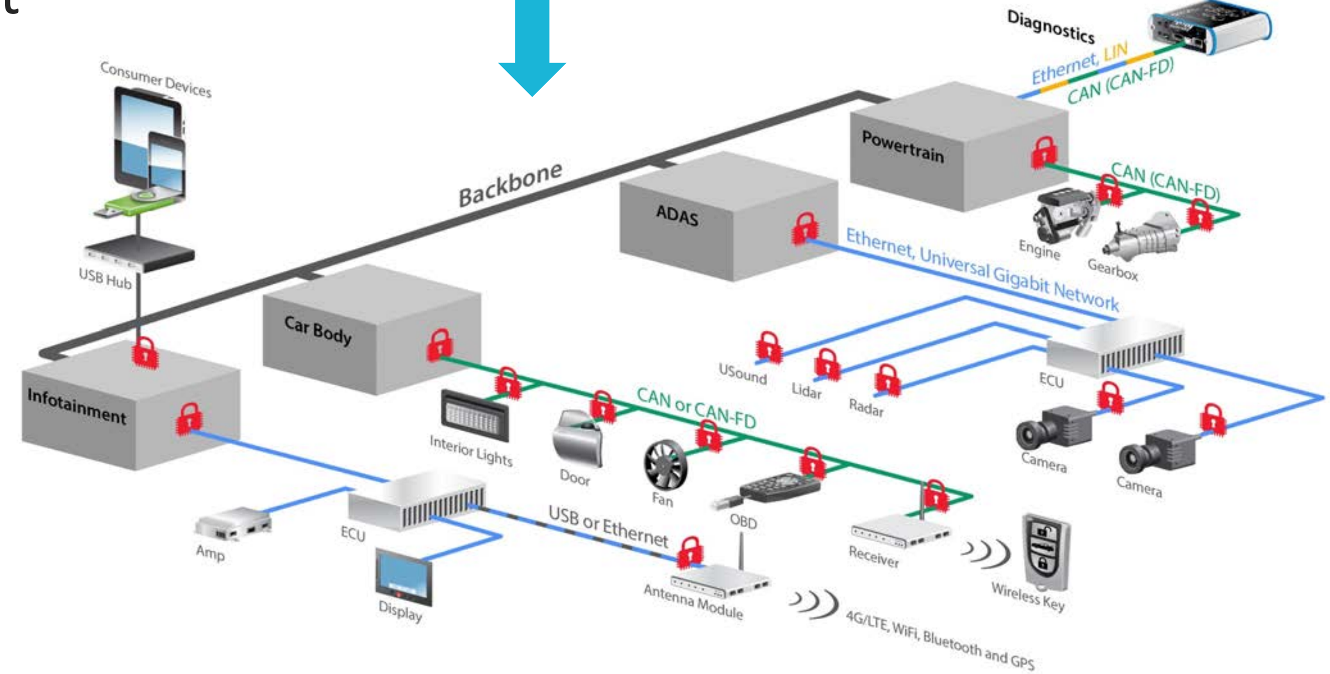
# Automotive In-Vehicle Network Test Challenges & Solutions

# In-Vehicle Network (IVN)



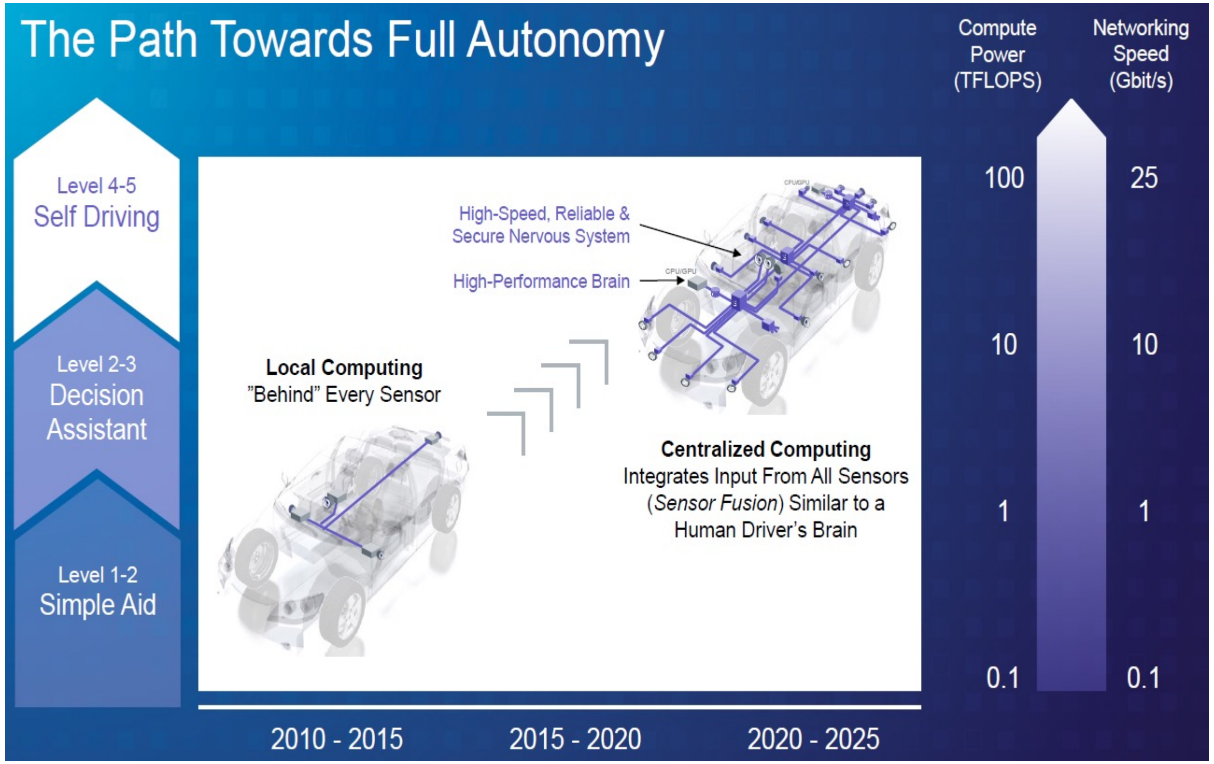
- Electronics inside the car communicate with each other over an In-Vehicle Network
- IVN wiring is the 3rd largest contributors to the overall weight of a car and 2nd largest contributors of overall BOM
- IVN requirements:
  - Reliable data transfer in Automotive harsh environment
  - EMI/EMC
  - Low weight, low cost, low power



