Microwave Interconnect Testing For 12G SDI Applications

Jim Nadolny, *Samtec*

Corey Kimble, Craig Rapp - Samtec
OJ Danzy, Mike Resso - Keysight
Boris Nevelev - Imagine Communications

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SPEAKER

Jim Nadolny

Principle SI and EMI Engineer, Samtec
jim.nadolny@samtec.com | samtec.com | @SamtecInc

Jim Nadolny received his BSEE from the University of Connecticut in 1984 and an MSEE from the University of New Mexico in 1992. He began his career focused on EMI design and analysis at the system and component levels for military and commercial platforms. For the last 20 years his focus has shifted to signal integrity analysis of multi-gigabit data transmission systems. Jim is chair of IEEE P370 TG1 a task group focused on standardized S-parameter testing of passive structures to 50 GHz and a frequent contributor to DesignCon and other conferences.

Outline

- Introduction
- Evolution of Video Transmission
- Electrical Requirements for 12G SDI
- Legacy Test Methods
- Improved Test Method
- Conclusions

Acknowledgments

- Significant contributions to this research included my colleagues from Samtec, Corey Kimble, Craig Rapp, David Blankenship and Chris Shelly.
- Boris Nevelev from Imagine Communications provided insight to the video broadcast industry as well as technical requirements above and beyond those defined in the SMPTE specification.
- Finally OJ Danzy and Mike Resso contributed on the proper use of PLTS, AFR and related instrumentation details.

Introduction

- Video transmission is evolving
  - 6 MHz analog bandwidth in the 1960's
  - 12 channels in VHF band
  - HDMI 2.0 up to 18 Gbps

- Key points
  - Video is now high speed digital
  - Interconnect requirements more challenging to meet

Introduction

- Focus of this paper is ***broadcast video***
  - Video over satellite, cable and terrestrial infrastructure
  - Think "recording studio"
  - Not HDMI to your "man cave"

- Standardization governed by Society of Motion Picture and Television Engineers (SMPTE)
  - Serial Data Interface (SDI)
  - 3G SDI, 6G SDI, 12G SDI

Courtesy of Imagine Communications

Evolution of Video Transmission

- SDI video retains legacy characteristics
  - 75 ohm coaxial connectors/cables
  - Single ended signaling

- Contrast with Ethernet
  - 100 ohm twinax cable
  - High density multipin connectors
 - Differential signaling

Courtesy of Imagine Communications

Electrical Requirements for 12G SDI

- SMPTE ST 2082-1:2015 defines 12G SDI performance
  - Binary encoding
  - Up to 40 dB of insertion loss at 6 GHz
  - Connectors and cables shall have an attenuation curve that follows $1/\sqrt{freq}$
 - Reflection loss should be "small" to achieve this attenuation curve

Electrical Requirements for 12G SDI

12G SDI Return Loss Requirement
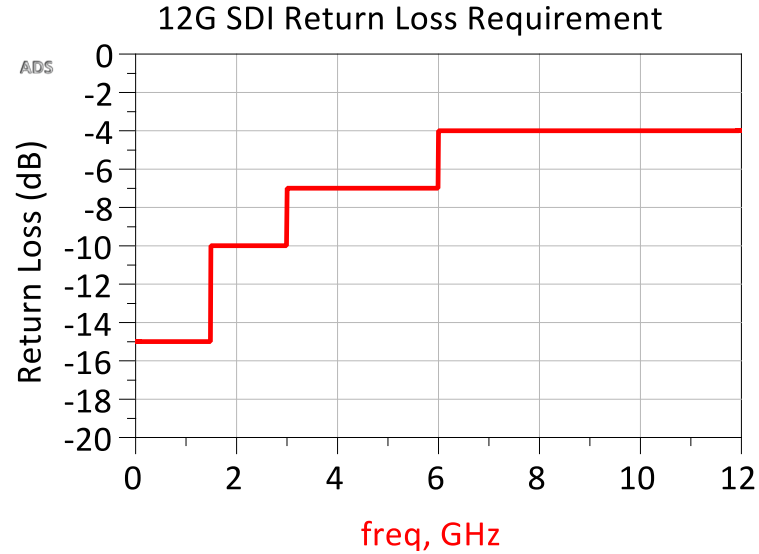
Electrical Requirements for 12G SDI

- "long" coax cables are required in video broadcast
  - Cable equalizers used to compensate for frequency dependent loss
  - Up to 40 dB of loss at Nyquist is expected

- Test question 1 –
  - How much crosstalk can be tolerated in video broadcast equipment?

