Video and UTP

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Abstract

In the ten years since this paper was originally presented, a great deal has been written and demonstrated using 'category' cables to run video signals. What was originally presented as a cutting-edge option, using premise/data cables to carry video, is now an accepted application. Surveillance cameras, for instance, now often provide an RJ-45 data connector, as well as the standard BNC or F, allowing the direct use of premise/data cables. Many thousands of installations attest to the practicality of such use.

Extensive testing in Belden's Engineering Center and other test facilities have been made, and will continue to be made, and will no doubt spur further expansion and updates. In the last year, there have emerged premise/data cables whose *primary* application is video. Some of these have network data as a *secondary* application! This paper is an overview of existing video applications and the suitability of various types of premise/data cables to carry these signals

Category 6 cable, as defined in the TIA/EIA 568B.2 specifications, further advances the non-data possibilities for installers and system integrators. For instance, Belden has *four* different *lines* of Category 6 cable. Some are specified up to 600 MHz per pair, twisted pair bandwidth unheard of only a decade ago. We are truly approaching coax cable performance in a twisted pair. Still, because of the differences between unbalanced coaxial cable and balanced-line twisted pairs, the differences between analog video and digital video, and the wide range of picture quality attainable, there continues to be some confusion.

There is also the emergence of 10gigabit networking, originally on fiber and now on UTP copper. Known as Category 6a, "augmented' Category 6, it is a considerable advance beyond standard Category 6. In the proposed specifications, the bandwidth has been increased from 250 MHz (Cat 6) to 500 MHz (Cat 6a). Interestingly, the key parameter seems to be cable-to-cable crosstalk, called "alien" crosstalk. Belden has a unique design that separates cable from cable to achieve the 100-meter requirement of these networks. A new section looking at the potential of 10gig is at the very end of this paper.

This paper is an attempt to sort out the various parameters and requirements and allow an end-user to make an informed decision. This paper also lists manufacturers of matching networks or “baluns” that make possible many of these video applications. Readers are urged to contact the author (shlampen@aol.com) if you know of other balun manufacturers. We will be glad to add their contact information and products to the lists below.

Each video application has its own set of requirements and system parameters. Twisted pair technology is ideal for a few applications, acceptable with some, and difficult or even impossible with others.

Twisted Pair Technology

Historically, computer data was sent over coaxial cable. In the late 1970's, IBM began to consider special constructions of twisted pair cables. These were very large constructions and bear little resemblance to current twisted pairs except for the fact that they showed the advantages of twisted pair technology in the data world. The key advantage was that these pairs could be run as “balanced lines” that feature common-mode noise rejection, a performance feature unavailable in coax. IBM Type 1 and IBM Type 2 were two versions of this cable. Originally intended to carry a 4 Mbps (Megabits per second) data rate, later versions were specified to carry 16 Mbps (IBM “Token Ring”). The last generation featured wider bandwidth (300 MHz) to carry FDDI-over-copper and video-to-the-desktop.

For over fifteen years, a wiring scheme has emerged in the data world that has overtaken every other. The idea was to make twisted pairs, a technology as old as the telephone itself, into higher-grade data versions. The data-grade twisted pairs used domestically in the United States, and many other countries, are commonly called UTP (unshielded twisted pairs). While shielded versions (STP, ScTP) also exist, they are rarely used in the United States.[Note 1] The vast majority of domestic installed premise/data cable is UTP. Any non-data applications should be able to make use of the most commonly installed cable, so this paper solely addresses the use of UTP in alternate applications. Part of the on-going testing in the Belden laboratory will be to compare performance including noise immunity of shielded versus unshielded cables, and is beyond the scope of this paper.

Users should note that some baluns and active matching networks mentioned below require *shielded* Category cables (STP, ScTP). These cables are harder to find, more expensive, and considerably harder to install. In some performance specifications, such as crosstalk, UTP designs can often be superior.

As data rates increased, it became apparent that some way of indicating the performance of the cable was needed. It was then that Anixter, a major distributor of cable products, suggested a system of “Levels”. The TIA/EIA, two groups that set standards for the data industry, adopted the plan and separated the data rates and other parameters into "Categories". Thus, we now have Category 3, 4, 5, 5e, and 6.

Category 3 is 16 MHz, and is most commonly used for telephone wiring. Category 4, a 20 MHz bandwidth version, is no longer recognized in the TIA/EIA standard. When Category 5e was ratified, Category 5 was also dropped from the standard. It is included here, because of the billions of feet of installed Cat 5 already in the field. Each category has more stringent performance requirements than the previous category. The specifications for current "standard" categories, Category 3, 5e, and 6, are spelled out in TIA/EIA 568B.2.

To the uninitiated, these cables often look identical to telephone cable. They use the same color code and come in many of the same pair counts and often use the same gage conductors. But the specifications they are made to, the materials used to make them, and the requirements to connect them, become more and more critical as data rates increase.

Basic UTP Specifications for Category 3, 5, 5e, and 6

Table 1 shows the EIA/TIA 568B.2 standard. While appropriate Belden part numbers are listed in the right hand column, actual cable performance is often better, sometimes dramatically better, than the specifications shown. See the Belden catalog elsewhere on this web page for full performance details, or see Mediaspec.

The "Belden Products" listed below are just the tip of the iceberg. Many of them are available in other versions, different pair counts, dual cables, low-smoke/zero halogen, low combustibility, stranded patch cable, shielded (STP and ScTP), ruggedized, armored, super-flexible "stage" versions, and many other configurations. The full product line can be seen elsewhere on this web page.

For instance, you will note that there are no Category 5 UTP products listed. In the EIA/TIA 568B.2 standard there are no longer specifications for Category 5. While Belden does make a few Category 5 products, they do not fall under the 'standard' four-pair UTP style. They are shielded, or 25-pair, or some other configuration.

Figure 1: Category 5e
Belden 1700A 'DataTwist 350"

Here is a short list of terms and definitions:

NEXT means "near-end crosstalk". At the near end (source end), the transmitted signal is the strongest. Transmitting pairs can energize pairs around them causing their signal to interfere with other signals on other pairs. This is called "crosstalk". The 568B.2 standard specifies the minimum crosstalk value at various frequencies. Video engineers may be surprised that good crosstalk numbers at analog video frequencies are obtainable in UTP.

TIA/EIA 568A Specifications (Partial) per 100 meters (328 feet)								
Category	**Frequency**	**Minimum PSNEXT**	**Maximum Attenuation**	**Minimum ELFEXT**	**Return Loss**	**Min. PSACR**	**Delay Skew**	**Belden Products**
3	1 MHz 4 MHz 10 MHz 16 MHz	41 dB 32 dB 26 dB 23 dB	--- 5.6 dB 9.7 dB 13.1 dB	Not specified	Not specified	Not specified	Not specified	1229A1 1245A2
5	.772 MHz 1 MHz 4 MHz 8 MHz 10 MHz 16 MHz 20 MHz 25 MHz 31.25 MHz 62.5 MHz 100 MHz	--- 62.3 dB 53.3 dB 48.8 dB 47.3 dB 44.3 dB 42.8 dB --- 39.9 dB 35.4 dB 32.3 dB	1.8 dB 2.0 dB 4.1 dB 5.8 dB 6.5 dB 8.2 dB 9.3 dB --- 11.7 dB 17 dB 22 dB	--- 60.8 dB 48.7 dB 42.7 dB 40.8 dB 36.7 dB 34.7 dB 32.8 dB 30.9 dB 24.8 dB 20.8 dB	--- 17 dB 18.8 dB 19.7 dB 20 dB --- 20 dB 19.3 dB 18.6 dB 16.5 dB 15.1 dB	--- 60.3 dB 49.2 dB 43 dB 40.8 dB --- 36 dB 33.5 dB 28.2 dB 18.4 dB 10.3 dB	45 nanoseconds	
5e	.772 MHz 1 MHz 4 MHz 8 MHz 10 MHz 16 MHz 20 MHz 25 MHz 31.25 MHz 62.5 MHz 100 MHz	64 dB 62.3 dB 53.3 dB 48.8 dB 47.3 dB 44.3 dB 42.8 dB --- 39.9 dB 35.4 dB 32.3 dB	1.8 dB 2.0 dB 4.1 dB 5.8 dB 6.5 dB 8.2 dB 9.3 dB --- 11.7 dB 17 dB 22 dB	--- 60.8 dB 48.7 dB 42.7 dB 40.8 dB 36.7 dB 34.7 dB 32.8 dB 30.9 dB 24.8 dB 20.8 dB	--- 20 dB 23 dB 24.5 dB 25 dB 25 dB 24.3 dB --- 23.6 dB 21.5 dB 20.1 dB	--- 60.3 dB 49.2 dB 43 dB 40.8 dB --- 36 dB 33.5 dB 28.2 dB 18.4 dB 10.3 dB	45 nanoseconds	1583A 1585A 1500A 1501A 1700A 1701A 7988R 7988P
6	.772 MHz 1 MHz 4 MHz 8 MHz 10 MHz 16 MHz 20 MHz 25 MHz 31.25 MHz 62.5 MHz 100 MHz 125 MHz 150 MHz 155 MHz 160 MHz 175 MHz 200 MHz 225MHz 250 MHz 300 MHz	74 dB 72.3 dB 63.3 dB 58.8 dB 57.3 dB 54.3 dB 52.8 dB --- 49.9 dB 45.4 dB 42.3 dB 40.9 dB --- 39.5 dB --- 38.7 dB 37.8 dB 37 dB 36.3 dB ---	1.8 dB 2 dB 3.8 dB 5.3 dB 6 dB 7.6 dB 8.5 dB --- 10.7 dB 15.4 dB 19.8 dB 22.4 dB --- 25.2 dB --- 26.9 dB 29 dB 31 dB 32.8 dB 36.4 dB	--- 64.8 dB 52.7 dB 46.7 dB 44.8 dB 40.7 dB 38.7 dB 36.8 dB 34.9 dB 28.8 dB 24.8 dB 22.8 dB 21.2 dB 20.9 dB --- 19.9 dB 18.7 dB 17.7 dB 16.8 dB ---	--- 20 dB 23 dB 24.5 dB 25 dB --- 25 dB 24.3 dB 23.6 dB 21.5 dB 20.1 dB --- 18.9 dB 18.8 dB 18.7 dB --- 18.0 dB --- 17.3 dB ---	--- 70.3 dB 59.5 dB 53.4 dB 51.4 dB 46.7 dB 44.3 dB --- 39.2 dB 30 dB 24.3 dB 18.5 dB --- 14.3 dB --- 11.8 dB 8.8 dB 6.1 dB 3.5 dB ---	45 nanoseconds	7881A 7882A 1872A 1874A 7851A 7852A 7989R 7989P

Table 1: The EIA/TIA 568B.2 Standard

PSNEXT is "power sum near-end crosstalk" that looks at the effect of all adjacent pairs to the one under test rather than just pair-to-pair. Such testing is then the "worst case" where all pairs are energized. Results of each combination are averaged.