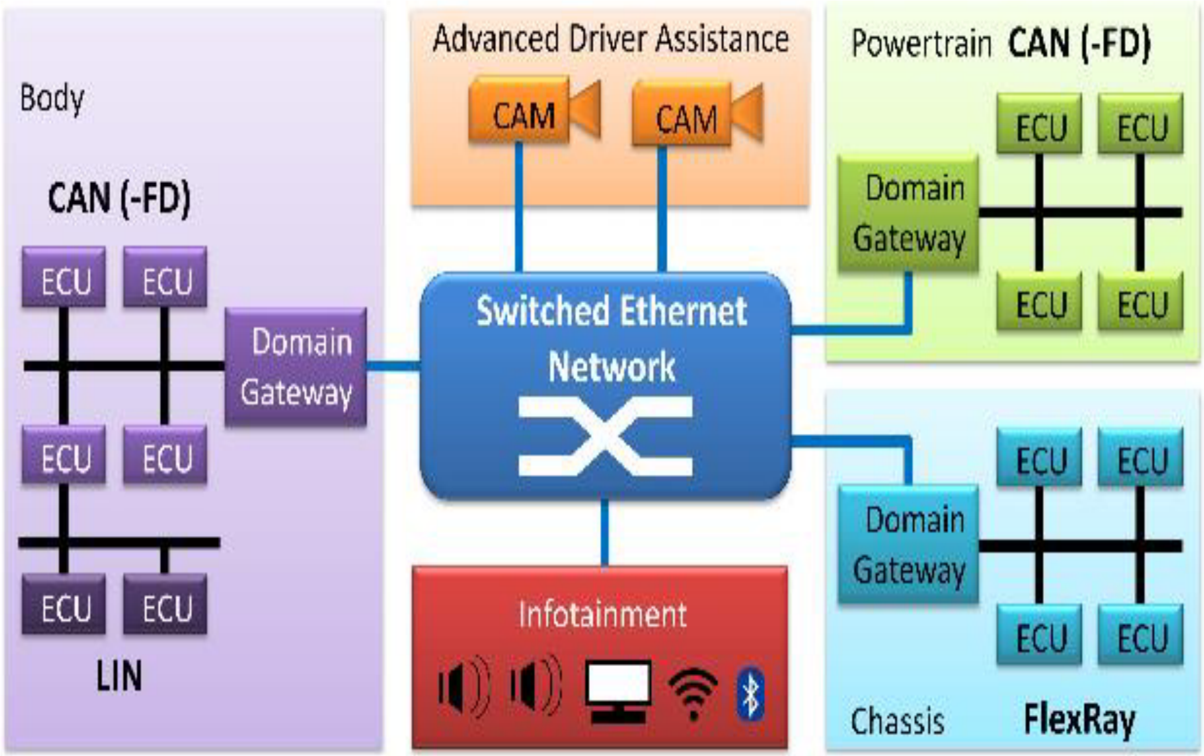


# Need for Higher Data Rate




ADAS System Requirement




Domain Architecture

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# IVN Testing

- Physical Layer Test
- Protocol Layer Test
- Channel Test
- Diagnostics
- EMI Test
- Interoperability Test

- Testing Phases
  - Component/Transceiver Level
  - ECU level
- Testing @ stages of production
  - Chip/system/harness

 

# A-PHY v1.0 Test

 

# A-PHY TX and RX Testing

- A-PHY addresses the need for asymmetric, high-throughput data connectivity within vehicles
- Used to connect sensors (e.g., Camera, Lidar, Radar, and others) and display devices located around a vehicle to and from the system CPU over high-speed links with optimal wiring, cost, and weight


- A-PHY provides a main unidirectional data stream, a bidirectional low-throughput command and control data stream and can optionally deliver the required power supply to peripheral units (i.e., the  sensors and/or displays at the edge of the network) directly via the A-PHY data lines

 

# A-PHY TX and RX Testing

**A-PHY v1.0 supports two profiles to fit different automotive market segments:**

- **Profile 1 (P1)** is aimed at lower downlink speeds and EMC requirement, with channel attributes and design characteristics enabling lower cost implementations. This profile is based on NRZ 8B/10B technology.
- **Profile 2 (P2)** is aimed at solutions requiring superior noise immunity and higher downlink speeds it also has a better bandwidth utilization (i.e., net data rate per gear).

***MIPI A-PHY v1.0–Profiles, Speed Gears and Modulation Schemes***

| | ***Downlink Mandatory Gears–Profile 1 and 2*** | | | ***Downlink Optional Gears–Profile 1 and 2*** | | |
|---|---|---|---|---|---|---|
| ***Downlink Gear*** Rate | ***Profile / Modulation*** | ***Modulation Bandwidth*** (GHz) | ***Max Net App Data Rate*** (Gbps) | ***Profile / Modulation*** | ***Modulation Bandwidth*** (GHz) | ***Max Net App Data Rate*** (Gbps) |
| ***G1*** 2 Gbps | ***P1*** NRZ-8B/10B | 1 | 1.5 | ***P2*** NRZ-8B/10B + RTS | 1 | 1.5 |
| ***G2*** 4 Gbps | ***P1*** NRZ-8B/10B | 2 | 3 | ***P2*** NRZ-8B/10B + RTS | 2 | 3 |
| ***G3*** 8 Gbps | ***P2*** PAM4 | 2 | 7.2 | ***P1*** NRZ-8B/10B | 4 | 6 |
| ***G4*** 12 Gbps | ***P2*** PAM8 | 2 | 210.8 | | | |
| ***G5*** 16 Gbps | ***P2*** PAM16 | 2 | 14.4 | | | |

