




SBE Ennes Lecture Series 2011

# Using Category 5e, 6 & 6a for Audio Applications

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## How Do We Compare?

**Can you use Cat 5e/6/6a for non-data applications?**

- What applications?
- What performance requirements?
- Compare to TIA/EIA 568 standard
  - ANSI/TIA 568-C.0
  - ISO 11801



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## What Applications?

Application	Format	Cable Type	Spec	End-User
Analog audio	Unbalanced	Single-conductor shielded	N/A	Consumer
	Balanced	Shielded twisted-pair	N/A	Professional
Digital audio	Unbalanced	Coaxial cable	S/PDIF	Consumer
	Balanced	Shielded twisted-pair	AES3	Professional

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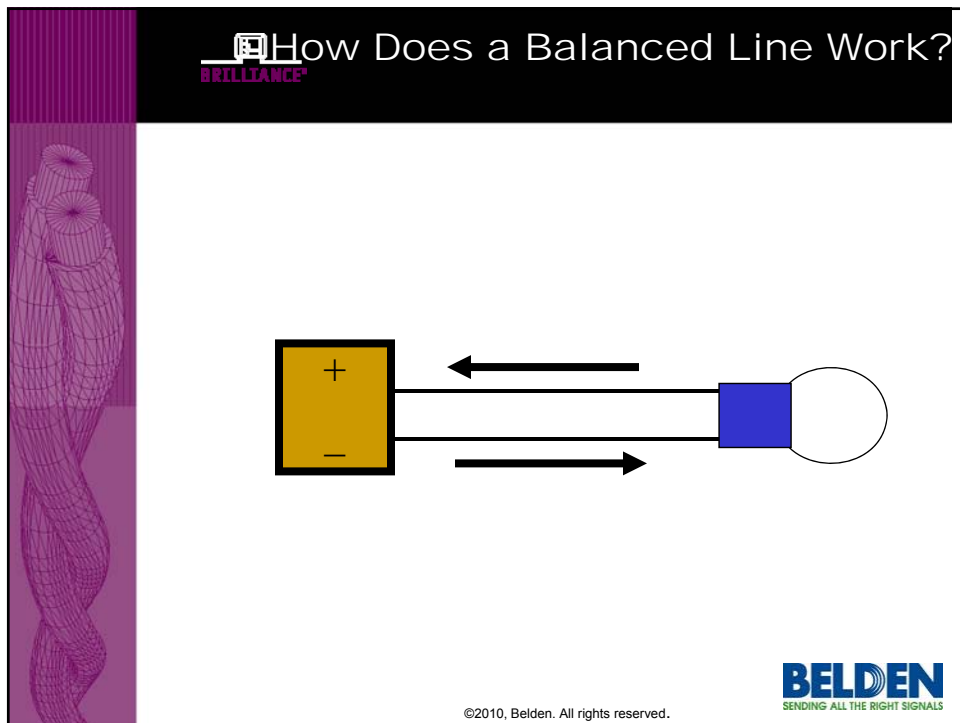
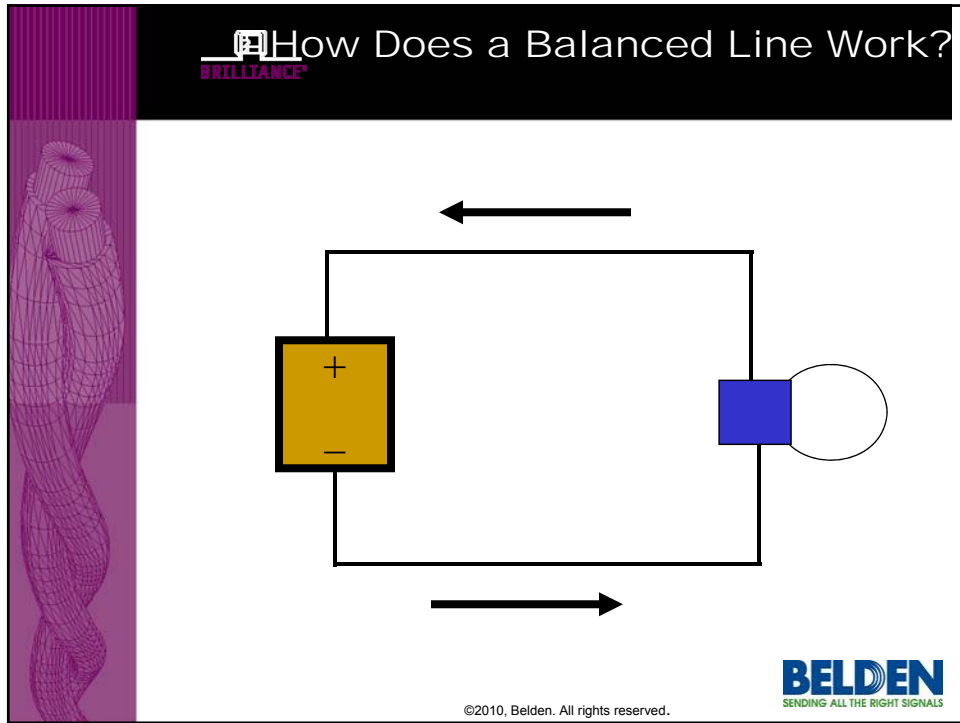
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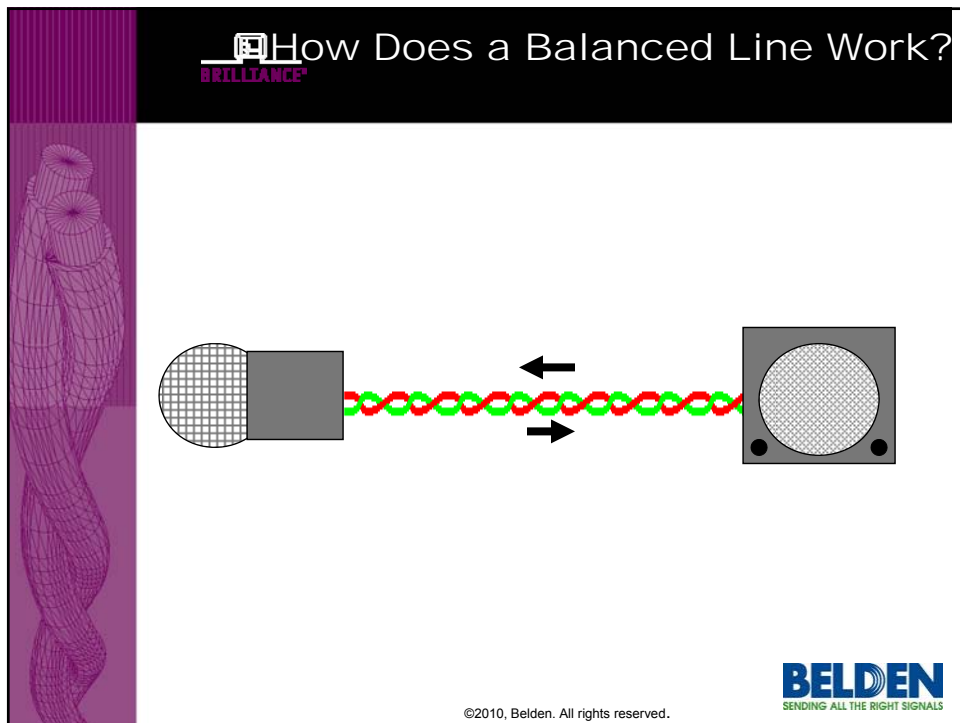
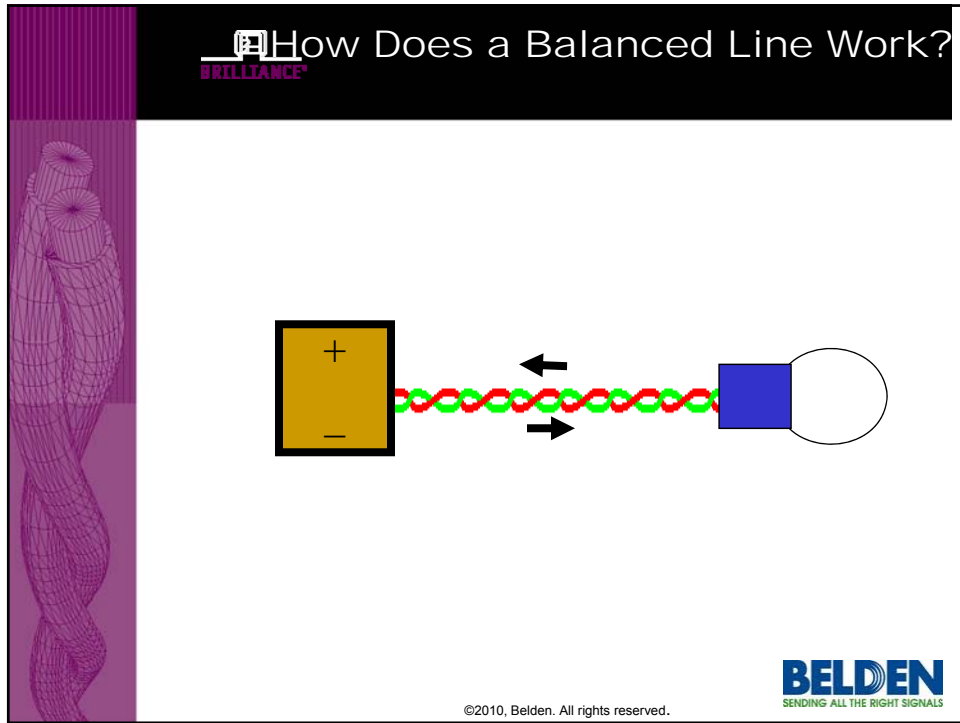
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## How Does a Balanced Line Work?

