4K Cabling Truths and Misconceptions for HDBaseT Cabling

Bob Ferguson
RCDD, CTS, HDBaseT Trainer
Belden
Agenda

• Standards Involved
• Convergence
• HDBaseT Signal
• Belden Testing
• Results
• Conclusion
Networking Standards

- EIA/TIA
  - 568 C-2 Category Cabling
  - 607 C – Grounding and Bonding
- ISO 11801
- BICSI
  - TDMM
- IEEE
  - 802.3 – Ethernet
AV Standards

HDBaseT 2.0
IEEE 1191*

*Currently in draft

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Convergence

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Technology Convergence

- The combination of technology on a single network (Ethernet)
  - Voice over IP
  - Audio over IP
  - Video over IP
Infrastructure Convergence

- The use of data cabling (i.e. Category Cable) to support different applications
  - Class 2 Circuits for Remote Signaling
  - Audio – Dante
  - Video – Include HDBaseT

Readily available at a low cost, but is it the best solution?
HDBaseT Signal
More Than Just Video or HDMI

- Uncompressed Video & Audio
- USB 2.0
- 100BaseT Ethernet
- Control Signals
- Power up to 100W

**HDBaseT 5Play™**

*5Play is a trademark of HDBaseT Alliance*
Video Need for Speed

- Ultra High Bandwidth of high quality 4K video over HDBaseT

<table>
<thead>
<tr>
<th>Color Depth</th>
<th>Frame Rate</th>
<th>Chroma Subsampling</th>
<th>Pixel Clock</th>
<th>8-Bit Color Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 bit</td>
<td>30 Hz</td>
<td>4:4:4</td>
<td>297MHz</td>
<td>8.91 Gbps</td>
</tr>
<tr>
<td>8 bit</td>
<td>60 Hz</td>
<td>4:2:0</td>
<td>297MHz</td>
<td>8.91 Gbps</td>
</tr>
</tbody>
</table>

**What’s Next?**

8K, Screen, 16 bits color, HDR* and 4:4:4 ~ 71.28 Gbps

*High Dynamic Range

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Issues in Market

• What cable to use to transmit 4K over HDBaseT?
• What distance can I run?
• What is an acceptable picture quality?
• What impact does noise or bundling have on the cable performance and distance?
Frequency Response

- Frequency Response of HDBaseT 4K/UHD Signal

- Area under curve is power defining HDBaseT signal
- PAM16, 8.91Gbps
- Nearly all power (94%) is under 425 MHz
Belden Testing Goals

• Determine key cable characteristics that drive best HDBaseT performance for 4K
• Provide distance chart for installers
  – Based on transparent testing – use same equipment on all cable
• Answer other common questions for installers:
  – Impact of bundling on shielded vs. unshielded
  – Bit error rates vs. visual impact
  – Impact of patch cords
  – Issues with PoH applications
Belden Testing

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HDMI Testing Standard

- HDMI – Set standard for commercial video quality
  - Uncompressed
  - Used as video transport for HDBaseT
  - Gold standard for testing criteria (Less than 1 in Billion)

Pass/Fail Standard: Transfer quality 1

$10^{-9} = 1 \text{ error per 1 billion pixels}$
Test Setup

Quantum Data Analyzer Setting

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Aspect Ratio</th>
<th>Color Depth</th>
<th>Frame Rate</th>
<th>Chroma Subsampling</th>
</tr>
</thead>
<tbody>
<tr>
<td>4K UHD</td>
<td>16:9</td>
<td>8 bit</td>
<td>30 Hz</td>
<td>4:4:4</td>
</tr>
</tbody>
</table>

Extenders Used:
- Common commercially available extenders rated for 4K/100 m and 70 m
- Matrix switcher rated for 4K – bundled testing
Belden Testing

- Over 30 different types of cables from Belden and other manufacturers
- 100 meter direct connect links using a Cat 6A field plug
- Sent 4K signal from Quantum Data analyzer and measured return signal on it
- If able to transmit signal, number of errors per 1000 frames recorded
- Repeated signal transmission 5 times
- Trim cable 10 meters, re-connectorized and repeated steps above
Results
## Observations:

- TIA and ISO Category requirements not sufficient for HDBaseT 4K transmission
- Cabling must meet basic Ethernet performance – up to 425 MHz
- Some correlation to AWG size; but stronger correlation to Insertion Loss

