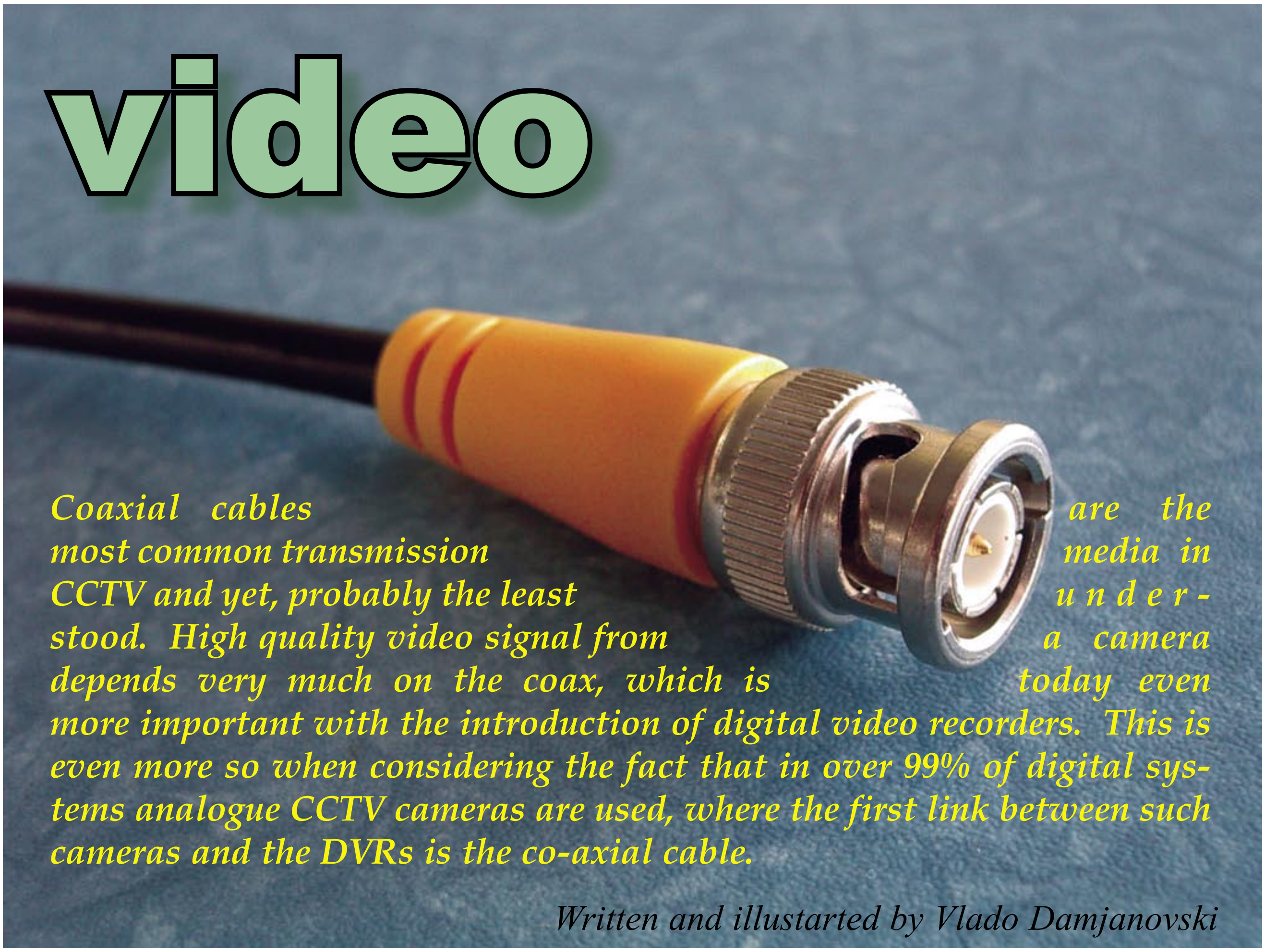
Coaxial video



Coaxial cables are the most common transmission media in CCTV and yet, probably the least under-stood. High quality video signal from a camera depends very much on the coax, which is today even more important with the introduction of digital video recorders. This is even more so when considering the fact that in over 99% of digital systems analogue CCTV cameras are used, where the first link between such cameras and the DVRs is the co-axial cable.

