VNAs FOR HIGH-SPEED DIGITAL APPLICATIONS

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COPPER MOUNTAIN TECHNOLOGIES

AGENDA

- High-Speed Digital Applications
- Testing the Media
  - Differential Conversion
  - IL, RL, NEXT and FEXT
- Impulse Response Analysis
- USB-C Cable Measurement Demonstration

HIGH-SPEED DIGITAL APPLICATIONS

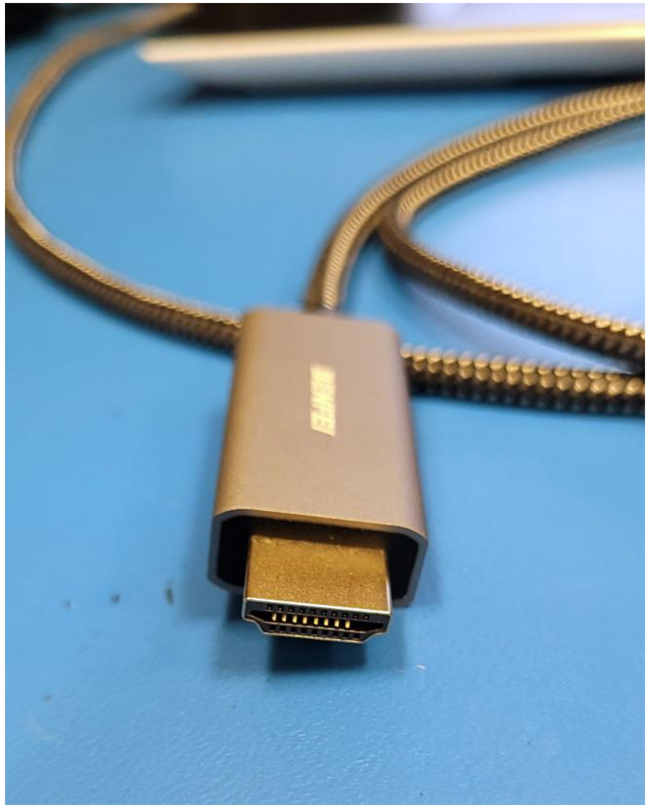
- In the automotive space, cameras and displays are ubiquitous
- A vehicle may have one or more displays for the driver and many more associated with self-driving
- Each 1920x1080 RGB display requires 3.5 GBps data rates

HIGH-SPEED DIGITAL APPLICATIONS

- Consumer goods rely on high-speed digital media
  - HDMI
  - USB-C
- Computer backplanes in servers must move mountains of data quickly

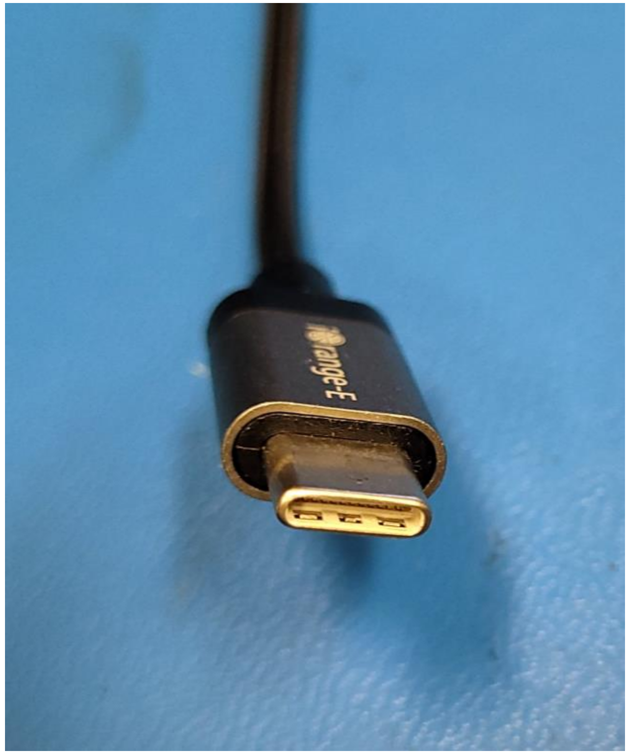
HIGH-SPEED DIGITAL APPLICATIONS

- HDMI continues to evolve
- HDMI Categories
    - Cat 1 4.95 GBps, 1080i or 720p
    - Cat 2 10.2 GBps, 1080p @ 30 Hz, 50 ft max
    - Cat 3 18 GBps, 4K @ 60 Hz, 25 ft max
    - Cat 3-8K 48 GBps, 8K @ 60 Hz, 4K @ 120 Hz



HIGH-SPEED DIGITAL APPLICATIONS

- USB-C is everywhere
- Data speed is steadily increasing
- USB 3 Gens 1 and 2
  - USB 3.2 Gen 1, 1 Lane 5 GBps
  - USB 3.2 Gen 1x2, 2 Lanes 10 GBps
  - USB 3.2 Gen 2x1, 1 Lane 10 GBps
  - USB 3.2 Gen 2x2, 2 Lanes 20 GBps



