CoaXPress White Paper

WP-2: Cabling Solutions

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1 Introduction

This document describes options for cables for CoaXPress, both options for single coax cables, and multi-cable solutions for very high bandwidth.

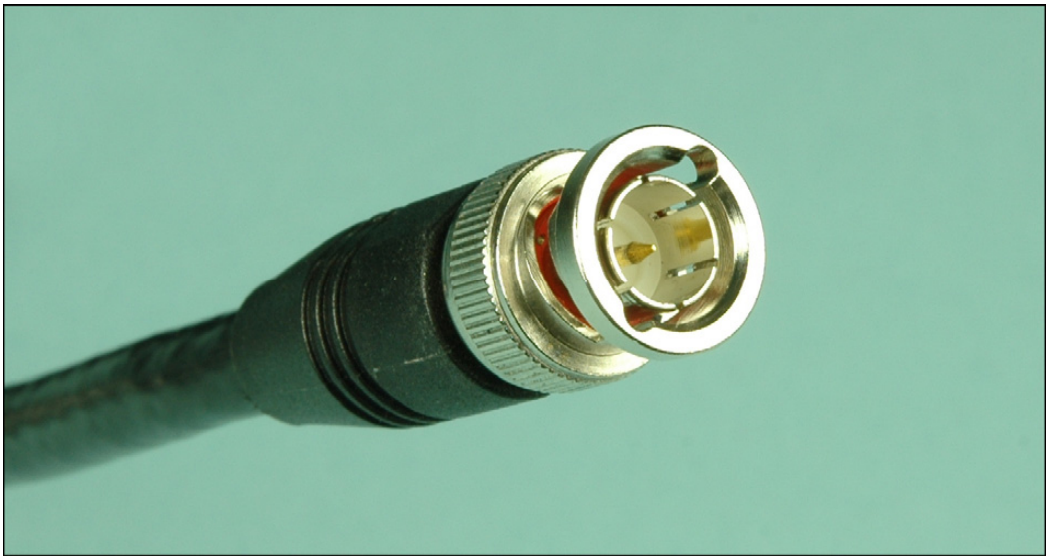
It is one out of a set of papers that describe the CoaXPress interface. Other White Papers discuss cables, implementation, roadmap etc in more detail.

The latest versions of the White Papers (as well as much more information about the standard), can be found at http://www.coaxpress.com.

For a complete description of CoaXPress you are referred to the formal specification document. The *Japan Industrial Imaging Association* is leading the World Wide standardization of CoaXPress. So for more information please visit the JIIA website at http://www.jiia.org.

2 Basic Cable Requirements

Most CoaXPress systems will use a 75 Ohm coaxial BNC cable:



This type of cable has been used for many years for traditional analog video cameras, and coax with BNC connectors is also widely used for many critical high frequency applications.

More recently 75 Ohm coax BNC cable has been used for the SMPTE serial digital video standards that are used in TV studios worldwide, and commonly referred to as SDI. The speeds have got quicker over the years, from original SD-SDI (usually 270 Mbps), through HD-SDI (1.485 Gbps) to 3G-SDI (2.97 Gbps).

As a result of the widespread use of these standards, and TV studios wanting very long cables between cameras on stages to equipment racks, there is now a very wide range of cables and connectors designed for use at gigabit speeds. There are cables optimized for length, ones designed for high flexibility, ones with minimum diameter etc. These cables and connectors are ideal for CoaXPress.

3 Why Use Coax?

- There is a legacy cable infrastructure.
- It is a low cost solution.
- A large variety of possible cables allowed: thick ones for large distance, thin or flexible for shorter distance.
- Coax does not suffer from intra-pair skew (i.e. a difference of length between the two wires forming the pair). Intra-pair skew is an important performance limiter for differential (twisted pair) cables at higher speed, because of the difficulty in making the cables with precisely matched lengths and twists. This is why high speed differential cables tend to be very stiff, because that helps maintain the integrity of the construction. Coax does not suffer from these problems, so long flexible cables are possible.
- Optimal bandwidth: a single-ended medium has less than half the loss than a shielded differential pair with same diameter.
- Very good EMI/EMC performance.
- Terminating several shielded twisted pairs in a common connector is an expensive manual time consuming task; terminating several coaxial cables in a common connector is much easier to achieve.
- The easy possibility to install and terminate connectors in the field.