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The concept

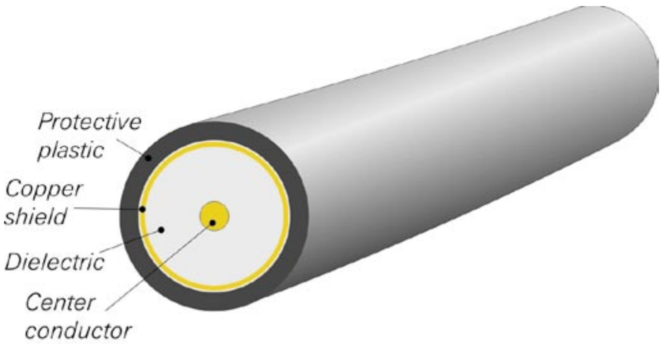
The coaxial cable is the most common medium for transmission of video signals and sometimes video and PTZ data together.

It is also known as **unbalanced** transmission, which comes from the concept of the coaxial cable (sometimes called "coax" for short).

A video signal travels through the center core of the coax, while the shield is used to common the ground potential of the end devices – the camera and the monitor, for example. And it not only commons the ground potential, but also serves to protect the center core from external and unwanted electromagnetic interference (EMI).

The idea behind the coaxial concept is to have all the unwanted EMI induced in the shield only. When this is properly grounded, it will discharge the induced noise through the grounds at the camera and monitor ends. Electrically, the coaxial cable closes the circuit between the source and the receiver, where the coax core is the signal wire, while the shield is the grounding one. This is why it is called an unbalanced transmission.

Electromagnetic intereferences



Cross section of a coaxial cable

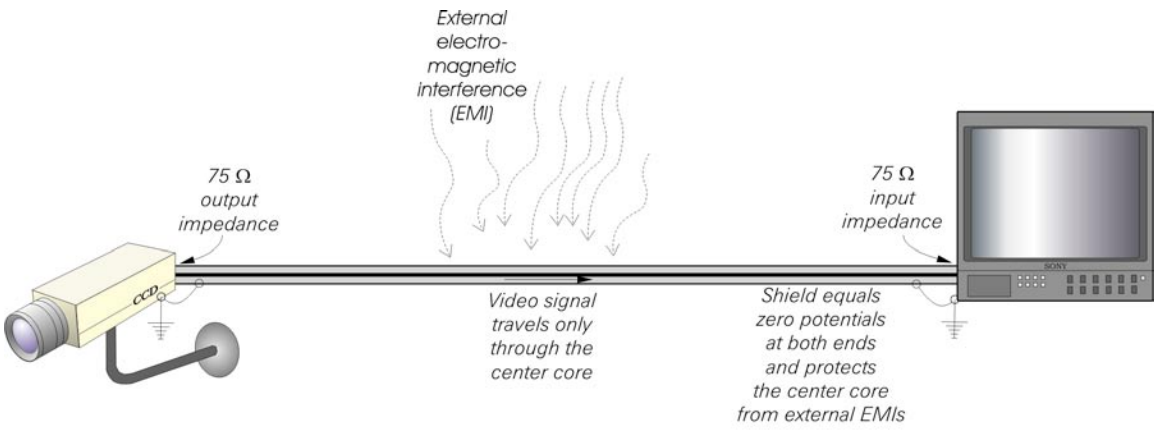
How well the coax shield protects the center core from noise and EMI depends on the percentage of the screening. Typically, numbers between 90 and 99% can be found in the cable manufacturer's specifications. Have in mind, though, even if the screening is 100%, it is not possible to have 100% protection from external interference. The penetration of EMI inside the coax depends on the frequency.

Theoretically, only frequencies above 50kHz are successfully suppressed and this is mostly due to the skin-effect attenuation. All frequencies below this will induce current in smaller or bigger form. How strong this current is depends on the strength of the magnetic field. Our major concern would be, obviously, the mains frequency (50 or 60Hz) radiation, which is present around almost all artificial objects.

