ROCKPILE SECURITY

WHITE PAPER

CCTV Cables & Connectors

from the Rockpile Security Buyer's Guide

I Introduction

Cables and wiring for CCTV / Digital Video Recorder (DVR) security camera systems as well as connectors for these systems come in many different types and styles. Each type of cable and connector has a specific purpose. The sheer number of options can be a little intimidating, however. This white paper attempts to present the most common video, power and data connector types along with a short description and the primary uses of each.

II Types of Cable & Connectors

There are typically four applications of cable/wire found in a CCTV security camera system:

- Power
- Video
- Telemetry
- Ethernet

First we'll review some general cabling design and selection information and then we'll look at each one of these cabling applications in some detail.

A. General Cabling Design and Selection

1. Impedance

The most important consideration when designing a CCTV cable run is impedance. Roughly speaking, impedance is a measure of how much of the electrical signal can pass through a cable at any given time. Impedance of a cable is affected by the type and size of conductors used in a cable, the spacing and orientation of the component cables, and the insulation surrounding the conductors.

When designing a CCTV video surveillance system, it is extremely important to match the impedance of the source, cabling and load. Mismatched impedance levels in any of these components will result in part of the video signal being reflected back along the cable. This phenomenon is what contributes to ghosted images as the same signal will arrive at the decoder at several different times. If you recall seeing ghosting with old broadcast ("rabbit ears") type television sets, you will be familiar with this phenomenon which occurs when the broadcast signal is reflected off of buildings, mountains, etc. and multiple copies of the signal arrive at the antenna at slightly different times.

Almost all CCTV systems, DVRs and security cameras have source and load impedance levels of 75 ohms. Cabling and connectors should also be selected with corresponding impedance levels. In the case of UTP (unshielded twisted pair) cable, which typically has impedance levels in the 100 to 150 ohm range, special equipment must be used to compensate. Fiber optic cable, of course, has no impedance level but the

equipment that translates the light signal to and from electrical signals must likewise be matched to the load and source.

2. Connections & Connectors

Connections and connectors are another critical part of the video quality puzzle. Every time a connection is made there will be a change in the impedance level at the connection. This will result in ghosting as discussed above. It is important, therefore, to minimize this effect by using only the proper connectors and minimizing the number of connections to the greatest extent possible.

3. Matching Cable & Equipment

Care must be taken to use the proper conversion equipment when attempting to mix different cable and connector types, especially when going from a "balanced" system to an "unbalanced" one. For example, you cannot simply attach a BNC connector to a UTP cable and expect good results. Special transmitters and receivers must be used to use UTP cables with equipment that requires coaxial input. With the correct equipment, excellent results can be achieved using UTP cables.

4. Cable Signal Loss

The ability of a particular cable to pass high frequency signals defines its overall performance. When a signal passes through a cable, high frequencies are lost faster than low frequency signals. In general, the higher quality a cable is, the longer the distance it can pass a particular frequency and all of those below it.

When considering CCTV video produced by most security cameras, we are concerned with a frequency range of 5 MHz and below. Since cables are generally designed to handle a particular range of frequencies well, care must be taken when selecting an appropriate cable. Copper-covered steel, for example, is designed to pass frequencies greater than 10 MHz and is not suitable for CCTV installations.

Transmission loss is specified by cable manufacturers as X dB per 100 Feet @ X Mhz. For video surveillance applications under 750 feet, therefore, we are typically looking for a cable with a minimum loss of 0.725 dB per 100 Feet @ 5 MHz. This requirement will become more stringent as the cable runs get longer. It should be noted that a 6 dB loss corresponds to a 50% loss in signal strength at the frequency specified so that for a 750 foot run, we will have a transmission loss of 7.5 * 0.725 dB or 5.4 dB (at 5 MHz) which is almost a 50% loss using an RG-59/U coax cable!

5. Signal Enhancement

<u>Repeaters</u>

For certain difficult installation situations, specialized equipment is available. For instance, if an installation must use existing poor quality cable or very long runs of cable, a repeater can be used to amplify the signal along the way. Each time a repeater is used, the signal suffers as the signal-to-noise ratio deteriorates so as a practical matter, no more than four repeaters can be used in this way. Repeaters can allow video signals to be transmitted over distances of up to 30 miles using good quality UTP or coaxial cable.

