Belden

TECHNICAL BULLETIN

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Digital Studio Cable Guide

We are in the midst of a digital revolution. Radio and television broadcasters are going digital. Digital formats have worked their way into recording studios, video post-production, film production and many associated applications, and the reason is clear — digital provides superior audio and video performance.

Binary coding is a vast simplification of complex audio and video signals. But because the signal is binary, receiving equipment can decipher the bit stream, ignore any noise and correct for any attenuation. Audio and Video signals are so sophisticated and complex however — reducing them to binary code requires much higher frequencies than if they were left in analog sine waves. Digital A/V cables need to handle ever-higher digital frequencies. Also because this is A/V, it must be processed in real-time, in sequence, and live. We only give alphanumeric "data" the luxury of re-transmits, processing delay, and blank screen tolerance. A/V signals must remain on-air, without any pause to "compile." These are the challenges broadcast quality A/V cables have to meet.

Digital is very stable, which reduces equipment adjustments significantly. Copies or reproductions retain the quality of the original. Signal degradation is virtually eliminated, and noise immunity is greatly improved. Whether it's a radio, TV or post-production application, all of these advantages result in improved picture and sound quality as well as interactivity, high-speed data and Internet access, pay-per-view services, simultaneous data/Internet access and personalized electronic news.

Although digital promises to revolutionize the A/V industry as we know it, it also poses a challenge when it comes to designing, choosing, and installing a new system. It has been estimated that there may be as many as 18 different DTV formats to choose from, with new ones being proposed all the time, all of which vary in the level of compression and transmission frequency. Various options also face the radio industry.

With all of these equipment options available, it becomes very important in the design phase to determine the correct cable to connect each of these pieces of equipment. The wrong choice in cable can be as costly as the wrong choice in equipment.

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Digital Audio

The specification for digital audio was developed jointly by the Audio Engineering Society and European Broadcast Union (AES/EBU). The two key electrical parameters in this specification that pertain to cable are the data rate, which depends on the sampling rate *(see table below)* and impedance of 110 ohms ±20% for twisted pair constructions and 75 ohms for coax designs.

Sampling Rate	Bandwidth
32.0 kHz	4.096 MHz
38.0 kHz	4.864 MHz
44.1 kHz	5.645 MHz
48.0 kHz	6.144 MHz
88.2 kHz	11.289 MHz
96.0 kHz	12.228 MHz
192.0 kHz	24.576 MHz

Twisted Pair Parameters

The AES/EBU specification, with its broad impedance tolerance, allows for cables with impedances from 88 ohms to 132 ohms to be used, with 110 ohms being ideal. The twisted pair should be shielded, and in the case of multi-pair, each pair individually shielded. Foil shielding is recommended for permanent installs, and foil plus braid for flexed applications. One pair is capable of carrying two channels of digital audio.

The cables are terminated with either XLR connectors or are punched down or soldered in patch panels. Most digital audio cables utilize foam polyethylene to minimize the cable's size. Standard foam polyethylenes are susceptible to crushing which can change impedance. Belden cables utilize a **special foam high-density polyethylene** that provides exceptional crush resistance when compared to standard foam insulations.

The advent of digital microphones requires AES/EBU cable designs with added flexibility, such as Belden 1800F, a 110 ohm design featuring our ultra-flexible "French Braid" construction.

Although AES/EBU specifications require shielding on each channel of data, data-grade UTP "Category 5" can easily meet the common mode balance requirements (-30 dB) without being shielded.

Can analog cables be used for digital? Yes, but only for distances of roughly 50 ft. or so. The actual length is determined by the error correction and jitter tolerance of the receiving device. The impedance of most analog cables ranges from 40 ohms to 70 ohms. This large mismatch from the nominal 110 ohms results in signal reflection and jitter causing bit errors at the receiver. Also, the high capacitance of analog cables greatly increases the rise time of the digital square wave.

Can digital cables (paired) be used for analog? Absolutely! The capacitance of digital cables is extremely low, making them a superior analog cable.

Digital Audio Over Coax

The transmission of digital audio over 75 ohm coax requires the use of baluns unless the device contains unbalanced coax AES inputs or outputs or the audio signal is embedded on a digital video signal. The baluns convert the unbalanced coax signal to a 110 ohm balanced transmission.