This is why we may have problems running a coaxial cable parallel to the mains. The amount of induced electromagnetic voltage in the center core depends firstly on the amount of current flowing through the mains cable, which obviously depends on the current consumption on that line. Secondly, it depends on how far the coax is from the mains cable. And lastly, it depends on how long the cables run together. Sometimes 100m might have no influence, but if strong current is flowing through the mains cable, even a 50-m run could have a major influence. When installing, try (whenever possible) not to have the power cables and the coaxial cables very close to each other, at least 30 cm would be sufficient to notably reduce the EMI.

The visual appearance of the induced (unwanted) mains frequency is a few thick horizontal bars slowly scrolling either up or down. The scrolling frequency is determined by the difference between the video field frequency and the mains frequency and can be anything from 0 to 1Hz. This results in stationary or very slow moving bars on the screen.

Other frequencies will be seen as various noise patterns, depending on the source. A rule of thumb is that the higher the frequency of the induced unwanted signal is, the finer the pattern on the monitor will be. Intermittent inducting, like lightning or cars passing by, will be shown as an irregular noise pattern.



Video transmission over coaxial cable

Characteristic impedance

Short wires and cables used in an average electronic piece of equipment have negligible resistance, inductance and capacitance and they do not affect the signal distribution. If a signal, however, needs to be transmitted for a longer distance, a lot of factors add up and contribute to the complex picture of such transmission media. This especially influences high frequency signals. Then, the resistance, inductance and capacitance play a considerable role and visibly affect the transmission.

A simple medium like the coaxial cable, when analyzed by the electromagnetic theory, is approximated with a network of resistors (R), inductors (L), capacitors (C) and conductors (G) per unit length. For short cable runs this network has a negligible influence on the signal, but for longer runs it becomes noticeable. In such a case the network of R, L and C elements becomes so significant, that it acts as a crude low pass filter that, in turn, affects the amplitude and phase of the various components in the video signal. The higher the frequencies of the signal are, the more they are affected by these non-ideal cable properties.

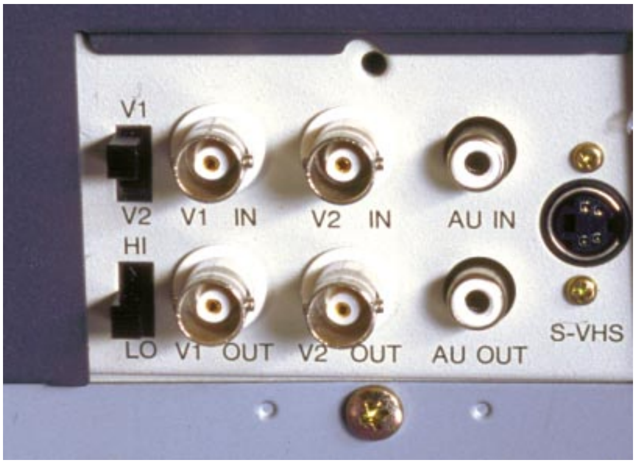
Each cable is **uniformly** built and has its own characteristic impedance, which is defined by the R, L , C and G per unit length.

The main advantage of the unbalanced video transmission is based on the fact that **the characteristic impedance of the medium is independent of the frequency** (refers mainly to the mid and high frequencies), while the phase shift is proportional to the frequency.

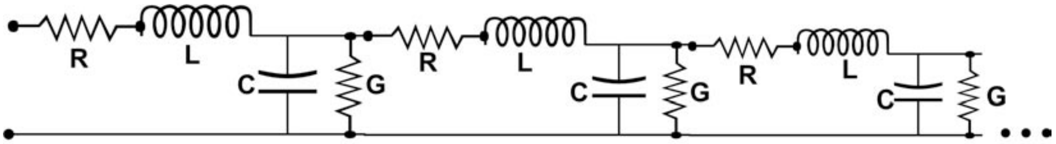
The amplitude and phase characteristics of the coax at low frequencies is very dependent on the frequency itself, but since the cable length in such cases is reasonably short compared to the signal wavelength, it results in negligible influence on the signal transmission.