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**How Does a Balanced Line Work?**

The diagram illustrates a balanced line where two conductors, one red and one black, carry signals in opposite directions. This creates opposing magnetic fields, shown as red and black loops around the conductors. A central yellow arrow points to the center of the pair, indicating the balanced nature of the line. The conductors are shown as part of a larger twisted pair structure on the left and right.

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**A Perfect Balanced Line**


Requirement	Variations in	Cable Parameter	Measured in
<b>Spacing</b>	Impedance	Return Loss	Decibels (dB)
	Capacitance	Capacitance Unbalance	Picofarads (pF)
<b>Size</b>	Resistance	Resistance Unbalance	Ohms ( $\Omega$ )
<b>Length</b>	Resistance	Resistance Unbalance	Ohms ( $\Omega$ )
	Timing	Phase	Degrees ( $^\circ$ )

“A balanced line is one where each of the two conductors, and all passive pieces attached to each conductor, are the same impedance in reference to ground.”

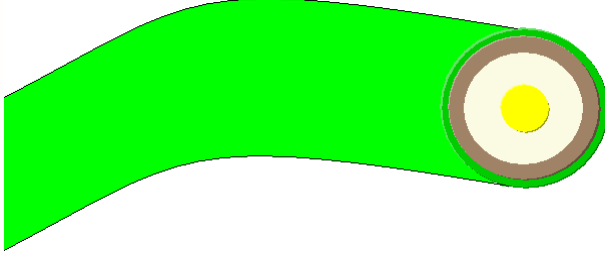
Bill Whitlock, Jensen Transformers

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## An Unbalanced Line




- Conductors aren't the same size.
- Conductors aren't the same length.
- Conductors aren't close together.


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## Consumer Analog Audio

	System Specs	Category 5e	Category 6	Category 6a
<b>Format</b>	Unbalanced	<i>Balanced</i>	<i>Balanced</i>	<i>Balanced</i>
<b>Capacitance</b>	30pF/ft. 98 pF/m	15 pF/ft. 49pF/m	15 pF/ft. 49pF/m	15 pF/ft. 49pF/m
<b>Impedance</b>	N/A	100Ω	100Ω	100Ω
<b>Gage</b>	22/24 AWG (?)	24 AWG	23 AWG	23 AWG
<b>Shield</b>	YES	NO	NO	NO


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## How Far Can You Go?