ATTENUATION is signal loss and is common to all signal carrying systems. Attenuation is measured in decibels (dB). Decibels are logarithmic. Data signals -40 dB down (one-ten thousandth of the original intensity) are fully and easily recovered. This is not surprising to most audio/video engineers considering that analog microphone signals are often –60 dB and easily recovered.

ACR is "attenuation-to-crosstalk ratio". By subtracting the crosstalk from the attenuation, a number is generated which can indicate the overall performance of a cable. Positive ACR, especially at high frequencies, can be an indicator of superior cable performance. ACR is very similar to "signal-to-noise ratio" in the analog audio/video world. Therefore, ACR can be valuable where multiple data signals travel down a four-pair cable, such as parallel gigabit networking. It can also be valuable for non-data applications that also use all pairs such as RGBS, VGA, or multiple baseband or broadband video signals.

PSACR is "power-sum attenuation-to-crosstalk ratio" where all pairs are energized around the measured pair and the results averaged.

DELAY SKEW is timing differences on a multipair cable. For all cables listed above, the maximum allowed is 45 nsec/100m (nanoseconds per 100 meters, 328 feet). Delay skew is important where multiple pairs deliver data simultaneously. Formats such as Gigabit Ethernet™ split the data between the four pairs. It is essential that the signals arrive at the end of the cable at the same time. Timing variations for a complete system should not exceed 50 nsec between any of the four paths. For cable alone, the maximum delay is 45 nsec/100m. Cables made with low skew, such as Belden MediaTwist and VideoTwist cables, are popular in non-data applications where this is critical such as RGB or VGA.

PAIR TWISTING (“Lay Length”). Tight pair twisting can greatly reduce crosstalk but also has a number of negative effects on the cable. There is more copper used per unit length so the price goes up. And more copper means the signal will take longer to travel down that pair (compared to other pairs) so attenuation and delay skew are worse. It doesn't matter how high your ACR is, or how low your crosstalk is, if you don't have enough signal strength to be recovered at the receiving end! What you truly want is a cable that improves both crosstalk and attenuation to improve ACR, to have positive ACR at a higher frequency, without affecting, or possibly even reducing, delay skew.

IMPEDANCE indicates the ability of a data cable to transfer a signal from one box to another. The impedance of the systems, and boxes it is attached to, specifies the impedance of the cable. The TIA/EIA standard for Category 5 is 100Ω ± 15Ω (ohms). Some Category 5 cables meet this spec. Others require the use of a smoothing formula called "Z_o-fit". This allows manufacturers to ignore rapid changes in impedance. Bonded-pair data cables, such as Belden DataTwist 350 (1700A, 1701A), Belden MediaTwist® (1872A, 1874A), Belden 600E (7851A, 7852A), and Belden Category 5e and 6 “VideoTwist” (7988R, 7988P. 7989R, 7989P) are tighter than ±15Ω *without* the Z_o-fit function.

RETURN LOSS shows all the variations in impedance within a cable. Impedance variations cause the signal to reflect back to the source, so return loss is the ratio between direct signal and reflected signal. It is measured in decibels (dB). With a larger negative number, more signal reaches its destination, and less of the signal is reflected back to the source. Return loss is especially effective in showing flaws in cable construction and installation, such as excessive bending or stretching, which affect the impedance of the cable. In link and channel tests, return loss can show the effect of poor, or badly installed, connectors, patch panels, and other passive hardware.

BANDWIDTH is the range of frequencies available to be used for signal carrying. It is the "size of the tunnel". However, knowing the size of the tunnel tells you nothing of how the traffic will move through it. This is because data can be *compressed* to take up less bandwidth. For instance, a 100 Mbps data signal can fit in a 100 MHz bandwidth. Or the data can be arranged and coded to fit in a 50 MHz bandwidth, a 30 MHz bandwidth, or even smaller. In fact, the 31.25 MHz numbers commonly seen in cable specifications are for a compressed 155 Mbps ("ATM") protocol. Since the coding scheme is not apparent, only the bandwidth in Megahertz (MHz) can be used to compare potential data handling capacity. If you want to compare the signal-carrying capacity of a cable, compare bandwidths.

COST. The advantage of twisted pairs is the cost/performance ratio. Dollar-for-dollar, you can buy and install twisted pairs significantly cheaper than coax or fiber. And, while the other two systems offer advantages in bandwidth, this advantage is rapidly decreasing. Standard premise/data cable contains four pairs in a single cable so the actual cost per pair is one-quarter of the per-foot price.

TESTING. While some manufacturers say that their cable is "tested to 350 MHz" (or some other high frequency), many offer no data (impedance, crosstalk, attenuation, ACR, delay skew etc.) at frequencies beyond the required 100 MHz for 100baseT. Impedance variation at higher frequencies can often be 100Ω±50Ω, rendering these cables virtually useless. If the cable chosen might be used at these elevated frequencies, it is essential to know just what performance to expect. As will be seen, some applications, such as broadband/CATV, can require frequencies and bandwidths far beyond even the most advanced twisted pairs.

DataTwist® 350, MediaTwist®, and 600E®.

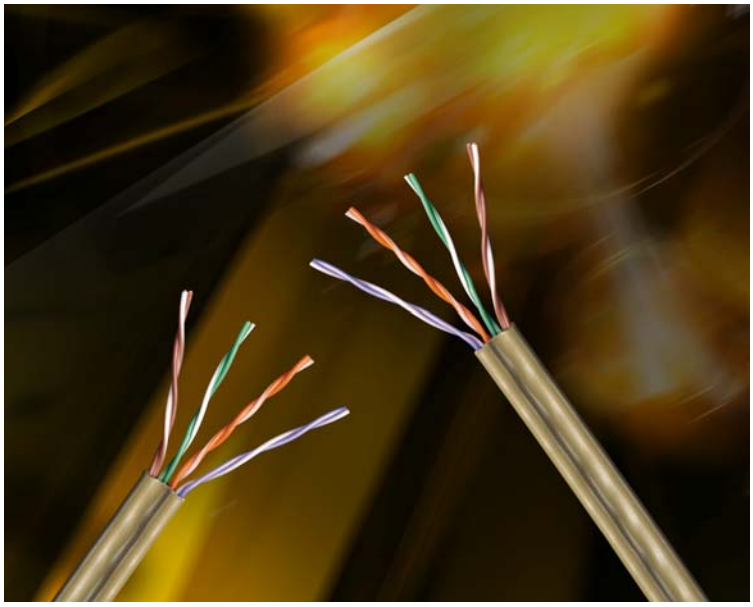

Figure 2: Category 6 – Belden 1872A MediaTwist

There are four families of Belden cables designed for improved performance over Category 5. The first is Belden DataTwist 350. The second is Belden MediaTwist. The third is Belden 600E. The following table compares the TIA/EIA 568B.2 standard with Belden DataTwist 350, MediaTwist, and 600E. Their specifications are in Tables 2, 3 and 4 below. The last family is Belden's new Brilliance® "Low Delay Skew" VideoTwist® (7988R, 7988P, through 6 contains the basic data for some of these cables

Cable	Frequency	Return Loss	PSNEXT	Attenuation	ACR	Skew
Belden 1700A DataTwist® 350 Category 5e	1 MHz	20 dB	65.3 dB	2 dB	63.3 dB	25 nsec max 15 nsec typical
	4 MHz	23 dB	56.3 dB	4 dB	52.3 dB	
	8 MHz	24.5 dB	51.8 dB	5.7 dB	46.1 dB	
	10 MHz	25 dB	50.3 dB	6.4 dB	43.9 dB	
	16 MHz	25 dB	47.3 dB	8.1 dB	39.1 dB	
	20 MHz	25 dB	45.8 dB	9.2 dB	35.2 dB	
	25 MHz	24.3 dB	44.3 dB	10.3 dB	34.1 dB	
	31.25 MHz	23.6 dB	42.9 dB	11.6 dB	31.3 dB	
	62.5 MHz	21.5 dB	38.4 dB	16.8 dB	21.6 dB	
	100 MHz	20.1 dB	35.3 dB	21.7 dB	17.1 dB	
	155 MHz	19 dB	32.5 dB	27.7 dB	4.7	
	200 MHz	19 dB	30.8 dB	32 dB	3-	
	250 MHz	18 dB	29.3 dB	36.4 dB	>0	
	300 MHz	18 dB	28.2 dB	40.5 dB		
	310 MHz	18 dB	27.9 dB	41.3 dB		
	350 MHz	17 dB	27.2 dB	44.3 dB		

Table 2: Specifications for Belden 1700A Category 5e

Cable	Frequency	Return Loss	POWER SUM NEXT	Attenuation	ACR	Skew
VideoTwist Category 5e 7988R	1 MHz	20 dB	65.3 dB	2 dB	60.3 dB	9 nsec max
	4 MHz	23 dB	53.3 dB	4.1 dB	49.2 dB	
	8 MHz	24.5 dB	48.8. dB	5.8 dB	43 dB	
	10 MHz	25 dB	47.3 dB	6.5 dB	40.8 dB	
	16 MHz	25 dB	44.3 dB	8.2 dB	36 dB	
	20 MHz	25 dB	42.8 dB	9.3 dB	33.5 dB	
	25 MHz	24.3 dB	41.3 dB	10.4 dB	30.9 dB	
	31.25 MHz	23.6 dB	39.9 dB	11.7 dB	28.2 dB	
	62.5 MHz	21.5 dB	35.4 dB	17 dB	18.4 dB	
	100 MHz	20.1 dB	32.3 dB	22 dB	10.3 dB	
	155 MHz	15.8 dB	29.5 dB	28.1 dB	2 dB	
	200 MHz	15 dB	27.8 dB	32.4 dB	1 dB	