When the characteristic impedance of the coaxial cable is matched to the video source output impedance and the receiving unit input impedance, it **allows for a maximum energy transfer between the source and the receiver.**

For high-frequency signals, as is the video, impedance matching is of paramount importance. **When the impedance is not matched, the whole or part of the video signal is reflected back to the source, affecting not only the output stage itself, but also the picture quality**. A 100% reflection of the signal occurs when the end of the cable is either short circuited or left open. The total (100%)



energy of the signal (voltage x current) is transferred only when there is a match between the source, transmission media and the receiver. This is why we insist that **the last element in the video signal chain should always be terminated with 75Ω** (the symbol stands for Ohms).



Theoretical representation of a coaxial cable

In CCTV, 75Ω is taken as a characteristic impedance for all the equipment producing or receiving video signals. This is why the coaxial cable is meant to be used with 75Ω impedance. This does not exclude manufacturers producing, say, 50Ω equipment (which used to be the case with some broadcast or RF equipment), but then impedance converters (passive or active) need to be used between such sources and 75Ω recipients.

Impedance matching is also done with the twisted pair transmitters and receivers, which will be discussed later in the media section.

The 75Ω of the coax **is a complex impedance, defined by the voltage/current ratio at each point of the cable. It is not a pure resistance and therefore it cannot be measured with an ordinary multimeter.**

There is a very interesting theory of calculation of the impedance and the approximation we have in practice which is beyond the scope of our magazine, but for the theory thirsty readers I would suggest them to check my book "CCTV".

The most commonly used coaxial cable in CCTV is the RG-59/U, which can successfully and without in-line correctors, transfer B/W signals up to 300m and colour up to 200m.

The other popular cable is the RG-11/U, which is thicker and more expensive. Its maximum recommended lengths are up to 600m for a B/W signal and 400m for a color signal. There are also thinner coaxial cables with 75Ω impedance, with only 2.5-mm diameter or even coax ribbon cables. They are very practical for crowded areas with many video signals, such as matrix switchers with many inputs. Their maximum cable run is much shorter than the thicker representatives, but sufficient for links and patches. Note that these numbers may vary with different manufacturers and signal quality expectations.

The difference between the B/W and color signal maximum run is due to the color subcarrier of 4.43 MHz for PAL or 3.58 for NTSC. Since a long coaxial cable acts as a lowpass filter, the color information will obviously be affected sooner than the lower frequencies, so the loss of color information will happen before the loss of details in the lower frequencies.

If longer runs are required, additional devices can be used to equalize and amplify the video spectrum. Such devices are known as **in-line amplifiers**, **cable equalizers, or cable correctors**. Depending on the amplifier (and cable) quality, double or even triple lengths are possible.

In-line amplifiers are best if they are used in the middle of the cable run because of the more acceptable S/N ratio, but this is quite often impossible or impractical due to the need for power supply and storage. So, the majority of in-line amplifiers available in CCTV are designed to be used at the camera end, in which case we actually have **pre-equalization** and **pre-amplification** of the

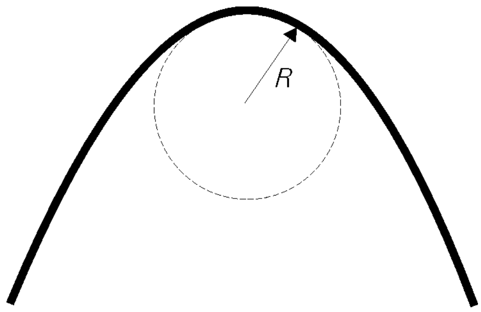
Coaxial cable	Impedance (Ω)	Overall diameter (mm)	Typical attenuation @10MHz (dB/100m)
RG-179B/U	75	2.5	17.4
RG-59B/U	75	6.15	3.3
RG-6B/U	75	6	2.2
RG-11B/U	75	10	1.3

video signal. There are, however, devices that are used at the monitor end and they have 1Vpp output with **post-equalization** of the video bandwidth.