-1 dB @ 20 kHz

Source Impedance	15 pF/ft. (49 pF/m)	20 pF/ft. (66 pF/m)	30 pF/ft. (98 pF/m)	50 pF/ft. (164 pF/m)
50 Ω	5406 ft. 1648m	4055 ft. 1236m	2703 ft. 824m	1622 ft. 495m
100 Ω	2707 ft. 825m	2030 ft. 619m	1353 ft. 413m	812 ft. 248m
150 Ω	1873 ft. 571m	1352 ft. 412m	901 ft. 275m	541 ft. 165m
600 Ω	451 ft. 138m	338 ft. 103m	225 ft. 68.6m	135 ft. 41.2m
1 kΩ	271 ft. 82.6m	203 ft. 61.9m	135 ft. 41.2m	81 ft. 24.7m
10 kΩ	27 ft. 8.2m	20 ft. 6.1m	14 ft. 4.3m	8 ft. 2.4m
50 kΩ	5.4 ft. 165cm	4 ft. 122cm	2.7 ft. 82cm	1.6 ft. 49cm




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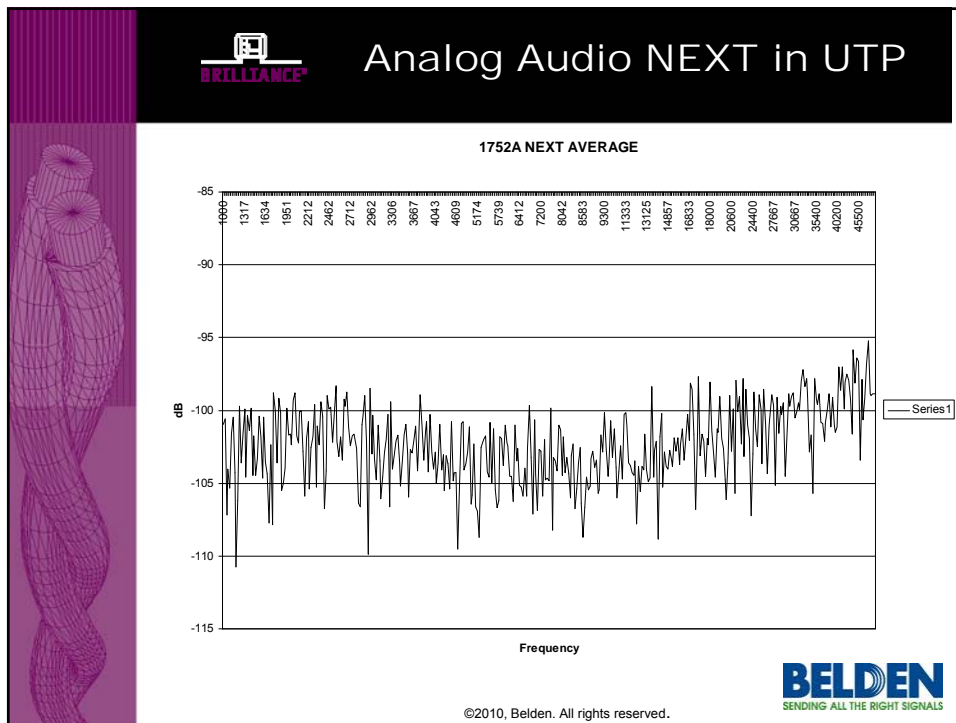
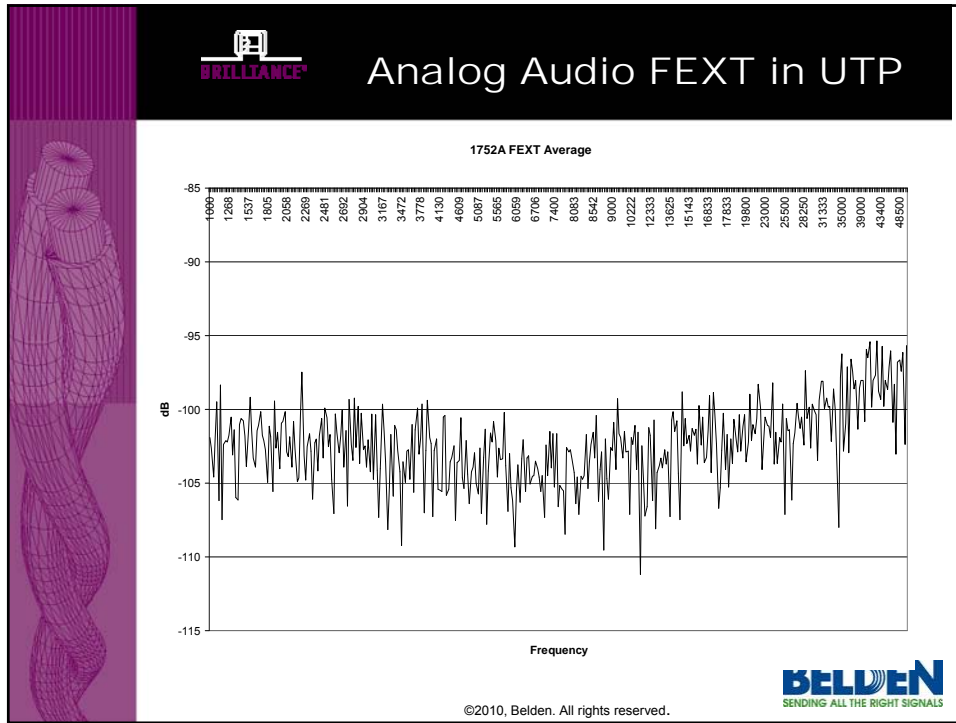