Much greater transmission distances are obtainable over coax as compared to twisted pair. The same coax used for digital video is ideal for digital audio. The coax used should have a pure copper center conductor (no copper covered steel or aluminum) and have good braid coverage (90% or more). Using one coax for both audio and video gives the added advantage of using one type of strip and crimp tool and one type of connector.

Embedding the audio is popular in TV applications. Embedded signals are often used in "pass through" installations such as cable head-ends. However, if audio manipulation is desired such as spot insertion or replacement, then audio must be "de-embedded" or de-multiplexed from the video stream. This is a complex and expensive procedure. For maximum versatility, separate audio and video runs are suggested.

Digital and HD Radio

When radio broadcast converts to digital – the cable selection will be equally critical and arguably more so. The basic specification parameters for digital audio cable are entirely different than for analog audio. The key attribute for the cable is no longer lower capacitance as in analog audio. The Digital Audio signal is impedance specific and it is the impedance of the cable that is now critical. Fortunately, by nature of their design, Digital Audio cables have built-in low capacitance which makes them excellent analog cables. (The converse is not true: almost no excellent (or even good) analog audio cables are suitable for digital, because they were not designed with digital audio's impedance in mind.) The point: whether you're converting to

digital now or later, whether you're converting wholly or partially, whether you'll be broadcasting 100% digitally or simulcasting analog and digital – Digital Audio cabling is essential to efficient design and value engineering. Even if your immediate needs are strictly analog, installing AES/EBU digital audio cable, like 1800B, now will give you the best performing analog audio service, and will spare you cable replacement when the day arrives that you upgrade to digital. This is the key to "futureproofing."

Where AES/EBU format is used, 110 ohm shielded balanced line cables are the standard. IP technology may be employed to integrate station data networking resources and requirements with programming and advertising content. Where IP technology is deployed, high quality UTP (Category 5e, Category 6 UTP, or MediaTwist®) can be used. Television stations may choose to use AES3 format, employ baluns, and multiplex digital audio over 75 ohm coax infrastructure. Where the environment may be electrically noisy, the shielded AES/EBU cables, or AES 3, and coax will be preferred.

Radio Broadcasts will benefit tremendously from Digital Conversion and will be driven by the benefits it offers – even without government mandate: AM clarity equal to current FM; FM clarity rivaling current CD's; new embedded text offering news, weather, traffic, and financial market information, interactivity, customization, and audio-on-demand. Digital Conversion in radio broadcasting may happen quickly because of low entry barriers: A low cost to convert, it's use of the existing spectrum, and the preservation of existing analog service permitting consumers to upgrade on their own timetable. However this revolution unfolds, and however your station deploys: Belden has the cable for AES/EBU, IP or AES 3 digital and HD Radio upgrades.

Digital Video (SDI)

The Society of Motion Picture and Television Engineers (SMPTE) has developed two different standards for serial digital transmissions (SDI). A third format that transmits at 540 Mb/s is under development. There is also a European standards body known as ITU (formerly CCIR) that developed the specifications for Europe known as PAL. Each of these specifications differs in frequency and transmission technology, i.e., composite or component.

> SMPTE 259M – Covers digital video transmissions of composite NTSC 143 Mb/s (Level A) and PAL 177 Mb/s (Level B). It also covers 525/625 component transmissions of 270 Mb/s (Level C) and 360 Mb/s (Level D).

> SMPTE 292M – Covers the newest format for HDTV transmissions at 1.458 Gb/s.

> SMPTE 344M – Covers component widescreen transmissions of 540 Mb/s.

> ITU-R BT.601 – International standard covers component PAL transmissions of 177 Mb/s.

Coax Parameters

All of the above standards were designed to work with standard analog video coax cables. It is true, analog coax cables of precision grade will work okay at the higher digital frequencies. However, newer coax constructions that have been designed specifically for digital transmissions offer performance advantages over the old analog designs. These new constructions employ several design parameters to provide the precision electrical characteristics required for high frequency transmissions over longer distances.

> **Center Conductor** – The center conductors are solid bare copper. Solid conductors provide better impedance stability and return loss (RL). RL expresses the amount of signal lost due to the signal reflecting back to the source. This reduces the signal reaching the receiver, thus increasing attenuation and decreasing effective transmission distance.

Digital transmissions contain low frequency elements that travel down the center of the conductor and high frequency elements that travel on the outside of the conductor due to skin effect. For these reasons, uncoated pure copper conductors are used for optimum performance.