### Results - Excerpt

<table>
<thead>
<tr>
<th>Category</th>
<th>Shield</th>
<th>AWG</th>
<th>Distance (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDBaseT</td>
<td>F/UTP</td>
<td>23</td>
<td>100</td>
</tr>
<tr>
<td>7A</td>
<td>S/FTP</td>
<td>22</td>
<td>100</td>
</tr>
<tr>
<td>7</td>
<td>S/FTP</td>
<td>22</td>
<td>100</td>
</tr>
<tr>
<td>6A</td>
<td>S/FTP</td>
<td>23</td>
<td>90</td>
</tr>
<tr>
<td>6A</td>
<td>F/UTP</td>
<td>23</td>
<td>90</td>
</tr>
<tr>
<td>6A</td>
<td>U/UTP</td>
<td>23</td>
<td>90</td>
</tr>
<tr>
<td>6A</td>
<td>S/FTP</td>
<td>24</td>
<td>70</td>
</tr>
<tr>
<td>6+</td>
<td>F/UTP</td>
<td>23</td>
<td>90</td>
</tr>
<tr>
<td>5e</td>
<td>SF/UTP</td>
<td>24</td>
<td>90</td>
</tr>
<tr>
<td>Non-ethernet</td>
<td>STP</td>
<td>22 str</td>
<td>10</td>
</tr>
</tbody>
</table>
# Narrowing Results – Best and Worse Cables Excerpt

<table>
<thead>
<tr>
<th></th>
<th>Best Cable 1</th>
<th>Best Cable 2</th>
<th>Worse Cable 1</th>
<th>Worse Cable 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Max Distance</strong></td>
<td>100</td>
<td>100</td>
<td>80</td>
<td>70</td>
</tr>
<tr>
<td><strong>Insertion Loss (Attenuation) @ 400 MHz</strong></td>
<td>-35.4</td>
<td>-37.3</td>
<td>-46.9</td>
<td>-41.6</td>
</tr>
<tr>
<td><strong>Worst Cap Unbalance (pf)</strong></td>
<td>74.2</td>
<td>28.5</td>
<td>52.9</td>
<td>182.0</td>
</tr>
<tr>
<td><strong>400 MHz Impedance AVG Value Forward</strong></td>
<td>105.0 +/- 5.7</td>
<td>103.7 +/- 10</td>
<td>99.2 +/- 5.9</td>
<td>104.4 +/- 6.4</td>
</tr>
<tr>
<td><strong>TCL Worst Mean (dB) 250-500 MHz</strong></td>
<td>-38.4</td>
<td>-32.4</td>
<td>-39.3</td>
<td>-38.0</td>
</tr>
<tr>
<td><strong>NEXT (dB) Worst 250-400 MHz</strong></td>
<td>-61.1</td>
<td>-38.4</td>
<td>-48.4</td>
<td>-60.3</td>
</tr>
<tr>
<td><strong>RL (dB) Worst ADSLM 300-400 MHz</strong></td>
<td>-22.9</td>
<td>-23.9</td>
<td>-21.474</td>
<td>-23.1</td>
</tr>
</tbody>
</table>
Regression Analysis

• Purpose to determine correlation between cable parameters and information capacity
  – If the Significance F is not less than 0.1 (10%) you do not have a meaningful correlation

<table>
<thead>
<tr>
<th>Cable Characteristics</th>
<th>Significance F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insertion Loss (IL)</td>
<td>0.08</td>
</tr>
<tr>
<td>Return Loss (RL)</td>
<td>0.22</td>
</tr>
<tr>
<td>Near End Crosstalk (NEXT)</td>
<td>0.18</td>
</tr>
</tbody>
</table>
Insertion Loss Analysis

- Cable lengths that provide fewest errors were dependent on cable construction.
- Number of errors increases exponentially.

![Graph showing errors vs. length for different types of cables.](chart.png)
Minimizing Pixel Errors

- Insertion loss of cabling designed for HDBaseT 4K UHD is better than category cabling.
- 10 errors per 1000 frames is same as 1 per billion.
Visual Errors

Good Quality

Issue: Unpredictable

- Location of errors on monitor
- Grouping of errors on monitor
- Dependent upon distance to monitor
- Overlapping – Not clear cut
Visual Errors

Poor Quality

Conclusion:
• 1 error per billion ensures quality
Visual Errors

No Picture

Worst Case:
• Intermittent to no picture!
Visual Errors

What’s Important?
Field Testers

• No standard for field testing
  – Cable that will pass 6A and Cat7A minimum, will fail HDMI standard @ 100 meters
• Lab Testing with Quantum Data 980B not practical in the field
• Recent releases of testers – still early
# HDBaseT 2.0/1.0 Classes

<table>
<thead>
<tr>
<th>Class</th>
<th>HDBaseT spec</th>
<th>Media</th>
<th>Max Resolution</th>
<th>Supported max Cable length</th>
<th>Cable category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A</td>
<td>1.0</td>
<td>Copper</td>
<td>1080p 4K</td>
<td>100m 70m</td>
<td>Cat5e Cat5e</td>
</tr>
<tr>
<td>Class B</td>
<td>1.0</td>
<td>Copper</td>
<td>1080p 4K</td>
<td>70m 35m</td>
<td>Cat6a Cat5e</td>
</tr>
<tr>
<td>Class C</td>
<td>2.0</td>
<td>Copper</td>
<td>1080p 4K 4K</td>
<td>100m 90m 100m</td>
<td>Cat5e Cat5e Cat6a</td>
</tr>
<tr>
<td>Class D</td>
<td>2.0</td>
<td>Copper</td>
<td>1080p</td>
<td>30m</td>
<td>Cat6a</td>
</tr>
<tr>
<td>Class E</td>
<td>2.0</td>
<td>Fiber</td>
<td>4K</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Information from HDBaseT Alliance
Different chipsets

