Putting Cable to the Test for Maximum 4K UHD HDBaseT™ Performance

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HDBaseT Trainer
Belden
Agenda

- Standards Involved
- Convergence
- HDBaseT Signal
- Belden Testing
- Results
- Bundling and Power
- Conclusion
Standards Involved
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
Convergence
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
HDBaseT™ 5Play™*

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

*HDBaseT and 5Play are Trademarks of HDBaseT Alliance
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
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
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?
• Professional AV Market tendency to go to higher & higher category rating
  – Diverged from original “simplistic” cabling approach
    • Cat 7A – 22 AWG/foil shielded pairs/braid
Belden Testing Goals

• Determine key cable characteristics that drive best HDBaseT performance for 4K
• Understand idiosyncrasies of higher bandwidth needs for 4K/UHD
  – 100 Meter (understand distance limitations)
  – Bundled cabling
  – Power Rating POH
  – Passing criteria: < 10^{-9} = 1 error per 1 billion pixels
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
$10^{-9} = 1$ 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-conectorized and repeated steps above
Results
Results - Excerpt

<table>
<thead>
<tr>
<th>Category</th>
<th>Shield</th>
<th>AWG</th>
<th>Distance (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDBaseT Cable</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>7</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>

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
# 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>Max Distance</td>
<td>100</td>
<td>100</td>
<td>80</td>
<td>70</td>
</tr>
<tr>
<td>Insertion Loss (Attenuation) @ 400 MHz</td>
<td>-35.4</td>
<td>-37.3</td>
<td>-46.9</td>
<td>-41.6</td>
</tr>
<tr>
<td>Worst Cap Unbalance (pf)</td>
<td>74.2</td>
<td>28.5</td>
<td>52.9</td>
<td>182.0</td>
</tr>
<tr>
<td>400 MHz Impedance AVG Value Forward</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>TCL Worst Mean (dB) 250-500 MHz</td>
<td>-38.4</td>
<td>-32.4</td>
<td>-39.3</td>
<td>-38.0</td>
</tr>
<tr>
<td>NEXT (dB) Worst 250-400 MHz</td>
<td>-61.1</td>
<td>-38.4</td>
<td>-48.4</td>
<td>-60.3</td>
</tr>
<tr>
<td>RL (dB) Worst ADSLM 300-400 MHz</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
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.

Errors per 1000 frames

- Cat6A TIA and Cat7 ISO Limit: 13,363 Errors
- Cat 7A ISO Limit: 1,252 Errors
- HDBaseT Optimized Cabling: <10 Errors
- 1 per Billion Limit Line
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?
Bundling and Power
Issues with Bundling

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

Up to 25% cable distance reduction
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
Power over HDBaseT - PoH

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

RX or TX
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
1. **Cable Heating Test (Safety)**

   - Similar to UL – LP
   - Measures temperature rise in bundle
     - 3 bundle sizes: 7, 61 & 192 (unlimited)
   - Method
     - Apply 0.5 amps, 50v each conductor
     - Measures inner most cable
   - Passing
     - Temperature rise over 25C ambient *not >* cable rating (90C)
2. Cable Elevated Temperature Performance Test

- Method:
  - Cut cable: 80m (Cat 5e); 90m (Cat 6/6A/7/7A)
  - Connect to RX & TX with 2x5m patch cords
  - Cable placed in thermal chamber
    - Temperature set at maximum temp measured in Cable Heating test
  - Runs HDBaseT Recommended Cable Test
Conclusion
## Important to 4K HDBaseT Performance

<table>
<thead>
<tr>
<th>Insertion Loss (IL)</th>
<th>• Better than Cat 6A or Cat 7A industry published standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shielding</td>
<td>• Reduces alien crosstalk when bundling</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>
<tr>
<td></td>
<td>• Use cable with PoH rating</td>
</tr>
</tbody>
</table>
## Misconceptions about HDBaseT Cabling

<table>
<thead>
<tr>
<th>Category Rating</th>
<th>• Higher category rating does not result in better HDBaseT performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricals</td>
<td>• Electricals above 425 MHz are not relevant to HDBaseT</td>
</tr>
<tr>
<td>&gt; 425 MHz</td>
<td></td>
</tr>
<tr>
<td>Braid or</td>
<td>• No improved results with braid or individually shielded pairs</td>
</tr>
<tr>
<td>Individually</td>
<td>in bundle testing</td>
</tr>
<tr>
<td>Shielded Pairs</td>
<td></td>
</tr>
</tbody>
</table>
Identified Issues

- Category cables not optimized for 4K 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

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