> **Dielectric** – The dielectric material (insulation) consists of solid or foam high-density polyethylene. The special formulation Belden uses is more crush-resistant than standard foam polyethylenes and is less prone to conductor migration. Both crushing and conductor migration can cause a change in the cables impedance which, in turn, will cause an increase in RL. While the nominal velocity of propagation of a solid dielectric is 66%, gas injection technology provides extremely consistent foaming and high velocities of propagation (82 to 84%). The velocity is kept very constant to minimize timing problems. Foam dielectrics reduce the size of the coax compared to older solid dielectric designs.

> **Shield** – Precision analog cables utilize double braid shields which are effective but not optimum for digital's high frequencies. Braid shields are ideal for frequencies under 10 MHz while foil shields work best above that frequency. Since digital transmissions contain both low and high frequencies, foil-braid designs are used.

> **Testing** – Lastly, to ensure that the cables are electrically sound, every reel must be 100% sweep tested for RL to at least the third harmonic of the fundamental frequency and exhibit no less than SMPTE's minimum suggested level of 15 dB. For HD cables at an uncompressed data rate of 1.485 Gb/s, this gives a bandwidth of 750 MHz and a third harmonic frequency of 2.25 GHz (3 x 750). Belden sweep tests all of its HD cables to 3 GHz, with guaranteed minimum RL steps of 23 dB to 850 MHz and 21 dB from 851 MHz to 3 GHz. More technical information on RL and other cable parameters can be found on Belden's Web site at www.belden.com.

Installable Performance®

When looking at guaranteed performance on a cable's data sheet, one naturally expects that the cable will deliver that same performance after it has been installed. This assumption doesn't always hold true, however, because the installation itself can dramatically alter the cable performance.

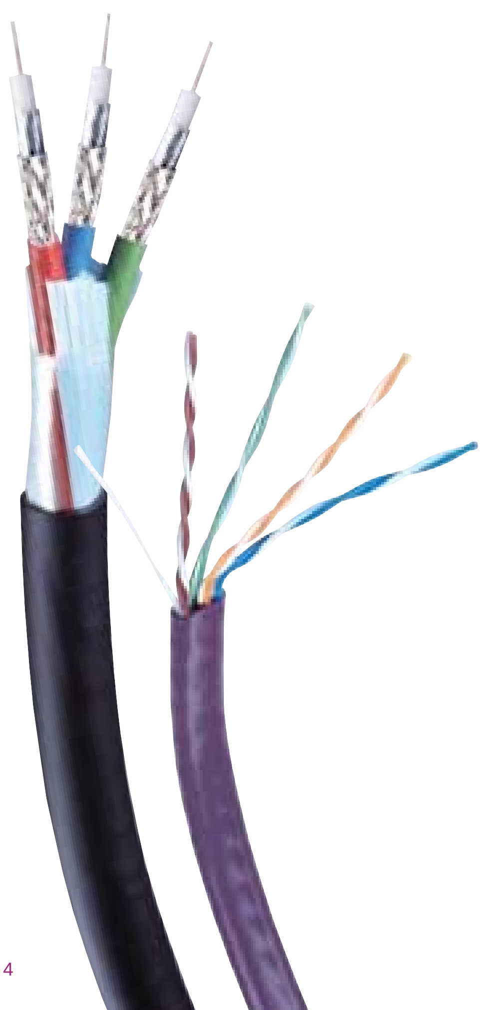
Typically, when cables are installed they are pulled and yanked on, bent around corners, stepped on, and may kink when coming off the reel. All of these factors can change the physical properties of the cable, which in turn may degrade the cable's electrical performance.

To help ensure that the cable's electrical performance is not compromised through improper installation techniques, three key cable attributes must be held to a high level: conductor adhesion, crush resistance and Return Loss.

Conductor Adhesion

Conductor adhesion is most important to connectorization and connector reliability. Improper levels of conductor adhesion can make the connectorization process harder and can cause connector failures both during and after installation. If adhesion levels are too low, the conductor can

With digital audio cables, much greater transmission distances are obtainable over coax versus twisted pair. The coax used should have a pure copper center conductor and good braid coverage.



move within the dielectric and actually migrate and appear to grow or lengthen in the cable. A cable with low conductor adhesion may appear to be fine prior to installation. However, the rigors of installation can break the conductor adhesion due to all of the pulling and bending that occurs. Once the bond between the conductor and insulation is broken, the conductor migration can, in some cases, result in the center pin of the BNC connector being pushed out of the casing. To prevent this from occurring, Belden uses a skin/foam insulation process that ensures a high degree of conductor adhesion. In addition, all Belden cables are tested for conductor adhesion to further ensure performance.