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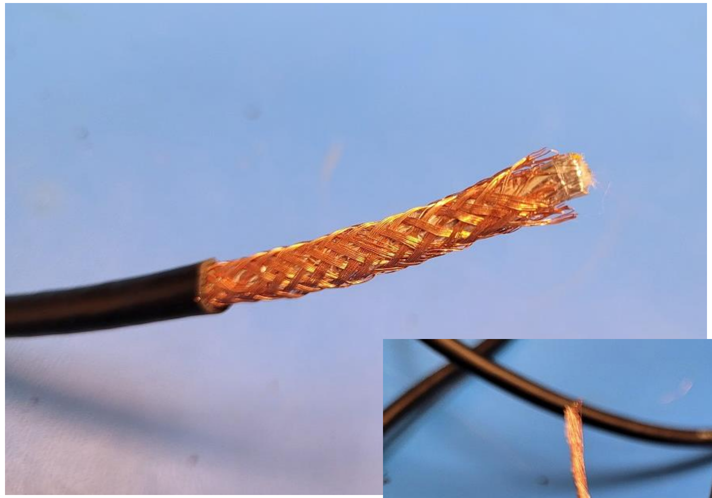
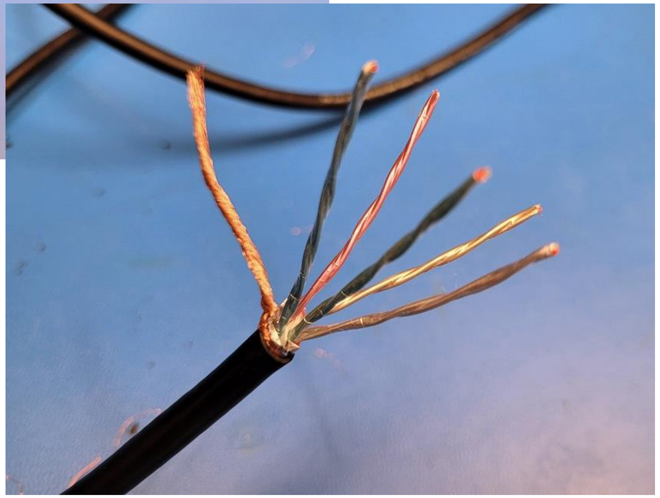
HOW DO WE VERIFY THE MEDIA?

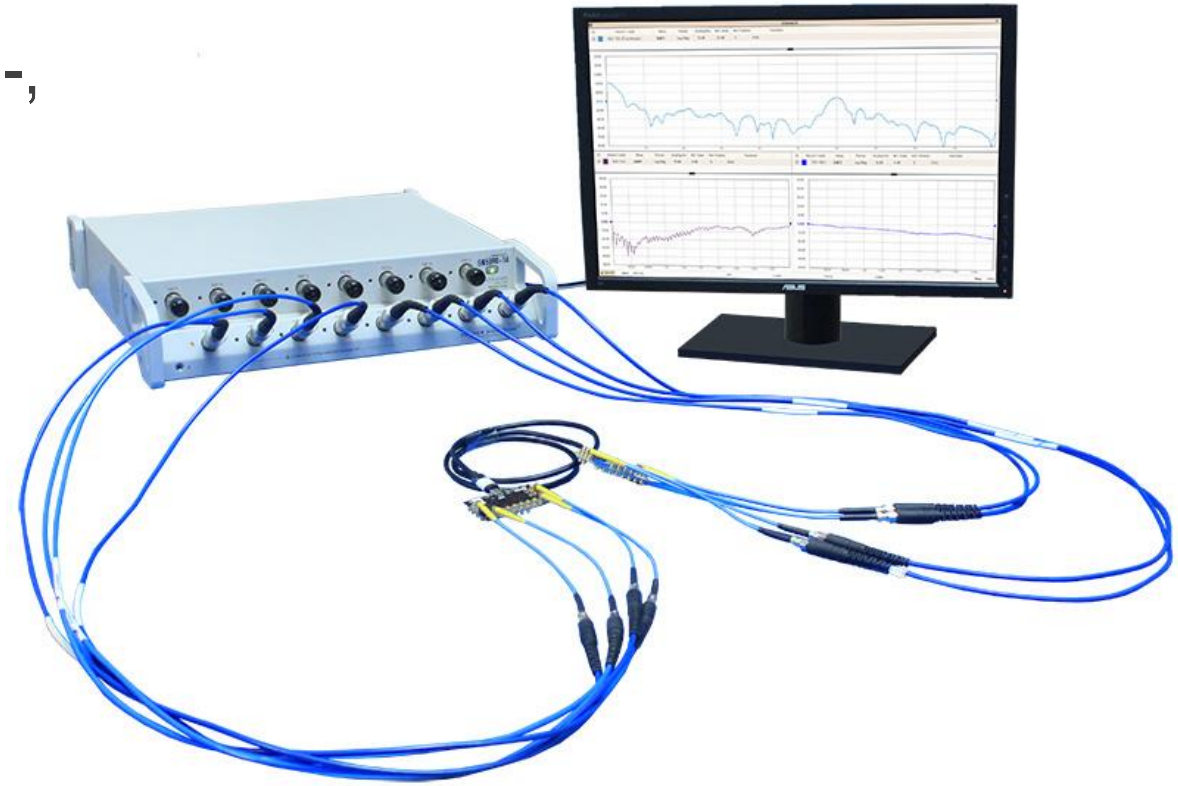
- An HDMI cable contains four 100Ω twisted pairs
- The cable is shielded with foil and braid
- Each twisted pair is foil shielded to promote pair-to-pair isolation