<u>Equalizers</u>

For a situation where video quality is poor and all other factors have been accounted for, an equalizer may improve the video quality. An equalizer allows the installer to tune each frequency band of the signal, possibly reducing frequency bands with high interference or increasing weak bands. Doing this correctly requires experience and specialized equipment but is rarely necessary.

B. Power Cables and Connectors

1. Camera Power

Almost all security cameras are either 24 Volt AC (VAC) or 12 Volt DC (VDC) systems. A small proportion use other power specifications.

Power Supply

Line voltage (either 220/240 VAC or 110/120 VAC) is converted to 24 VAC or 12 VDC in a security power panel made specifically for this purpose. For most standard cameras, in-panel transformers are used to step the line voltage down to 24 VAC 4 Amp circuits. Though all electricity can be dangerous under the right circumstances (wet skin, open wounds, etc.), 24VAC 4 Amp systems are typically safe. Note however, that some security cameras, notably Pan/Tilt/Zoom cameras, use 24VAC power supplies capable of delivering around 80 Amps of current. This is approximately equivalent to a 120 VAC 15 Amp circuit which is standard line voltage and can be quite dangerous.

NOTE: all electrical work should be performed by licensed technicians. Unless you are a licensed electrician, you should not attempt to wire your security power system yourself. Not only is it most likely illegal, it can be dangerous!

In a 24 VAC system, power is typically transmitted via 14-18 Gauge* stranded copper wire. The ends of the wire are either terminated with bullet style connectors, tinned**, or left bare depending on the style of the receptacle. On the power supply end, usually the wire is stripped and used bare (without a connector) or a spade connector is used to connect the wire to the screw type terminal block.

* Gauge is a measure of a wire's diameter. The lower the number, the greater the diameter of the wire.

** Tinning is the process of heating the stripped end of stranded copper wire until solder wicks into the wire. This results in a solid (non-stranded) wire termination that can be easily inserted into various styles of receptacles.

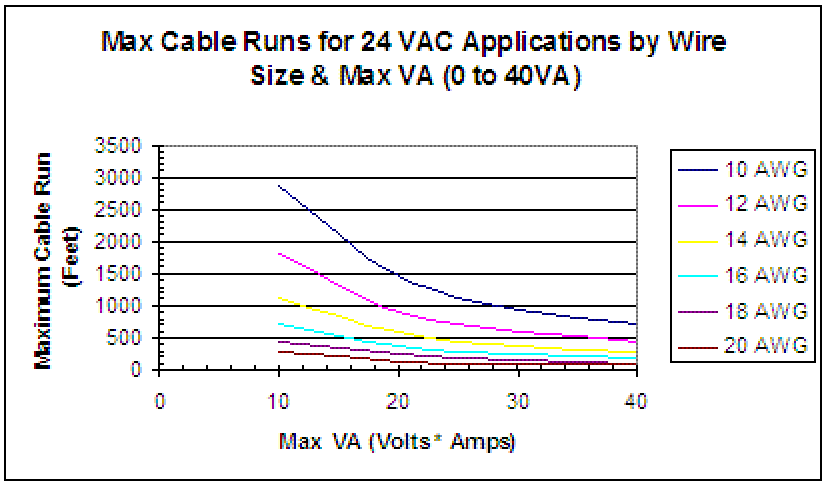
At the camera end, bullet connectors (or optionally tinned wire) are used as the wires are inserted into a push style terminal block.

Solar Power

Outdoor applications can also use a solar power system where power would otherwise be unavailable.

Wire Size Selection

Wire size is selected based on the peak rated power consumption of the device and the length of the cable run according to the following chart.



2. Power for Digital Video Recorders (DVRs) and Other Equipment

Digital Video Recorders, security monitors (flat panel and CRT), RAID arrays and other equipment almost always runs on standard line voltage. In other words, you just plug them into the wall – no special power connections are required.