Table 3: Specifications for Belden 7988R “Low Skew” Category 5e

Cable	Frequency	Return Loss	PSNEXT	Attenuation	PSACR	Skew
Belden 1872A MediaTwist® Category 6	1 MHz	20 dB	72.3 dB	1.9 dB	70 dB	25 nsec max 15 nsec typical
	4 MHz	23 dB	63.3 dB	3.7 dB	59 dB	
	8 MHz	24.5 dB	58.8 dB	5.3 dB	53 dB	
	10 MHz	25 dB	57.3 dB	5.9 dB	51 dB	
	16 MHz	25	54.3 dB	7.5 dB	46 dB	
	20 MHz	25 dB	52.8 dB	8.4 dB	44 dB	
	25 MHz	24.3 dB	51.4 dB	9.5 dB	42 dB	
	31.25 MHz	23.6 dB	49.9 dB	10.6 dB	39 dB	
	62.5 MHz	21.5 dB	45.4 dB	15.4 dB	30 dB	
	100 MHz	21 dB	42.3 dB	19.8 dB	25 dB	
	155 MHz	21 dB	39.5 dB	25.1 dB	14 dB	
	200 MHz	21 dB	37.8 dB	29 dB	10 dB	
	250 MHz	18 dB	36.3 dB	32.8 dB	3 dB	
	300 MHz	18 dB	34.2 dB	35.2 dB	0 dB	
	310 MHz	18 dB	34.9 dB	37.1 dB	-	
	350 MHz	17 dB	34.2 dB	39.8 dB	-	
	400 MHz	14 dB	33.3 dB	43 dB	-	
	500 MHz	14 dB	31.8 dB	49 dB		

Table 4: Specifications for Belden 1872A Category 6

Cable	Frequency	Return Loss	POWER SUM NEXT	Attenuation	PSACR	Skew
VideoTwist Category 6	1 MHz	20 dB	72.3 dB	2 dB	70.3 dB	10 nsec max
	4 MHz	23 dB	63.3 dB	3.8 dB	59.5 dB	
	8 MHz	24.5 dB	58.8 dB	5.3 dB	53.4 dB	
	10 MHz	25 dB	57.3 dB	6 dB	51.3 dB	
	16 MHz	25 dB	54.3 dB	7.6 dB	46.7 dB	
	20 MHz	25 dB	52.8 dB	8.5 dB	44.3 dB	
	25 MHz	24.3 dB	51.3 dB	9.5 dB	41.8 dB	
	31.25 MHz	23.6 dB	49.9 dB	10.7 dB	39.2 dB	
	62.5 MHz	21.5 dB	45.4 dB	15.4 dB	30 dB	
	100 MHz	20.1 dB	42.3 dB	19.8 dB	22.5 dB	
	155 MHz	18.8 dB	39.5 dB	25.2 dB	14.3 dB	
	200 MHz	18 dB	37.8 dB	29 dB	8.8 dB	
	250 MHz	17.3 dB	36.3 dB	32.8 dB	3.5 dB	

Table 5: Specifications for Belden 7989R “Low Skew” Category 6

Cable	Frequency	Return Loss Belden 600E	POWER SUM NEXT Belden 600E	Attenuation Belden 600E	ACR Belden 600E	Skew Belden 600E
Belden 7851A 600E Category 6	1 MHz	-20 dB	80.3 dB	1.9 dB	80.5 dB	38 nsec Maximum
	4 MHz	-23 dB	71.3 dB	3.6 dB	69.7 dB	
	8 MHz	-24.5 dB	66.8 dB	5.1 dB	63.7 dB	
	10 MHz	-25 dB	65.3 dB	5.7 dB	61.6 dB	
	16 MHz	-25 dB	62.3 dB	7.2 dB	57 dB	
	20 MHz	-25 dB	60.8 dB	8.1 dB	54.7 dB	
	25 MHz	-25 dB	59.3 dB	9.1 dB	52.3 dB	
	31.25 MHz	-25 dB	57.9 dB	10.2 dB	49.7 dB	
	62.5 MHz	-25 dB	53.4 dB	14.7 dB	40.7 dB	
	100 MHz	-25 dB	50.3 dB	18.9 dB	33.4 dB	
	155 MHz	-22.8 dB	47.5 dB	23.9 dB	25.5 dB	
	200 MHz	-21.6 dB	45.8 dB	27.5 dB	20.3 dB	
	250 MHz	-20.5 dB	44.3 dB	31.2 dB	15.3 dB	
	350 MHz	-19.8 dB	40.2 dB	37.7 dB	6.5 dB	
	400 MHz	-19.5 dB	39.3 dB	40.6 dB	2.6 dB	
	500 MHz	-18.4 dB	37.8 dB	46.2 dB	0 dB	
	550 MHz	-18 dB	37.2 dB	48.8 dB	-	
	600 MHz	-17.6 dB	36.6 dB	51.4 dB	-	

Table 6: Specifications for Belden 7851A Category 6

Baluns

Many of the applications mentioned in this paper require baluns. Baluns are devices that primarily match balanced cable to unbalanced cable, hence the name BAL-UN. They can also contain devices, such as transformers, to match impedances of cable, or to change the source impedance of a device and allow for greater cable distance.

Most people think of baluns as passive devices. In those versions, they are often bidirectional and can be used regardless of the direction of signal flow. In other words, they can “match” a balanced line to an unbalanced line or vice versa. However, we have expanded the definition of ‘balun’ to include active devices that can only go in a single direction. They still, however, convert balanced to unbalanced signals and still deserve to be called baluns. Some of these active devices don’t even use transformers, and instead contain ‘active balancing circuitry’ to accomplish the same goal.

Analog Baseband Video

"Analog baseband video" is single channel point-to-point video with a bandwidth of (typically) DC to 4.2MHz. There are three key problems using UTP for analog video. First, the majority of video equipment uses coaxial connectors, BNC’s for professional installations and RCA’s for consumer applications. The second is the output impedance of coaxial systems is 75Ω while UTP has an impedance of 100Ω. The third difference is that UTP technology is a "balanced line" system while coax is "unbalanced". You can solve all three problems with a balun.

Low frequencies are one of the major problems with baluns, not the high-frequency limit. Very low frequencies are difficult to pass through a transformer and other similar devices. Higher frequencies are much easier to pass. If you wish to use UTP for analog video, be sure you get performance data on the baluns that show the entire operating range. Broadcast-quality video requires performance all the way down to DC. Since a traditional transformer cannot pass DC, other methods are used to design these baluns, such as a “common-mode choke”.

Balance is also a critical parameter. The nature of a balanced line means that the two conductors in the twisted pair are identical (identical length, identical size). The more identical they are, and the closer together they are, the easier it is for the balun to reject noise and interference generated outside the pair. When you realize that the noise hits both conductors, and a resultant noise "pulse" is generated in both wires, the more identical the noise on each wire at the end of the cable, the greater the noise rejection ('common mode rejection') can be obtained in the balanced line. The less identical the two conductors, and standard POTS lines are often *very* unequal, the more noise that will be passed through. To help reduce this problem, a number of companies have special passive and active devices to attempt to balance lines more perfectly. As you might assume, the active ones (active meaning they must be plugged in to work) contain circuitry to "adjust" the balancing can send a video signal much farther than a passive device, but often cost more.

Another solution to balancing problems is to choose a cable that is very well balanced. Category 5 is better balanced than Category 3. Belden bonded-pair products, such as Belden DataTwist 350®, MediaTwist®, 600E®, and VideoTwist®, are better still. Balancing is specified by the amount of capacitance difference ('capacitance unbalance') built up over a given distance. Capacitance in cables is measured in picofarads (pF). The standard for Category 5 is 1000 pF/1000 ft. capacitance unbalance. Belden 1872A MediaTwist® is less than 150 pF/1000 ft.

Point-to-point wiring is most common for analog baseband video. Video surveillance, one such as in casinos, is only *one image per cable*. Monitors in airports carry *one image per cable*. Classroom closed-circuit television (CCTV) is one image per cable. In classroom, and similar installations, the choice of program material is often made by remote control from a distant central facility. Control is most often provided by using the telephone. One dials the correct number, enters a security code, and selects the video to be watched from a master list. The tape is loaded manually, automatically, or played from a master server (and converted to analog). The player (or server) is switched to the appropriate cable for the classroom requesting the video. Thus, one may have hundreds of videos to choose from but the medium to deliver it is still a *single pair of UTP*. In this application, the difference with the Categories (3, 5, DT350) is the distance from that central room to the classroom, and the interference rejection of signals within the cable ("pair-to-pair crosstalk"), or from other nearby cables ("alien crosstalk"). The higher the quality of the cable, the lower the attenuation, the lower the crosstalk, the farther the signal can go.

Baseband Analog Video

Table 3 is a list of vendors of active and passive baseband point-to-point analog-video-over-twisted-pairs devices, listed in alphabetical order. You will note that this list is so extensive that it covers almost three pages! If you know of other vendors, the author would be happy to add them to the list. (steve.lampen@belden.com)

Manufacturer	Model/Part #	Passive/ Active	Cable	Distance	Picture Quality
Altinex 592 Apollo Street Brea, CA 92821 USA 714-990-6088 www.altinex.com	MT-103-122 MT103-123	Active		400-800 ft.	
Anixter International, Inc. 2301 Patriot Blvd. Glenview, IL 60025-8020 224-521-8000 www.anixter.com	CCTP	Active	Special Cat 6	100m (328 ft.)	Surveillance
BH Electronics 12219 Wood Lake Dr Burnsville MN 55337 (612) 894-9590 www.bhelectronics.com info@bhelectronics.com	Fox VMA 040-0045	Passive	Cat 3, 4, 5	1200 ft.	10 MHz bandwidth
Channel Plus Division of SmartHome 16542 Millikan Ave Irvine, CA 92606-5027 www.smarthome.com/channelplus.html	CP-SVC10 CP-SVC10R	Active	Cat 5	Adjustable	
ETS 43353B Osgood Rd. Fremont CA 94539 800.752.8208 www.etslan.com info@etslan.com	PV843 PV844B PV845 PV848 PV849 PV860 PV861B PV862 PV863 PV864B PV950	All passive	Any UTP	2000 ft B&W 1000 ft .color	Depends on cable performance 1300 ft. color with Belden MediaTwist®
Foresight CCTV 800 Richmond St. West #1112 Toronto Ontario CANADA M6J 3N8 416-203-9271 1-888-GO-2-CCTV www.foresight-cctv.com info@foresight-cctv.com	TTP111V TTP111VT TTP111VL TTP111VH TTA111V TTP111VP TTP111VPJ GB001	Passive Passive Passive Passive Active Passive Passive Passive	Cat 5	600m (1968 ft.) B&W 400m (1312 ft.) color 50m (164 ft.) 1km (3280 ft.)	Inserts power in Cat 5 W/ground loop isolator
FSR 244 Bergen Blvd. West Paterson NJ 07424 973-785-4347 www.fsrinc.com sales@fsrinc.com	Twister	Active	Cat 5e	800 ft.	
Intelix 8001 Terrace Ave, Middleton, WI 53562 866-4MATMIX (462-8649) 608-831-0880 intelix@intelix.com www.intelix.com	V1 V1-AR V1-PTZ V1-CV V1-ST		Cat 3 or 5	2500 ft.	