***Uplink Mandatory Gears - Profiles 1 and 2***

| ***Uplink Gear*** Rate | ***Modulation*** | ***Modulation Bandwidth*** (MHz) | ***Max Net App Data Rate*** (Mbps) |
|---|---|---|---|
| ***U1*** 100 Mbps | NRZ-8B/10B | 50 | 54 |

***Profile 1 (P1)*** ***Profile 2 (P2)***

# A-PHY v1.0 Gears and Measurements

- A-PHY operates under different speeds
- A-PHY defines 5 discrete downlink gears: G1, G2, G3, G4 and G5. A-PHY downlink shall operate at the defined data rates
- The A-PHY uplink shall be 100 Mbps
- An A-PHY device supporting Gear N (i.e., N could be 1–5) shall support all mandatory lower gears
- Profile 1 (P1) is based on NRZ 8B/10B
- Profile 2 (P2) is based on multiple modulation schemes
- TX measurements are applicable for both Profile 1 and Profile 2
- PAM-X linearity is applicable for a PAM4 signaling
- EYE opening is applicable for NRZ signaling
- Downlink RX bit error rate is measured with presence of noise on the signal
- Symbol rate frequency tolerance measured with noise as well as rate variance up to 100 ppm

| *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* |

| TX Measurement | RX Measurements |
|---|---|
| TX Power spectral density | Down link RX bit error rate |
| TX Maximum droop | RX symbol rate Frequency tolerance |
| TX Timing jitter | |
| TX Symbol rate accuracy | |
| TX Down link EYE opening | |
| PAM-X Transmitter linearity | |

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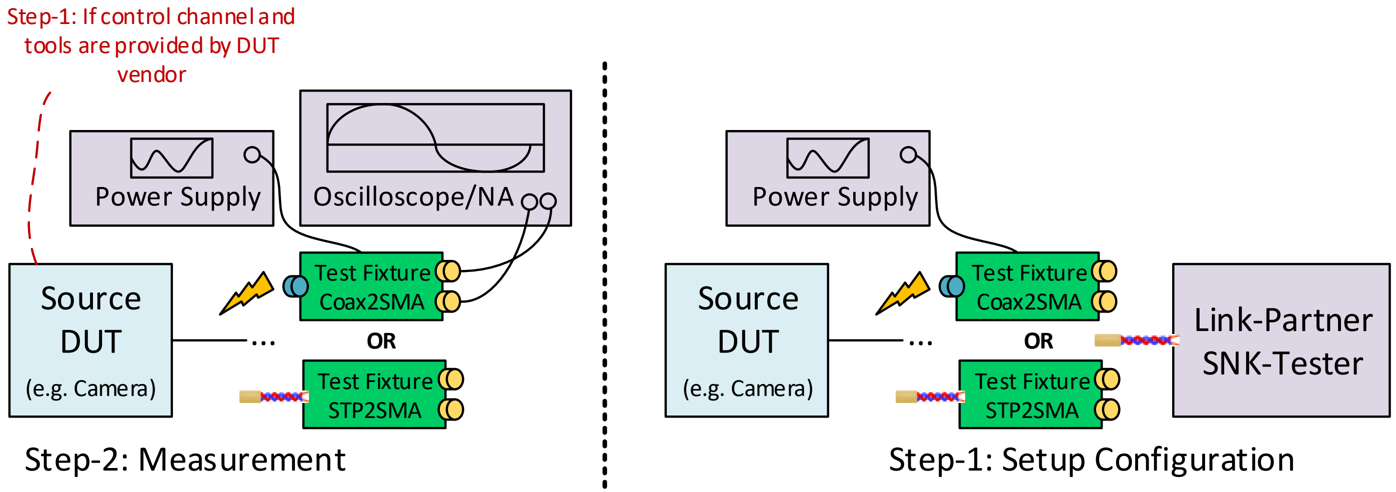
# A-PHY v1.0 Transmitter Testing

# A-PHY TX Testing

- TX testing divided as downlink and uplink. Downlink is high speed signal with both NRZ or PAM signal.
- Gears 1 & 2 are NRZ. Gears 3,4 & 5 are PAM4 signal, but optionally Gear 3 also supports NRZ .
- Today we shall cover the TX testing for Gear 3 for both NRZ as well as PAM based signal. The measurements are based on signaling type.
- TX downlink measurements are PSD, Droop, Timing Jitter, Symbol Rate Accuracy, and Eye opening, PAM Transmitter linearity.
- Test modes TM1 to TM4 used for all TX measurement.



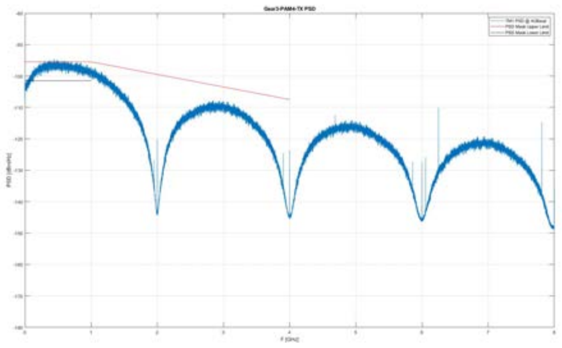

If source DUT has provision with control you can set it to Test mode. The alternate option is to use the Link partner and Force the DUT to the Test mode.