Starting from the above theoretical explanation of the impedance, it can be seen that the cable uniformity along its length is of great importance for fulfilling the characteristic impedance requirements. **The cable quality depends on the precision and uniformity of the center core, the dielectric and the shield. These factors define the C and L values of the cable, per unit length. This is why careful attention should be paid to the running of the cable itself and its termination.** Sharp loops and bends affect the cable uniformity and consequently the cable impedance. This results in high-frequency losses, i.e., fine picture detail loss, as well as double images due to signal reflections. So, if a short and good quality cable is improperly run, with sharp bends and kicks, the picture quality will still be far from perfect.

Bends no smaller than 10 times the diameter of the coax are suggested for best performance. This is equivalent of saying "bending radius should not be smaller than 5 times the diameter, or 10 times the radius of the cable." This means an RG-59/U cable should not be bent in a loop with a diameter smaller than 6cm (2.5″) and an RG-11/U should not be bent in a loop smaller than 10cm (4″) in diameter.

Copper is one of the best conductors for a coaxial cable. Only gold and silver will show a better performance (resistance, corrosion), but these are too expensive to be used for cable manufacturing. A lot of people believe that copper-plated steel makes a better cable, but this is not correct. Copper-plated steel can only be cheaper and perhaps stiffer, but for longer lengths, in CCTV, copper would be the better choice. Copper-plated steel coaxial cables are acceptable for master antenna (MATV) installations, where the transmitted signals are RF modulated (VHF or UHF). Namely, with higher frequencies



Minimum bending radius

the so-called skin effect becomes more apparent where the actual signal escapes on the copper-plated surface of the conductor (not the shield, but the center conductor). CCTV signals are, as explained, in the basic bandwidth and this is why a copper-plated steel coaxial cable might be OK for RF signals but not necessarily for CCTV. So always look for a copper coaxial cable.

BNC connectors

A widely accepted coaxial cable termination, in CCTV, is the BNC termination. BNC stands for **Bayonet-Neil-Concelman** connector, named after its designers. There are three types: screwing, soldering and crimping.

Crimping BNCs are proven to be the most reliable of all. They require specialized and expensive stripping and crimping tools, but it pays to have them. Of the many installations done in the industry, **more than 50% of problems are proven to be a result of bad or incorrect termination**. An installer doesn't have to know or understand all the equipment used in a system (which will be commissioned by the designer or the supplier), but if he or she does proper cable runs and terminations, it is almost certain that the system will perform at its best.

There are various BNC products available on the market, of which the male plug is the most common. Female plugs are also available, as well as right angle adaptors, BNC-to-BNC adaptors (often called "barrels"), 75Ω terminators (or "dummy loads"), BNC-to-other-type of video connection and so on.

Breaking the cable in the middle of its length and terminating it will contribute to some losses of the signal, especially if the termination and/or BNCs are of a bad quality. A good termination can result in as small as 0.3 to 0.5 dB losses. If there are not too many of them in one cable run, this is an insignificant loss.

There are silver-plated and even gold-plated BNC connectors designed to minimize the contact resistance and protect the connector from oxidation, which is especially critical near the coast (salt water and air) or heavily industrialized areas.

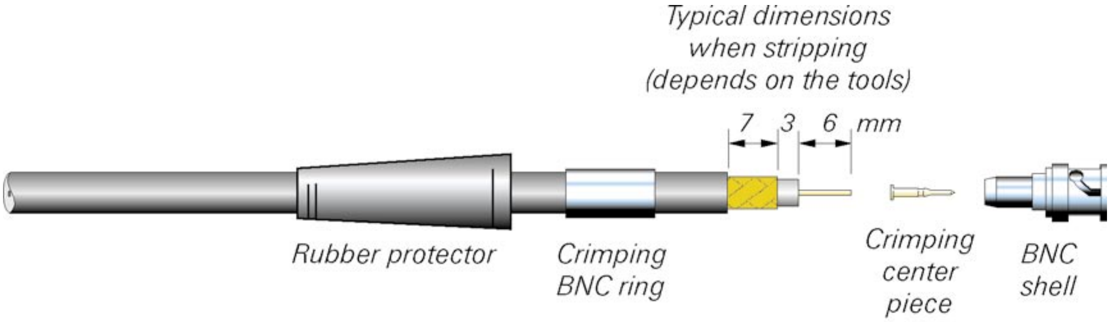
A good BNC connector kit should include a gold-plated or silver-plated center tip, a BNC shell body, a ring for crimping the shield and a rubber sleeve (sometimes called a "strain relief boot") to protect the connector's end from sharp bends and oxidation.