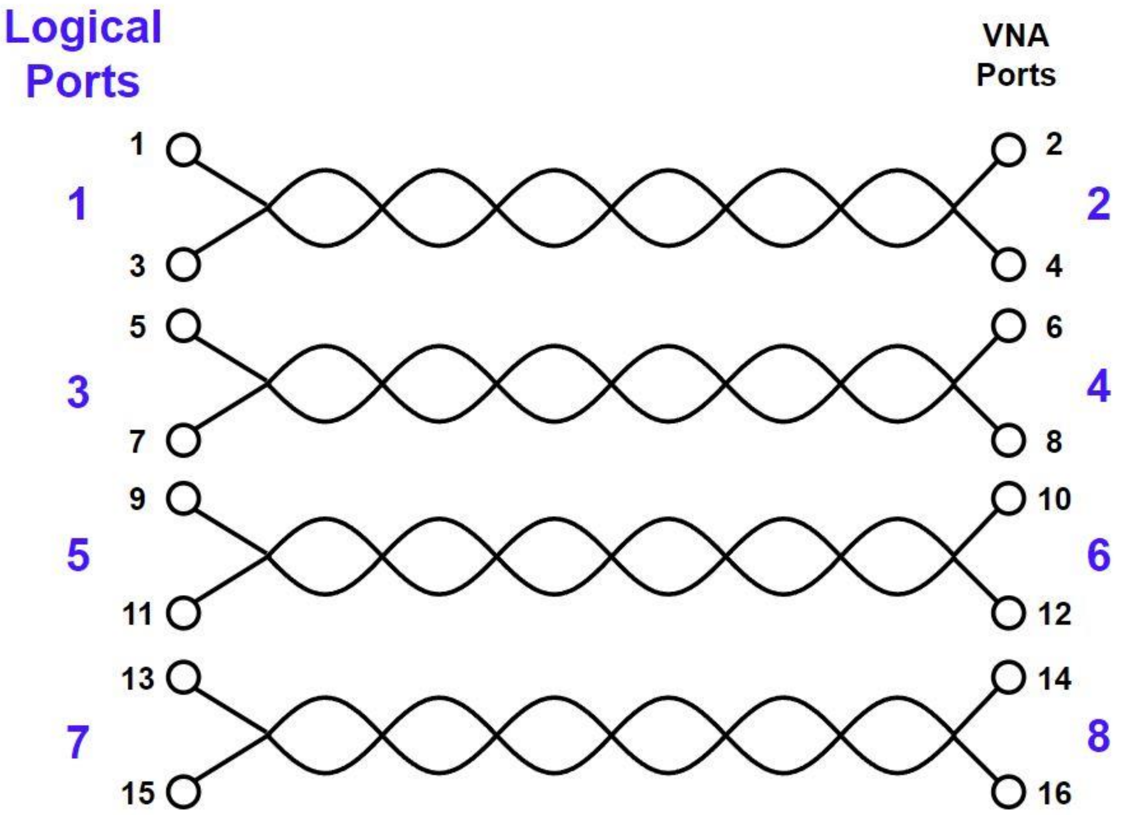
HOW DO WE VERIFY THE MEDIA?

- The SN5090 is a multiport VNA with 6-, 8-, 10-, 12-, 14- or 16-ports
- Frequency range from 300 kHz to 9 GHz with +10 dBm output power
- Dynamic range is 140 dB and measurement speed is 24 µS typical



HOW DO WE VERIFY THE MEDIA?

- Each wire of a pair can be connected to a port on a VNA
- The 16-port SN5090-16 can be connected to all four pairs
- Pairs are grouped into logical ports as shown
- Balanced responses are calculated from the unbalanced measurements



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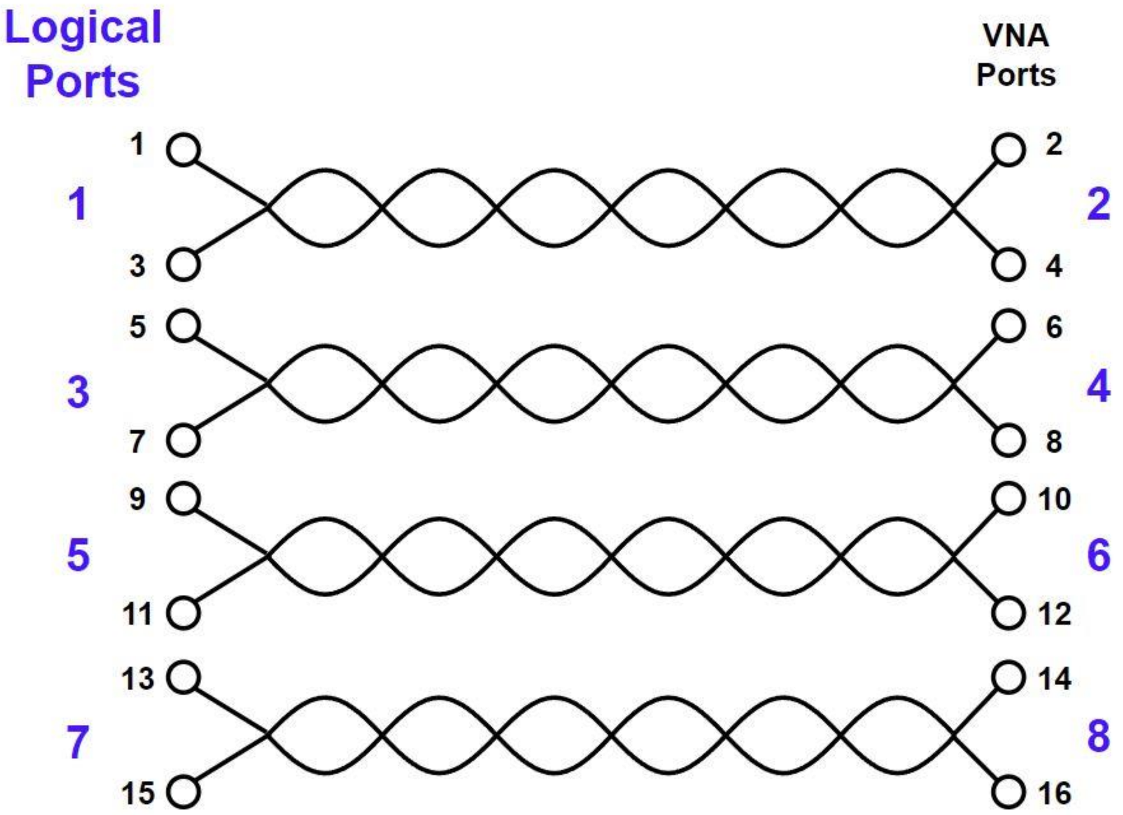
HOW DO WE VERIFY THE MEDIA?