## Balanced Analog Audio

	System Specs	Category 5e	Category 6	Category 6a
<b>Format</b>	Balanced	Balanced	Balanced	Balanced
<b>Capacitance</b>	30pF/ft. 98 pF/m	15 pF/ft. 49pF/m	15 pF/ft. 49pF/m	15 pF/ft. 49pF/m
<b>Impedance</b>	N/A	100Ω	100Ω	100Ω
<b>Gage</b>	22-24 AWG	24 AWG	23 AWG	23 AWG
<b>Shield</b>	YES	NO	NO	NO




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 **BALANCED PAIRS AND SHIELDING**

- Ground Loops.
  - Shields can become ‘antennas’.
    - Feed noise into the pair
    - Not protecting the pair from noise.
- With UTP we ‘fixed the pair’.
  - As symmetrical as possible.
  - As balanced as possible
    - No shielding to fall back on.
- And now “InstaSnake”

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 **ANALOG AUDIO AND MEDIA TWIST**




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## How to Measure "Balance"




- Noise is "common mode".
- Balanced lines reject noise.
- How much?
  - Common-mode rejection ratio
  - CMRR
    - Measured in dB



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## What is Good CMRR?




SSL	
Mic Input	
50 Hz	>115 dB
1 kHz	>100 dB
10 kHz	>70 dB
Line Input	
50 Hz	>90 dB
1 kHz	>100 dB
10 kHz	>50 dB