Coaxial cables and proper BNC termination

Never terminate a coaxial cable with electrical cutters or pliers. Stripping the coaxial cable to the required length using electrical cutters is very risky. First, small pieces of copper fall around the center core and one can never be sure that a short circuit won't happen. Also, the impedance changes even if they do not short circuit the core and the shield. Second, using normal pliers for fixing the BNC to the coaxial cable is never reliable. All in all, these are very risky tools to terminate crimping BNCs and they should only be used when no other tools are available (remember to always take utmost care when using them).

If you are an installer, or a CCTV technician that regularly terminates coaxial cables, get yourself a proper set of tools. These are: precise cutters, a stripping tool and a crimping tool.

Make sure you have the crimping and stripping tools for the right cable. If you are using RG-59/U (overall diameter 6.15mm) don't get it confused with RG-58/U (overall diameter 5mm) even though they look similar. For starters, they have a different



Suggestions for a correct BNC termination (dimensions depend on stripping tool)

impedance, i.e., RG-59/U is 75Ω , compared to RG-58/U which is 50Ω . Next, RG-59/U is slightly thicker, both in the center core and the shield. There are BNC connectors for the RG-58/U which look identical externally, but they are thinner on the inside.

The best thing to do is to waste one and try terminating it before proceeding with the installation. Sometimes a small difference in the cable's dimensions, even if it is RG-59/U, may cause a lot of problems fitting the connectors properly.

Technically, a solid center core coaxial cable is better, both from the impedance point of view (the cable is stiffer and preserves the "straightness") and from the termination point of view. Namely, when terminating the solid core cable it is easier to crimp the center tip, than compared to the stranded core cable which is too flexible. Some people may prefer a stranded center core coax, mainly because of its flexibility, in which case care should be taken when terminating as it is very easy to short circuit the center core and the shield because of its flexibility.

If there are no other tools available, it is best to get the soldering type BNC connectors and terminate the cable by soldering. Care should be taken with the soldering iron's temperature, as well as the quality of the soldering, since it can easily damage the insulation and affect the impedance. In this instance, a multi-stranded core coax would be better.

If you have a choice of crimping connectors, look for the ones that are likely to last longer in respect to physical use and corrosion, like silver-plated or gold-plated BNCs. A good practice would be to use "rubber sleeves" (sometimes called "protective sleeves") for further protection of the interior of the BNC from corrosion and to minimize bending stress from plugging and unplugging.

In special cases, like with pan/tilt domes, there might be a need for a very thin and flexible 75Ω coaxial cable (due to constant panning and tilting of the camera). Such cables are available from specialized cable manufacturers, but don't forget that you need special BNCs and tools for them.

Even if such a cable could be as thin as 2.5mm, as is the case with the RG-179 B/U cable, the impedance would still be 75Ω, which is achieved by the special dielectric and center core thickness. The attenuation of such a cable is high but when used in short runs it is negligible.

For installations where much longer runs are needed, other 75Ω cables are used, such as RG-11B/U with an overall diameter of more than 9mm. Needless to say, an RG-11 cable also needs special tools and BNCs for termination. Some installers use machines purposely built to strip or label coaxial cables. Although these machines are expensive and hard to find they do exist and if you are involved in very large installations they are worthwhile investment.