- Important balanced measurements are differential Insertion Loss, Return Loss, and Isolation
- The differential Insertion Loss and Return Loss of the first pair would be:

$$SDD_{21} = \frac{S_{21} - S_{23} - S_{41} + S_{43}}{2}$$

$$SDD_{11} = \frac{S_{11} - S_{13} - S_{31} + S_{33}}{2}$$



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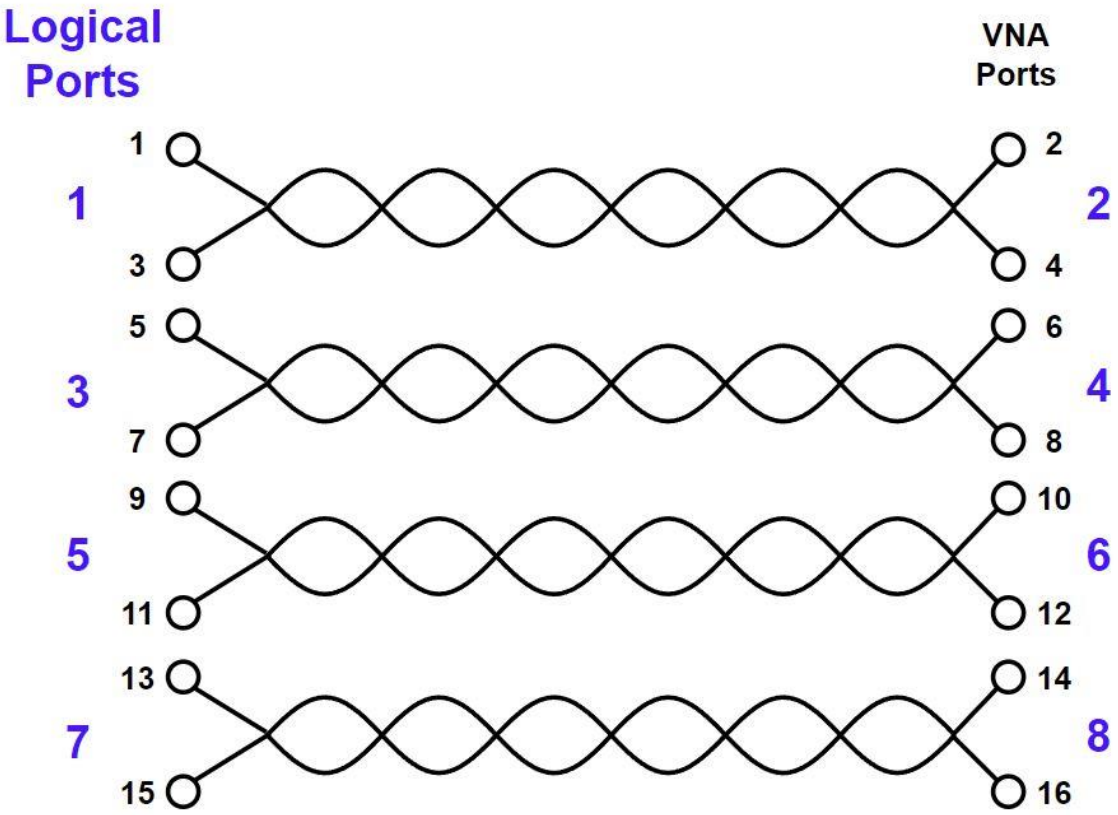
HOW DO WE VERIFY THE MEDIA?