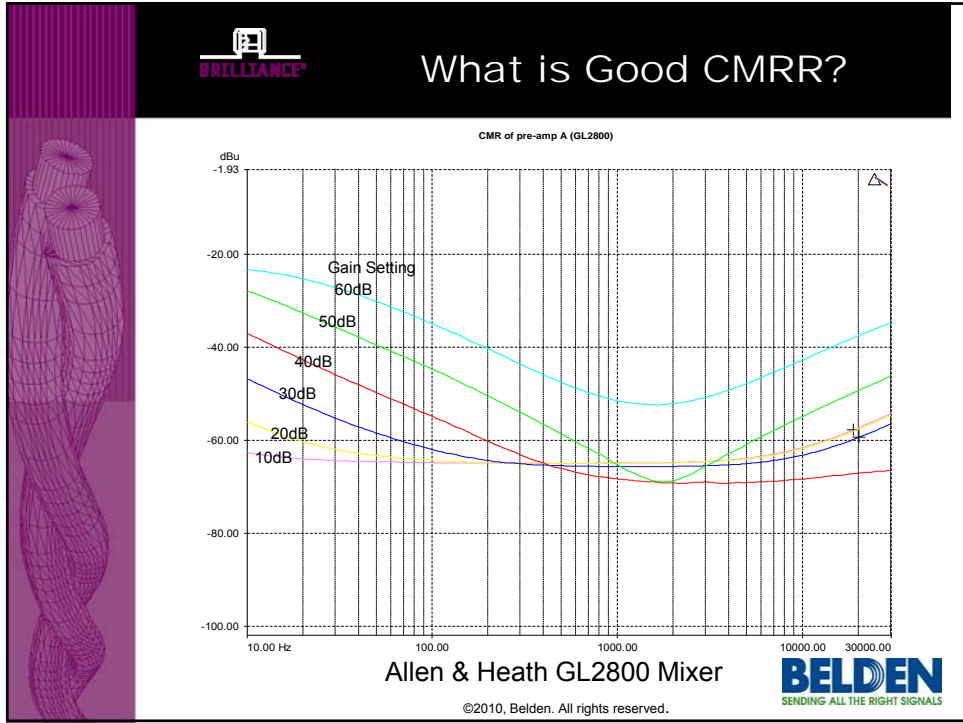
Calrec	
Mic Input	
1 kHz	>80 dB
15 kHz	>65 dB
Line Input	
1 kHz	>60 dB
10 kHz	>40 dB

Mackie	
Mic Input	
50 Hz	>70 dB
1 kHz	>70 dB
10 kHz	>60 dB

- Based on frequency
- Analog performance, not digital




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- 
- ### What is Good CMRR?
- Good CMRR from a chip!
    - 90 dB at 60 Hz
  - Designed by Bill Whitlock
    - CEO, Jensen Transformers
  - T.H.A.T. Corporation
    - InGenius® 1200 Series
    - [www.thatcorp.com](http://www.thatcorp.com)
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**BRILLIANCE** More Chips with Good CMRR



The LMV831 family of EMI-hardened op amps claim to deliver the industry's highest EMI rejection ratio of -120 dB. These devices provide a CMRR of -93 dB.

*National Semiconductor,  
Santa Clara, CA (October, 2008)*

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**BRILLIANCE** Re-balancing bad CMRR



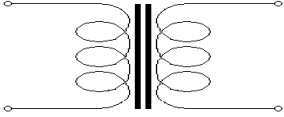
**ETS PA-819**

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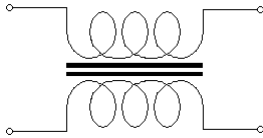
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## Re-balancing bad CMRR





**Inside a BALUN**  
Impedance matching,  
Balanced to unbalanced



**Inside a RE-BALANCER**  
“Common-mode choke”  
Passes DC, phantom power

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## Digital Audio

Sampling Rate	To Determine Bandwidth	Actual Bandwidth
44.1 kHz	x128	5.6448 MHz
48 kHz	x128	6.144 MHz
88.2 kHz	x128	11.2896 MHz
96 kHz	x128	12.288 MHz
176.4 kHz	x128	22.5792 MHz
192 kHz	X128	24.576 MHz

AES5 *proposed* X-140 “SuperMAC” uses Category 5, 5e, 6, ‘7’

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## S/PDIF Consumer Coax

**44.1 kHz x128 = 5.6448 MHz (6 MHz)**

	System Specs	Category 5e	Category 6	Category 6a
<b>Format</b>	Unbalanced	<i>Balanced</i>	<i>Balanced</i>	<i>Balanced</i>
<b>Capacitance</b>	20pF/ft. 66pF/m	15 pF/ft. 49pF/m	15 pF/ft. 49pF/m	15 pF/ft. 49pF/m
<b>Impedance</b>	75Ω	100Ω	100Ω	100Ω
<b>Gage</b>	23-24 AWG	24 AWG	23 AWG	23 AWG
<b>Shield</b>	YES	NO	NO	NO
<b>Crosstalk 6 MHz</b>	-30 dB (?)	-50.6 dB PSNEXT	-60.6 dB PSNEXT	-60.6 dB PSNEXT