Jensen Transformers, Inc. 7135 Hayvenhurst Avenue Van Nuys, CA 91406 (818) 374-5857 (818) 763-4574 www.jensen-transformers.com info@jensen-transformers.com	ISO-MAX VB-1BT transmitter ISO-MAX VB-1TB receiver	Active	Category 5	up to 1,500 feet	broadcast - quality color
Knoll Systems 145 Tyee Drive, #1206 Point Roberts, WA 98281 (604) 272 4555 (800) 566 5579 (800-KNOLL-SY) www.knollsystems.com mail@knollsystems.com	UB-Send UTP-Send UB-Receive UTP-Receive UR-P3 UR-V3 US-P3 US-V3	Active	Category 5	1,000 ft.	50 MHz -3dB
Leviton Voice & Data Division 2222 - 222nd Street S.E. Bothell, WA 98021-4422 425.486.2222 800.722.2082 www.levitonvoicedata.com	Decora Media System	Active	Category 5/5e	300m (1000 ft.)	50 MHz bandwidth -75 dB THD
Magenta Research 934 Federal Road. Brookfield, CT 06804 USA Tel: 203-740-0592 Fax: 203-740-0596 www.magenta-research.com sales@magenta-research.com	MultiViewUTx™ MultiViewAK1500	Active	Category 5	1500 ft. (457m)	Highest resolution
MuxLab Inc. 5450 Cote De Liesse, Montreal, Quebec, H4P 1A5 Tel: 877-689-5228 Intl: 514-905-0588 www.muxlab.com videoease@muxlab.com	500000 500001 500007 500009 500012 500015 500022 500023 500024 500029	Passive Passive Passive Passive Passive Active Passive Passive Passive Passive	Category 5	2200 ft. 2200 ft. 1,400ft 2200 ft. 2200 ft. 5000 ft. 2,200 ft 2,200 ft 500 ft Not specified	Composite video Composite video, audio Composite + PTZ Composite video Composite video Composite video Video/power/control Composite video +24/28v AC power CCTV + power
Nitek 5410 Newport Dr. #24 Rolling Meadows, IL 60008 800-528-4343 847-259-8900 www.nitek.net info@nitek.net	VB37 VB39 TS515 TS560 EX560 EX1120	Passive Active Active	Any UTP	1000 ft. 1500 ft. 3000 ft. 6000 ft. 9000 ft. color 12,000 ft. B&W	
NVT 4005 Bohannon Dr. Menlo Park CA 94025 (800) 959-9870 650.462.8100 www.nvt.com info@nvt.com	NV-211T-M NV-213A NV-213A-M NV-652R NV-653T NV-314A NV-418A NV-518A	Passive Passive Passive Active Active Passive Passive Active	Any Category Category 2,3 Category 2,3 Category 5 Category 2,3 Category 5 Any Category	750 ft. transmitter 3,000 ft w/NV-652R 750 ft./3,000 ft w/652R 750 ft./3,000 ft w/652R 3,000 ft. Receiver 5000 ft. w/653T 8,000 ft. w/653T 5000 ft. w/652R 8,000 ft. w/652R 750 ft. to NV-314A 3000 ft. to NV-518A 750 ft. to NV-418A 3000 ft. to NV-518A 3000 ft. to NV-518A	Near-broadcast Quality Near-broadcast Quality
Pragmatic Communications Systems, Inc. 2934 Corvin Drive, Santa Clara, CA 95051 (408) 735-0300 www.wireless-experts.com sales@wireless-experts.com	CATS	Active	Category 5	1000 ft.	-1db @ 5 MHz DVD quality

Seco-Larm 16842 Millikan Avenue Irvine CA 92606-5012 949-261-2999 http://seco-larm.com/ info@seco-larm.com	EVT-PB1	Passive	Cat 5	Color 1300 ft. B&W 1950 ft.	
Smarthome 16542 Millikan Avenue Irvine, CA 92606-5027 800-SMARTHOME (800-762-7846) (949) 221-9200 x109 www.smarthome.com	7805A 7805AT 7805B 7805C	Passive	Cat 3 or 5		
Vbaluns Division of Vimasoft 150-26 14th Avenue Whitestone NY 11357 888-546-8641 http://www.vbaluns.com	VBP-1200 VBP-1200Thin VBA-1500MR VBA-1500MT	Passive Active	Any UTP	1200 ft. color 1800 ft. B&W	
Videobaluns Unlimited Framingham MA 508-620-1002 www.videobaluns.com info@videobaluns.com	BL3265 BL3725	Passive Passive	Category 3 or 5		
Vigitron, Inc. 13906 Sparren Avenue, San Diego, CA 92129 –USA 888-574-8942 (858) 484-5209 info@vigitron.com www.vigitron.com	VB 1000 VI 1000 VB 1001M VI 1003M VI 1050M VI 1004 VI 1110	Passive	Any UTP Any UTP Any UTP Any UTP Cat 5 Any UTP Any UTP	1000 ft. 1000 ft. 1000 ft. 1000 ft. 1000 ft. 1000 ft. 1000 ft.	
Visual Circuits 5155 East River Rd. # 401 Minneapolis, MN 55421 763 571-7588 800 250-5533 www.visualcircuits.com info@visualcircuits.com	Marathon AV	Active 4-channel transmitter 1-channel receiver	Category 2 and above	5000 ft,	"No signal degradation."
Visions Televideo Technologies. 2000E West Governors Circle • Houston, TX 77092. 713-686-8409 www.vtti.com	VTT747 VTT1000 VTT2000 VTT3000 VTT3000S VTT5000 VTT7000	Passive Active	Category 2-5 Category 2-5	<800 ft. <1200 ft <3000 ft <3500 ft. (Repeaters every 3500 ft, to 5 miles)	Max. 1.5 dB attenuation down listed length. Bandwidth 50Hz-10MHz. 36 dB CMRR 800 lines 61 dB S/N Meets RS-170A
Vortex Communications Ltd. 75 The Grove Ealing, London W5 5LL ENGLAND 011-44(0)20-8579 2743 www.vtx.co.uk info@vtx.co.uk	PBE-920 PB301SC-301R PB303SR PBE840 PBE845				

Table 7: Baseband Analog Video Balun Manufacturers and Products

CCTP®

First on Table 3 above is a recent addition to UTP Category 6 applications called CCTP, "Closed Circuit over Twisted Pairs". This is a surveillance camera system marketed by Anixter, a major distributor of cable and other products. It features a unique 22AWG Category 6 bonded-pair cable with associated devices for handling analog cameras. The four-pair data cable is also used to carry power for the camera and PTZ (pan-tilt-zoom) controls, all on the same cable. The extra large conductors (22AWG) help extend the distance for DC power which is the distance limiting factor.

When digital cameras are substituted, no cable change is necessary. Further, when surveillance cameras are networked, again, no cable change is necessary as the Category 6 UTP has a 250 MHz bandwidth. For more information on CCTP click on: http://web.anixter.com/anixter/anixter.nsf/0/1933F7341E766AEE86256D7A0045D761?OpenDocument

Shared-Sheath Non-Data Applications

One advantage to the use of video on UTP is the associated uses of that cable. Data cables such as Category 6 can, of course, carry data, such as 10baseT, 100baseT, 1000baseT, Token Ring or Ethernet networks. Applications can telephone, fax, modem, DSL, ISDN, T-1 or other phone company applications. Analog and digital audio, up to eight channels of digital audio on a four-pair UTP, are also possible. Thus, one could wire up a school, hospital or other facility with nothing but Category 6 UTP and do almost anything.

Installers should be aware that in TIA/EIA 568B.2, while it does not specifically disallow multiple uses for any cable, if such multiple uses are installed, that cable will *not be certifiable as being 568B.2 compliant* even if other requirements are met. Failure, while difficult to predict, is usually based on the belief that crosstalk (NEXT) will be compromised for the data signals. This does not mean that the cable *next to it* in the bundle is or isn't compliant. Designate which cables will be 568B.2 compliant and to install them to that standard. The shared-sheath, non-standard cables, can be wired as needed.

It is also possible to install *all cables* to be 568B.2 compliant, and to make the non-standard applications appear *outside* each wall jack. In that way, all wiring could, at any time, be part of a 568B.2 compliant network and yet, at the change of a patch cord, be a video feed, telephone, T-1 line, RGB cable, or many other uses.

The Analog Video Image

In analog video, bandwidth requirements are well known. Only the quality of the image is unspecified. Table 8 is a chart of picture quality based on frame rate and line resolution.

Analog Bandwidth	Frame Speed	Line Resolution	Picture Quality
4.2 MHz	< 15 fps	< 100 lines	Very poor, jumpy
4.2 MHz	> 15 fps	> 100 lines	Tolerable
4.2 MHz	30 fps	> 200 lines	Standard home reception quality
4.2 MHz	30 fps	> 400 lines	Standard in-studio quality
4.2 MHz	30 fps	RGB component	Very high resolution

Table 8: Subjective Specifications for Video Images

Bandwidth. In an analog color television, the signals required for a picture are standardized as "luminance" (black and white picture information), and "chrominance" (color picture information which overlays the black and white). Audio, commonly stereo audio, is included. The total bandwidth for these signals is 4.2 MHz.
The only way to limit or reduce the amount of information in its analog form is to send each picture as black-and-white only or send each "frame" slower than normal. Cables that carry the entire video signal are *composite* video cables.