Electrical Requirements for 12G SDI

BNC Isolation, Microstrip Trace Routing
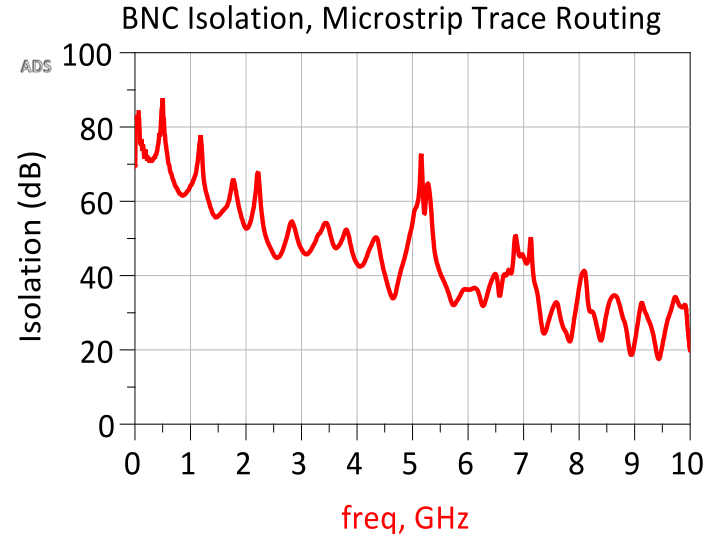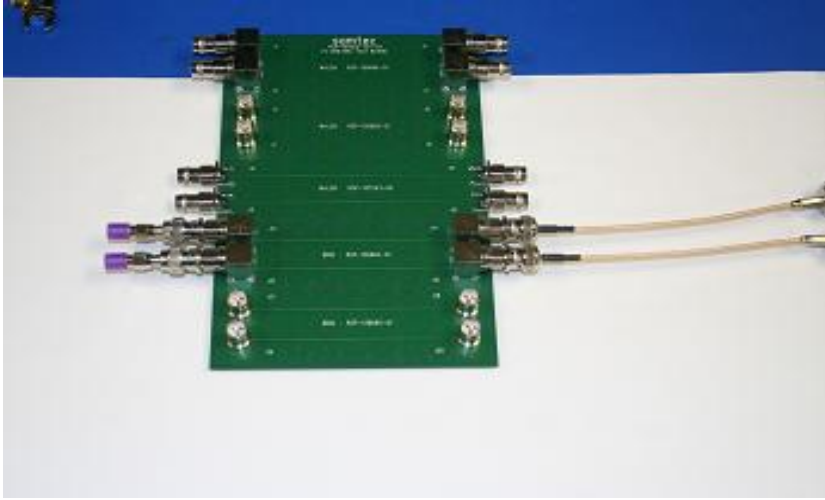
Is this adequate isolation for 40 dB of cable loss?

Electrical Requirements for 12G SDI

- "all we have to do is"
    - test a 75 ohm coaxial connector
   - up to 12 GHz
    - mounted on a PCB

How hard can it be?

Electrical Requirements for 12G SDI

- Challenges
  - Limited availability of 75 ohm calibration kits and adapters with 12 GHz bandwidth
  - The need to include the PCB footprint in the RL measurement

- Approach
  - Custom calibration standards
  - Fixture removal techniques

Electrical Requirements for 12G SDI

- Footprint optimization
  - Full wave simulation
    - Pad size
    - Ground plane cutout (antipad)
    - Drill size
    - PCB stackup