4 Can I Use Very Cheap Cables?

If you search on the web, a good quality gigabit rated BNC cable for SDI use and manufactured in Europe or the USA is typically $15 to $25 for a 5 meter long cable (1 off pricing). You can also find cables that look identical for as little as $5. So what's the difference?

Part of the confusion is from the "RG" numbers like RG59, RG6 and RG11. Both the $5 cable and the $25 cable may claim to be "RG59". These numbers relate to long-obsolete military specifications, but now only really refer to the impedance (50 or 75 Ohms) and the overall build of the cable – the approximate diameters of the center conductor and the overall cable. Therefore they give no indication of the *quality* of the cable.

Gigabit rated cables will be built to closer tolerances, use better materials (especially for the dielectric that separates the center and outer conductors), have better shielding on the outer conductor, and are often sweep tested for every reel of cable manufactured. The cable's datasheet will specify attenuation at a range of frequencies, typically up to 4.5 GHz. (Note that a 6.25 Gbps bitrate corresponds with a frequency of 6.25 / 2 = 3.125 GHz).

However a cheap cable may work – as an example the demonstration system running on Active Silicon's booth at Robots and Vision in June 09 was running perfectly at 3.125 Gbps over approximately 50 meters of budget priced RG59 style cable (deliberately chosen to show that CoaXPress is very tolerant, and does not require ultra-high specification cable to work at all!). The shorter the cable, and the lower the frequency that the camera operates at, the more likely it is to work.

The risk with cheap cables is that there may be cable to cable variation (one may work fine, the next out of the box may not), if they do work, that they may be marginal (e.g. high bit error rate) and EMC issues may be a problem (both immunity and emissions).

Overall, cheap cables are not recommended for use, especially in critical applications, but may work reliably at lower speeds and with shorter cables. Therefore in some applications (e.g. CCTV) it may be practical to upgrade from an analog camera to a CoaXPress one without replacing the infrastructure cabling.

5 Gigabit Cable Types

Many manufacturers make gigabit rated cable. Well known firms include Belden (USA), Canare (Japan) and Gepco (USA). Selected types of their cables with specifications quoted at 3.125 GHz[1] are listed in the following sections. As a general rule, the larger the cable's diameter, the better the performance, and the greater the price. Cables are therefore listed in size order, with the largest first.

CoaXPress length figures are estimates based on the cable's specification and actual testing with selected cables, rounded down to allow for losses in the connectors and PCBs. Note that with the thinner cables, the length at lower speeds can be limited by DC resistance which has to meet Power over CoaXPress requirements.

5.1 RG11 Style

These offer the longest lengths. Downsides are that they are relatively thick and inflexible cables, and are the most expensive. While thick by coax standards, note that they are no thicker than typical Camera Link cables, yet offer much longer operation (although they may be considered too inflexible for many imaging applications).

Type	Diameter	CoaXPress Max length at 1.25 Gbps	CoaXPress Max length at 3.125 Gbps	CoaXPress Max length at 6.25 Gbps
Belden 7731A	10.3mm	194m	147m	58m
Canare L-7CFB	10.2mm	165m	122m	46m
Gepco VHD1100	10.3mm	212m	169m	68m

5.2 RG6 Style

A bit thinner and cheaper than RG11. Belden 1694A is a bit of an "industry standard", but for many imaging applications a thinner and more flexible RG59 cable is a better solution.

Type	Diameter	CoaXPress Max length at 1.25 Gbps	CoaXPress Max length at 3.125 Gbps	CoaXPress Max length at 6.25 Gbps
Belden 1694A	6.99mm	130m	100m	40m
Canare L-5CFB	7.7mm	118m	71m	28m
Gepco VSD2001	6.91mm	140m	110m	44m

[1] Canare currently only give specifications up to 2 GHz, therefore the lengths quoted at 6.25 Gbps are based on extrapolation.

5.3 RG59 Style

These are one of the most common types, offering a good compromise between price, performance and size.

Type	Diameter	CoaXPress Max length at 1.25 Gbps	CoaXPress Max length at 3.125 Gbps	CoaXPress Max length at 6.25 Gbps
Belden 1505A	5.94mm	107m	86m	35m
Canare L-4CFB	6.1mm	94m	71m	28m
Gepco VPM2000	6.15mm	109m	86m	35m

5.4 High-Flex RG59 Style

There are some high-flex options in RG59 sized cables. These use a multi-stranded inner core, unlike the single core found on most coax cables, even quite flexible ones. The downside of the multiple strands is worse attenuation performance, and hence shorter allowable cables.