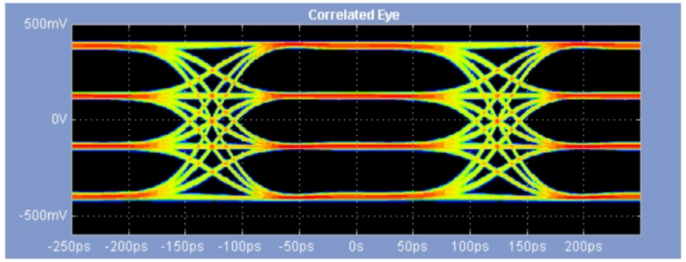
Power supply is used when the DUT needs to be powered

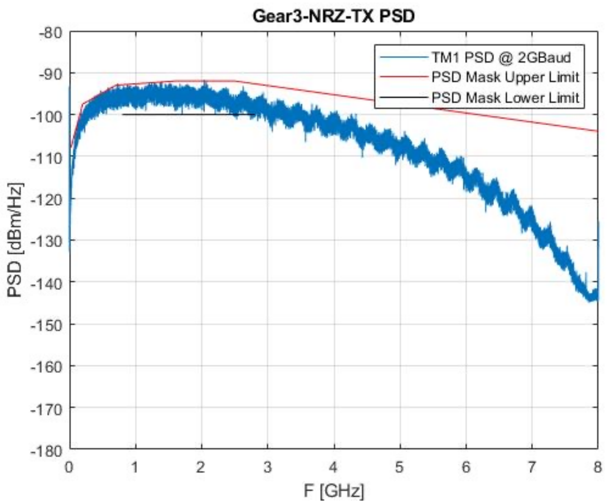
 

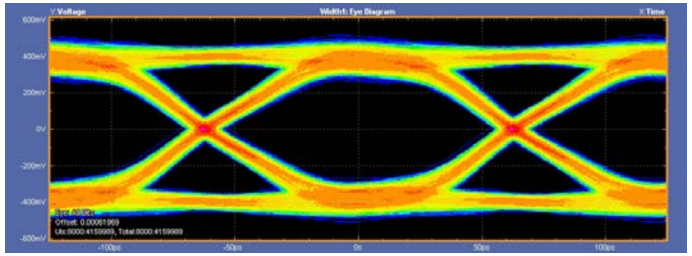
# A-PHY TX Measurement PSD

- Procedure
  - Configure the source DUT to transmit Test mode 1 signal
  - Connect the TPA to the acquisition device set to capture “Max_hold” with resolution bandwidth of 120 Khz and sweep count to 8
  - If using DSO, configure the DSO to oversample for 8X
  - After 8 sweeps worth of TM1 symbols are collected, process the capture using post processing methods  and measure the PSD
  - Compare the PSD measured value with limit line





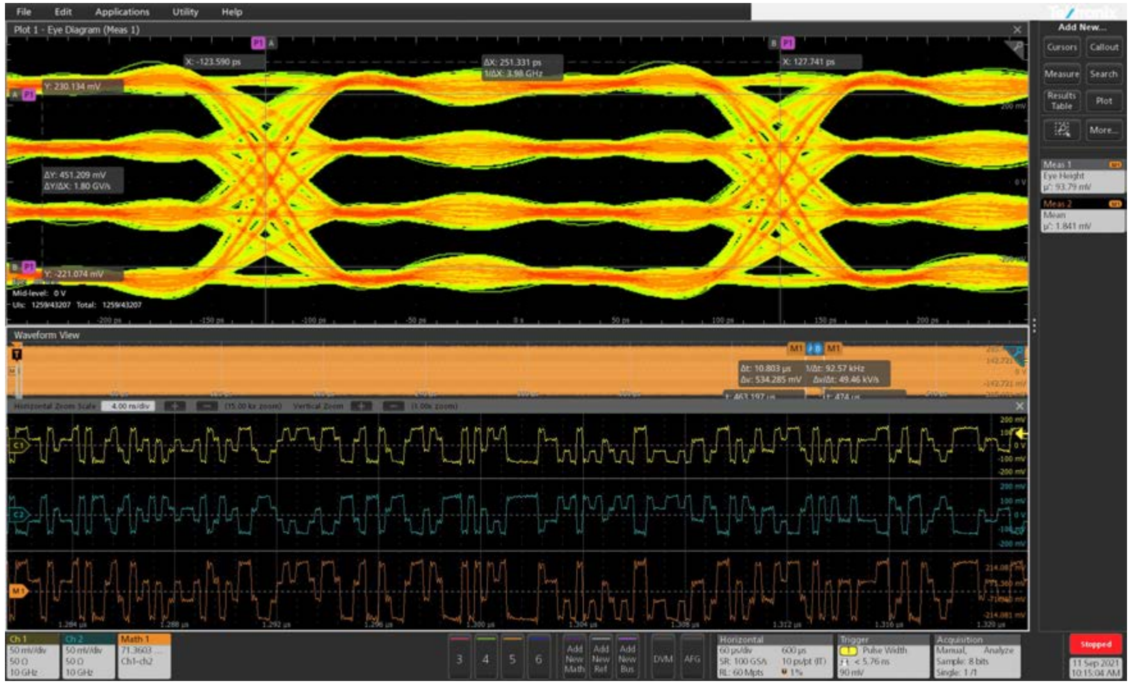
# A-PHY PAM-X Transmitter Linearity

- Requirement is to measure RMS and Distortion peak

$$dB\left(\frac{DistortionRMS}{CapturedSignalRMS}\right) \leq \left(-44 + 6 * \left(4 - \log_2(M)\right)\right) dB$$

$$dB\left(\frac{DistortionPeak}{CapturedSignalRMS}\right) \leq \left(-30 + 6 * \left(4 - \log_2(M)\right)\right) dB$$

- Capture 32 duration of TM4 cycles with oversampling
- Create single averaged cycle TM4 cycle
- For each of the sample interval in UI:
  - Find the correlation between the TM4 known cycle with averaged cycle
  - Compute ideal linear canceller, by filtering the TM4 known cycle data using mean square estimate error
  - Compute the distortion and ensure 4 consecutive UI phase is less than limit values




```
DistrotionRMSPerPhase_dB =

  Columns 1 through 9

    -37.54      -38.61      -38.45      -36.49      -34.01      -31.97
30.57      -29.78      -29.49

  Column 10

    -29.58

DistrotionPeakToRMSPerPhase_db =

  Columns 1 through 9

    -20.62      -25.94      -25.43      -23.18      -21.33      -19.80
18.80      -18.23      -17.89

  Column 10

-17.76
```