- Testing also required to validate footprint design
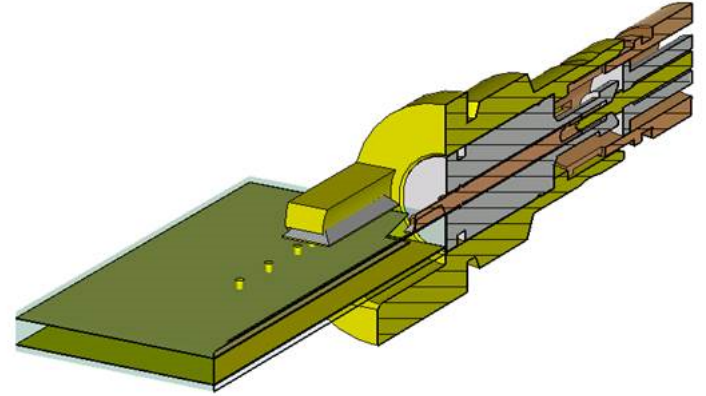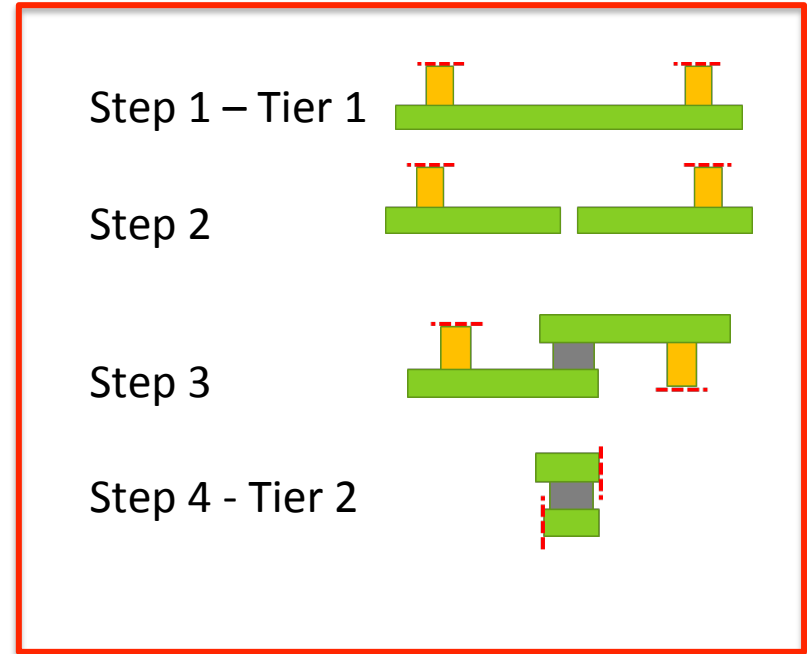
Electrical Requirements for 12G SDI
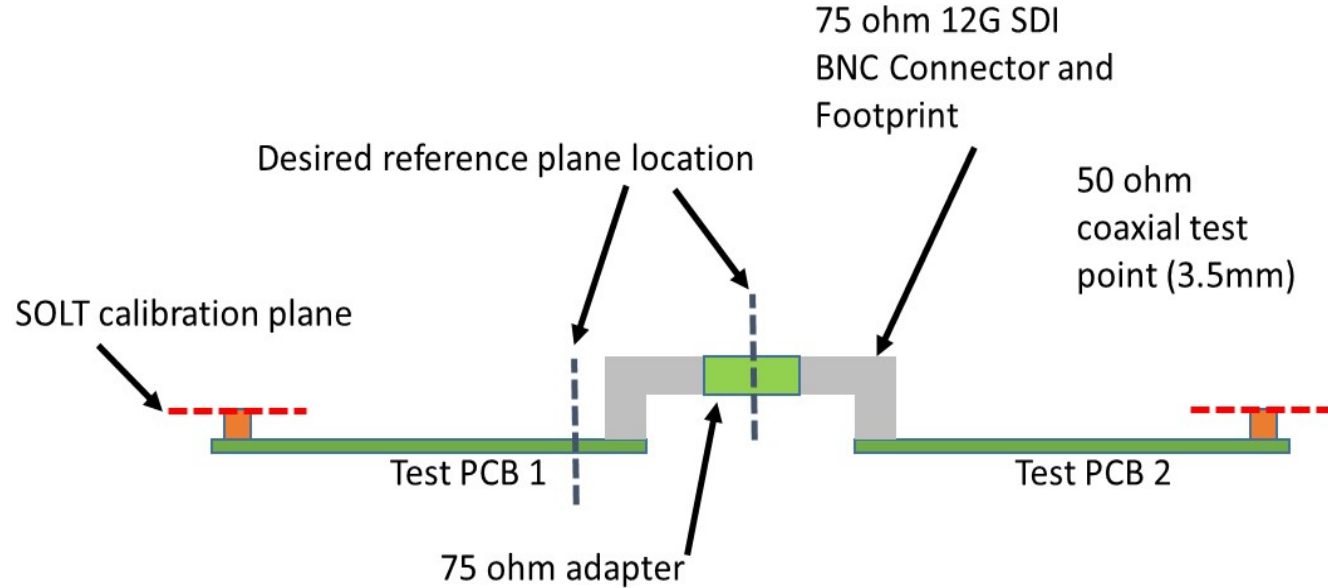
Legacy Component Test Methods

- Time domain gating
  - Transform to time domain
  - Apply gates to remove fixture effects