Frame Speed is the number of images per second displayed. In broadcast receivers, the standard is 30 frames per second or "fps". Each frame is split into two "fields", each 1/60th of a second. In Europe, the frame rate is 25 fps and the field rate 50.

These fields are "interlaced" which means each field shows every other line (i.e., the first field shows its image on odd-numbered lines and the second field shows its image on even-numbered lines). You only see half of the picture at any instant in time. This compromises picture detail. However, latency (flickeriness sometimes visible when viewing motion pictures) is greatly reduced. An effect in the human brain called “persistence of vision” puts these two fields together and we see a whole picture.

Motion pictures are shot at 24 fps (25 in Europe) and latency (flicker), especially with bright objects on screen, can be very noticeable. 30 frames per second/60 fields per second (25/50 in Europe) is broadcast quality. Fewer frames is less than broadcast quality.

In computer monitors and displays, the picture information is displayed in "progressive" scan, that is one line right after another. This gives these displays excellent detail (which is required in the computer field) but poor in image latency and requiring double the amount of information as an analog broadcast receiver to display a picture.

Line resolution is the measure of detail in an analog picture. Horizontal and vertical resolution are the two kinds of resolution measured. Resolution is the ability of a television screen to show detail and is usually determined by the number of lines that can be discerned. A test pattern can be shown on a television screen from which the lines of resolution can be determined.

In North America, the number of horizontal lines is standardized by the NTSC (National Television Systems Committee) at 525 lines. European television (PAL) uses 625 lines. So, all other things being equal, PAL has the potential to deliver higher resolution and more detail. The vertical resolution of each line, therefore, is really the only measure of resolution and detail over which a broadcaster has any control.

Cameras and monitors, especially those used for broadcast purposes, specify their horizontal resolution as so many "lines". As can be seen in the previous chart, 200 lines or so is what the average consumer receives off the air. Cable, while theoretically able to deliver more lines, rarely does. Most camcorders used for home recording can do 200 to 300 lines. Broadcast facilities, especially in-house, are capable of recording and playing back 400 to 700 lines, 2-1/2 times the quality they are able to transmit to the customer! It is interesting to note that many television receivers made in the late 1960's and 1970's *reduced* horizontal resolution. Doing so reduced noise on the screen dramatically and gave the *appearance* of a sharper, clearer picture which was not, in fact, the case.

S-Video

S-video stands for “super-video”. This is also called S-VHS™ or “super-video home system” [VHS is a trademark of JVC].

To increase sharpness, the video signal is split into two components, the black & white signal, (“Y”), ‘luminance’, and the color signal (“C”) ‘chrominance’. Thus, we have the official designation of Y-C for such a signal.

Originally intended as a high-quality consumer format, S-video has found its way into “pro-sumer” applications where the low cost of equipment and the decent image quality are hard to resist. Cost of media, editing, and storage also make this a favored choice for borderline-professional applications, such as industrial video, training or educational video. It is popular wherever ultimate image quality is not of key importance.

Table 9 on the next page is a list of S-video (Y-C) balun manufacturers.

Manufacturer	Model/Part #	Passive or Active	Cable	Distance
Altinex 592 Apollo Street Brea, CA 92821 1-800-ALTINEX 714-990-2300 sales@altinex.com www.altinex.com	DA1930CT DA1931CT MT103-122 MT103-123	Active	Cat 5 or 6	400 - 800 ft.
ETS 43353B Osgood Rd. Fremont CA 94539 800.752.8208 www.etslan.com info@etslan.com	PV900 PV901	Passive	Any UTP	Unspecified
Channel Plus Linear LLC Carlsbad, CA 800.999.5225 www.channelplus.com	CP-SVC10 CP-SVC10R	All Active	Cat 5	Adjustable
Intelix 8001 Terrace Ave, Middleton, WI 53562 866-4MATMIX (462-8649) 608-831-0880 intelix@intelix.com www.intelix.com	SVA2	Passive	Cat 3 or 5	1,000 ft.
Knoll Systems 145 Tyee Drive, #1206 Point Roberts, WA 98281 (604) 272 4555 (800) 566 5579 (800-KNOLL-SY) www.knollsystems.com mail@knollsystems.com	UDR-SVID	Active	Cat 5	1,000 ft.
Magenta Research 934 Federal Road. Brookfield, CT 06804 USA Tel: 203-740-0592 Fax: 203-740-0596 www.magenta-research.com sales@magenta-research.com	MultiViewUTx™ MultiViewAK1500	Active	Category 5	1500 ft. (457m)
MuxLab Inc. 5450 Cote De Liesse, Montreal, Quebec, H4P 1A5 877-689-5228 514-905-0588 www.muxlab.com videoease@muxlab.com	500016 500017 500200	Passive Passive Active	Cat 5 Cat 5 Cat 5	1,000 ft 1,000 ft + Audio 1,000-2,200 ft
NVT 4005 Bohannon Dr. Menlo Park CA 94025 (800) 959-9870 650.462.8100 www.nvt.com info@nvt.com	NV418A NF411A RV518A NV652R	Passive Active		
Smarthome 16542 Millikan Avenue Irvine, CA 92606-5027 800-SMARTHOME (800-762-7846) (949) 221-9200 x109 www.smarthome.com custsvc@smarthome.com	7805SV	Passive	Cat 3 or 5	
Vortex Communications Ltd. 75 The Grove Ealing, London W5 5LL ENGLAND 011-44(0)20-8579 2743 www.vtx.co.uk info@vtx.co.uk	PBE902	Passive	Any UTP	

Table 9: S-video (Y-C) Balun Manufacturers and Products

RGB

RGB stands for the three primary colors in a video image: red, green, and blue. Your television shows a color image based on groups of colored pixels. The eye blends them into the rainbow of colors we expect to see.

When working in analog video, separating the picture into its component colors is called "component" television. While images are never transmitted through the air in this format, they are often processed in this format in studios or editing facilities to increase the quality and detail. Groups of coaxial cables (often colored red, green, and blue to aid in their connection) are used to carry these signals from place to place. Below is a list of manufacturers that are supporting RGB down twisted pairs.

Manufacturer	Model/Part #	Passive or Active	Cable	Distance	Picture Quality
Altinex 592 Apollo Street Brea, CA 92821 1-800-ALTINEX 714-990-2300 sales@altinex.com www.altinex.com	DA1930CT DA1931CT	Active	Cat 5 or 6	400 ft.	
ETS 43353B Osgood Rd. Fremont CA 94539 800.752.8208 www.etslan.com info@etslan.com	PV890 PV891 PV894 PV920 PV921	All passive	Any UTP		
FSR 244 Bergen Blvd. West Paterson NJ 07424 973-785-4347 www.fsrinc.com sales@fsrinc.com	MMTP-RGBTX MMTP-RGBRX	Active transmitter Active receiver	Cat 5	>800 ft.	RGBHV YUV
Hall Research Technologies 3613 W. Mac Arthur Blvd. Santa Ana, CA 92704 1-800-959-6439 www.Hall Research.com info@hallresearch.com	UV-1-CP	Active Active (2-channels) Active (8-channels) Active (24-channels)	Cat 5 Cat 5 Cat 5 Cat 5	500 ft. 150m	RGB or Y Pb Pr
Intelix 8001 Terrace Ave, Middleton, WI 53562 866-4MATMIX (462-8649) 608-831-0880 intelix@intelix.com www.intelix.com	V3	Passive	Category 3 or 5	500 ft.	
Magenta Research 934 Federal Road. Brookfield, CT 06804 USA Tel: 203-740-0592 Fax: 203-740-0596 www.magenta-research.com sales@magentaresearch.com	MultiViewUTx™ MultiViewAK1500	Active	Category 5	1500 ft. (457m)	Highest resolution

MuxLab Inc. 5450 Cote De Liesse, Montreal, Quebec, H4P 1A5 Tel: 877-689-5228 Intl: 514-905-0588 www.muxlab.com videoease@muxlab.com	500002 500021	Passive Passive	Category 5 Category 5	500 to 1,000ft 1000 ft.	RGB YPbPr (HD) YPbPr/480/720pHD
NVT 4005 Bohannon Dr. Menlo Park CA 94025 (800) 959-9870 650.462.8100 www.nvt.com info@nvt.com	202A NV-1702A 314A 418A 518A	Passive Passive, (PC module) Passive Passive Active	Category 2, 3, 4, or 5	500 ft. 500 ft 500 ft. 500 ft. 2000 ft.	Capable Capable Passable Receive Receive
Videobaluns Unlimited Framingham MA 508-620-1002 info@videobaluns.com	BL3265 BL3725	Passive Passive	Category 3 or 5		
Visual Circuits 5155 East River Rd. # 401 Minneapolis, MN 55421 763 571-7588 800 250-5533 www.visualcircuits.com info@visualcircuits.com	Marathon AV	Active 4-channel transmitter 1-channel receiver	Category 2 and above	5000 ft,	"No signal degradation."
Visions Televideo Technologies. 2000E West Governors Circle • Houston , TX 77092. 713-686-8409 www.vtti.com/	VTT747 VTT1000 (+ control) VTT2000 VTT3000 (+audio) VTT3000S (+ stereo) VTT5000 (+ control) VTT7000	Passive Active	Category 2-5 Category 2-5	<800 ft. <1200 ft <3000 ft “ (Repeaters every 3500 ft, to 5 miles)	Max. 1.5 dB atten down listed length. Bandwidth 50Hz-10MHz. 36 dB CMRR, 800 lines 61 dB S/N Meets RS-170A
Vortex Communications 75 The Grove Ealing, London W5 5LL ENGLAND 011-44(0)20-8579 2743 www.vtx.co.uk info@vtx.co.uk	PBE890	Passive		1968 ft.	

Table 10: RGB (Component) Balun Manufacturers and Products

Multiple pairs can carry a component video image. Each pair handles a portion of the final picture, and the delivery or “timing” of the arrival of picture elements is critical. Called *skew* or *delay skew* in the data world, timing is the different arrival times of the picture elements. Broadcast standards require a maximum timing error (skew) of 40nsec.

No Skew and Low Skew Cables

In component video, the red, green, and blue (“RGB”) component colors of video are sent separately. This produces the highest quality analog video image. Normally, a cable with multiple coaxes is used to carry the components. However, it was recognized early on that this might be one of the non-data applications for ‘category’ cables.