- Pair-to-Pair Isolation is measured either from the same end or from opposite ends of the cable
  - These are Near-End Crosstalk, (NEXT) and Far-End Crosstalk, (FEXT)

$$SDD_{31} = \frac{S_{51} - S_{53} - S_{71} + S_{73}}{2}$$

$$SDD_{41} = \frac{S_{61} - S_{63} - S_{81} + S_{83}}{2}$$



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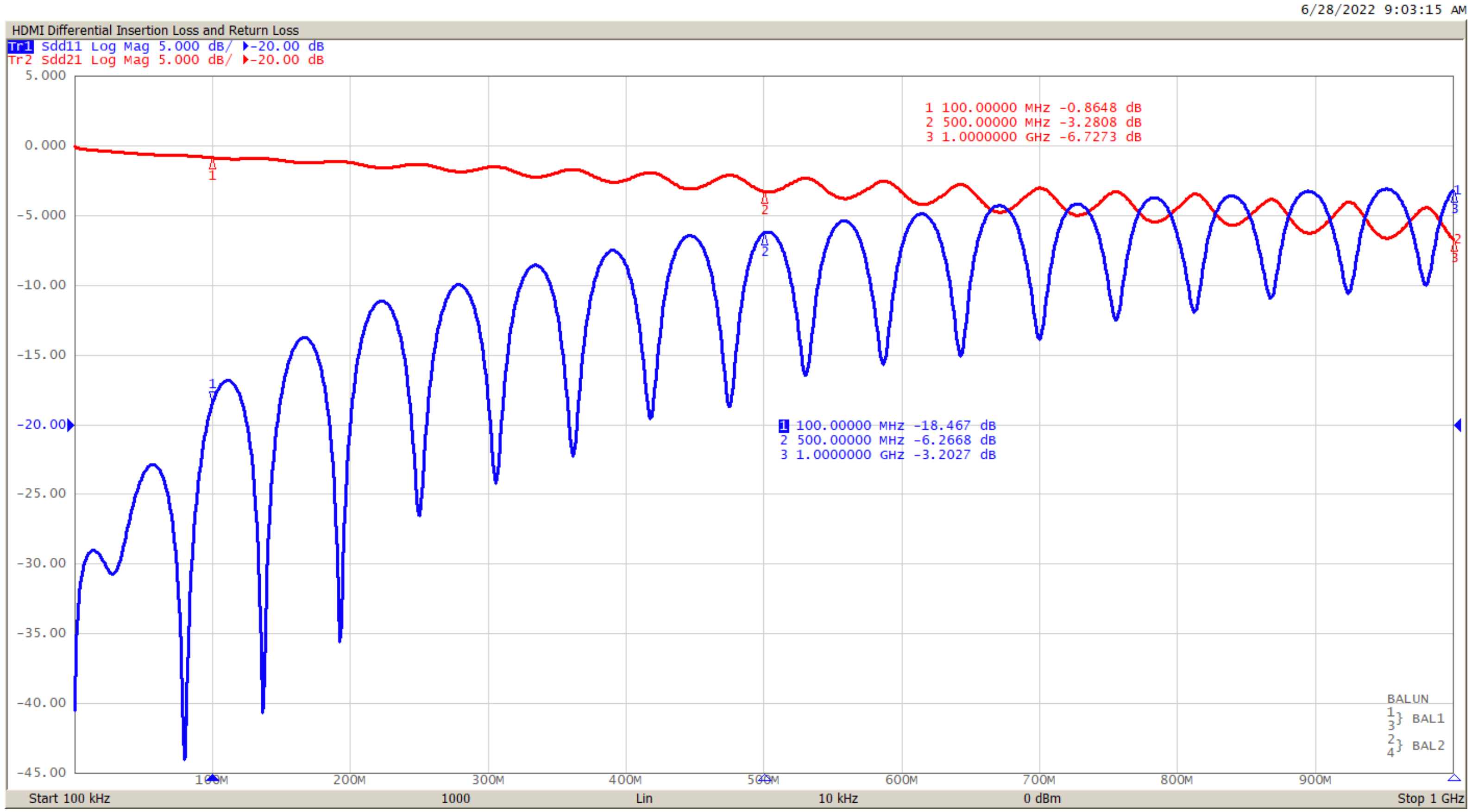
HOW DO WE VERIFY THE MEDIA?

- Differential Insertion Loss and Return Loss of one HDMI pair might look like this
- The VNA automatically does the unbalanced to balanced conversion



