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

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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

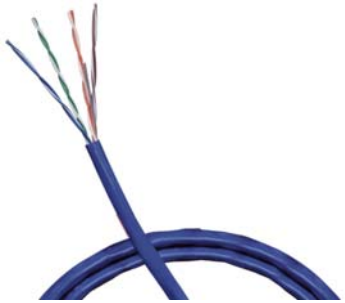
Convergence

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

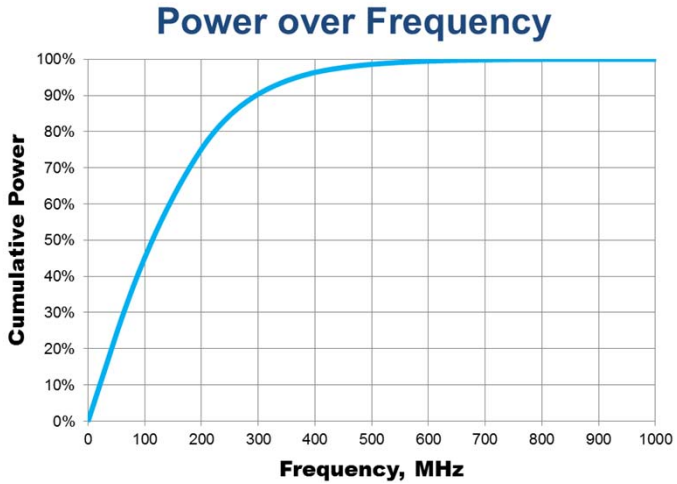
Power up to 100W

*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

Color Depth	Frame Rate	Chroma Subsampling	Pixel Clock	8-Bit Color Bandwidth
8 bit	30 Hz	4:4:4	297MHz	8.91 Gbps
8 bit	60 Hz	4:2:0	297MHz	8.91 Gbps

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

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

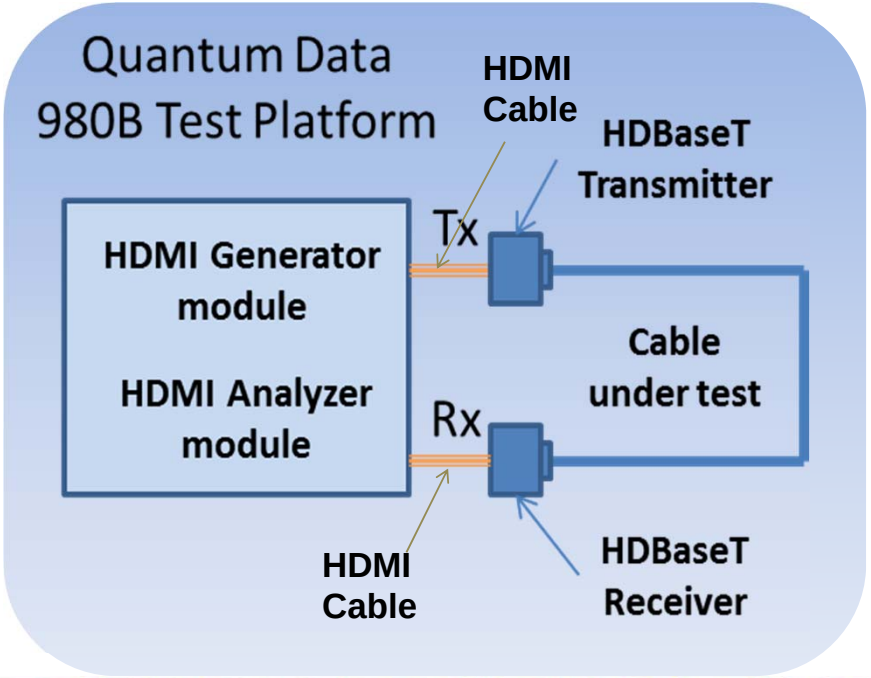
Test Setup

Quantum Data Analyzer Setting

Resolution	Aspect Ratio	Color Depth	Frame Rate	Chroma Subsampling
4K UHD	16:9	8 bit	30 Hz	4:4:4

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 type 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

Results - Excerpt

Category	Shield	AWG	Distance (meters)
HDBaseT Cable	F/UTP	23	100
7A	S/FTP	22	100
7	S/FTP	22	100
7	S/FTP	23	90
6A	F/UTP	23	90
6A	U/UTP	23	90
6A	S/FTP	24	70
6+	F/UTP	23	90
5e	SF/UTP	24	90
Non-ethernet	STP	22 str	10