If you send RGB down multiple cables, you need to have the signals arrive at the same time. Multiple coaxes then need to be "timed" or trimmed by hand to the same length. That electrical length may not be the same as the physical length so, especially in long runs, one coax might be significantly longer or shorter than the others.

The *de facto* broadcast standard is a timing error of less than 40 nanoseconds (nsec) between the coaxes delivering the signal. Identical signals fed into one end should arrive at no more than 40 nsec difference at the destination. With 40 nsec of timing difference between the primary colors, an expert eye could discern shifts of colors and loss of detail on a video monitor. Belden's bundled RGB coaxes are typically guaranteed to have no more than 4 nsec per 100 ft. timing variation, (some products are 5-nsec/100 ft.) For a bundled coax guaranteed to be 4-nsec/100 ft., when compared to the 40 nsec maximum, such a cable could go 1000 ft. before it is *out of time*.

Does that mean you could send an RGB signal a thousand feet? That depends on the attenuation of the cable. For many smaller cables the attenuation would make the signal unusable, too low in level, long before that 1,000 ft. distance. What Belden's timing guarantee means, therefore, is that timing is simply not a consideration. Just cut and connectorize the cable. No hand timing is required.

On twisted-pairs, the timing variations are now between the four pairs. Since you are required to connectorize all four pairs at the same time, you cannot lengthen or shorten any pair. You are dependant upon the delay skew built into the cable. In the data world, "timing", now called "skew" or "delay skew", has exactly the same effect. This measurement becomes important when applications, such as 1000baseT "gigabit" networking, are introduced. Gigabit networking runs data simultaneously down all four pairs, and in both directions. Signals sent at one end need to arrive at the same time at the other end. Interestingly, the maximum delay skew in TIA/EIA568B.2 is 45 nsec between all four pairs at 100 meters, 328 feet (surprisingly close to the 40 nsec of RGB).

A skew of 45 nsec, and a video component requirement of 40 nsec, means that a generic Category cable could go 40/45 x 328 = 292 feet before it is "out of time". While 292 feet may seem like a long way, there are a number of vendors who feel this is a serious limitation to the use of UTP for RGB. For a long time, MediaTwist (25 nsec) was the lowest skew cable available. 40/25 x 328 = 525 ft. One would think that would certainly be far enough.

So why not a cable with *no* skew. The reason there is skew at all is that all four pairs in a UTP cable are twisted differently. This is essential to reduce crosstalk between pairs. But, if crosstalk isn't at issue, why couldn't you simply twist all the pair identically? Extron and others had cables manufactured for them with identical lay length (pair twists). Belden has such a cable called Nanoskew® (7987R, 7987P), but don't look for Belden to include the specifications with the other UTP premise/data cables above.

Because the twists are identical in all four pairs, we don't even test this cable for crosstalk. We know that it will not even pass Category 3 requirements. It's only recommended applications are where crosstalk is a non-issue, and timing is everything. And no cable, no matter how perfectly it is manufactured, will have 'zero' skew. In fact, the delay skew on 7987R/P is a maximum of 2.2 nsec/100m (a timing distance of almost 6,000 ft. to the 40 nsec maximum).

The advantages over bundled coaxes are obvious. These cables are much smaller than even miniature RGB cables. They are easy to connectorize with RJ-45 data connectors, and easy to install. Where plenum RGB coaxes are expensive, quite time-consuming to strip and connectorize, plenum versions of Category-style cables are significantly easier and faster to install, and the large number of customers and huge installed base keeps the price reasonable.

The one unproven part is the effect of crosstalk on RGB signals. Won't these color signals bleed into each other? Perhaps the ability of the eye to see color bleed is considerably less sensitive than timing variations and detail. The empirical evidence, both from vendors of equipment and installers of the cable, is that this crosstalk color bleed seems to be of no consequence. The other limitation is that this cable design is specifically for RGB and VGA-type signals. Even though it looks like, and connects like, data cable, it is not data cable. It only has one family of applications, RGB, VGA, and similar applications.

Wouldn't it make sense if we could produce a cable that could be a true UTP data cable, like a Category 5e or Category 6, which also had very low skew? Belden has produced a whole line of low-skew VideoTwist® cables. These include Belden 7988R and 7988P, which are Category 5e UTP with a skew of 9 nsec/100m, and Belden 7989R and 7989P, which are Category 6 UTP with a skew of 10 nsec/100m.

All of these use Belden's patented bonded-pair technology for very stable and consistent impedance performance. These cables can be used as either RGB or premise/data cables. More data on the cables can be found in the new product bulletin, NP 212.

VGA

One additional application for these cables is VGA, "Video Graphics Array", and its offshoots (SVGA, XGA, SXGA, UXGA). Many of these applications are beyond the 100 MHz limit of Cat 5 or 5e, some up to 245 MHz. Care should be taken to choose a cable that has bandwidth specifications that match or exceed the signal to be carried.

Belden VideoTwist® 7988R and 7988P (Category 5e), 7989R and 7989P (Category 6), were produced for these extended-bandwidth applications. These cables are fully tested to 350 MHz specifically for high-resolution applications, such as SXGA or UXGA. New product bulletin NP212 also contains distance and loss charts to determine maximum recommended distances. Table 11 below is a list of VGA balun manufacturers:

Manufacturer	Model/Part #	Passive or Active	Cable	Distance
Altinex 592 Apollo Street Brea, CA 92821 1-800-ALTINEX 714-990-2300 sales@altinex.com www.altinex.com	DA1930CT DA1931CT MT103-122 MT103-123	Active	Cat 5 or 6	400 – 800 ft.
ETS 43353B Osgood Rd. Fremont CA 94539 800.752.8208 www.etslan.com info@etslan.com	PV930 PV931 PV932 PV937-2 PV938 PV939-2	Passive Active	Any UTP Cat 5 or better	Unspecified
Extron 1230 South Lewis Street Anaheim, CA 92805 800.633.9876 714.491.1500 Fax: 714.491.1517 www.extron.com	SW2MTPT15HDA SW4MTPT15HDA SW6MTP15HDA MTPR15HDA	Active	Single UTP	600 ft. (185m) XGA 400ft. (135M) UXGA
FSR 244 Bergen Blvd. West Paterson NJ 07424 973-785-4347 www.fsrinc.com sales@fsrinc.com	MMTP-RGBTX MMTP-RGBRX	Active transmitter Active receiver	Cat 5	>800 ft. UXGA compatible with low skew cable
Hall Research Technologies, Inc. 3613 W. Mac Arthur Blvd., Santa Ana, CA 92704 1-800-959-6439 www.Hall Research.com info@hallresearch.com	UV-1 UVA-2 UVA-8 UVA-24 URA URA-SC URA-SCL	Active transmitter Active 2-channel transmitter Active 8-channel transmitter Active 24-channel transmitter Active receiver Active receiver w/skew compensation Active receiver w/skew compensation	Cat 5	500 ft. 150m 400 ft. 800 ft.
Intelix 8001 Terrace Ave, Middleton, WI 53562 866-4MATMIX (462-8649) 608-831-0880 intelix@intelix.com www.intelix.com	VGA9 VGA2	Active Passive	Cat 3 or better Shielded Cat 5	350 ft. 450 ft.
Magenta Research 934 Federal Road. Brookfield, CT 06804 USA Tel: 203-740-0592 Fax: 203-740-0596 sales@magenta-research.com www.magenta-research.com	450A transmitter AK1000 receiver AK1500 receiver	All active Requires skew compensation board or Belden 7987R or 7987P “NanoSkew”	Cat 5	450 ft. 1000 ft. 1500 ft.
MuxLab Inc. 5450 Cote De Liesse, Montreal, Quebec, H4P 1A5 Tel: 877-689-5228 Intl: 514-905-0588 www.muxlab.com videoease@muxlab.com	500010 500011 500014	Passive Passive Passive	Cat 5 STP Cat5 STP Cat5 STP	350 ft (800x600) 350 ft (800x600) 350 ft (800x600)
Vortex Communications Ltd. 75 The Grove Ealing, London W5 5LL ENGLAND 011-44(0)20-8579 2743 www.vtx.co.uk info@vtx.co.uk	PBE930 PBE937-2	Passive Active	Cat 5 or better Any UTP	 328 ft.

Table 11: VGA Balun Manufacturers and Products

Digital Baseband Video

Digital video is different from analog. It is already data, ones-and-zeros. It is very robust (like data) and is much more immune to interference. It can be easily broken up, transmitted, and reassembled. If all the bits arrive in the right order, the thousandth copy of a digital signal is identical to the original, making digital the ideal medium for recording, duplication, and playback. The only real stumbling block is data rates.

The data rate for true broadcast quality video is at least 45 Mbps, and broadcast manufacturers usually specify 143 Mbps (71.5 MHz) to 270 Mbps (135 MHz). Category 6 data cables are only now covering these data rates and bandwidths. Using generic Category 5 or 5e presents a problem since it only has a tested bandwidth of 100 MHz.

Network designers who create "video-to-the-desktop" have three solutions to this problem. The first trick is a compression scheme that reduces the bandwidth dramatically, called "bit rate reduction" or BRR, without affecting picture quality. Image quality in digital can be very subjective, especially to those familiar with home-video quality. Compression or BRR of 100-1 is considered "high-quality-video-to-the-desktop" (close to a T-1 data rate of 1.544 Mbps). Very few end-users have this quality available to them. Most of the time, the video to the desktop is a quarter T-1 (384Kbps) or even less.

The second trick is to hide the lack of data. The video image is placed on a small portion of the display monitor. If you only have a few thousand pixels responding, the lost data will be imperceptible. It is only when you fill the screen completely with the image, or have a very large monitor, or blow the image up with a projector in an auditorium, that the lack of quality will be apparent.

The third trick is to reduce the frame rate. Since this is just another form of data, it is very easy to reduce the frame rate to 20 or less frames per second. Once below 15 frames, however, the latency in the human eye will begin to see the transition between frames and watching such an image can become tiring.

One of the key advantages to a digital video image, even of low quality, is the lack of noise and interference. To many who have grown up with an analog picture full of snow (low signal strength) or ghosts (multipath), a digital image is noiseless and ghostless, thus appearing "sharp" when, in fact, the actual data being viewed is orders-of-magnitude worse than a standard home television picture.