- Limitations
  - Can be difficult to replicate results without precise definition of gate location
  - Only obtain RL, not IL or [S]
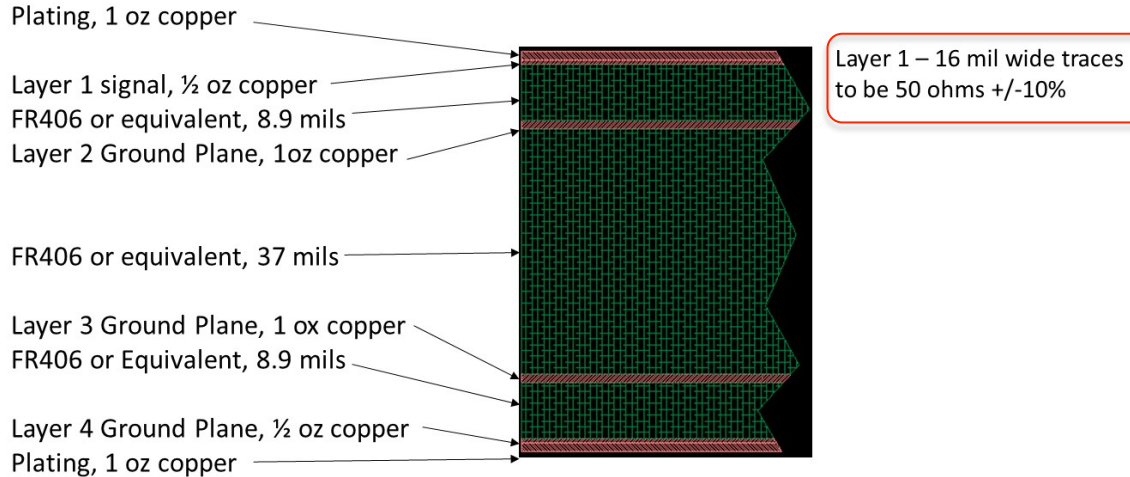 - Need "appreciable" separation between gate location and desired reference plane
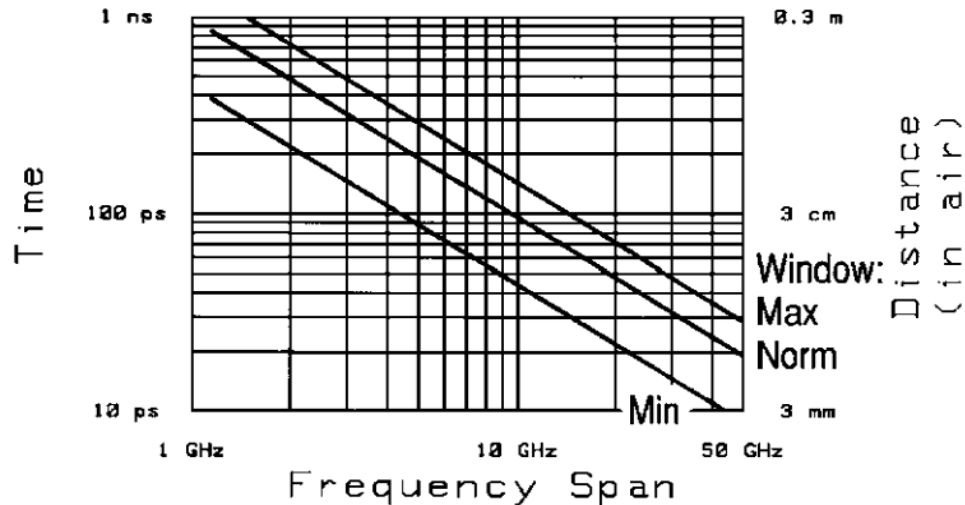
Improved Test Method

- Two tier VNA calibration

    - Tier 1 is a traditional 50 ohm SOLT calibration

    - Tier 2 measures "2X thru" for fixture removal

Step 1 – Tier 1

Step 2

Step 3

Step 4 - Tier 2

Improved Test Method

- Fixture design begins with a stackup that supports a 75 ohm trace impedance

Plating, 1 oz copper

Layer 1 signal, ½ oz copper
FR406 or equivalent, 8.9 mils
Layer 2 Ground Plane, 1oz copper

FR406 or equivalent, 37 mils

Layer 3 Ground Plane, 1 ox copper
FR406 or Equivalent, 8.9 mils

Layer 4 Ground Plane, ½ oz copper
Plating, 1 oz copper

Layer 1 – 16 mil wide traces to be 50 ohms +/-10%

By starting with a wide 50 ohm trace we can reduce the width to achieve 75 ohms
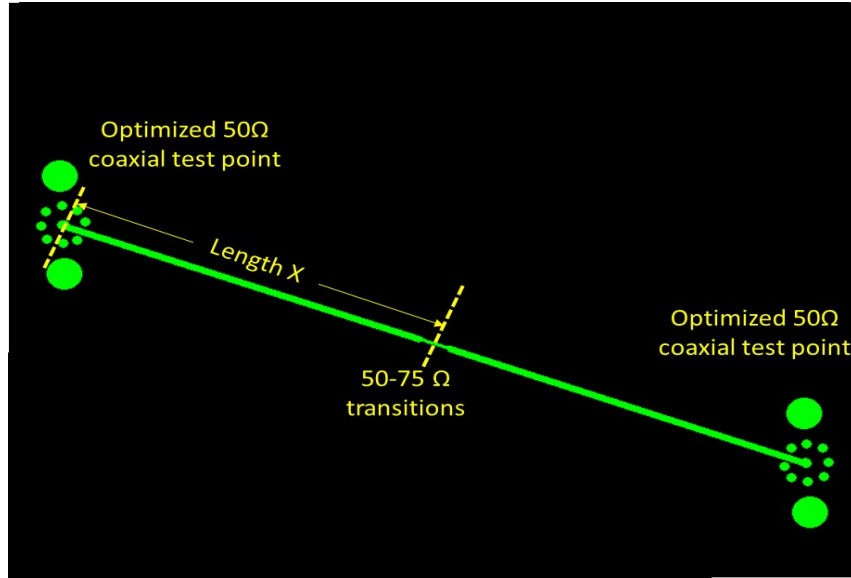
Improved Test Method