Crush Resistance

As stated earlier, most of the cables used for SDI are foam dielectrics. Foam dielectrics are, by nature, softer than their solid counter parts. If the cable is improperly handled or installed, the dielectric can be crushed and deformed thereby changing the impedance and causing RL. The special proprietary formulation Belden uses is more crush-resistant than standard foam polyethylene making it far less prone to deformation.

Return Loss Headroom

In order to ensure the SMPTE minimum level of 15 dB RL is met, the cables used must be several dB better to ensure the minimum level is met after the rigors of installation. Other components in the transmission chain can also degrade RL such as a bad termination or improper patch bay connections. Belden's guaranteed minimum level of 21 dB RL gives the user 6 dB of RL headroom to account for such potential inconsistencies.

Careful attention to all of the above attributes ensures that the cable the customer receives from Belden will meet performance specifications after installation. After all, that is what Installable Performance is all about.

Can analog coax cables be used for digital? Yes, only if it is of precision video grade. Standard video cables may have stranded center conductors or copper covered steel. They also may not have adequate shielding as mentioned above. Standard video cables are usually not tested for RL. Beware of plain old coax!

Can digital coax cables be used for analog? Yes, but only if your plant has cable equalization (EQ) designed to work within the loss characteristics of the particular coax. If the transmission distance is short, equalization may not be a problem. Many equipment manufacturers are now making equalization cards designed specifically for the new digital cables when running analog.

Can I mix foam and solid polyethylene designs together in the same run?
If you run analog in short un-equalized runs, you can mix cables together. However, you will have two connectors, with different dimensions, two different stripping tools, and two different crimping tools. For longer EQ'd runs you will need two different EQ cards as well. Belden suggests you standardize on one cable for as long as you can. Foam core cables have a delay of 1.24 ns/ft compared to 1.54 ns/ft. for solid polyethylene. The loss characteristics of the cables will also be different. Both parameters must be taken into consideration if mixing cable types. As a rule of thumb, it's best to stay with one design throughout.

Video Connectors

Most connectors used for analog video are 50 ohm BNCs. In analog video, where the quarter wavelength of the signal is approximately 60 feet, the impedance mismatch of a 1/2 inch BNC connector, or even a dozen in a row, is minimal. However, the quarter wavelength of a digital signal can be as short as three inches at HD frequencies. While one or two 50 ohm connectors would probably not have an effect, a dozen of them (6 inches) is significant and will result in a RL problem. Most video signals go through many connectors in a typical studio. For this reason, it is recommended to use not only 75 ohm connectors, but also connectors demonstrated to maintain their impedance up to at least the third harmonic (2.25 GHz).

Cable Installation

Care must be taken when installing digital, and especially high definition, coax. Improper handling, cable pulling and installation techniques can deform the cables which can in turn cause a RL problem. The following practices should be utilized when installing any digital cable.

Installation Basics

> Do not step on the cables.

> Do not lay equipment on the cables.

> Do not kink the cables.

> Cable pulls should be done in a slow steady fashion – no jerking. Do not exceed the cables maximum pulling tension (call the manufacturer for this information).

> Do not exceed the minimum bend radius of the cable: 10 times the diameter of the cable.

> Do not cinch cable ties too tightly. If you cannot move any cable inside a tied bundle, the cable tie is too tight.

> Do not put cable ties or J hooks at identical distances apart. This can lead to deformation at a given wavelength, which can cause RL. Place cable ties at random distances.

> Cables should be supported by cable trays, J-hooks, etc. to take the gravitational forces off of the cable. Cable sag should be less than 8 inches.

> Conduit runs in excess of 90′ and/or with more than two 90° equivalent turns should include a pull box. Each 90° turn is equivalent to the friction of a 30′ straight conduit run.

> If cable is pulled into conduit, an anti-friction lubricant should be used that is compatible with the cable jacketing material.

> **Maintain the original physical shape of the cable.**

Testing Digital Video

Currently there are no standards to test digital video or HDTV. However, Belden suggests measuring and documenting the RL on every link to ensure that the SMPTE minimum suggested level of 15 dB is met. RL is the measurement of reflected signal caused by impedance discontinuities in the channel. These discontinuities are caused by connectors, cable, transition devices, patch panels and improper cable installation or handling. Any reflected energy reduces the power of the transmitted signal. Measuring RL will give a good expectation of just how well each link will do with SDI or HD video.