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

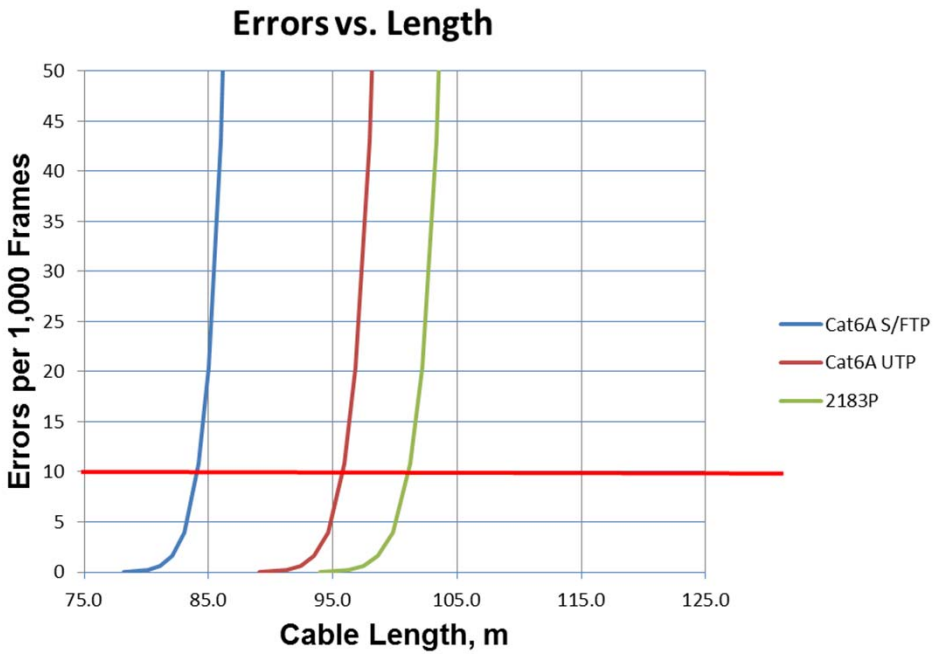
	Best Cable 1	Best Cable 2	Worse Cable 1	Worse Cable 2
Max Distance	100	100	80	70
Insertion Loss (Attenuation) @ 400 MHz	-35.4	-37.3	-46.9	-41.6
Worst Cap Unbalance (pf)	74.2	28.5	52.9	182.0
400 MHz Impedance AVG Value Forward	105.0 +/- 5.7	103.7 +/- 10	99.2 +/- 5.9	104.4 +/- 6.4
TCL Worst Mean (dB) 250-500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

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

Cable Characteristics	Significance F
Insertion Loss (IL)	0.08
Return Loss (RL)	0.22
Near End Crosstalk (NEXT)	0.18