C. Video Cable & Connectors

Video can be transmitted using one of many different methods. Within each method, several different options often exist as to cable and connector types. The most popular methods for video transmission are:

- RCA	Less Than 20 Feet
- Coax	Up to 750 Feet
- Unshielded Twisted Pair (UTP)	Up to 2,000 Feet
- Fiber Optic Cable	More Than 2,000 Feet
- Telephone	Unlimited (typically used for long distance transmission only)
- Wireless Video	Varies – Up to 30 Miles LOS (Line of Sight)
- Ethernet (TCP/IP)	Unlimited
- Wireless Ethernet	Up to 30 Miles LOS

You'll notice that we've given a "Cable Run" figure for each cable type. If you look around, you will find claims of longer runs for a particular cable type. The figure we've provided is what we consider to be the maximum cable run *without noticeable loss in video quality*. Longer runs are possible but video quality may suffer.

1. RCA

Cable Run: < 20 Feet

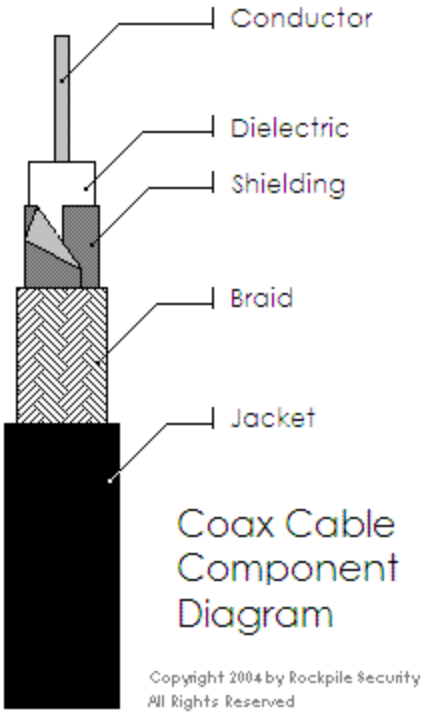
RCA cables are the cheapest pre-terminated cable type available. They consist of a relatively thin, coax type wire with a push-on RCA connector. RCA cables work fine for cable runs under 20 feet but are unsuitable for longer runs as even the highest grade RCA cables experience significant high-frequency losses in longer lengths.

2. Coax

Cable Run: Up to 750 Feet

Coaxial cable or “Coax” is the most common method for transmitting video data. Coax cables come in many different pre-fabricated lengths with molded connectors already attached, though a trained technician can create custom cables of any length.

Coax cable consists of a solid or stranded center conductor (wire) surrounded by a heavy layer of dielectric (insulation). An optional foil sheath may surround the dielectric, itself covered by a braided, grounded cylindrical copper or aluminum conductor. For CCTV applications, a typical indoor coax cable selection would be RG-59 cable with a 20 gauge solid copper conductor, foamed polyethylene dielectric and a 95% bare copper braid.



The following is a brief description of some typical materials used for each coax component:

Conductor

Solid conductors are the most common conductor type but stranded conductors are easier to handle in situations where the cable must be bent/pulled around sharp corners.

- Bare Copper
- Silvered Copper
- Tinned Copper
- Copper Clad Aluminum
- Copper Covered Steel

Dielectric

Foamed dielectrics have better electrical properties but absorb moisture more readily. For high moisture applications (e.g. buried cable) solid dielectrics are preferred.

- Polyethylene (solid)
- Polyethylene (foamed)
- Teflon® / Fluorinated Ethylene Propylene (solid)

- Foamed Teflon® / Fluorinated Ethylene Propylene
- Air Dielectric / Polyethylene

Shielding

The optional shielding reduces RF (radio frequency) interference which results in better quality video images.

- Aluminum Foil (Double-sided polypropylene or polyester tape)

Braid

The braid reduces RF (radio frequency) interference which results in better quality video images. Braid coverage is given as a percentage of coverage (e.g. 95%).

- Aluminum Sheath
- Aluminum Braid
- Bare Copper Braid
- Silvered Copper Braid
- Tinned Copper Braid

Jacket

The jacket (outside of the cable) will vary depending on the application. For example, cable intended to be run in vents, air ducts or plenum spaces will use a fire resistant Teflon® or Kynar® jacket. Cable intended to be buried will use an armored, irradiated PVC jacket.

- Teflon® / Fluorinated Ethylene Propylene (plenum cable)
- Kynar® / Polyvinylidene Fluoride (plenum cable)
- Polyethylene
- Polyvinylchloride (PVC)

Types & Grades

Coax cable comes in many different types and grades. The two most common types are RG-58 (50 Ohm) and RG-59 (75 Ohm). Almost all CCTV applications require 75 ohm cable, thus RG-59 is the coaxial cable of choice. For cable runs longer than RG-59 can accommodate, equivalent cables with larger conductors can be used. as shown in the chart below.