# A-PHY v1.0 Receiver Testing

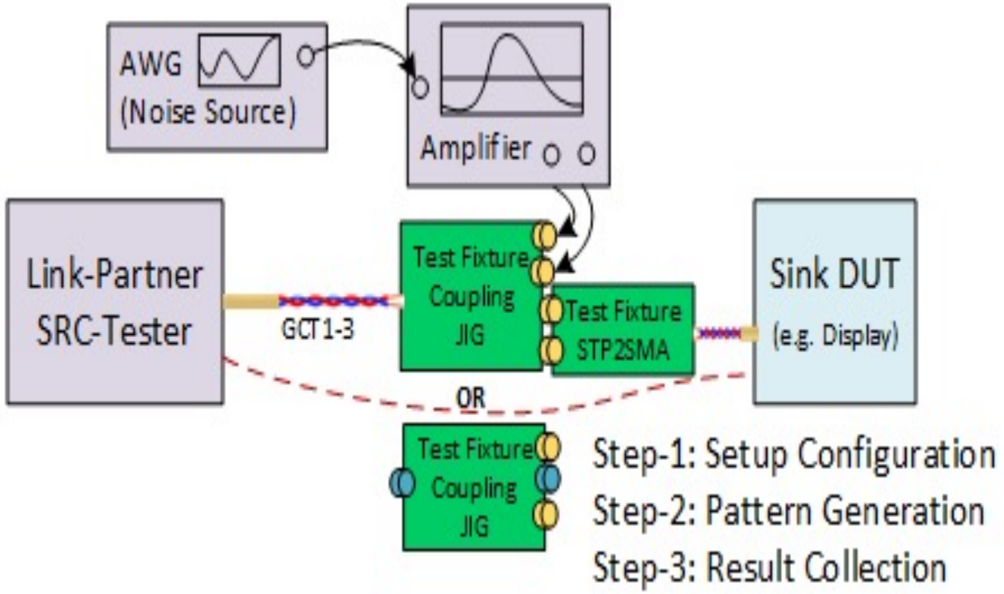
# Down Link RX Testing: BER and Frequency tolerance Testing

**Setup:**

- Link partner used as data generator for RX testing
- Link partner signal is passed through the GCT1- golden cable so that signal will have impact of the channel effect
- Test fixture will couple the signal from link partner with signal from AWG
- The coupling fixture has attenuator (because of directional coupling) so the AWG signal need to be amplified to the required level so that signal at the receiver input will have noise at specified level

**Testing:**

- Connect the sink DUT with link partner golden cable
- Use the link partner and put the DUT in relevant test mode
- Operate in test mode 6
- Generate the required EMC noise signal using AWG, couple it to the test signal using test coupling jig
- After testing, read the error register using link partner or read the register using control channel on the DUT.

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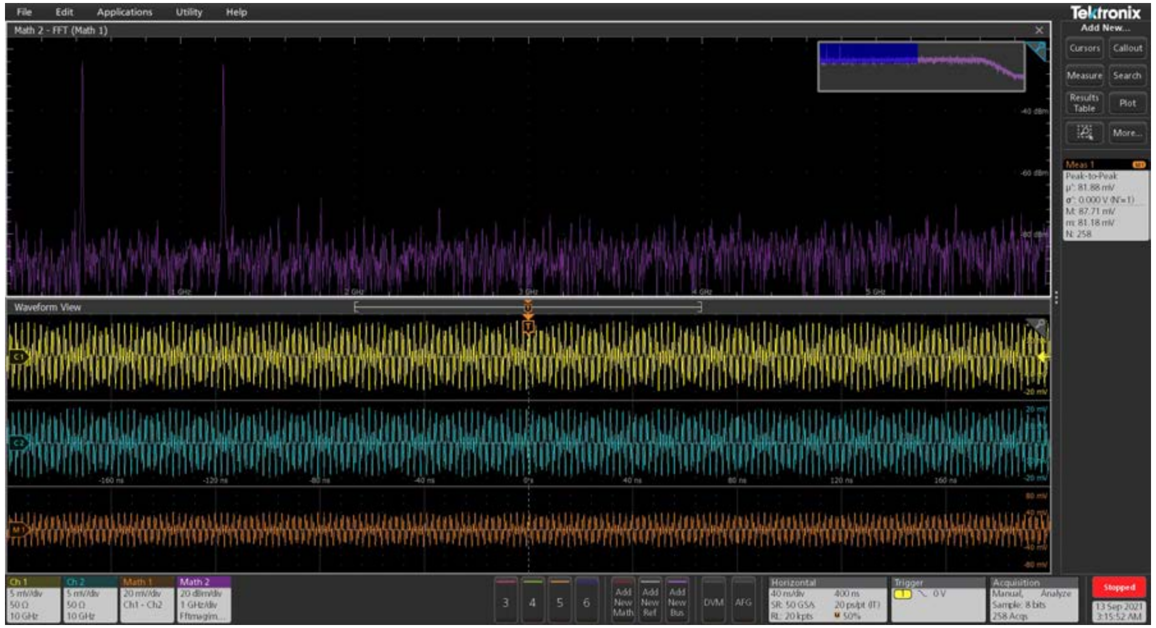
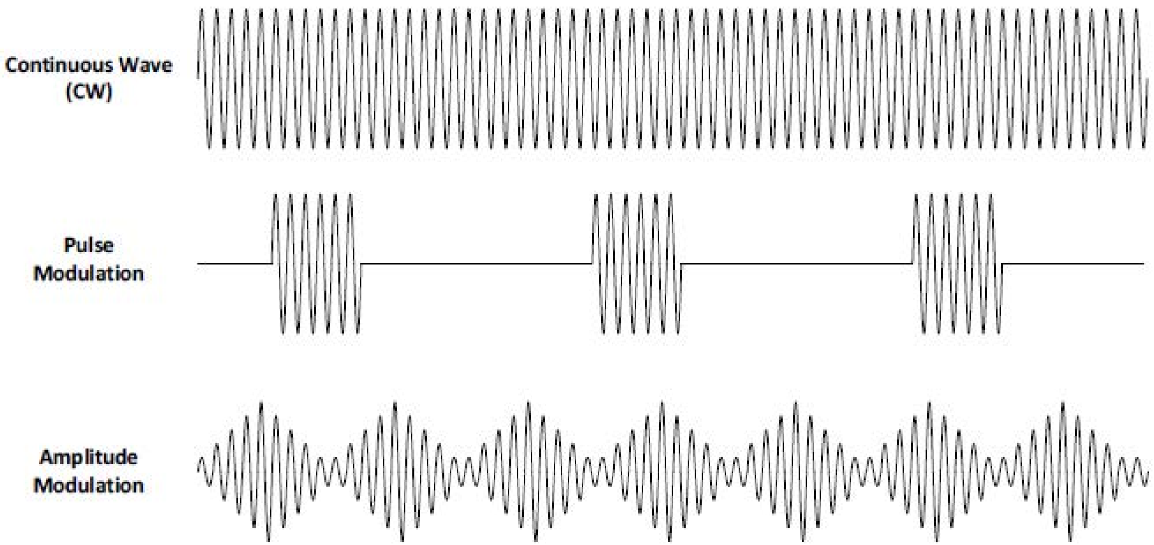
# RX Signal Generation - Ingress Noise