- Fixture Design – location of impedance transition near 75 ohm connector
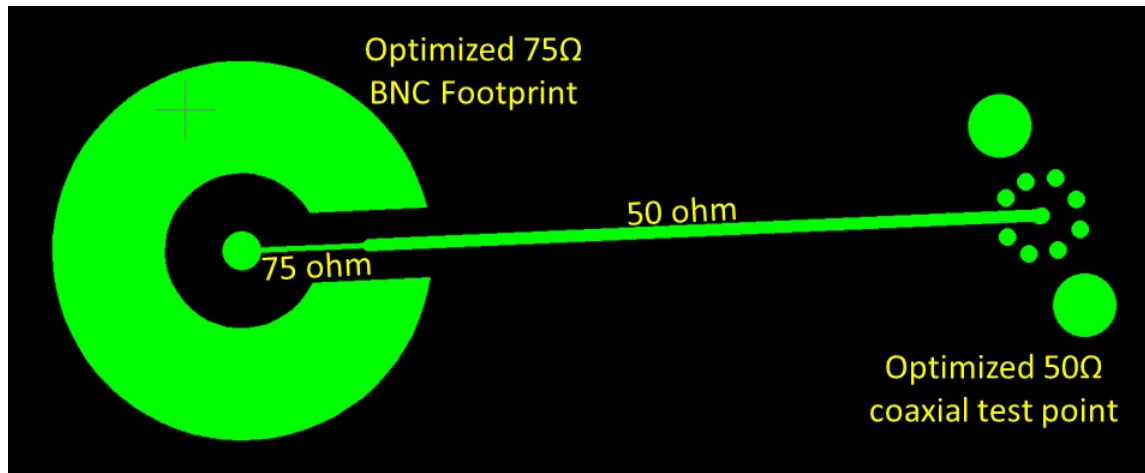
50-75 ohm transition location

Improved Test Method

- Fixture Design – Calibration structure(s) depends on de-embedding algorithm. In this case a single 2x thru calibration structure is required.
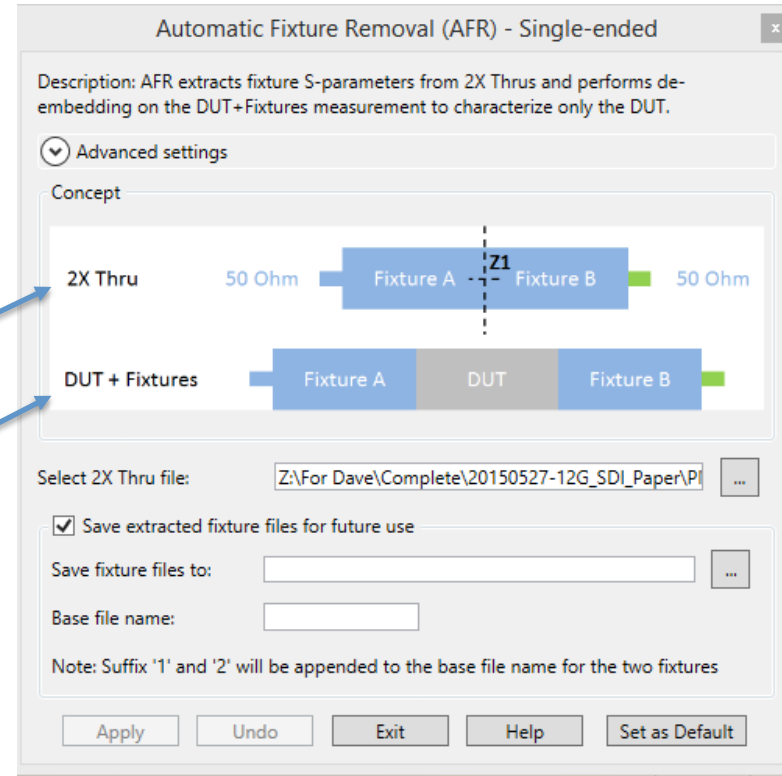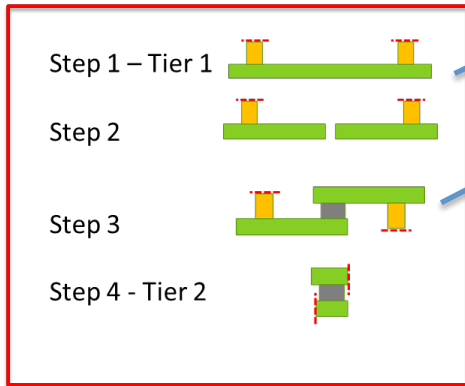