Table 12 below is a list of balun manufacturers for digital video. You will note that the distance that can be achieved is directly related to the data rate. The data rate is directly related to compression and frame rate. Unless these devices carry ‘uncompressed’ 30 frame video, they certainly cannot be considered “broadcast quality”. Nevertheless, it is amazing how much “cell phone video” appears on national television. After all, content is everything!

Manufacturer	Part Number	Cable	Data Rate	Distance
Bal Buckingham Close - Unit 3 Bermuda Trading Estate Nuneaton, Warwickshire England CV10 7JW +44 (0)24 7637 5827 Fax+44 (0)24 7664 2375 www.bal.co.uk sales@bal.co.uk	SVC5012 C5SV012	Cat 5 Cat 6 2-pairs = 1 coax	SDI 144Mbps 177 Mbps 270 Mbps	115m
ETS 43353B Osgood Rd. Fremont CA 94539 800.752.8208 www.etslan.com info@etslan.com	DVMC 850 (Passive)	Belden DataTwist 350™ Belden MediaTwist®	143 Mbps 177 Mbps 270 Mbps	>400 ft. >450 ft.
Gyyr 1515 S. Manchester Anaheim, CA 92802 (800) 854-6853 www.silentwitness.com/ comments.security@honeywell.com	FasTrans 2000 (Active)	Any UTP	Variable 8 fps "Low Quality" 20 sec/frame "High Quality"	Unlimited
NVT 4005 Bohannon Dr. Menlo Park CA 94025 (800) 959-9870 650.462.8100 www.nvt.com	VideoExpress™ (Active)	Any UTP	T-1 1.544 Mbps	Unlimited
Pairgain 14402 Franklin Ave. Tustin CA 92680 (714) 832-9922	Campus-TI (Active) Campus E-1 (Active)	Any UTP	784 Kbps per pair (1.544 Mbps for 2-pair) 1 Mbps per pair (2.048 Mbps for 2-pair)	2.3 miles 2.2 miles Based on 24 AWG copper.
Vortex Communications Ltd. 75 The Grove Ealing, London W5 5LL ENGLAND 011-44(0)20-8579 2743 www.vtx.co.uk info@vtx.co.uk	PBE-SDI	Cat 5e or better	SMPTE 259M	

Table 12: Digital Video Balun Manufacturers and Products

For lower data rates, the lower the rate the easier it is to ship signals around. Category cables are specified to run up to 100 meters (328 ft.) at their maximum data rate. At T-1 or lower data rates, high quality twisted pairs could go much farther.

DVI and HDMI

These cables send digital video to consumer/home high-definition display devices, such as plasma screens. DVI ("Digital Video Initiative") and HDMI ("High-Definition Multimedia Interface") both use twisted pairs for delivery. The only question is how the bandwidth of the DVI and HDMI signals, over 1.5 GHz, can work on Cat 5 cables that are tested and verified to 100 MHz.

Even Belden 7851A ("600E") is only specified to 600 MHz, and 10GX32 "10gig" UTP is "only" 625 MHz per pair. Potential users of Cat 5/6 for DVI or HDMI should therefore be

cautious when considering the use of these devices. Table 13 shows the short list of balun manufacturers for these applications.

Manufacturer	Part Number	Cable	Distance	Notes
Intelix 8001 Terrace Ave, Middleton, WI 53562 866-4MATMIX (462-8649) 608-831-0880 intelix@intelix.com www.intelix.com	Active DVI	2 Cat 5 cables	150 ft.	HD-SDI and VESA resolutions, DDWG standard.
Svideo.com 711 E. Main St. Riverton, WY 82501 307-851-0215 www.svideo.com sales@svideo.com	EXT-DVI-CAT5 EXT-HD-SDI-CAT5	Cat 5 Cat 5	150 ft. 150 ft.	
Gefen Inc. 6265 Variel Ave. Woodland Hills, CA 91367-9897 800-545-6900 818-884-6294 www.gefen.com sales@gefen.com	DVI-CAT5 CAT5-5000HD	Cat 5 Cat 5 or Cat 6	150 ft. 150 ft .	DVI + USB keyboard/mouse Extends two 1920 x 1200 displays.

Table 13: DVI and HDMI Balun Manufacturers and Products

Analog Broadband Video

A number of system manufacturers are looking at UTP for broadband delivery. Also known as CATV or “cable” delivery, broadband systems transmit groups of channels simultaneously down one cable in a multiplex protocol.

Where these channels fall on standard television broadcast frequencies, standard televisions can de-multiplex the channels for viewing. Where the multiplexed channels are scrambled, sent in other bands or groups of frequencies, converters are used to convert them to standard broadcast frequencies.

To fully understand how coax or UTP can handle broadband/CATV channels or off-air broadcast television channels, one must understand how these channels are assigned. The assignment of channels by the FCC is anything but sensible. Off-air transmitted television channels cover a number of frequency bands. These sometimes do, and sometimes do not, correspond to the cable television industry channel assignments.

In fact, as will be seen from the chart below, some CATV channel numbers have no relationship to their frequency. For instance, CATV assigned channels 14-22 come between off-air channels 6 and 7.

Table 14 is a chart of cable and off-air assigned channels.

BAND	FREQUENCY (MHz)	BROADBAND/CATV CHANNELS	OFF-AIR TV CHANNELS	NOTES
	6 - 48	T-7 through T-13		Interactive/ experimental
VHF	54 - 72	Channels 2, 3, 4	Channels 2, 3, 4	
VHF	76 - 88	Channels 4, 5, 6	Channels 4, 5, 6	
FM+	88 -118	Channels A-1 to A-5		Channels in reverse order
UHF	120 - 174	Channels 14 - 22		
VHF	174 -216	Channels 7 - 13	Channels 7 - 13	
UHF	216 - 1002	Channels 23 - 158		Channels assignments do not align
UHF	470 - 764		Channels 14 - 60	

Table 14: Television Channels and the Frequencies they Occupy

These channel assignments are carried over to digital television. That is, channel 50 can be analog or digital. Eventually, when analog is "turned off" there will only be digital signals. But the 6 MHz size of the channel will remain the same regardless of the type of signal, analog or digital, on that frequency. So coaxial cable that says "Digital Ready" or "HD-SDI Ready" is a joke. The cable you've had for years will work fine. And UTP can easily carry a 6 MHz signal, analog, digital, or HD-SDI. The only question is how *many* channels?

Television channels from 69-83 have been sold to cellular telephone companies by the FCC (Federal Communications Commission) and now run your cell phone. In the same way, Channels 60-69, and possibly even some lower channels, will be re-purposed by the FCC and auctioned off for other uses. The new assignments, of course, have nothing directly to do with the cable that carries these signals.

You will note some 'gaps' in the frequency listing above. These frequencies are assigned by the FCC to various non-television services by the FCC, such as FM radio, aircraft navigation, land and fixed mobile, and are therefore beyond the scope of this paper. However, it should be realized that many of these application could also be supported by UTP (as they are currently supported by coax.)[Note 2]

Not shown in the chart above is the progression to digital television (DTV). This is a reassignment of a second channel to existing broadcasters. The second channel is specifically for digital transmission. These digital signals can include *high-definition* video. Also not shown is direct broadcast satellite television (DBS) as these systems extend beyond 1 GHz and are therefore far beyond the current capabilities of UTP.

There are many differences between coaxial cable, the standard copper cable for broadband/CATV, and twisted pairs. First difference is bandwidth. Standard broadband coaxial cable can handle up to 1 Gigahertz (1000 Megahertz) of bandwidth (158 channels). Special versions can handle up to 2.25 GHz (~300 channels). Cable companies are now requiring that coaxial cable be tested up to 3 GHz for future expansion. The broadband capability of most cutting-edge UTP/STP is still *nowhere near* this bandwidth, except for the emerging 10 gigabit cable.

The second difference between coax and twisted pairs is attenuation. Industry standards require 24 AWG twisted pairs for Category 5 or 5e, 23 AWG or 22 AWG for Category 6. Resistance of these wires is higher than standard RG-6 coax. And there are many other factors, such as return loss or crosstalk, where twisted pairs cannot compete with coax.

It is doubly amazing, therefore, to consider that this application, broadband/CATV delivery over twisted pairs, is the *most requested* non-data application! In many broadband/CATV applications the 150+ channel capacity of coaxial cable is not essential. In schools, hospitals and other controlled environments, only a small number of channels are required. In those instances, UTP could be a very cost-effective solution. All that is required is a broadband balun. Table 15 below is a list of CATV/broadband balun manufacturers for UTP.

The VHF television broadcast band does not start until 54 MHz (Channel 2) and covers Channel 2 through 13. While the bandwidth, 54 MHz to 216 MHz, is equal to 27 channels, the off-air equivalence is only 12 channels. But a dozen channels is still sufficient for many educational or commercial applications.

Impedance variations, mismatches, and structural return loss seem to indicate that the limiting factor is less and less the cable and more and more the baluns and other hardware. Belden MediaTwist®, specified out to 350 MHz, and Belden 600E®, with a bandwidth of 600 MHz per pair, are ideal cables for use with any broadband balun. 350 MHz is equivalent to 45 cable channels. 600 MHz is equivalent to 86 channels.

The loss characteristics of twisted pairs at these high frequencies are dramatically different than the loss on coaxial cable. The author is unaware of any equalization (“tilt”) amplifiers made for UTP to help reduce this loss, although tilt amplifiers are a standard product for coax.