Type	Diameter	CoaXPress Max length at 1.25 Gbps	CoaXPress Max length at 3.125 Gbps	CoaXPress Max length at 6.25 Gbps
Belden 1505F	6.15mm	80m	60m	23m
Gepco VHD2000M	6.15mm	81m	61m	24m

5.5 Thin non-RG Styles

There are many thin cables which still give good performance, and are inherently flexible. VDM230 is a cable widely used in outside broadcast (OB) vans where a reliable and flexible cable is needed, and is an excellent general purpose cable for CoaXPress.

Type	Diameter	CoaXPress Max length at 1.25 Gbps	CoaXPress Max length at 3.125 Gbps	CoaXPress Max length at 6.25 Gbps
Belden 1855A	4.03mm	55m	55m	25m
Canare L-2.5CFB	4.0mm	43m	43m	20m
Gepco VDM230	4.16mm	66m	62mm	25m

6 Connectors

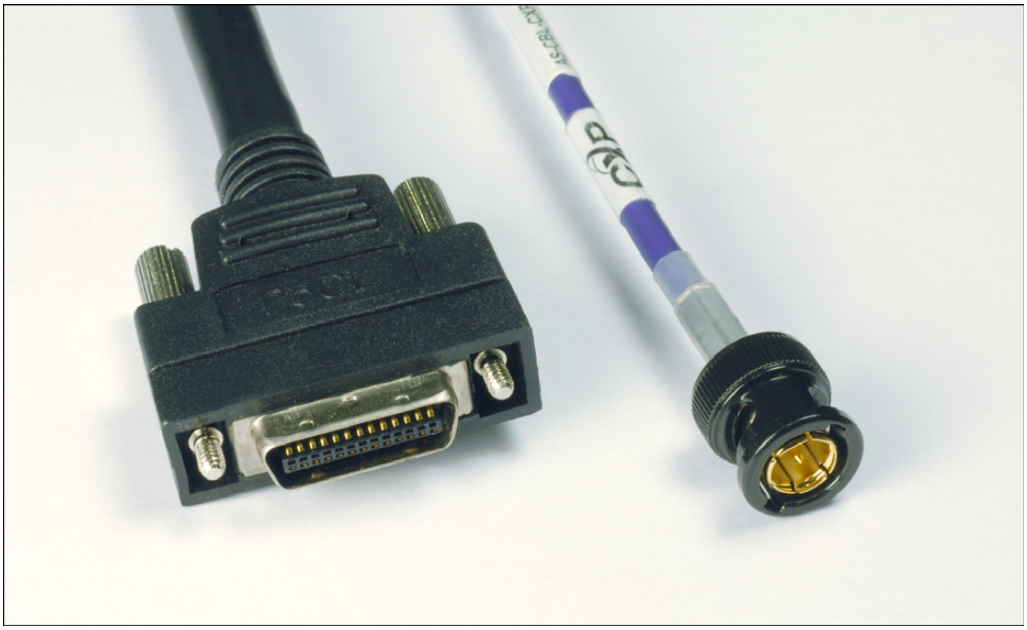
Like the cable, the connectors need to be chosen for high frequency use. Similarly there are connectors available which are often targeted at the broadcast industry and which are ideal for CoaXPress.

Firms such as Canare (Japan) and Trompeter (USA) supply cable plugs. Samtec (USA) has recently launched a full range of 3G-SDI connectors for both cable and PCB.

Note that many PCB mount gigabit BNC connectors are edge feed type (i.e. they solder onto the edge of the PCB, with the centre pin flush with the PCB) because this offers the easiest way of achieving the required performance. While these may be ideal in a camera, in general a frame grabber needs a conventional right angle connector. AMP (USA) make a widely used suitable right angle connector.