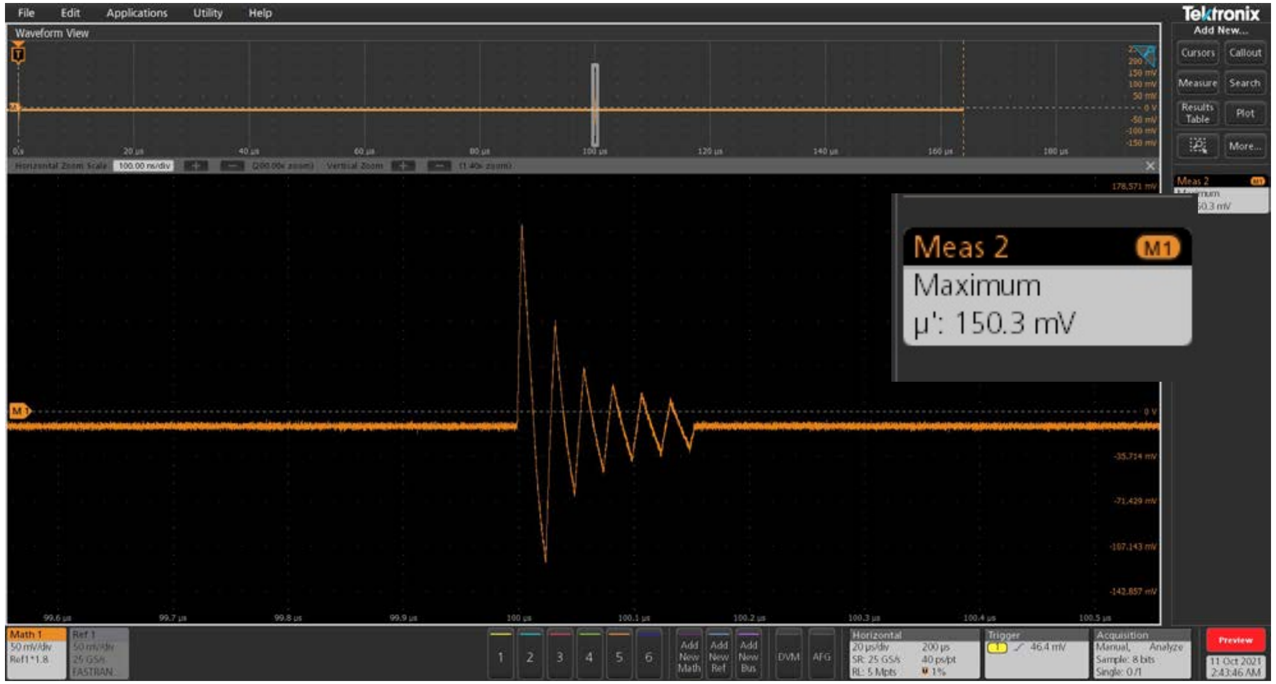
- There are many environmental stresses that include ingress noise combination of both continuous wave and pulse modulation wave
- The measured Pk to Pk is ~80 mV, with 40 mV pk.

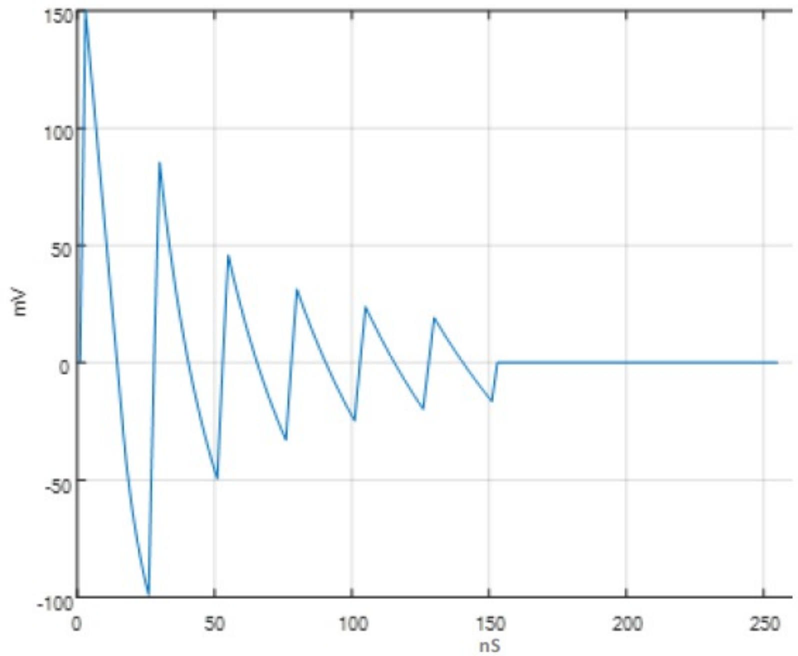


# RX Signal Generation – Fast Transient

- Fast transient is the transient immunity to fast and slow pulses based on ISO and it is extended pulse frequency up to 40 Mhz. The levels are defined for Profile 1 and Profile 2. Profile 2 need is about 150 mV for 150 nsec, up to 40 Mhz fundamental frequency
- Repetition  rate is 100 usec. Fast transient magnitude is 150 mV pk.