The extender model you choose makes a difference on transmission distance

- Chip sets & implementation in equipment matter
- Same equip. manufacturer - Different levels of performance in different products
- Some chip sets & equipment not capable of 100 meters

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Direct Connect

Crimp On Type
- Performance dependent on cable construction due to crimp attachment

PCB Type
- Performance not dependent on cable construction due to IDC attachment

Direct Attach
- Equipment
- Cable terminated in RJ45 plugs
- RJ45 plugs terminated in factory or in field

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2 Connector Model

- HDBaseT standard allows for two connector model shown below
- Belden testing shows you can exceed 5 meter by reducing horizontal by equal amounts
- Patch cord need equal to or better electrical performance

HDBaseT 2.0 5m 90m 5m
Shielding

• Benefits
  – Shielding helps with heat dissipation
  – Reduce alien cross talk noise

• Issues
  – Potential group loops
  – Potential shorting issues

• Consult local codes for grounding safety requirements
• 607C - Recommends termination of shield on both ends
HDBaseT – Shield Termination

• Floating Power Supplies
  – Connect the cable shield on one end of the cable
    • High differential voltage developed between the Tx and Rx

• PoE Implementation
  – Connect the shield on both ends of the cable

• Chassis Grounded System
  – If both sides are chassis grounded, terminate the shield on both ends
  – If one side is chassis grounded and the other is floating, connect the shield on the chassis terminated side
Power over HDBaseT - PoH

• How is being used today
  – Power transmitter or receiver
• Potential to power a small display or camera
PoH

- Compatible with IEEE 802.3at and standard IEEE 802.3af
  - Input power 44-57v DC
  - Max current per pair – 1A
- Delivery of up to 100 watts
- Initiate all 4 pairs

- POH is fully interoperable with POE
  - Power will be driven on the twisted pair only after negotiation
  - Power level is based on the highest mutually supported
- Meet power electricity safety regulation

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Issues with Bundling

- Alien Crosstalk
- Performance Degradation (Temperature Rise)
- Safety

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Bundling – NEC Safety

• Communication cables carrying over 60 watts power
• Meet bundle size chart for gage and temperature rating (NFPA 725.144)
• Or have separate Limited Power Rating (LP)
  – Cable is rated by the maximum current per conductor
  – LP (0.5A) can handle up to 100 watts for 4 pair cable
    • HDBaseT maximum power
• Does not cover the performance of cables
Bundling and Alien Crosstalk

- HDBaseT signal is very susceptible to alien crosstalk
  - Recent testing
    - 8 around one (worst case connector testing)
  - Shielded cables recommended when bundling
    - Only overall foil shield necessary to protect signal
    - Category rating not factor if shielded
  - Cat 6A required if unshielded
Bundling and Heat Degradation

- HDBaseT 2.0 Spec
  - 9.18 PoH Annex A: Maximum number of cables per bundle
- Shielding can help dissipate heat build up
- Install bundles in open air or tray

Temperature  \[ \uparrow \]  Channel Insertion Loss  \[ \uparrow \]  \[ = \]  Up to 25% cable distance reduction
Conclusion
## Important to 4K HDBaseT Performance

<table>
<thead>
<tr>
<th>Category</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insertion Loss (IL)</td>
<td>• Better than Cat 6A or Cat 7A</td>
</tr>
<tr>
<td>Shielding</td>
<td>• Reduces alien crosstalk</td>
</tr>
<tr>
<td></td>
<td>• Reduces heat when bundling</td>
</tr>
<tr>
<td>Patch Cords</td>
<td>• Use quality connector</td>
</tr>
<tr>
<td></td>
<td>• Use patch cords with same/better IL as horizontal cable</td>
</tr>
<tr>
<td>RX/TX rated to 100 meters for 4K</td>
<td>• Equipment critical</td>
</tr>
<tr>
<td>Bundling</td>
<td>• Limit size of bundles – may impact cable distance</td>
</tr>
<tr>
<td></td>
<td>• Safety – Follow NFPA 725.144 or use LP rated cables</td>
</tr>
</tbody>
</table>

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Misconceptions about HDBaseT Cabling

- **Category Rating**
  - Higher category rating does not result in better HDBaseT performance

- **Electricals > 425 MHz**
  - Electricals above 425 MHz are not relevant to HDBaseT

- **Braid or Individually Shielded Pairs**
  - No improved results with braid or individually shielded pairs in bundle testing

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Identified Issues

- Category cables not optimized for HDBaseT
- Field testing standards uncertain
- Optimum results require HDMI error limit
- Power and bundling effects transmission
- Video technology advancements will require increasing bandwidth
Thank You for Your Time

Bob Ferguson
Regional Sales Engineer – Broadcast & AV Solutions
bob.ferguson@belden.com
www.belden.com
(214) 789-4626