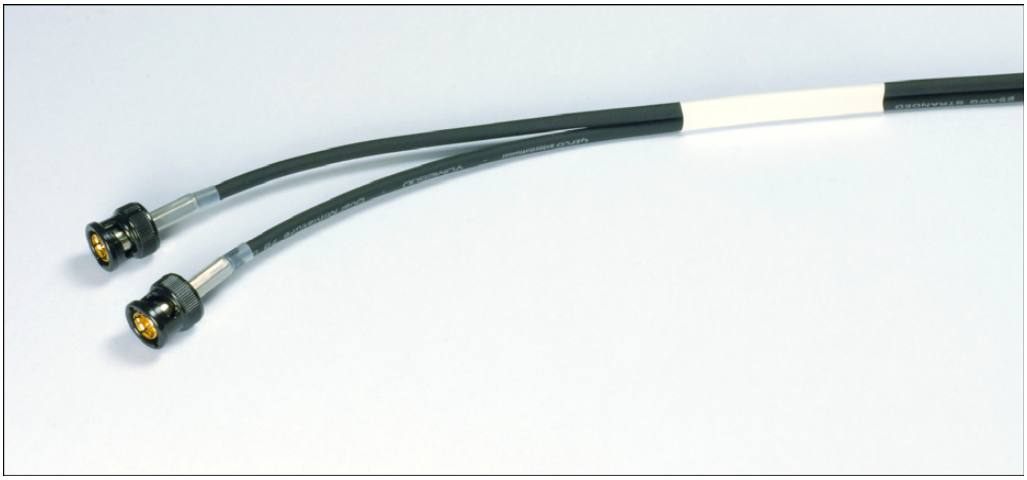
7 Photographs

The following photographs show some example CoaXPress cables.



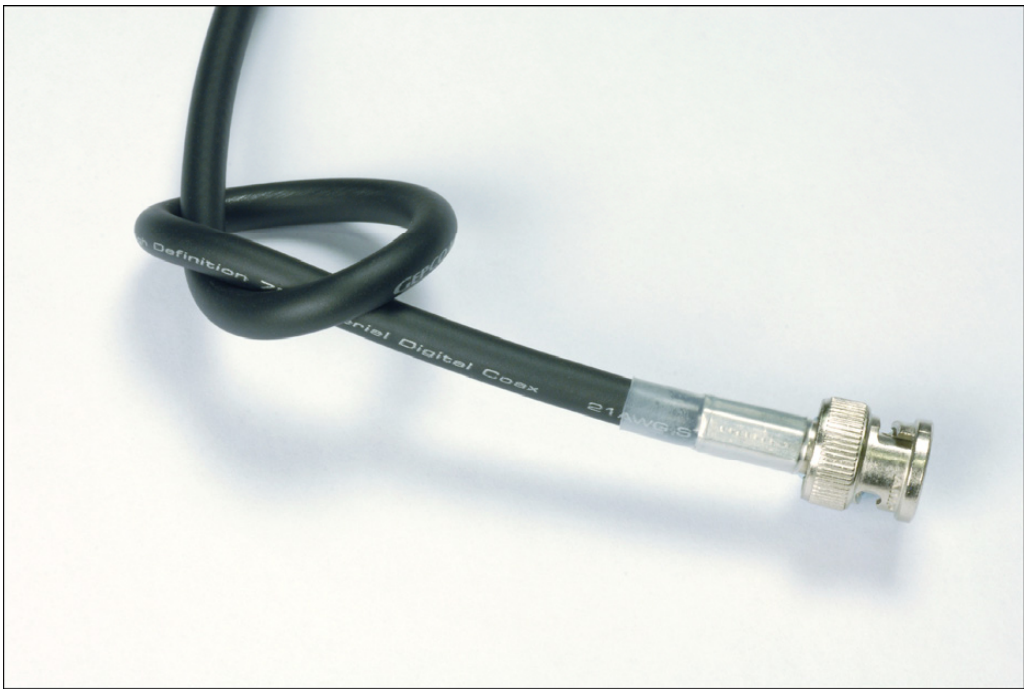
Camera Link Cable on the Left, CoaXPress VDM230 on the Right

The Camera Link cable is limited to 7m, and gives around 2.5 Gbps at an 85 MHz clock. The CoaXPress cable shown uses VDM230, is only 4mm diameter, and 25m is possible at 6.25 Gbps, or 66m at the same 2.5 Gbps as the Camera Link cable.



Dual CoaXPress Cable

This is a “zipper” style figure of eight cable, ideal for cameras up to 12.5 Gbps.



Flexible VHD2000M CoaXPress Cable

This shows how flexible this cable is! The knot can be undone with no residue twist in the cable.

8 Multi-Cable Options

CoaXPress allows more than one BNC cable to be used to link the camera to the frame grabber, so allowing higher speeds than is possible with a single cable.