Cable Type	Impedance (Ohms)	Loss (db per 100 Feet) @ 5MHz	Maximum Cable Run
RG59U	75	0.726 dB	750 Feet
RG6U	75	0.500 dB	1,000 Feet
RG11U	75	< 0.500 dB	1,500 Feet

The highest grade RG-59 coax cable can be used for *straight* cable runs up to about 1,000 feet. Bends in the cable reduce the cable's performance (and therefore the maximum cable run) so when deciding on cable type, 750 feet is usually the maximum run you should consider with RG-59 coax based on performance alone. Note, however, that for cable runs over about 500 feet, it is generally more cost effective to use UTP (Unshielded Twisted Pair) / NVT (Network Video Technologies) technology.

Connectors

Coax is typically terminated in one of two ways: "F" Type and BNC. F Type connectors are commonly used in older home theater equipment and are likely the type of connector your cable company uses. These

connectors are not typically used with CCTV applications where BNC connectors are the rule. F Type connectors can be push on or screw on.

BNC connectors are high quality connectors that provide a positive twist and lock attachment via a slot & pin arrangement formed into the male and female connectors.

NOTE: Most digital video recorders (DVRs) use this type of connector, therefore even if another type of cable is used, an adapter will probably be necessary to convert to a BNC connector format on the DVR end.

Siamese Cable

A special type of cable called "Siamese" cable is available which combines an RG-59 coax cable w/ 2 18 gauge twisted pair conductors in the same jacket. This enables the installer to run a single cable for power and video.

3. Unshielded Twisted Pair (UTP)

Cable Run: Up to 2,000 Feet

Traditionally, video has been transmitted along coax cables while twisted pair cabling has been reserved for large cable and telephone networks. This is rapidly changing, however, as the amplifiers, transmitters and receivers necessary to make UTP installations work has come down in price and is now widely available. The most common standard for UTP hardware is known as the Network Video Technologies (NVT) standard. Most UTP installations use equipment made by, or licensed from Network Video Technologies.

UTP wire consists of two insulated but unshielded (usually stranded) copper wires twisted one about the other with a "slow" twist of about 1 to 2 twists every three feet. The two wires may be encased in plastic sheathing or left exposed. Multiple "sets" of UTP are often run within the same sheath. Common telephone wire is an excellent example of this. The wires are twisted together to reduce inductive interference with each other as the twisting keeps them from being parallel at any point along their length.

UTP wire comes in a broad range of impedance levels. For CCTV applications, an impedance in the range of 100-150 ohms is generally selected.

UTP has several significant advantages over coax:

1. It is cheaper. The cable itself is roughly 25% of the cost of coax. This is offset to some degree by the extra NVT transmitters and receivers that are required. Nevertheless, NVT installations break-even with coax installations at cable runs of about 500 feet.

2. UTP has much lower high frequency losses than coax and can therefore be used for much longer cable runs.

3. UTP is much smaller, typically half the diameter or less of coax. It is also not as stiff and is therefore easier to run than coax.

4. RF interference is reduced. UTP is known as a "balanced" cable system whereas coax is "unbalanced". Balanced wire relies on special equipment (e.g. NVT transmitters and receivers) to reject interference while unbalanced wire relies primarily on shielding. Because RF interference can be actively rejected, it is suitable for much longer cable runs.

These days, many cameras have NVT transmitters built in and likewise some digital video recorders have NVT receivers built-in. These models are slightly more expensive but the convenience is often worth the slightly higher cost. Even if the DVRs and security cameras do not have built in NVT equipment, stand-

alone transmitters and/or receivers are available so that UTP cabling can be used with almost any video surveillance equipment on the market today.

As with coax cable, UTP cable comes with various jacket (sheath) types including plenum and underground versions.

4. Fiber Optic Cable

Cable Run: Up to ~15 miles without repeaters. Virtually unlimited with proper equipment.

Fiber optic cable is very different from the other types of cable discussed so far. It is made by encasing a hollow or solid glass core in a light-proof casing *and transmits light rather than electricity*. Because of it's highly specialized nature, fiber optic cabling is not suitable for every situation.