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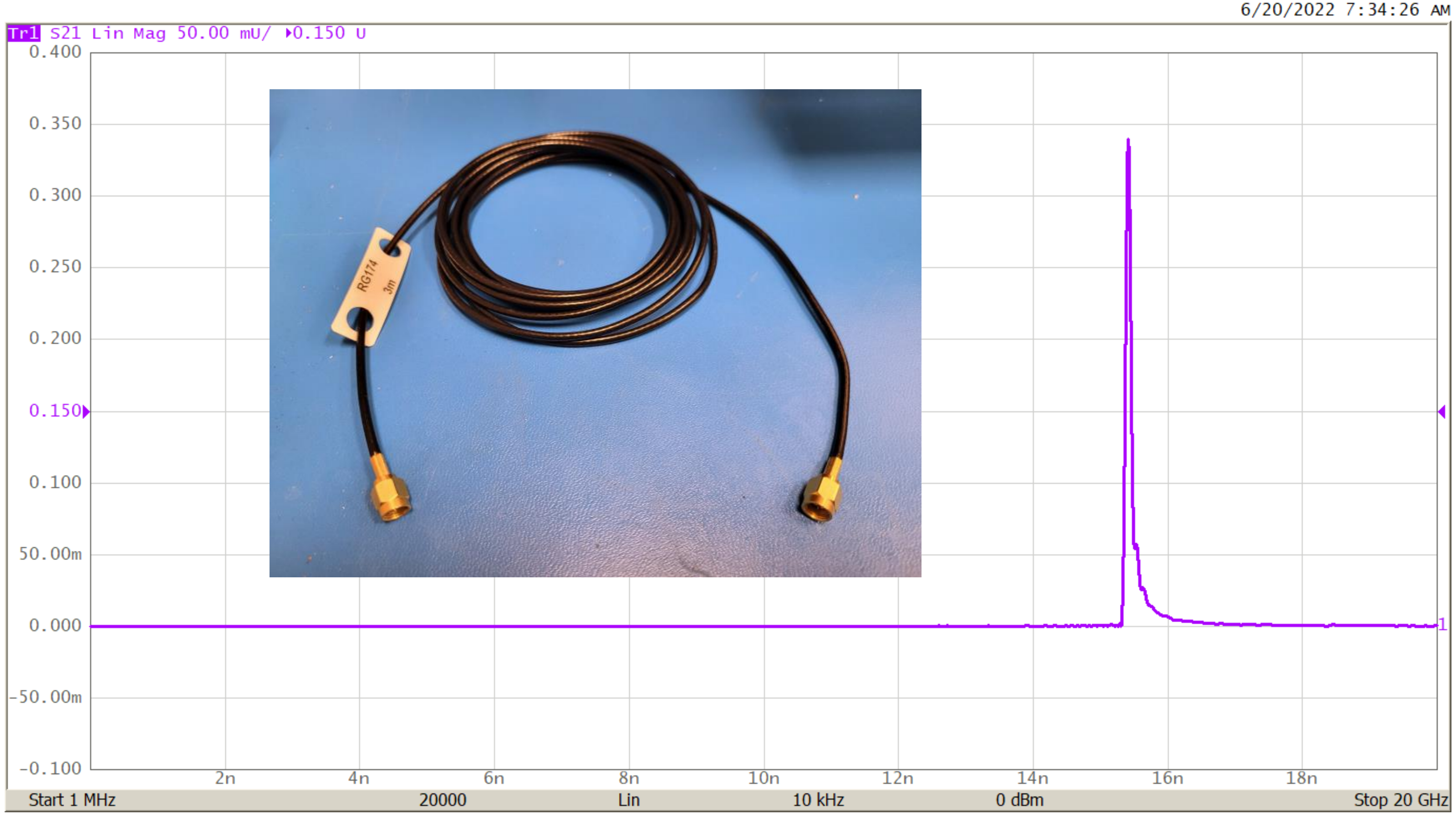
HOW DO WE VERIFY THE MEDIA?

- Using Time Domain mode, the SDD21 impulse response of a cable may be measured
- This is from a 3m length of RG174 cable
- The 15.4 nS delay can be seen



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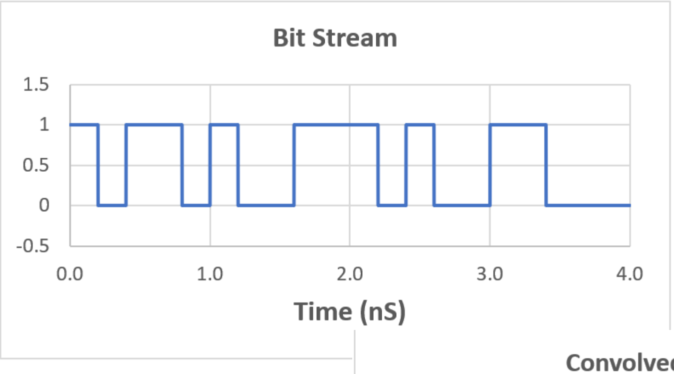
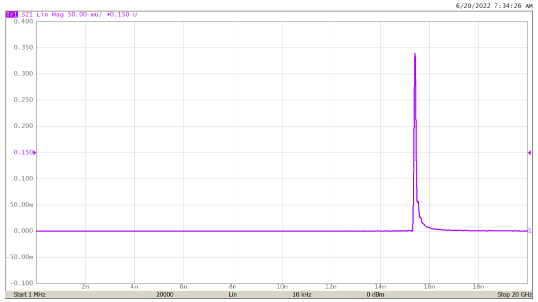
USING THE IMPULSE RESPONSE DATA

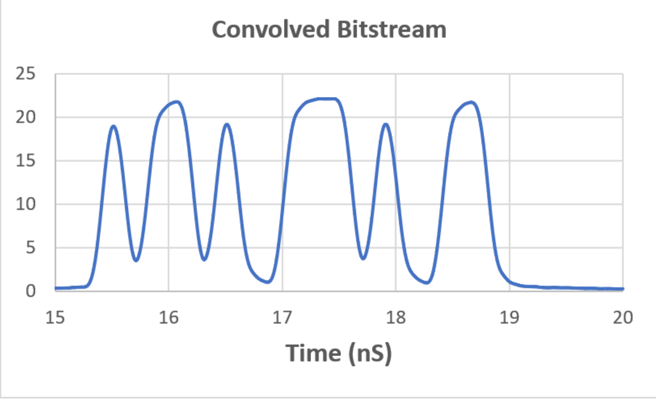
- The Impulse response of the media can be convolved with a digital data stream to estimate the effect of the media on the data.
- The impulse response can be taken from saved csv data and convolved with oversampled digital data