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## AES3-id Professional Coax

	System Specs	Category 5e	Category 6	Category 6a
<b>Format</b>	Unbalanced	<i>Balanced</i>	<i>Balanced</i>	<i>Balanced</i>
<b>Capacitance</b>	20pF/ft. 66pF/m	15 pF/ft. 49pF/m	15 pF/ft. 49pF/m	15 pF/ft. 49pF/m
<b>Impedance</b>	75Ω	100Ω	100Ω	100Ω
<b>Gage</b>	20-24 AWG	24 AWG	23 AWG	23 AWG
<b>Shield</b>	YES	NO	NO	NO
<b>Crosstalk 6 MHz (48 kHz)</b>	-30 dB (?)	-50.6 dB PSNEXT	-60.6 dB PSNEXT	-60.6 dB PSNEXT
<b>Crosstalk 25 MHz (192 kHz)</b>	-30 dB (?)	-41.4 dB PSNEXT	-51.4 dB PSNEXT	-51.4 dB PSNEXT




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BRILLIANCE		Balanced AES			
	System Specs	Category 5e	Category 6	Category 6a	
<b>Format</b>	Balanced	Balanced	Balanced	Balanced	
<b>Capacitance</b>	13pF/ft. 43pF/m	15 pF/ft. 49pF/m	15 pF/ft. 49pF/m	15 pF/ft. 49pF/m	
<b>Impedance</b>	110Ω ±20%	100Ω ±15Ω	100Ω ±15Ω	100Ω ±15Ω	
<b>Gage</b>	24 AWG	24 AWG	23 AWG	23 AWG	
<b>Shield</b>	YES	NO	NO	NO	
<b>Crosstalk</b> 6 MHz (48 kHz)	-30 dB (?)	-50.6 dB PSNEXT	-60.6 dB PSNEXT	-60.6 dB PSNEXT	
<b>Crosstalk</b> 25 MHz (192 kHz)	-30 dB (?)	-41.4 dB PSNEXT	-51.4 dB PSNEXT	-51.4 dB PSNEXT	
<b>Crosstalk</b> 50 MHz (384 kHz)	-30 dB (?)	-37.6 dB PSNEXT	-47 dB PSNEXT	-47 dB PSNEXT	

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- | BRILLIANCE   |  | Four, Three, Two, One-Pair |  |
|--|--|----------------------------|--|
| <ul style="list-style-type: none"> <li>• Four pair standard                             <ul style="list-style-type: none"> <li>–3 pair (RGB) waste a pair</li> </ul> </li> <li>• Two pair standard</li> <li>• One pair??                             <ul style="list-style-type: none"> <li>–Belden 1353A</li> </ul> </li> </ul> |  |                            |  |
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## Networked Audio

Product Name	Company	Type	Channels	Top Specs
A-Net Pro 64	Aviom	100baseT	64	Aviom.com
ASI 2416	Audio Science	100baseT	16	48kHz 24-bit
AudiaFLEX	Biamp	100baseT	?	?
Audinate Dante	Yamaha	100baseT	16	96kHz 24-bit
Axia	Telos	100baseT	?	48kHz 24 bit
CobraNet	Cirrus Logic	100baseT	128	96 kHz 24-bit
E-Snake	Whirlwind	100baseT	64	800-733-9473
Ethernet Audio	360 Systems	100baseT	2	48 kHz 16-bit
EtherSound	Digigram	100baseT	64	48 kHz 24-bit
Hydra	Calrec	1GbaseT	512	?
iLive	Allen & Heath	100baseT	64	?
IQ Net	Crown	100baseT	128	96 kHz 24-bit
MaGIC	Gibson	1GbaseT	320	48 kHz 24-bit
Mongoose	Rane	100baseT	32	?
WheatNET-IP	Wheatstone	100baseT	64	48 kHz 24-bit




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## 100baseT Audio Quality

Sample rate	Channels
32 kHz/38 kHz	128
44 kHz/48 kHz	96
88 kHz/96 kHz	64
176 kHz/192 kHz	32

See AES47 and AES51 standards.



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