Samples of bad BNC terminations

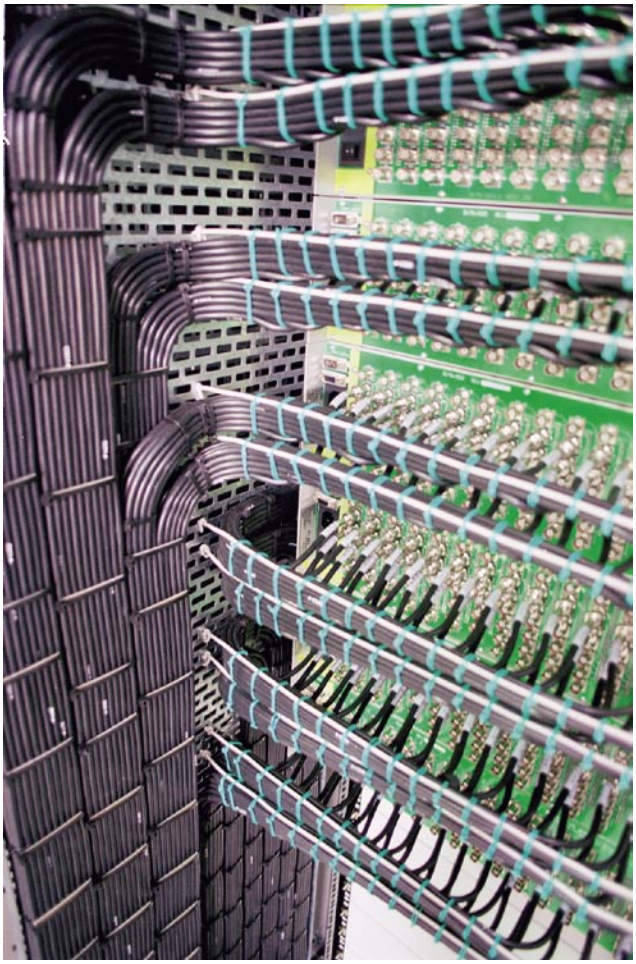
Installation techniques

Prior to installation, it should be checked what cable length can be obtained from the supplier. Rolls of approximately 300m (1000 feet) are common, but 100m and 500m can also be found. Naturally, it is better to run the cable in one piece whenever possible. If for some reason the installers need a longer run than what they have, the cable can be extended by terminating both, the installed and the extension cable. In such a case, although it is common practice to have a BNC plug connected to another BNC plug with a so-called "barrel" adaptor, it is better to minimize joining points by using one BNC plug and one socket (i.e., "male" and "female" crimping BNCs).

Before cable laying commences, the route should be inspected for possible problems such as feed-through, sharp corners, clogged ducts and the like. Once a viable route has been established, the cable lengths should be arranged so that any joints, or possible in-line amplifier installation, will occur at accessible positions.

Whenever possible, the cable should be run inside a conduit of an adequate size. Conduits are available in various length and diameters, depending on the number of cables and their diameters. For external cable runs, a special conduit with better UV protection is needed. In special environments, like railway stations, special metal conduits need to be used. These are required because the extremely high electromagnetic radiation that occurs when electric trains pass.

Placing a coaxial cable on cable trays and bending it around corners requires observing the same major rule: **minimum bending radius.** As mentioned, the minimum bending radius depends on the coaxial cable size, but the general rule is **the bending radius should not be smaller than 5 times the diameter of the cable (or 10 times the radius)**. The minimum bending radius must be observed even when the cable tray does not facilitate this. The tendency to keep it



neat and bend the coaxial cable to match power and data cables on the tray must be avoided. Remember, **bending coax more than the minimum bending radius affects the impedance of the cable and causes a video signal quality loss.**

The pulling of coaxial cables through ducts is performed by using a steel or plastic leader and then joining and securing all the cables that need to go through. Some new, tough plastic materials, called "snakes," are becoming more popular.

The types of cable ties normally used to tie the cables together are generally satisfactory, but remember, excessive force should not be applied, as it squashes the coax and therefore changes the impedance again.

Between the secured points of a cable it is wise to allow a little slack rather than leaving a tightly stretched length that may respond poorly to temperature variations or vibration. ☺