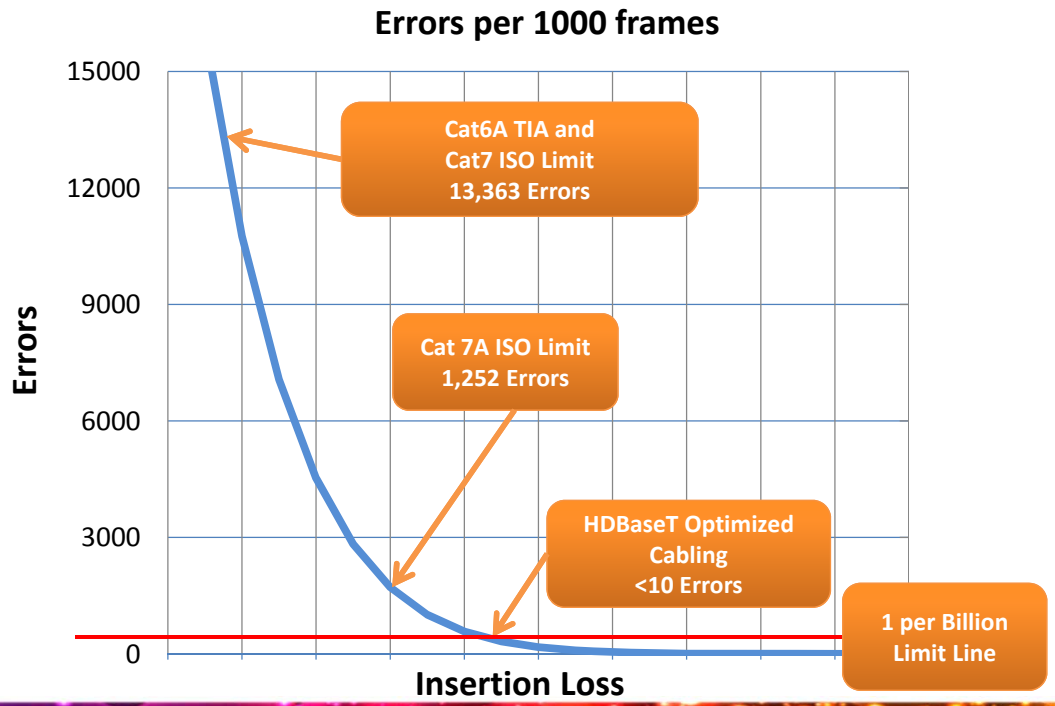
Insertion Loss Analysis



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

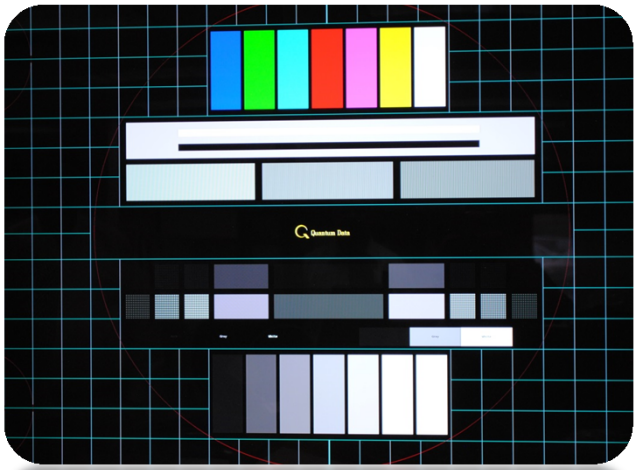
Minimizing Pixel Errors

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



Visual Errors

Good Quality

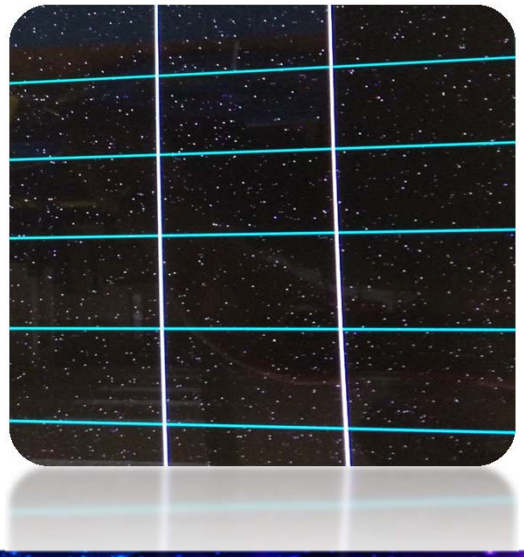


Issue: Unpredictable

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

Visual Errors

Poor Quality

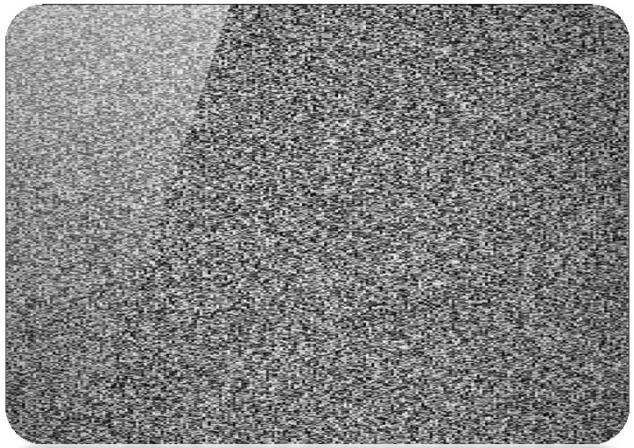


Conclusion:

- 1 error per billion ensures quality

Visual Errors

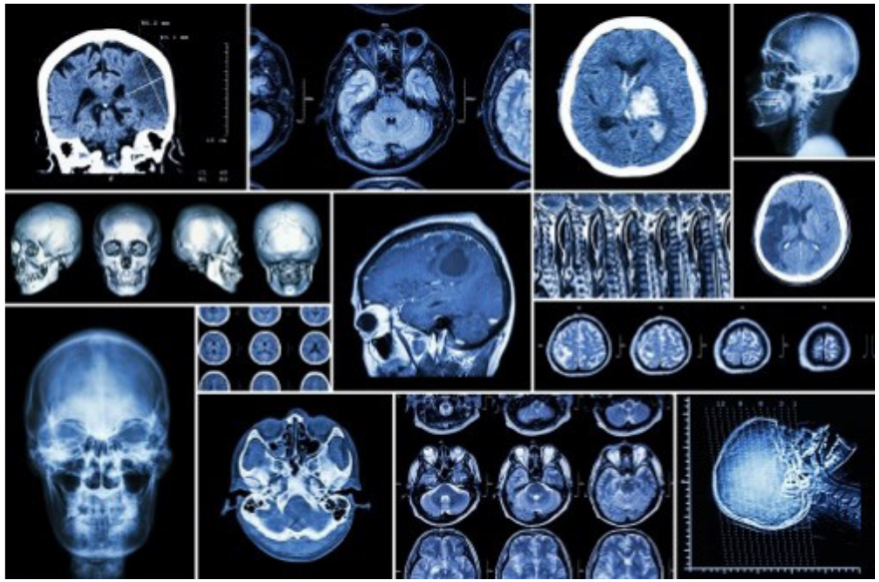
No Picture



Worst Case:

- Intermittent to no picture!