$$(f * g)_n = \sum_{m=0}^{k} f_m * g_{n-m}$$

Where f is the digitized data and g is the impulse response







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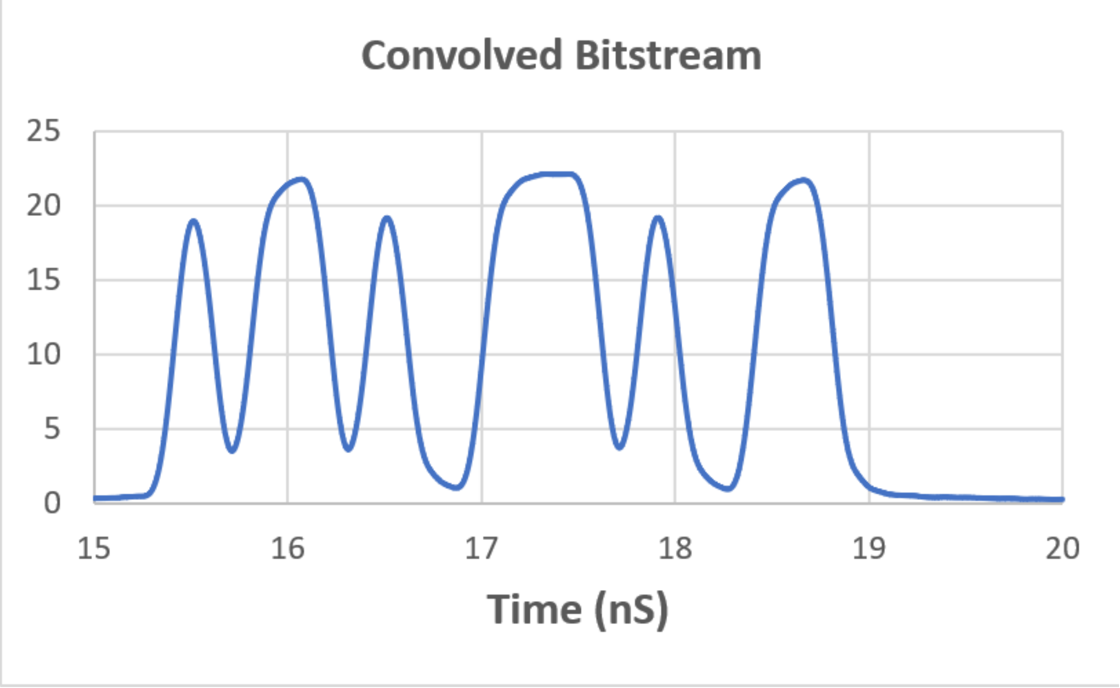
USING THE IMPULSE RESPONSE DATA

- It is clear that the high-speed data is impaired by the effects of the cable
- The single bits don't reach full amplitude resulting in poor amplitude balance



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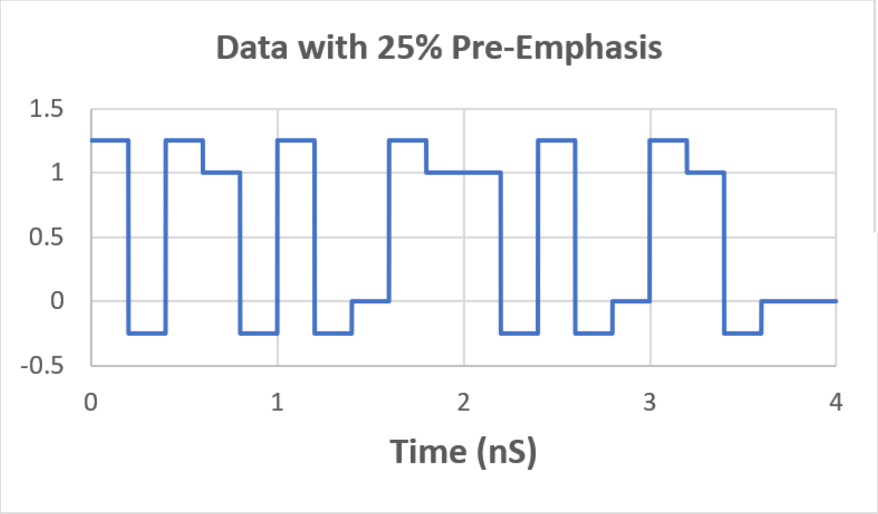
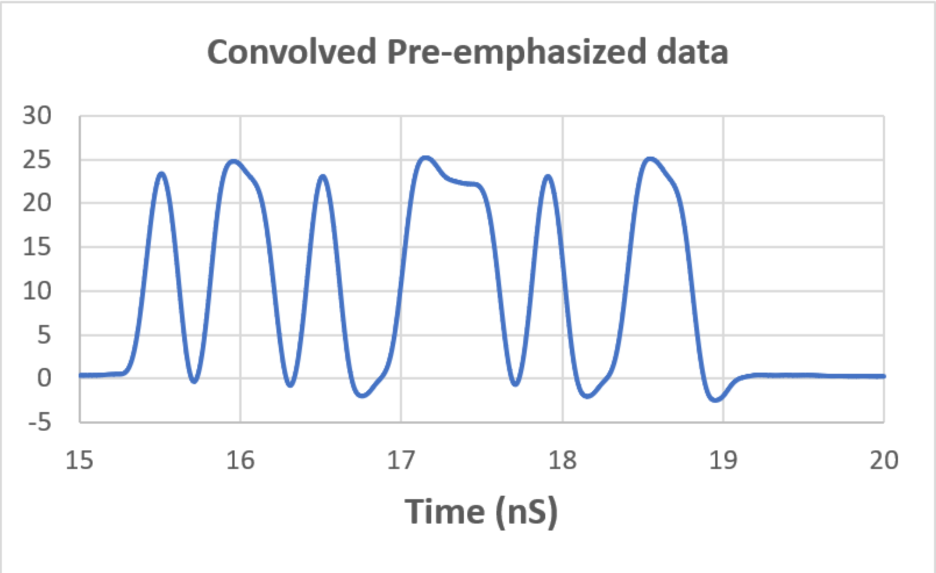
USING THE IMPULSE RESPONSE DATA