50-75 ohm transition in 2x thru calibration structure
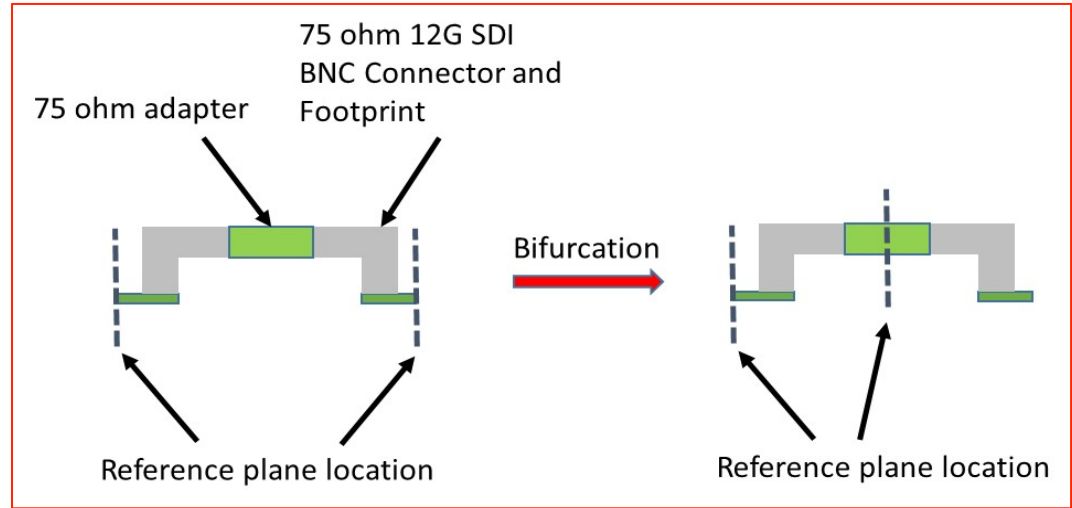
Improved Test Method

- Test Process Advancement
  - Keysight Physical Layer Test System (PLTS) with Automatic Fixture Removal (AFR) option
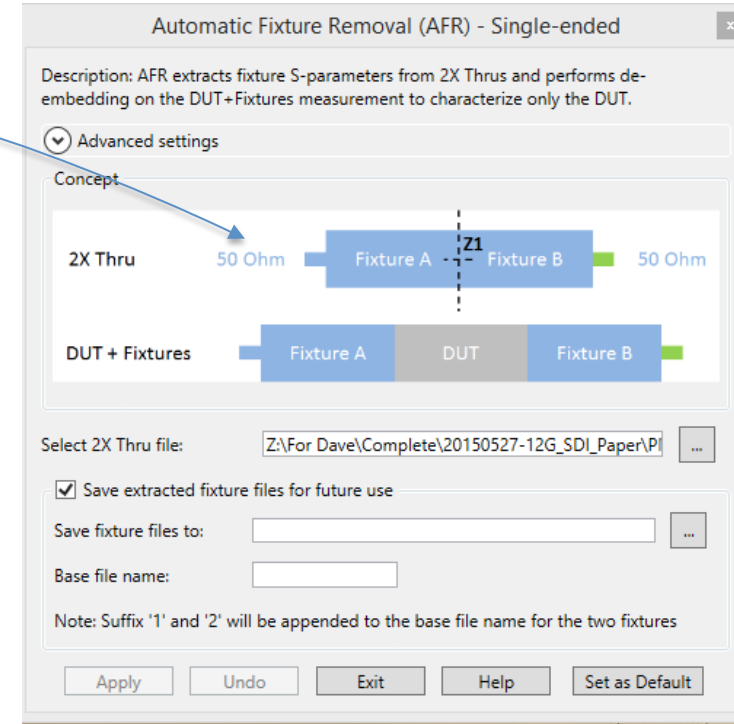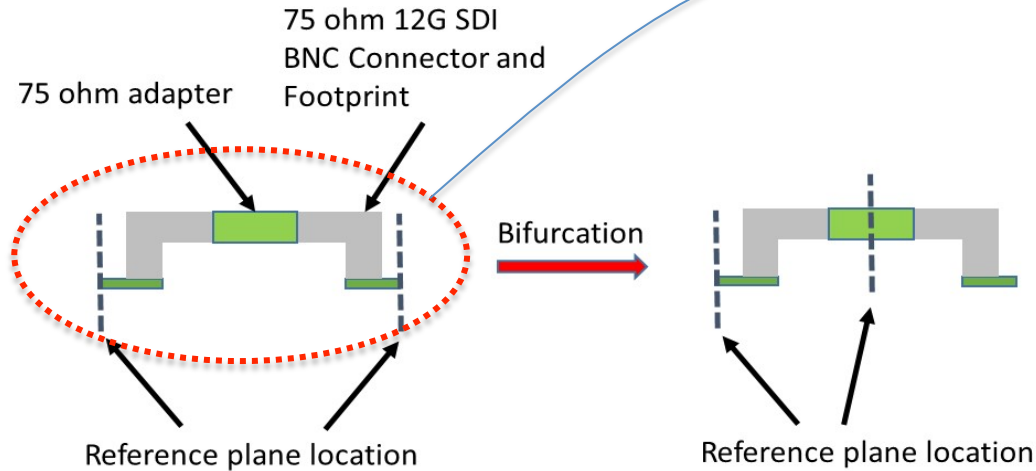 - Automates the matrix math associated with S-parameter de-embedding