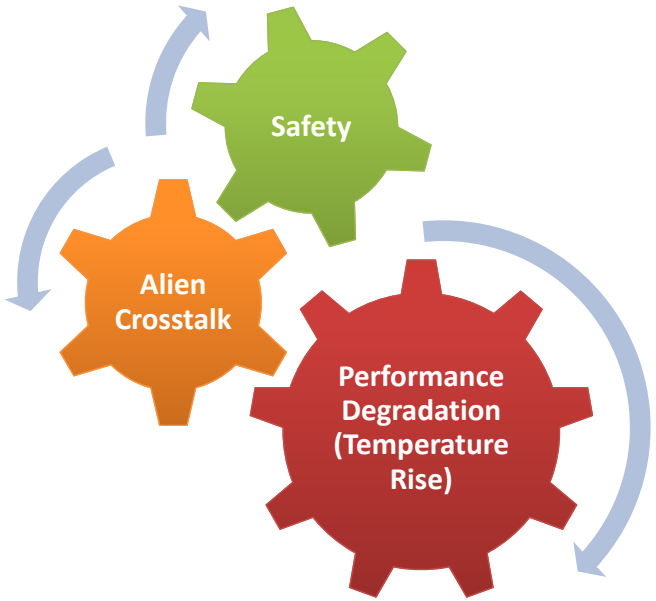
Visual Errors



What's Important?

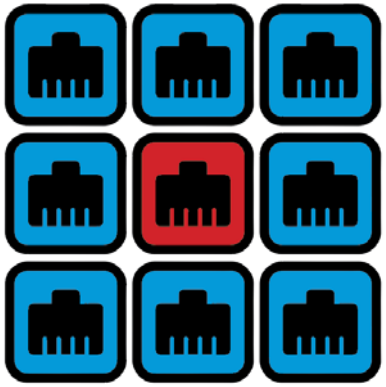
Bundling and Power

Issues with Bundling



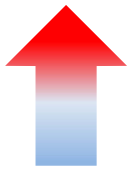
Bundling and Alien Crosstalk

- 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

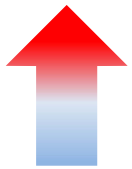


Bundling and Heat Degradation

- 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



Channel Insertion Loss

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

ENERGY STAR

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

PoH – UL4299

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)

PoH™
Power over HDBaseT

PoH – UL4299

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

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

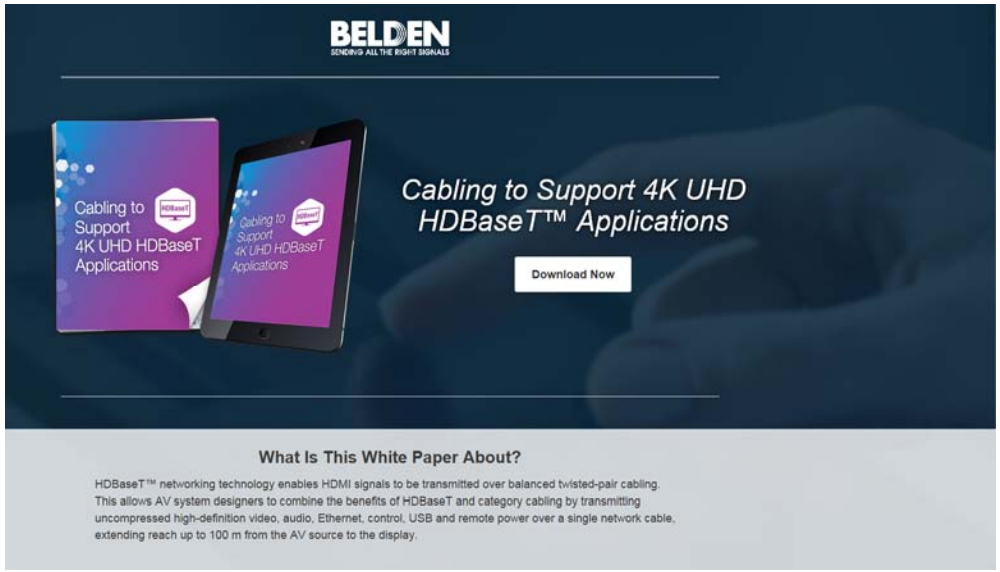
Misconceptions about HDBaseT Cabling

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

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

Belden White Paper



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