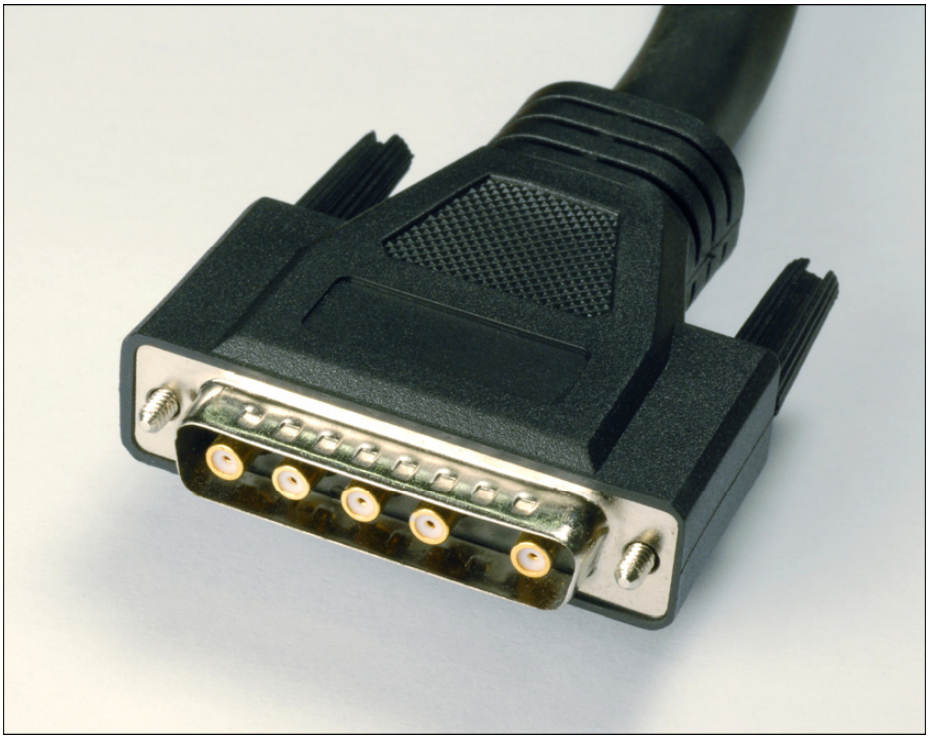
While two or maybe even three separate cables may be considered OK, at very high speeds a neater solution is needed. This is an area where work is still on-going, with further investigation and testing needed.

8.1 5W5 Cable

Conventional D-sub connectors are available with coaxial inserts in numerous configurations. Many in the industry will remember the 13W3 connectors used for many years by Sun Microsystems on their workstation monitor cables. In this terminology, 13W3 means 13 ways total, 3 of which use coax (so 10 conventional pins).

A 5W5 solution has been chosen for investigation because it allows 5 coaxial cables in a "B" sized shell (as used on a conventional 25 way D-sub), so allowing up to 31.25 Gbps. A "B" shell fits both standard PC cards, and common industrial form-factor computers. It should also fit cameras of this performance.

A photo of a sample cable is shown below:



5W5 Cable

The cable construction has five coaxial cores, each of diameter approximately 4.1mm, and enclosed in an overall jacket giving a diameter of 14mm. The cable chosen for the sample is Gigabit rated, so should give similar performance to VDM230.

Note that, unlike the twisted pairs in Camera Link cables, there is no problem of skew between the multiple coax cables because each link is self clocking. Therefore the only data alignment issue needed is in the frame grabber FPGA, which needs to do byte level alignment of the data streams (much like between the outputs of the Camera Link receivers in a Camera Link FPGA design).

8.2 Alternatives

Connector and cable firms are looking into compact multi-cable solutions for high speed cameras. The 5W5 shown above is simply one example of what can be done. Part of the standardization work will be to evaluate the proposals and choose one type to add to the standard.

9 Pricing

Example prices for selected cable options are shown below. These are low volume prices.

Type	Length	Price
"Budget" Serial Digital broadcast cable	4.6m (15 ft) 15.2m (50 ft)	$11.50 $26
Gepco VDM230 based (US made)	5m 15m 50m	$26 $38 $85
Belden 1694A based (US made)	4.6m (15 ft) 15.2m (50 ft)	$25 $46
5W5 cable	5m 15m 50m	$45 $80 $195