Improved Test Method

- Options exist to further shift the reference plane locations
  - Allows for a precise measurement of a single 75 ohm connector and it's footprint
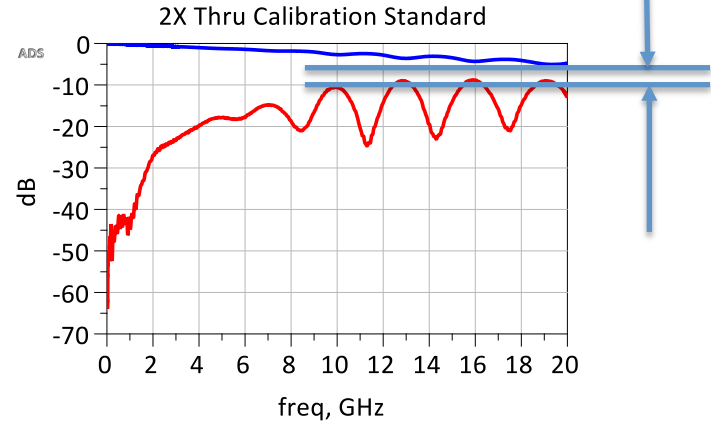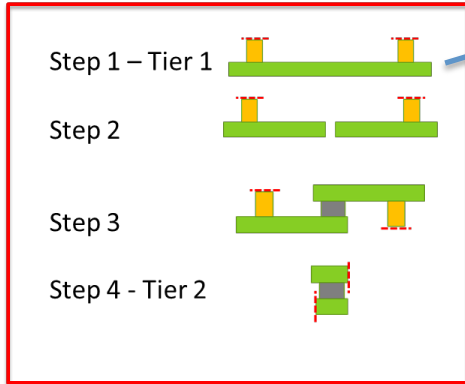
Improved Test Method

75 ohm adapter

75 ohm 12G SDI BNC Connector and Footprint

Bifurcation

Reference plane location

Reference plane location

Automatic Fixture Removal (AFR) - Single-ended

Description: AFR extracts fixture S-parameters from 2X Thrus and performs de-embedding on the DUT+Fixtures measurement to characterize only the DUT.

⌄ Advanced settings

Concept

| 2X Thru | 50 Ohm | Fixture A | Z1 | Fixture B | 50 Ohm |

| DUT + Fixtures | Fixture A | DUT | Fixture B |

Select 2X Thru file: Z:\For Dave\Complete\20150527-12G_SDI_Paper\Pl [...]

☑ Save extracted fixture files for future use

Save fixture files to: [ ] [...]

Base file name: [ ]

Note: Suffix '1' and '2' will be appended to the base file name for the two fixtures

| Apply | Undo | Exit | Help | Set as Default |

Apply the AFR bifurcation algorithm a 2nd time to obtain the S-parameters for a single 75 ohm video connector and footprint
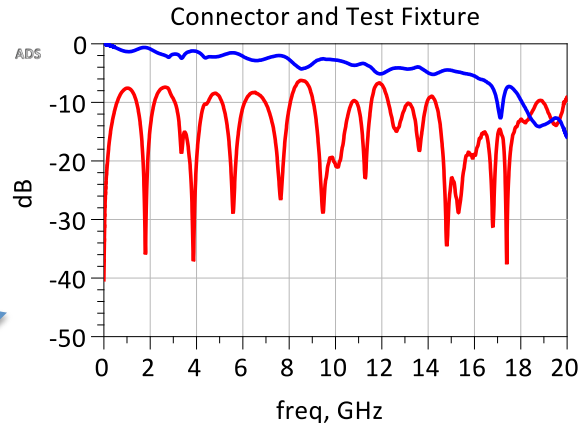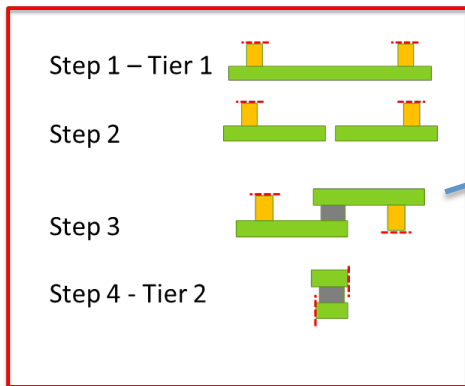
Improved Test Method