Digital Camera Cables

In 1998 the Society of Motion Picture and Television Engineers (SMPTE) developed the industry standard SMPTE 311 for High-Definition Television Camera cables to assure clear, reliable transmission of audio, video and camera control cables.

Belden's new composite cable incorporates two tight-buffer, single-mode 10µm optical fibers for video, four 20 AWG or two 16 AWG conductors (depending on the design) are used for power and two 24 AWG conductors for control and sound. The fibers, color-coded blue and yellow, permit long-haul transmission of critical audio and video signals with extraordinary reliability and clarity. The new standard provides a cable smaller in diameter and lighter in weight than traditional camera cables resulting in easier handling during installation or in field applications.

Belden's SMPTE 311 cables are 7804R and 7804C. 7804R is made with tight buffer fiber designs and (4) 20 AWG auxiliary (power) conductors per traditional design parameters. 7804C has been designed with breakout fibers to enhance ruggedness and with (2) 16 AWG auxiliary (power) conductors to simplify termination and reduce installation time. In addition, a central stainless steel strength member is used for additional durability during installation. The overall jacket is black Belflex® providing exceptional flexibility.

The Future

Unshielded Twisted Pairs (UTP)

The digitization of audio and video signals has given rise to a convergence with data wiring technology, which utilizes unshielded twisted pairs.

It is a misconception to equate digital A/V signals to digital data signals though, simply because "they are both digital." Ethernet is digital coding of very discreet alphanumeric data: 26 letters and 10 numbers. And Ethernet protocols allow for the use of packets which may be scrambled, transmitted, certain packets re-transmitted, unscrambled and recompiled before the information is presented. All that processing and reprocessing introduces delay which we tolerate for this media. A/V signals are comprised of millions of colors, hues and tones, with different volumes, inflections, tempo and motion. And we require its playback to occur live and in real time. Just as a picture is worth a thousand words and can be taken in the blink of an eye — A/V signals are much more than "data" — even when they are digital.

While almost any UTP cable can handle low-bandwidth or low data-rate applications (such as a telephone), few cables can handle signals like 270 Mb/s digital video for appreciable distances. Like coax, it's a question of what bandwidth (frequency) or data rate and how far. Distance is the key.

The consistency of a UTP cable determines the transmission distance. Physical characteristics of concentricity, conductor-to-conductor and pair-to-pair spacing relationships, and how well they are maintained along the length of the cable determine how far a signal at a given frequency can be carried without excessive attenuation. The quality of the cable determines the quality of the signal at a distance.

NanoSkew®

NanoSkew (7987R) is a 4-pair, 100 ohm 24 AWG UTP cable with no EIA/TIA data category rating. It is designed for the lowest possible skew delay difference between pairs, which is the critical factor for component video applications. NanoSkew is designed specifically for video, and is *strictly* for video applications. It should not be used where Ethernet data will be transmitted. See Belden new product bulletin *NP212* for complete details about NanoSkew Cables.

Brilliance VideoTwist®

Brilliance VideoTwist cables are Category 5e and Category 6 cables incorporating low-skew characteristics for video performance. Ethernet cables not designed with video in mind do not pay as close attention to minimizing skew and to delivering consistent skew performance. The insulated conductors of each pair are bonded together so they maintain their spacing and orientation throughout the run, around bends, and enduring the rigors of installation. This gives them the consistent physical characteristics so important for stable impedance. Their blend of Video performance (low skew between pairs) and Data rating make Brilliance VideoTwist the ideal choice for shared sheath applications, for video over IP, for KVM applications, and where one cable is preferred for both data circuits and for video circuits. Belden bulletin *NP212* gives the full details of Brilliance VideoTwist.

Fiber Optic Cables

At some point, either in bandwidth or distance, copper cables may not be able to perform the task at hand. In these cases, fiber optic cables are an option. Fiber comes as either single-mode or multimode core constructions. Multimode has a 50 micron or 62.5 micron fiber core. 62.5 micron fiber has a modal bandwidth of 160 MHz at 850 nm and 500 MHz at 1300 nm. Single-mode has an 8.3 micron core with a theoretical exit bandwidth into the gigahertz, essentially unlimited. Technologies are now extending even these bandwidths. Multimode and single-mode connectors are easy to install and can be field installed in minutes. Belden offers a comprehensive line of fiber optic cables.