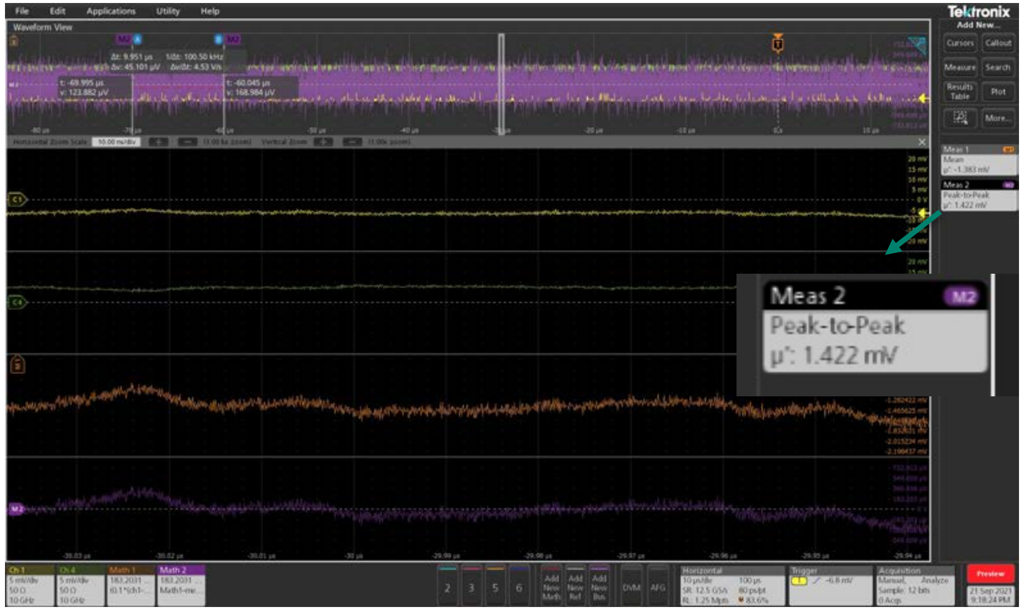


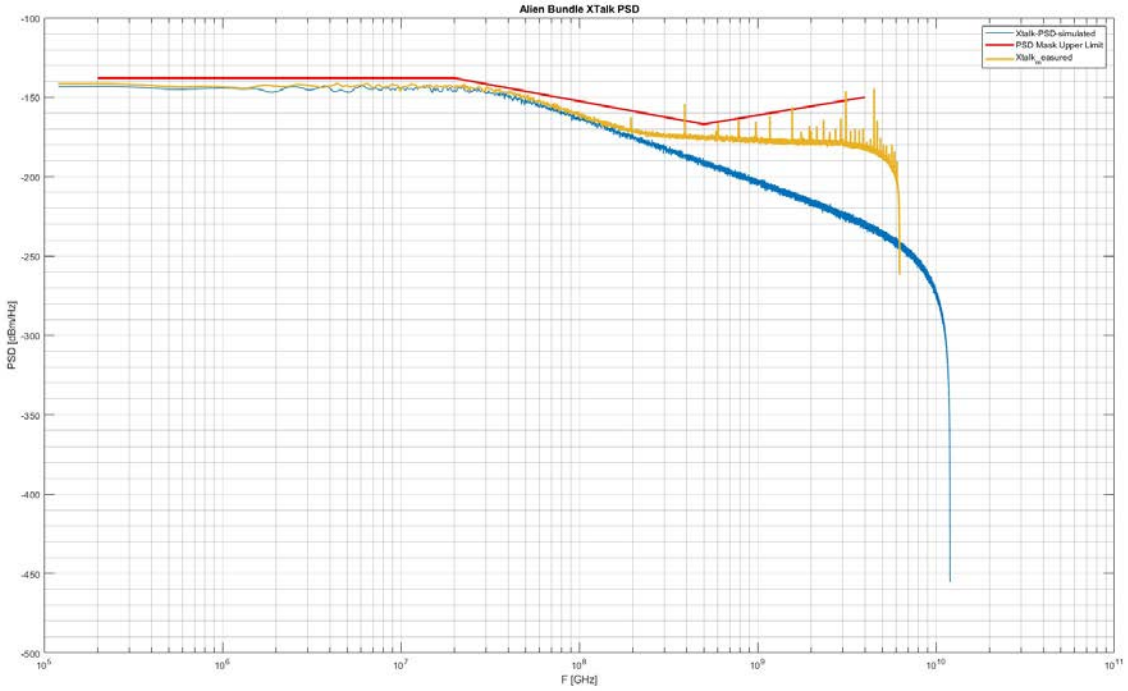



# Xtalk Signal Generation

- The Xtalk noise related to cable bundle is broadband noise and tolerance is tested with this noise signal. The PSD of this noise is shown below
- The noise level is very low. It is possible to generate such a low signal but we need to use an external attenuator of 10 dB so that we can attain the frequency response needed to meet the PSD levels