There are two primary ways to run fiber for video: multi-core fiber or multiplexed fiber.

With multi-core cable, the cable itself contains multiple fiber strands. Each strand is dedicated to one video or telemetry channel. Aside from the converter needed to convert the optic data to standard data type, no extra equipment is necessary.

With multiplexed fiber, a single strand of fiber is used to transmit multiple channels of video/telemetry data by using different frequencies of light for each channel. In this arrangement, multiplexers are required at each end of the fiber cable.

As indicated, converting the light pulses to electrical pulses that the security cameras and digital video recorders (DVRs) can use requires special equipment which adds cost. On top of that, the fiber itself is more expensive than high-quality conductive video cable and terminating fiber cables is more difficult and adds additional cost.

Fiber optic cable is also relatively fragile compared to standard conductive wire and is limited in it's minimum acceptable bend radius, so care must be taken when running it. In addition, it must be installed by a technician trained in fiber optic cabling. Properly laying and terminating fiber optic cables is a tricky business.

Despite these shortcomings fiber has it's place. For one thing, it is really the only practical option if you need to run video cable over distances of 2,000 feet. No other technology will easily allow you to make such long cable runs.

But fiber optic cable has other advantages as well. Some big ones!

For one thing, fiber is impervious to lightning. This can be a big deal with outdoor camera installations (rooftops, parking garages, etc.) as a lightning strike on a security camera in a conventionally wired (conductive) system *can destroy every component in the system* including all of the other security cameras, alarm panels, DVRs, etc. Because fiber optic cable does not conduct electricity (it is, in fact, an insulator), the damage from a lighting strike on a security camera is limited to that camera alone. It is possible to install conventional lightning barriers in a conductive system but 1) they are expensive, fiber will likely be cheaper; and 2) they don't always work as lightning is an extremely high-voltage, high-energy phenomenon. When considered in this light, the extra expense of fiber becomes cheap insurance.

Another advantage is that fiber has a very high bandwidth (the amount of data it can transmit). In fact, the bandwidth is so high that a single fiber optic cable can transmit video from 32 different security cameras! This obviously reduces the expense of running multiple cable trunk lines through walls, floors and ceilings. It also helps mitigate the cost of the fiber system as 32 twisted pair or coaxial cables can be replaced with just one fiber optic cable!

Finally, fiber is very noise resistant and is virtually lossless. In fact, compared to a typical coaxial cable like RG-59, which has a loss rating of 0.726 dB per 100 feet, a typical fiber cable has a loss rating of 0.016 dB per 100 feet. In other words, RG-59 coax cable has a loss rating 45 times greater than a typical optical fiber. Another way to look at this is that for a 6dB (50%) loss, an RG-59 cable run will be 827 feet. With fiber, the same loss will occur with a cable run of over 7 miles!

5. Telephone

Cable Run: Unlimited.

Another option for transmitting video data, especially across long distances, is via telephone line. This isn't a cable type so much as it is an existing infrastructure. The telephone company may use multiple technologies to transmit your data including twisted pair, microwave and fiber. Nevertheless, it is worth briefly discussing as it may be a viable option in certain circumstances.

Two primary types of phone networks exist: Public Switched Telephone Network (PSTN) and Integrated Services Digital Network (ISDN). The difference between the two technologies is that PSTN uses an analog network while ISDN is digital. PSTN is being phased out and in most areas has been replaced by ISDN. As you would expect ISDN is capable of transmitting at much higher rates than PSTN.

ISDN leased lines come in different capacities and the higher capacity versions can be used to transmit full motion video. It should be noted that there is a cost associated with leasing the individual lines and that other technologies, while higher in initial cost, may be less expensive in the long run.

6. Wireless Video

Cable Run: Wireless! Up to 30 Miles.

With the use of special equipment (including very rigid mounts with some technology), video data can be transmitted wirelessly. This can be quite useful in certain situations such as open-air mines, parking lots or across railroad rights-of-way or surface streets where the cost of running conventional cable would be prohibitive or may not be possible at all.

Wireless video systems consist of special transmitters, receivers and transceivers designed specifically to work with conventional security cameras and digital video recorders (DVRs). They transmit high-quality video streams and can do everything that a normal CCTV security camera system can do including pan/tilt/zoom (PTZ) camera control and DVR system administration.