- Calibration structure insertion loss and return loss determine bandwidth of S-parameters
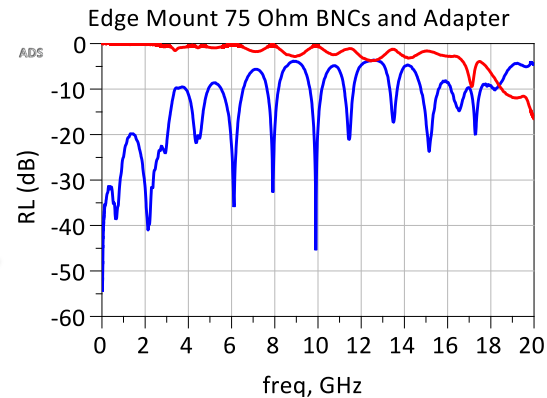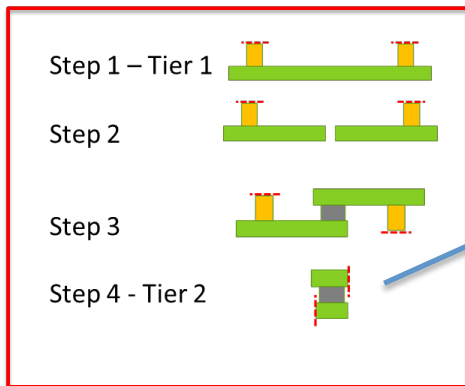 - Need ~5 dB separation

Step 1 – Tier 1

Step 2

Step 3

Step 4 - Tier 2

2X Thru Calibration Standard

ADS

dB

freq, GHz

Improved Test Method

- Results before Tier 2 calibration

Connector and Test Fixture

Step 1 – Tier 1

Step 2

Step 3

Step 4 - Tier 2

Improved Test Method

- Results after Tier 2 calibration

Edge Mount 75 Ohm BNCs and Adapter
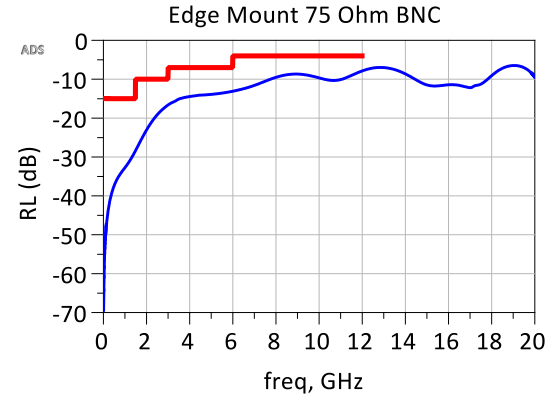
Step 1 – Tier 1

Step 2

Step 3

Step 4 - Tier 2

Improved Test Method

Edge Mount 75 Ohm BNCs and Adapter

Edge Mount 75 Ohm BNC

Bifurcation

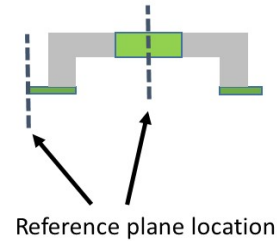75 ohm 12G SDI BNC Connector and Footprint

75 ohm adapter

Reference plane location
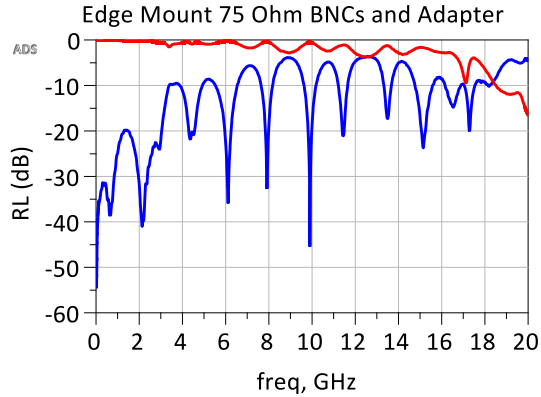
Bifurcation
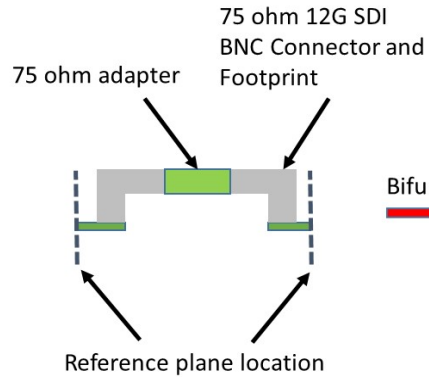
Reference plane location

Conclusions

- The single largest reflection in most video broadcast interconnects is the connector to PCB interface
- This interface needs to be included in PCB mount connector characterization
- An improved test method has been demonstrated which permits precise reference plane adjustment using a simple 2x thru calibration structure

Thank you!

QUESTIONS?