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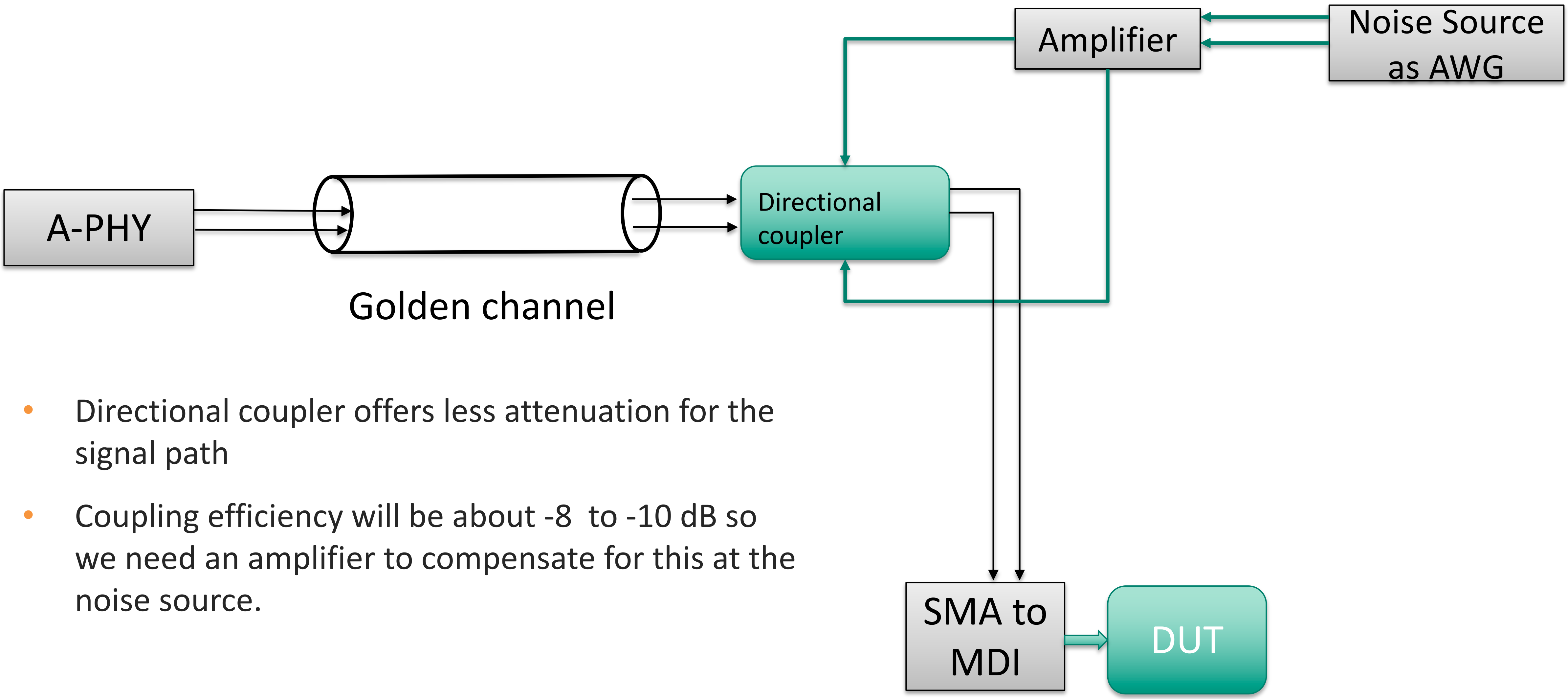
# Option#1: Configuration using Directional Coupler




- Directional coupler offers less attenuation for the signal path
- Coupling efficiency will be about -8  to -10 dB so we need an amplifier to compensate for this at the noise source.

# Summary

- Serial data testing in IVN testing is unlike the testing of consumer interfaces – due to different environment, higher safety & reliability needs
- Interoperability testing needs to NOT only cover PHY level but also include applications layers
- Serial data link testing is not only limited to compliance or interoperability requirements – the need is to evaluate all sorts of functional requirements

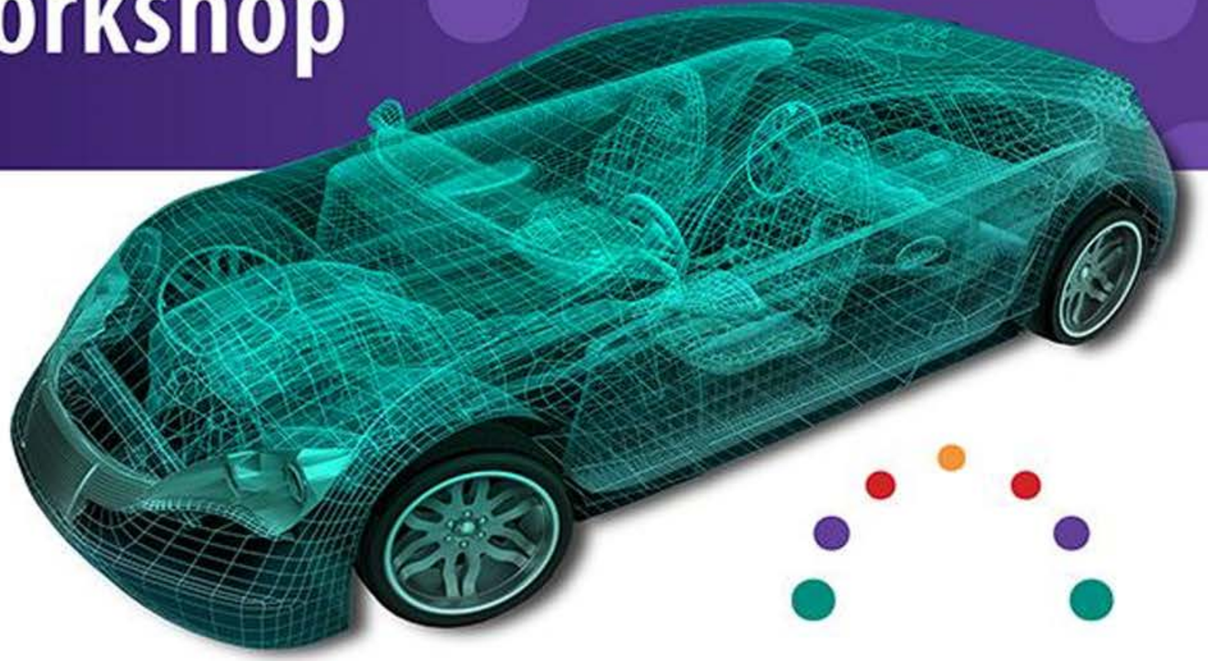
# References

- Tektronix Webinar
- A-PHY specification Version 1.0
- Reference compliance Test Suite for A-PHY specification
- Application Note for MIPI-A-PHY Specification
- www.mipi.org/specifications/a-phy

# MIPI Automotive Workshop

*An in-depth look at the MIPI Automotive SerDes Solutions (MASS) framework*



# Q&A