There are three primary types of wireless video transmission:

1. FM RF (Radio Frequency) which has a range up to about 400 feet;

2. Infrared which has a range up to about ½ mile; and

3. Microwave which has a range up to about 30 miles.

They are more expensive than traditional cable and camera systems but considering that installation labor is less, and that they are only used in specialized areas of your overall security system, they are worth considering in some situations.

7. Ethernet (TCP/IP) and Wireless Ethernet

Cable Run: Ethernet: Unlimited. Wireless Ethernet: 400 Feet

While almost all modern professional video surveillance systems allow you to view, control and administer your CCTV system over an Ethernet connection, they still transmit video from the cameras to the digital

video recorder (DVR) using a standard analog video signal over a coax or twisted-pair cable. Ethernet based systems, on the other hand, use your existing TCP/IP network to transmit video as digital data. These types of systems are very different from traditional video surveillance systems using completely different hardware and software and while they may be used in very small, low-quality security applications, they are probably not appropriate for commercial applications of any size due to several serious drawbacks.

Problems with Web-Based Security Systems

1. Bandwidth requirements are very high. Streaming digital video takes huge amounts of data. A system with just a couple of cameras can quickly bring your local area network to its knees, causing all other network operations (e.g. printing, file-sharing, internet access, etc.) to operate very slowly, if at all.

This is the biggest problem with IP based security cameras (i.e. "web cams").

2. Video quality is generally poor. Due to the nature of the packet based video transmission used in IP video systems, video is often marred by numerous digital artifacts and erratic, stuttering frame rates.

3. Hardware selection is limited. You won't be able to get the types and styles of cameras appropriate for any but the most basic surveillance system. Sophisticated feature sets (such as electronic irises, automatic gain control, etc.) which are readily available (and very inexpensive) with professional video surveillance systems aren't available at all with IP based equipment. It should be noted that the situation is improving - but slowly. Because of the bandwidth problem, web cameras aren't popular with large installations and it is these larger installations that drive quality and features.

4. Hardware quality is often low. Because IP based hardware is generally made by small, mom and pop manufacturers, it often lacks the fit and finish present in professional video surveillance equipment. This can significantly impact video quality and reliability.

Professional DVR Systems vs. IP-Based Sytems

All of this is not to say that Ethernet, PC-based CCTV security systems are not viable in certain situations. They do have their place though the differences are still substantial. As technology improves, web-based systems are becoming more viable and there are some exciting things on the horizon that involve these systems. However, you need to consider carefully your situation against the fairly severe limitations of an Ethernet based IP system before you decide to go with one. Whatever you decide, your security equipment integrator can help you make the right decision and can provide you with a professional quality DVR based system or an Ethernet based IP system if you decide one will work for you.

D. Data Cable & Connectors

Some video security cameras, notably Pan/Tilt/Zoom (or PTZ) cameras require telemetry data to control the pan/tilt/zoom functions.

1. Data Cable Specifications

While you should always read and follow the specific instructions that come with your model of security camera, data (or telemetry) cable typically requires an unshielded twisted pair (UTP) 24 gauge solid copper conductor with an impedance of 100 Ohms. One type of cable that fits this specification is Category 5 (or Category 5 Enhanced) Ethernet cable. Cat5/Cat5e Ethernet cable contains 4 UTP pairs in a single plastic sheath, is convenient, readily available and relatively inexpensive.

2. RS485 Addressable Device Standard

The RS485 protocol is an upgrade from the RS422 protocol. Up to 32 serial devices can be controlled over a single pair of UTP cables using the RS485 protocol supported by most modern digital video recorders

(DVRs). One pair of wires (Tx+ and Tx-) is reserved for transmission and one pair of wires (Rx+ and Rx-) is reserved for receiving data signals. Many PTZ security cameras will require only one-way (simplex) communication and thus only one UTP cable will be required. Special adapters exist to convert RS232 serial ports to RS485 ports.

III About Rockpile Security

For more information regarding any information contained in this white paper, please feel free to contact us.

Rockpile Security
888-ROCKPILE (888-762-5745)
contact.us@RockpileSecurity.com
www.RockpileSecurity.com

We'd be happy to answer any questions you might have, provide you with further information or help you design a security system that meets your exact needs.

IV Notices

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