MANUFACTURER	MODEL	PASSIVE/ ACTIVE	CABLE	DISTANCE	NO. OF CHANNELS
AMP PO Box 3608 Harrisburg PA 17105 (800) 526-5142 FAX (800) 522-6752	BOB 415337-1 BOB 415521-1	Active Unidirectional Active Bi-directional	Cat 5	328 ft. (568A)	29 NTSC (T7-T14, 2-22) 5-216 MHz
AT&T 505 N. 51st Ave. Phoenix AZ 85043 (800) 344-0223	384A	Passive	Cat 5	328 ft.	28 channels (Bandwidth 55.25MHz to 253.25MHz)
BH Electronics 12219 Wood Lake Dr. Burnsville MN 55337 (612) 894-9590	Lynx	Passive	Cat 3 Cat 5	154 ft.	Channels 2 - 61 (54-450 MHz)
ETS 43353B Osgood Rd. Fremont CA 94539 800.752.8208 www.etslan.com info@etslan.com	PV882 PV883 PV884 PV885	Passive	MediaTwist Cat 6	55 meters (180 ft.)	Channels 2-77 Channels 2-120
Intelix 8001 Terrace Ave, Middleton, WI 53562 866-4MATMIX (462-8649) 608-831-0880 intelix@intelix.com www.intelix.com	VB	Passive	Cat 3 or better	180 ft.	Channel 120
MuxLab Inc. 5450 Cote De Liesse, Montreal, Quebec, H4P 1A5 Tel: 877-689-5228 Intl: 514-905-0588 www.muxlab.com videoease@muxlab.com	500006	Passive	Cat. 5	100m (330 ft)	Channels 77 (550 MHz Bandwidth)
Vortex Communications Ltd. 75 The Grove Ealing, London W5 5LL ENGLAND 011-44(0)20-8579 2743 www.vtx.co.uk info@vtx.co.uk	PBE850SR				

Table 15: CATV/Broadband Balun Manufacturers and Products

Emission

One key subject that seems to have been successfully avoided, especially when discussing broadband/CATV applications, is the emission off UTP running at high frequencies. In the data world, significant work has been done to keep actual running frequencies low. Below 30 MHz, the FCC has no radiation/emission specifications. Therefore, one of the key drivers to compression technology has been to get systems at or near that number to avoid the requirements of the FCC.

Broadband/CATV applications cannot use such compression technology and are required to meet very stringent emission specifications. These are spelled out in the FCC Rules and Regulations, 47, Part 15, Subpart B. Any device, and the cable that wires it up, must meet one of these specifications.

It is interesting to note the only category cables that have ever been tested for emission, are bonded-pairs such as Belden 1700A “DataTwist 350” and 1872A “MediaTwist®. (If other manufacturers’ products have been tested, they suspiciously have not released the test results.) MediaTwist was tested with Sony 270 Mbps/135 MHz digital video machines, and PV850 digital video baluns manufactured by ETS (listed above) by Underwriter Laboratories in Chicago.

These cables were awarded a certificates by UL for *"Class A Digital Devices"*. You can download a copy of either of these UL certificates. They can be found at http://bwcecom.belden.com/college/Techpprs/tpewmawd.htm

It should be pointed out that this application, Component Serial Digital Baseband Video, is only 135 MHz bandwidth, and does not mean that MediaTwist or any other UTP product is functionally equal to coax cable.

We are 'approaching' coax performance, but we're not there yet. And meeting the FCC broadband emission standards, especially at UHF frequencies, even with Category 6, is something yet to be verified.

Internet Video

Our last application is video over the internet. This is different from all previous delivery systems as the delivery “medium” is the internet and not a network cable. While Cat 5, 5e, or 6 are no doubt part of the delivery chain, at the beginning and end of the chain, they are incidental to this application, and their performance has little effect on the actual video image. As long as the network requirements are met for each end-user computer, server, or other device, the performance and quality of the video image will be directly related to the *data speed on the IP connection*.

Recent experiments have delivered uncompressed (1.5 Gbps) digital HD signals through internet connections. However, these experiments were done ‘in the lab’ and no current equipment exists to accomplish this amazing feat. Just the idea that this HD signal, a thousand times a T-1 signal, could be carried by the Internet is staggering, and the possibility of many such huge data signals traveling across the ‘net will require even more bandwidth. Current top-speed for “standard” technology twisted pairs is 1000baseT which is “only” one gigabit per second. There is significant work being done in the 10gig world of tomorrow. Whether this can be done on today’s cable designs, or even on copper cables of tomorrow, remains to be seen.

“Non-Baluns”

It should be mentioned that some manufacturers of connectors and connecting hardware have begun to produce video modules that fit in wall plates. The ‘footprint’ for these modules is the same as the standard RJ-45 data connector. These manufacturers offer RCA, F, BNC, S-video, and even fiber connections. Where they are *feed-through* style, where the connector type is the same in the front and back of the module, they work very well, and can be very versatile.

However, there are some, specifically RCA and S-video, which offer those connectors on the front and a “110-style” punch-down block on the back. These modules look like they offer a very fast way to attach these connectors to UTP, but they both suffer from one fatal flaw. RCA and S-video normally connect to coaxial cable. S-video is, in fact, two coaxial cables. Those cables and the signals they carry are, by definition, *unbalanced*. The cable most likely to be punched down to the 110-block on the other side is a UTP Category premise/data cable, but those UTP twisted pair cables are *balanced*.

To adapt a balanced-to-unbalanced signal, one simply uses a balun, as we have discussed here at great length. However, in these “modules”, there are no baluns, no transformers, no matching networks of any kind. Simply attaching an unbalanced signal to a twisted pair makes that pair unbalanced as well. All noise rejecting properties are removed and that pair can radiate signals to other pairs or other cables and pick up external noise.

Further, the very limited distance of unbalanced audio (usually less than 30 feet), and the similar restrictions of S-video (usually less than 50 feet) are not improved by these “adaptors” and, in fact, may be reduced because of the susceptibility to noise and interference.

Some of these manufacturers have admitted that the design of these modules is less than ideal and are working on versions that do indeed contain baluns. Until then, we would strongly suggest avoidance of these RCA-to-110 and S-video-to-110 adaptors. The distances that signals could travel when these adaptors do contain true baluns will be much greater, possibly many hundreds of feet.

10 Gigabit Networking

This emerging new standard promises to be a major breakthrough in copper cables. The cable itself is a new version of Category 6. In fact, its official name is Category 6a (“augmented” Category 6). The standard is still ‘in progress’ and considering it took Category 6 over fourteen drafts before approval, 10gig will not be appearing in its final form any time soon.

That being said, much of the standard concerning connectivity, cable, connectors, patch panels, patch cords, has been written and looks unlikely to change. So a number of manufacturer, including Belden, have 10gig solutions already available and on the market.

Running 10 gigabits per second is an immense data load. And the only way to accomplish this over twisted pairs is extensive compression and number-crunching. Using Category 6 cable is a significant limiting factor, and the proposed specifications will probably limit that solution to a maximum of 55 ft.

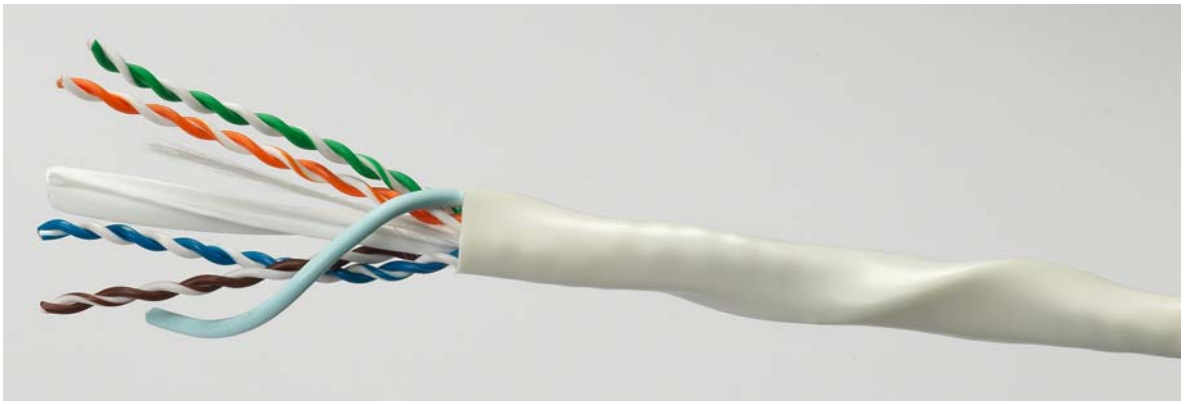

Figure 3: Belden 10GX32 "10gig" UTP

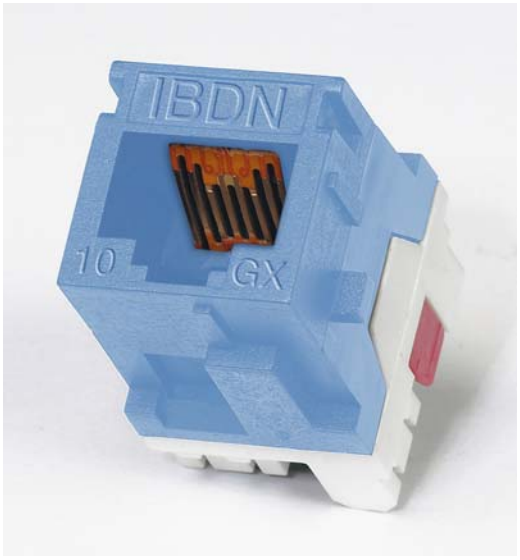

Figure 4: Belden "10gig" RJ-45 Jack

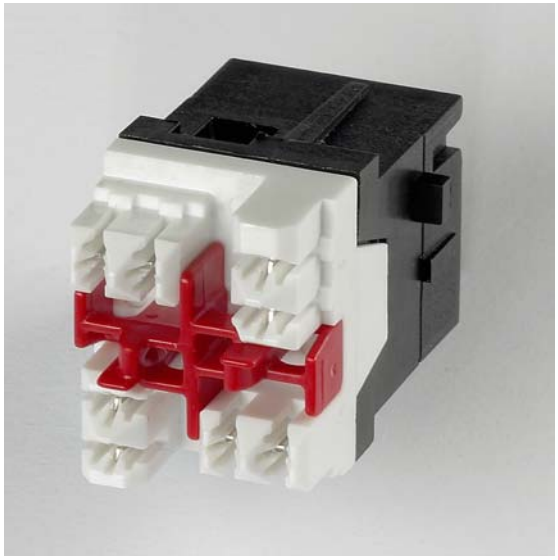

Figure 5: Belden "10gig" RJ-45 Jack

Postscript

This is the seventh revision of the original paper. No doubt, there will be more revisions as technology progresses, manufacturers change or refine their product lines and more information and testing data becomes available. If any reader of this paper has information to add, or questions any part of this document, you are urged to contact the author, Steve Lampen, at shlampen@aol.com

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Note 1: While shielded cable is rare in standard networked architecture, it still has some adherents in places such as wi-fi applications or industrial control. Check out Belden 1300A (New Product Bulletin 230) and Belden 7933A and 7921A (New Product Bulletin 231) elsewhere on this web page.

Note: In fact Belden makes specific twisted-pair cables for wi-fi installations. These are shielded Category 5e cables, such as Belden 1300A (New Product Bulletin 230).