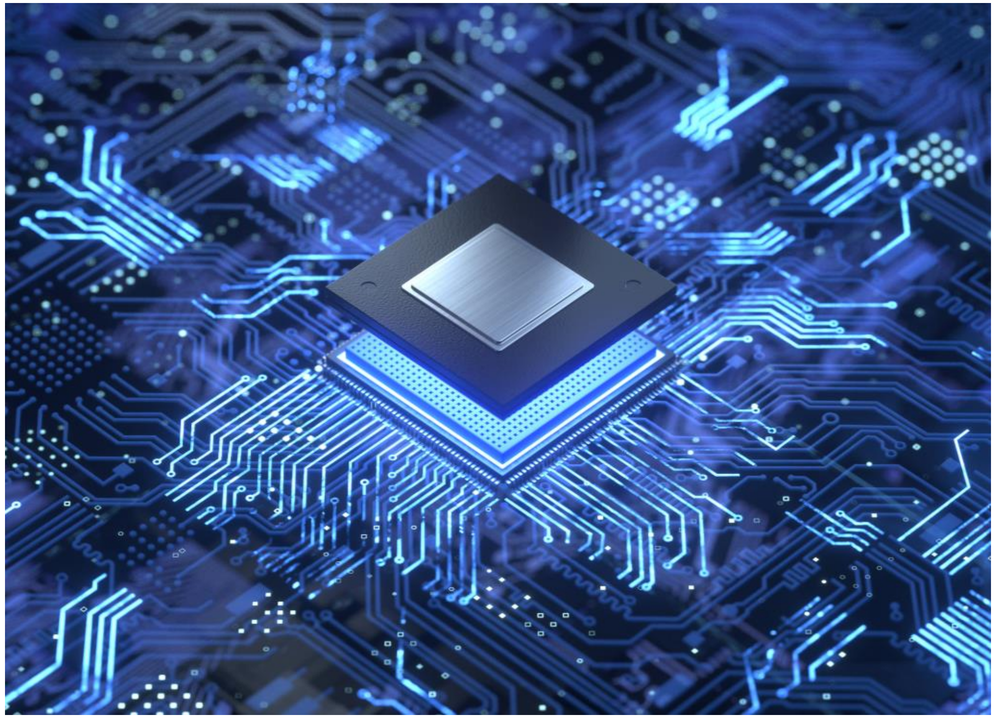
- If digital pre-emphasis is applied to the data, there is some improvement of amplitude balance





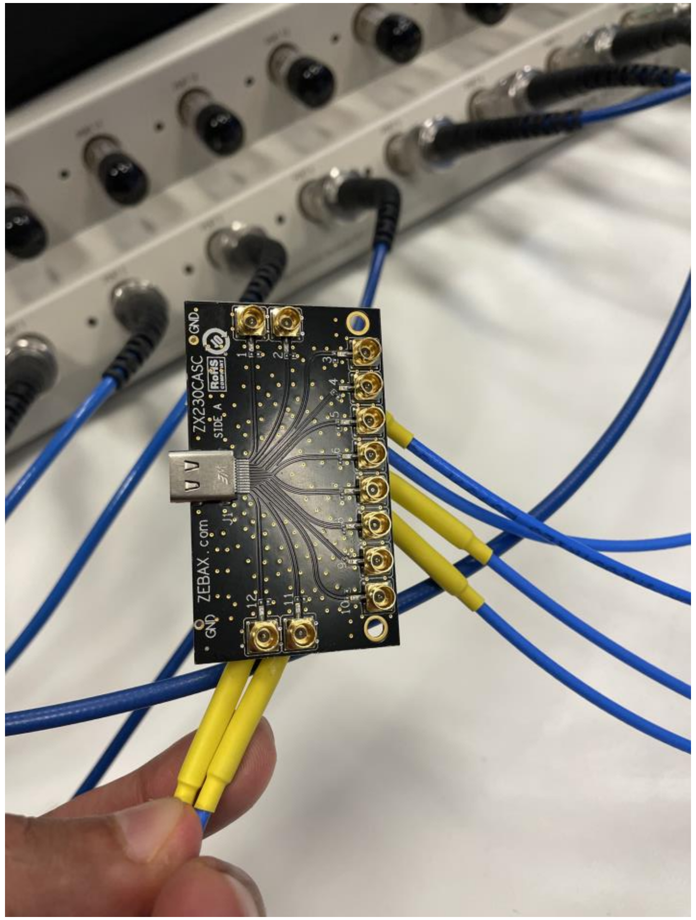
USING THE IMPULSE RESPONSE DATA

- It's clear that post processing with the measured impulse response is a powerful method for determining expected digital signal impairment
- Python code which was used to perform convolution of the saved impulse "csv" file and the oversampled digital bitstream will be made available on our website



USB-C CABLE MEASUREMENT

- The SN5090-16 will be used to measure a USB-C cable
- We'll be able to see differential Insertion Loss, Return Loss, NEXT and FEXT measurements on all the twisted pairs



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